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Non-GPS Navigation using the method Okamura-Hata and Wolfish-Ikegami

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***Abstract* — Mobile communications must be enhanced by establishing a non-GPS technology that can detect the positions of mobile stations precisely. In this paper, we propose methods of used Okamura-Hata and Wolfish-Ikegami. The purpose of this work is carrying out of complex researchers of features and the supervision organization objects by means of GPS**
***Keywords* — GSM, Non-GPS, NLOS, LOS**

I. INTRODUCTION

In mobile communications, the establishment of very precise mobile station detection technologies is an important goal. Some of the existing technologies utilize only the mobile communication system itself. One example is the cell based mobile location approach. The subject of researchers in mobile systems GSM on Non-GPS navigation. The purpose of this work is carrying out of complex researchers of features and the supervision organization objects by means of GPS. For achievement of the given purpose, it was necessary to solve following problems:

-To consider types of control mobile systems and to show advantages of application GPS navigation control systems, mobile objects. At carrying out of researches in the given work, it is if results can be used practically for an authentic estimation capacity of supervision mobile objects on GPS and workings out of recommendations. Because of the spent researchers following scientific results are received:

- Features and advantages of application and exact calculation of trajectory GPS by the mobile system and using method tensor are shown a dual network.

In the research the cover zone of one basic station two methods - a method the Okamura-Hata and a method Wolfish-Ikegami settles. During calculations, it will be proved that the difference in calculations by the given methods is insignificant. At term performance, it is required to define cover zone BTS of standard GSM, allocated according to the job in regions are Tashkent, using two methods:

Empirical model of a prediction the Okumura-Hata or COST231-Hata, specified in the job;

Model Walfish-Ikegami (WIM);

To compare results of calculation;

The covering cell radius is defined in three directions: the north, the southeast, and the southwest. It is necessary to define also the MS cover zone one of the offered methods (on a choice). On the drawing to specify the configurations of cover zones BTS received by various methods, and the MS cover zone. The height of the antenna a mobile station (MS) is accepted equal 1,5 m.

TABLE 1
HEIGHT SUSPENSION ANTENNAS BS

Height rising of antenna BS h BTS, m	40
Standard GSM	1800
Calculation models	COST231- Hata

TABLE 2
STANDARD VALUES OF PARAMETERS BTS AND THE MS

Designation	The name and unit of measure	Value
PT_x BTS	Capacity of transmitter BTS, dBWt	13
GT_x BTS	Factor transmitting antenna BTS gains, dB	18
$f\,T_x$ BTS	Band of operational frequencies of transmission BTS, MHz	935-960
PR_x BTS	Sensitivity of receiver BTS, dBWt	-138
GR_x BTS	Factor receiving antenna BTS gains, dB	18
fR_x BTS	Band of operational frequencies of reception BTS, MHz	890-915
PT_x MS	Capacity of the transmitter of the MS, dBWt	-3
GT_x MS	Factor gains of the transmitting antenna of the MS,	0 dB
$f\,T_x$ MS	Band of operational frequencies of transmission of the MS, MHz	890-915
PR_x MS	Sensitivity of the receiver of the MS, dBWt	-104
GRx MS	Factor gains of the receiving antenna of the MS, dB	0
fR_x MS	Band of operational frequencies of reception of the MS, MHz	935-960

The lay the land in service area Δh_{BTS} systems of a mobile radio service is defined on a district map taking into account layout of three-sector antenna K730380 in location BTS. The equal accepts the coefficient of the coordination of the antenna with a wireless signal on polarization (for the transmitter and the receiver)

$$\xi_{R_x} = \xi_{T_x} = 0{,}9$$

Efficiency of transferring and receiving feeders is accepted by the equal

$$\eta_{FT_x} = \eta_{FR_x} = 0{,}95 \qquad (1)$$

Determination of a cover zone three-sector BTS by means of prediction models, the registration of propagation loss of radio waves. The basis of territorial planning is made by energetic calculation in which process the architecture of a network and its space coordinates taking into account quality of service and information loading is defined. The given quality of the accepted signal is defined by the sensitivity receiver. In a general view, the transmission equation can be presented as

$$P_{R_x} = \frac{P_{T_x} \cdot \eta_{T_x} \cdot G_{AT_x} \cdot \xi_{T_x} \cdot G_{AR_x} \cdot \eta_{R_x} \cdot \xi_{R_x}}{L_\Sigma} \qquad (2)$$

