## Practical work №1

**Calculation of the radio coverage area of the base station using the Okumura-Hata model**

1. **Purpose of work**

- To study the principle of frequency-domain design in the mobile communication network.

- Mastering and learning the methods of calculating the radio coverage area of the base station using the Ok a mura-Hata model.

**2. Task**

1. GSM, UMTS , and LTE mobile communication system standards.
2. Studying the methods of calculating the radio coverage area of the base station based on the Ok u mura-Hata model.
3. Experimental measurement of the radio coverage area of a base station using input data provided by the Ok u mura-Hata model.
4. Preparation of a report on completed works .

**3. Brief theoretical information**

The arrow is a symbol ( English ) *Okumura )* is the basis of the model In Tokyo, there are many measurements conducted in the frequency range from 150 to 1920 MHz .

Error ( in English ) *Error )* The model was developed by fitting empirical formulas to graphs established by Okumura and his followers. Therefore, in practice it is called the Okumura-Hata model. These formulas provide a good approximation of the graphs in a certain range of carrier frequencies on a quasi-smooth Earth.

The empirical model of Okumura-Hata is usually used to calculate the coverage area of TS. This is due to its recommendation by the International Radiocommunication Consultative Committee (ICRC) and its simplicity of use. This model makes it possible to determine the losses in the parameters of radio lines and base stations of a certain area .

According to the Okumura -Hata model , The average loss level in the audio path is determined as follows :



(dB).

here

- *f* = [100:3000] – operating frequency , (MHz);

- *Yes , sir.*= [3:300] – height of TS antenna , (m);

- *r* = [1:100] – intermediate distance between TS and subscriber station age (AS) , (km);

- *h as* = [1:3] - subscriber station yas i height of the antenna , (m);

**-** coefficient taking into account the height of the AS antenna ( for small and medium-sized cities , for large cities ),











**-** local condition - coefficient taking into account the conditions ( for rural areas , suburban area , for cities ),

- coefficient reflecting the effect of dense buildings, (%) - building density;

-

The coefficient for taking into account the Earth's sphere (0.2Р 0 < *р* ≤ 0.8Р 0 )is introduced, where *R 0* is the direct visual distance).

**4. Task for the account**

The calculation of the coverage area of the mobile communication network in Tashkent, where the building density is 35%, should be carried out on the basis of the requirements for ensuring signal quality based on the initial parameters given in Table 1.1.

Table 1.1.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Initial parameters​ | Version 1 | Version 2 | Version 3 | Version 4 |
| *f* | 700 | 1800 | 2100 | 2500 |
| *Yes, sir.* | 25 | 30 | 25 | 20 |
| *yes​* | 1.5 | 1.5 | 1.5 | 1.5 |

1. **Accounting method**

Based on the Okumura-Hata empirical model on the example of the GSM-900 network, it is necessary to determine the average indicators of losses in the radio path .

***An example of loss accounting based on the Okumura -Error model***









, for the city ( ) .



Average loss indicators in R adiotrass a :



(dB);

(dB).

2. *P* ( dBm ) is the output power of the transmitter , *S(* dB ) is the amount of losses and *Q* ( dBm ) is the required signal level at the input of the receiver *.* the equation defining *R* – TS and AS ensuring the quality of communication at the level of demand ( i.e. *r max* ) is the maximum distance between :



here *L –* Average loss index determined in the first step using the error model .



Relevant *P* ( dBm ), *C* ( dB ) and Given the parameters *Q* ( dBm ) ( Table 1.2), the reliable communication distance *R* can be determined .

Table 1. 2

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Beginning parameters​​ | Version 1 | Version 2 | Version 3 | Version 4 |
| *P* ( dBm ) | 44 | 40 | 44 | 40 |
| *C* (dB) | 20 | 22 | 18 | 22 |
| *K* ( dBm ) | - 96 | -100 | -104 | -102 |

3. On the basis of the available data, from the point of view of the signal quality, the coverage area of the TS is established ( without taking into account the traffic load and the transmission capacity of the TS ).

Thus, taking into account the required signal level and depending on the frequency range used, 10-20 TS can be considered sufficient for the coverage of Tashkent city satellite communications . In practice , more is required, since when designing a satellite network, it is necessary to take into account the intended subscriber load for each satellite. It is not difficult to imagine that a cell with a radius of 10 km in a large city like Tashkent will not be able to fulfill the existing load as a result of “covering” a large number of subscribers (and, of course, traffic). Therefore, based on the assumptions about the subscriber load in the cell, there is a need to reduce the coverage areas and increase the number of TS.

1. **Structure of the report**
2. Presenting the results of experimental calculations of the TC coverage area based on the Okumura -Hata model together with the proposed initial data .
3. shows the coverage area based on the calculations of the radio coverage area, which were carried out in order to maximize the coverage of a given area using the minimum number of coverage areas . ( Sample maps of Tashkent city are in Appendix 1 ) cited ).
4. **Control questions**
5. What is meant by frequency-domain design of mobile radio communication networks and what is the need for them?
6. What methods of frequency-area design are used in practice? Describe them.
7. What do you know about the classes of signal propagation models in the radio coverage area ?
8. What are the differences between different models ?
9. What are the advantages and disadvantages of accounting for TS of the coverage area based on the Okumura -Hata model ?

## PRACTICAL WORK №2

**GSM network base station using the Walfish-Ikegami model**

1. **Purpose of work**

- To study the principles of frequency - area planning of mobile communication networks .

- Learning and mastering the method of calculating the radio coverage area of TS in mobile communication networks using the Walfish-Ikegami model.

1. **Task**
2. Studying the coverage area calculation method of mobile communication network TS based on the Walfish-Ikegami model.
3. Calculation of coverage area of TS based on initial data provided by Walfish-Ikegami model.
4. Preparing a report on the work carried out.

**3. Brief theoretical information**

*Walfish-Ikegami for urban constructions model​​*​

This model is " C ooperation in the field ofC scientist c​ and T echni c al" ( C OST) program and 231 Developed within the framework of the ITU project . The book gives its full name C OST 231 Walfisch -Ikegami Model and its abbreviated name - W IM .

the Walfish-Ikegami model , urban constructions are taken into account as parameters, and they are presented in Figure 2.1 . The range of changes of the main parameters for this model is given :

* frequency *f* = 800 …2000 MHz
* Height of TS antenna *ҳ 1* = 4 …50m
* AS is the height of the antenna *ҳ 2*= 1 …3m
* distance *d km* = 0.02 …5 km.

Typically, construction parameters are selected based on the following limits :

* the height of the building *h r* = 3 ( number of floors ) + 3m ( if the roof is sloping if the construction has age );
* destruction of buildings *b* = 20 …50m
* the width of the street *w* = 0.5 *b* .
* angle across the street to the base station *ϕ= 90 °*

In non-permanent constructions *, b, w, h r* as their average indicators obtained for the distribution routes are used ( as in Figure 2.2 ) .

Walvis Bay-Ikegami The model allows to determine the median loss of the signal strength in two opposite cases of distributions - in cases where there is a direct view between TS and AS and when there is no.

1. In the absence of direct views, median losses are expressed as:

, (2.1)

here *L 0* – losses in propagation along the open field ( svobodno e prostranstv o) ,

*L rts* - signal propagation losses due to the phenomenon of diffraction under the roof of the building ( roof -top-to -street diffraction​​ loss ),

*L msd* – losses due to reflection of multiple signals along the walls of the building ( multis c reen diffraction​​ loss ).