Where P_{R_x} - capacity of a wireless signal on a receiver input (it is defined by sensitivity of the receiver);

P_{T_x}- Capacity of the transmitter;

η_{T_x}, η_{R_x} - efficiency of transferring and receiving feeders;

G_{AT_x}, G_{AR_x} - gain amounts of transferring and receiving antennas;

ξ_{T_x}, ξ_{R_x} - coefficients of the coordination of antennas with a wireless signal on polarization;

L_Σ - Total attenuation of radio-waves on a route.

The value of the capacity a wireless signal on a receiver input is convenient for expressing in decibels concerning watt. Thus, the equation becomes.

$$P_{R_x}(dB\,/\,Wt) = P_{T_x}(dB\,/\,Wt) + \eta_{T_x}(dB) + G_{AT_x}(dB) + \xi_{T_x}(dB) + G_{AR_x}(dB) + \eta_{R_x}(dB) + \xi_{R_x}(dB) - L_\Sigma(dB) \qquad (3)$$

Under this formula, it is simple to define the total energetic losses arising on a route of radio propagation

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$$L_{\Sigma}(dB) = P_{T_x} + \eta_{T_x} + G_{AT_x} + \xi_{T_x} + G_{AR_x} + \eta_{R_x} + \xi_{R_x} - P_{R_x} \quad . \qquad (4)$$

For BTS total attenuation of radio waves on a route is equal

$$L_{\Sigma\mathrm{BTS}}(dB) = P_{T_x\,BTS} + \eta_{T_x\,BTS} + G_{AT_xBTS} + \xi_{T_xBTS} + G_{AR_xMS} + \eta_{R_xMS} + \xi_{R_xMS} - P_{R_xMS} = 13 + 0{,}95 + 18 + 0{,}9 + 0 + 0{,}95 + 0{,}9 + 104 = 138{,}7(dB). \qquad (5)$$

For the MS total attenuation of radio waves on a route is equal

$$L_{\Sigma\mathrm{MS}}(dB) = P_{T_x\,MS} + \eta_{T_x\,MS} + G_{AT_xMS} + \xi_{T_xMS} + G_{AR_xBTS} + \eta_{R_xBTS} + \xi_{R_xBTS} - P_{R_xBTS} = -3 + 0{,}95 + 0 + 0{,}9 + 18 + 0{,}95 + 0{,}9 + 138 = 156{,}7(dB). \qquad (6)$$

Let us define total attenuation of radio waves as losses of propagation for appropriate type of terrain L_C the correction and considering lay of land

$$L_{CLL}\,, \quad L_{\Sigma} = L_C + L_{CLL}\,. \qquad (7)$$

Let us define the correction, considering a lay of the land. For this purpose around rough location BTS on a map of the city we select a place, which will satisfy simultaneously to following conditions:

For antenna BS layout in appropriate region there is approaching on conditions of the job a building or a support on which it is possible to rent the area for antenna BS layout;

In front of the antenna BS on distance, approximately 5 km for GSM-900 and 3 km for GSM-1800 should not be the considerable heights (screens), it is desirable in all three directions for which calculation (the north, the southwest, and the southeast are produced). In the given picture the building on which the basic station will be installed also is marked.

Let us calculate height of the given building together with the antenna:

We build in three directions a lay of the land. On a relief, we specify heights for following points of terrain: the first point - a point of the layout of antenna BS; following points it is sampled through 5 km for standard GSM-900 in each direction and through 3 km for standard GSM-1800 in each direction. We receive on 6 points in each direction, connecting which the smooth line; we define in an appropriate direction a lay of the land. In the given operation the three-sector antenna is used, we divide terrain into 3 sectors: sector A- 0º, sector B - 120º, sector C - 240º.

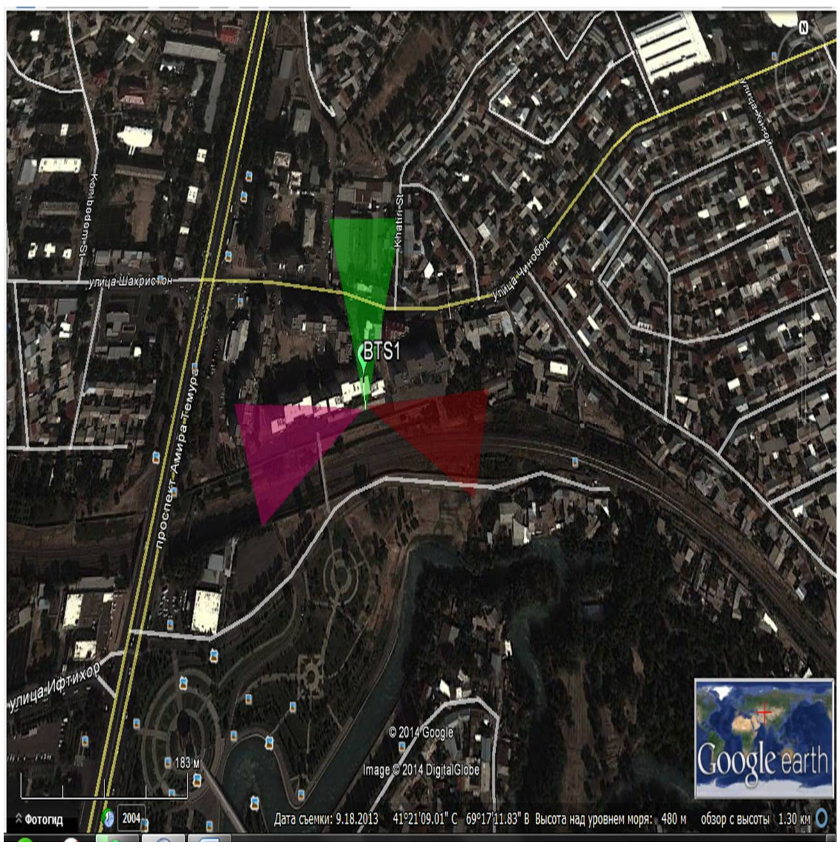

Fig. 1 Three sectors of terrain

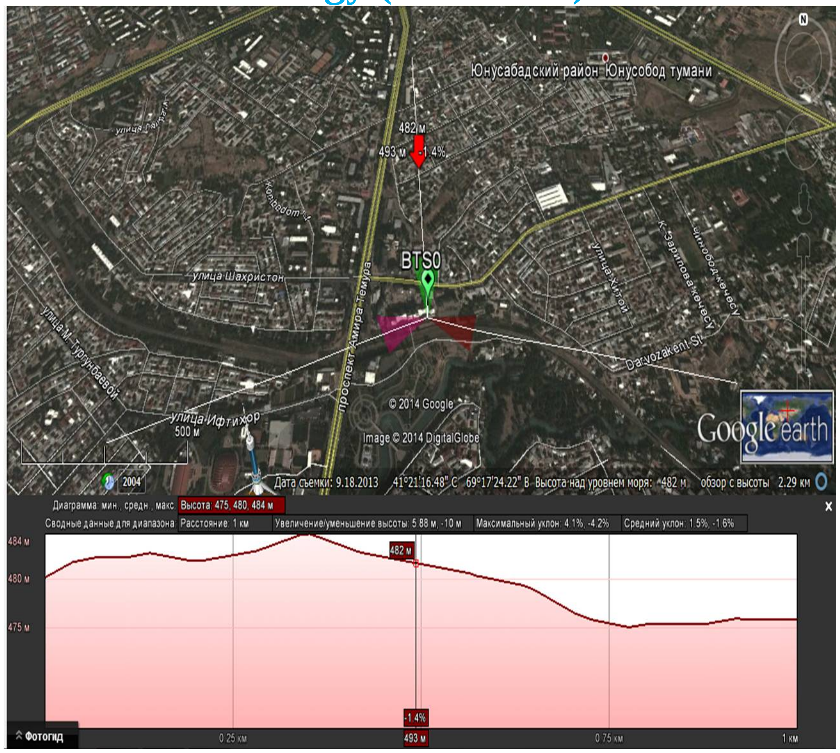

Fig. 2 Lay of land in a direction to the north from BTS

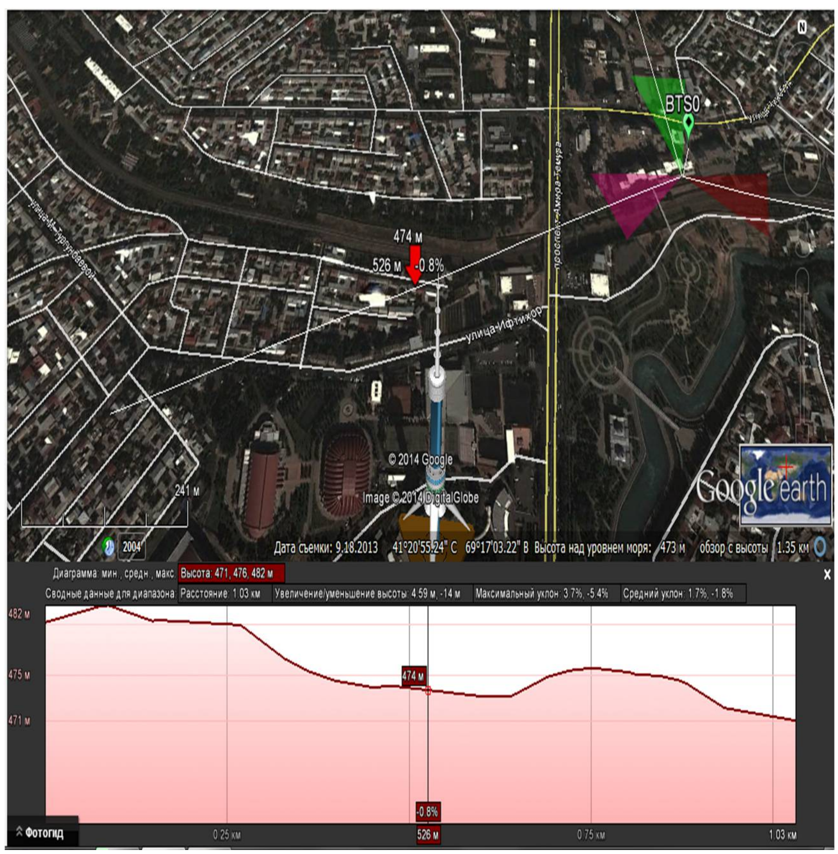

Fig. 3 The lay of land in a direction to the southwest from BTS

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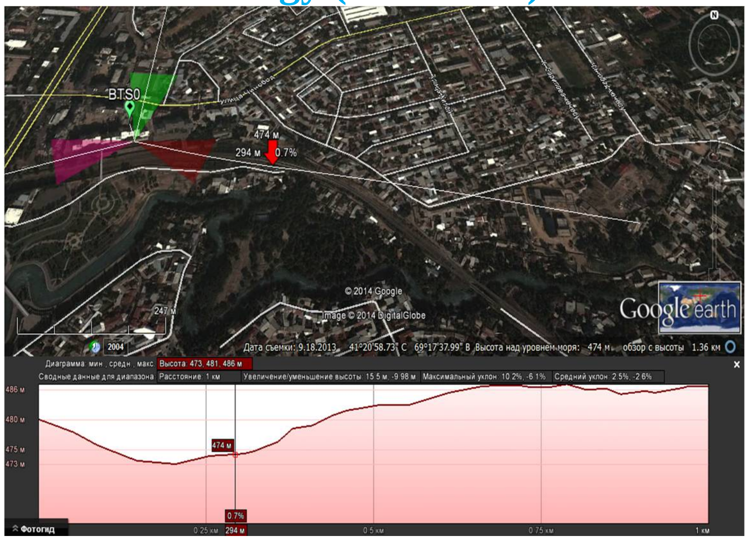


Fig. 4 The lay of land in a direction to the southeast from BTS

Let us define the corrections considering a lay land for all three directions. Coefficient L_{CLL} is defined, interpolating between schedules of a Figure 3.12, Figure 3.10

At $\Delta h = 81$ $L_{CLL} = \frac{2.5+3.5}{2} = 3\ dB$ -sector A-00 , (8)

At $\Delta h = 172$ $L_{CLL} = \frac{7,5+10}{2} = 8,75\ dB$ - sector B - 120º, (9)

At $\Delta h = 142$ $L_{CLL} = \frac{6+8}{2} = 7\ dB$ - sector C - 240º , (10)

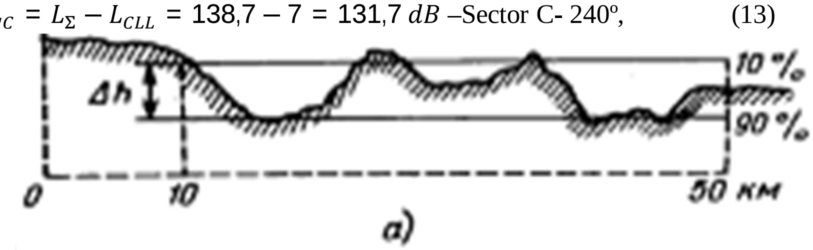
Let us define losses of propagation for appropriate type of terrain:

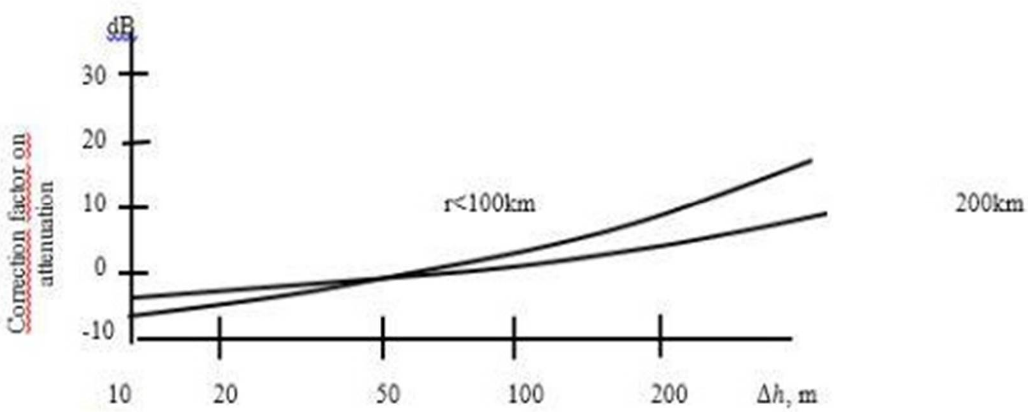
From BTS to the MS:

$L_C = L_\Sigma - L_{CLL} = 138,7 - 3 = 135,7\ dB$ – Sector A - 0º, (11)

$L_C = L_\Sigma - L_{CLL} = 138,7 - 8,75 = 130,2\ dB$ – Sector B - 120º, (12)

$L_C = L_\Sigma - L_{CLL} = 138,7 - 7 = 131,7\ dB$ –Sector C- 240º, (13)





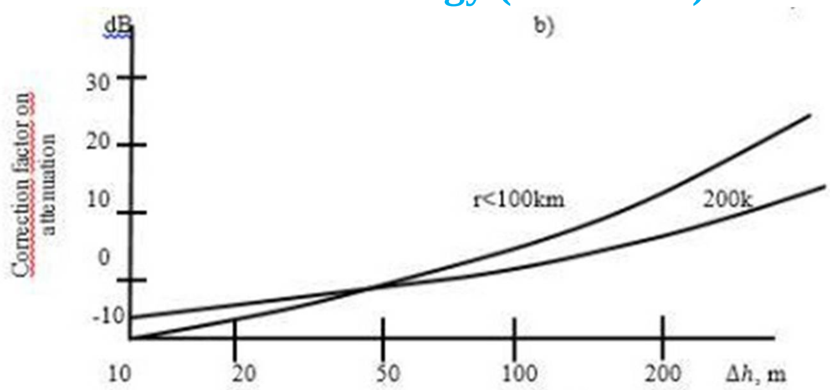


Fig. 3.12 Schedules for determination of the correction considering a lay of the land.

From the MS to BTS

$$L_C = L_\Sigma - L_{CLL} = 156{,}7 - 3 = 134{,}7\ dB \text{ – Sector A - 0º}, \qquad (14)$$

Defining from loss of propagation for appropriate type of terrain L_C, it is possible to start determination of cell radius of a covering of basic station by means of empirical models of Okumura and the Hata, Walfish-Ikegami (WIM).

Model COST231-Хата: Mergence with coauthors suggested to expand models of Okumura and the Hata on frequency range from 1,5 to 2 GHz. In this range usage, a model of Okumura and the Hut leads to signal attenuation underestimation. Model COST231-Hata is valid for carrying frequencies in a range from 1.5 to 2GHz, the height of the antenna the basic station from 30 to 200 m, the height the antenna mobile station from 1 to 10 m and to distance in between from 1 to 20 km. The model allows estimating attenuation under the formula

$$L_C = 46{,}3 + 33{,}9\lg(f_0) - 13{,}83\lg(h_b) - a(h_m) + [44{,}9 - 6{,}55\lg(h_b)]\lg r + C\,. \qquad (15)$$

Where with a constant: for average cities and suburbs with moderate vegetation C = 0 and for centers of big cities C = 3.

Formally models of Okumura and the Hata and COST231-Hata can be used only for the height of the antenna of the basic station exceeding 30м, however, their application is possible and for lower heights provided that adjacent structures are considerably below the antenna.

Model COST231-Hata does not approach for signal attenuation estimation at distances between mobile and basic stations less than 1 km. In this case, attenuation strongly depends on terrain topography in which there is signal propagation. This model also cannot be used for an estimation of propagation of a signal on streets with high structures (on so-called street canyons).

$h_b = 40$ m- Height of the antenna of basic station,

$h_m = 1{,}5$ m - Height of the antenna of mobile station,

A. From BTS the MS

$$f_0 = 1850\ MHz$$

$$a(h_m) = [1{,}1\cdot\lg(f_0) - 0{,}7]\cdot h_m - [1{,}56\cdot\lg(f_0) - 0{,}8], \qquad (16)$$

$$a(h_m) = [1{,}1\cdot\lg(1850) - 0{,}7]\cdot 1{,}5 - [1{,}56\cdot\lg(1850) - 0{,}8] = 0{,}044\,,$$

$$A = A(f_0, h_b, h_m) = 46{,}3 + 33{,}9\cdot\lg(1850) - 13{,}83\cdot\lg(40) - 0{,}044 = 134{,}8566\quad, \qquad (17)$$

$$B = B(h_b) = 44{,}9 - 6{,}55\cdot\lg(40) = 34{,}40650\quad, \qquad (18)$$

$$L_C = A + B\cdot\lg(r)\ , \qquad (19)$$

$$r = 10^{\frac{L_C - A}{B}}\ , \qquad (20)$$

1. Sector A - 0º: $r = 10^{\frac{L_C-A}{B}} = 10^{\frac{135{,}7-134{,}8566}{34{,}40650}} = 1{,}058\ km$

2. Sector B - 120º: $r = 10^{\frac{L_C-A}{B}} = 10^{\frac{130{,}2-134{,}8566}{34.40566}} = 0{,}732\ km$

3. Sector C - 240º $r = 10^{\frac{L_C-A}{B}} = 10^{\frac{131{,}7-134{,}8566}{34{,}40650}} = 0{,}809\ km$

B. From the MS to BTS

$$f_0 = 1750\ MHz$$

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$$a(h_m) = [1{,}1 \cdot \lg(f_0) - 0{,}7] \cdot h_m - [1{,}56 \cdot \lg(f_0) - 0{,}8] \ , \quad (21)$$

$$a(h_m) = [1{,}1 \cdot \lg(1750) - 0{,}7] \cdot 1{,}5 - [1{,}56 \cdot \lg(1750) - 0{,}8] = 0{,}04187$$

$$A = A(f_0, h_b, h_m) = 46{,}3 + 33{,}9 \cdot \lg(1750) - 13{,}83 \cdot \lg(40) - 0{,}04187 = 134{,}04063\,, \quad (22)$$

$$B = B(h_b) = 44{,}9 - 6{,}55 \cdot \lg(40) = 34{,}40650\,,$$

$$L_C = A + B \cdot \lg(r), \quad (23)$$

$$r = 10^{\frac{L_C - A}{B}},$$

2.1 Sector A - 0º: $r = 10^{\frac{L_C - A}{B}} = 10^{\frac{134{,}7 - 134{,}04063}{34{,}40650}} = 1{,}045115\ km$

TABLE 3

RESULTS OF CALCULATIONS OF MODEL OF OKUMURA AND THE HATA

The direction of sector BTS concerning the joint venture, hailstones.	Propagation loss, LP, dB		The expected distance between BTS and the MS, km	The expected distance between the MS and BTS, km
	BTS and MS	MS and BTS		
Sector S	135,7	134,7	1,058	1,045
Sector South-east	130,2		0,732	
Sector South-east	131,7		0,809	

Model of Walfish-Ikegami (WIM)

Losses of propagation the appropriate type of terrain shows that the signal level noticeably fluctuates because of change of height of buildings, the width streets, relief. Therefore, defining cell radius of covering BTS on the model specified in the job, it is necessary to repeat the calculation of cell radius of a covering, using the model of Walfish-Ikegami (WIM), found wider application in the field of mobile technologies. Model WIM is used at attenuation calculation in the city environment. The model can be applied in cases when the antenna of the basic station is allocated as above, and below a line of the level of roofs of city building. Set of the empirical factors considered by the rated formula includes heights of antennas of basic and mobile stations, the width of streets, distances between buildings, the height of buildings and orientation of streets concerning a signal propagation axis.

In the model, WIM distinguishes two cases LOS (direct visibility) and NLOS (non-line-of-sight, i.e. in the case of indirect visibility). In case of LOS if on a straight line of propagation of a signal from the transmitter and the receiver there are no barrages the WIM-model is described by the equation:

$$L_{LOS} = 42{,}64 + 26 \lg d_{km} + 20 \lg f_{MHz}, \quad d_{km} 0{,}02 \ , \quad (24)$$

Losses in a free space:

$$L_{f_s} = 32{,}45 + 20 \lg d_{km} + 20 \lg f_{\ MHz}, \quad (25)$$

$$L_{LOS} = L_{f_s} + 10{,}19 + 6 \cdot \lg d_{km} = L_{f_s} + 6 \cdot \lg(50 \cdot d_{km}) = L_{f_s} + 6 \cdot \lg(\frac{d_{km}}{20}) \quad . \quad (26)$$

Where d_m - distance in meters.

The parameters also used in NLOS WIM: h_b - height of the antenna of basic station (40-50 m from the earth); h_m - height of the antenna of the subscriber (1-3 m from the earth); h_B - height of buildings;

$\Delta h_b = h_b - h_B$- Height of the antenna of basic station from level of roofs; distance between buildings (20-50);

ω - width of streets (it is normal b/2);

Now we consider some variants in case of NLOS WIM.

$$\Delta h_b > 0,$$

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$$L_{NLOS} = 69{,}55 + 38 \cdot \lg d_{km} + 26 \cdot \lg f_{MHz} - 10 \cdot \lg \omega - 9 \cdot \lg b + 20 \cdot \lg \Delta h_m - 18 \cdot \lg(1 + \Delta h_b) + L_{LOS}. \quad (27)$$

$$\Delta h_b \leq 0,\ d_{km} \geq 0{,}5,$$

$$L_{NLOS} = 69{,}55 + (38 + 15|\Delta h_b|/h_b \cdot \lg d_{km} + 26 \cdot \lg f_{MHz} - 10 \cdot \lg \omega - 9 \lg b + 20 \cdot \lg \Delta h_m + 0{,}8 \cdot \lg|\Delta h_b| + L_{LOS}. \quad (28)$$

$$\Delta h_b \leq 0,\ d_{km} < 0{,}5,$$

$$L_{NLOS} = 69{,}55 + (38 + 15|\Delta h_b| / h_b \cdot \lg d_{km} + 26 \cdot \lg f_{MHz} - 10 \cdot \lg \omega - 9 \lg b + 20 \cdot \lg \Delta h_m + 0{,}8 \cdot \lg|\Delta h_b| \cdot (d_{km}/0{,}5) + L_{LOS}. \quad (29)$$

As a rule, city regions are built up by unequal height buildings. The width of streets and distance between buildings also fluctuate largely. Therefore at calculation on model WIM some conditions are accepted:

The height of one floor in a residential building is accepted equal 3 m;

In one-storied residential buildings the height of a no planar roof is accepted equal 2 m;

Distance between one-storied buildings not less than 5 m;

Width of the streets which have been built up with one-storied houses, not less 10 m;

The distance between many-storied buildings is accepted equal 20м;

The width of the streets which have been built up with many-storied buildings is accepted region 20 m;

The height of one floor in office educational and etc. a location is accepted regions 3,5 m;

The height of one floor of the industrial enterprise is accepted region 7,5 m.

Hence, it is necessary to know the percent of the building of region in which antenna BS, is allocated by buildings of various type. Because of it the average height of buildings, the average distance between buildings and an average width of streets for all regions defined in the job is defined.

Building height on which antenna BS will be allocated, it is not recommended to average. Knowing height of this building and height of position of antenna BS according to the job, it is possible to define h_b - height of the antenna of basic station from level of roofs $h_b = 40\ m$, $h_m = 1{,}5\ m$,

$$h_B = \frac{27+27+27+10}{4} = 22{,}75\ m \quad (30)$$

$$\Delta h_b = h_b - h_B = 40 - 22{,}75 = 17{,}25\ m \quad (31)$$

$$b = 24\ m, \quad \omega = 12 m$$

LOS $$d_{km} = 10^{\frac{L_C - 42{,}64 - 20 \cdot \lg f]}{26}}, \quad (32)$$

NLOS $$d_{km} = 10^{\frac{L_C - 69{,}55 - 26 \cdot \lg f + 10 \cdot \lg \omega + 9 \cdot \lg b - 20 \cdot \lg h_m + 18 \cdot \lg(1 + \Delta h_b)}{38}}, \quad (33)$$

1. From BTS to the MS $f_0 = 1850\ MHz$, Sector A - 0º,

LOS $d_{km} = 10^{\frac{135{,}7 - 42{,}64 - 20 \cdot \lg f 1850}{26}} = 11{,}641843\ km$

NLOS: service station attendant $d_{km} = 10^{\frac{135{,}76 - 69{,}55 - 26 \lg(1850) + 10 \lg(12) + 9 \lg(24) - 20 \lg(1{,}5) + 18 \lg(1 + 17{,}25)}{38}} = 4{,}2330\ km$

Sector B - 120º:

LOS: $d_{km} = 10^{\frac{130{,}2 - 42{,}64 - 20 \cdot \lg 1850}{26}} = 7{,}1529\ km$

NLOS: $d_{km} = 10^{\frac{130{,}2 - 69{,}55 - 26 \lg(1850) + 10 \lg(12) + 9 \lg(24) - 20 \lg(1{,}5) + 18 \lg(1 + 21{,}4)}{38}} = 3{,}0222\ km$

Sector C - 240º:

LOS: $d_{km} = 10^{\frac{131{,}7 - 42{,}64 - 20 \cdot \lg 1850}{26}} = 8{,}16912\ km$

NLOS: $d_{km} = 10^{\frac{131{,}7 - 69{,}55 - 26 \lg(1850) + 10 \lg(12) + 9 \lg(24) - 20 \lg(1.5) + 18 \lg(1 + 21{,}4)}{38}} = 3{,}30986\ km$

2.From the MS to BTS: $f_0 = 1750\ MHz$

Sector A- 0º

$$d_{km} = 10^{\frac{134{,}7 - 69{,}55 - 26 \lg(1750) + 10 \lg(12) + 9 \lg(24) - 20 \lg(1.5) + 18 \lg(1 + 21{,}4)}{38}} = 5{,}056\ km$$

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TABLE 4

RESULTS OF CALCULATIONS OF MODEL OF WALFISH-IKEGAMI (WIM)

The direction of sector BTS concerning the joint venture, hailstones.	**Propagation loss, LP, dB**		**The expected distance between BTS and the MS, km**	**The expected distance between the MS and BTS, km**
	BTS-MS	**MS-BTS**		
Sector C	135,7	134,7	4,238	5,056
Sector South-east	130,2		3,022	
Sector South-west	1131,7		3,309	

II. CONCLUSIONS

Maintenance of reliable and steady functioning of networks of mobile radiotelephone (cellular) communication with the account requirements of information security. Modern radio-electronic equipment GSM represents a difficult complex which structure except most GSM includes a control system of processes in GSM. Now, modern mobile systems it is used for many purposes. This work is devoted one of the types of information technology GPS which give the information from time and a position of investigated objects. Now, this technology is very important because it gives the information on navigation and management of objects and for the definition to people of ways in cities and everywhere where this inquiry is necessary for them. For reliable work GPS, it is necessary to demand much on reliable work of mobile system GSM. Therefore, the research problem of methods of the check of working capacity of mobile GPS object is actuals.

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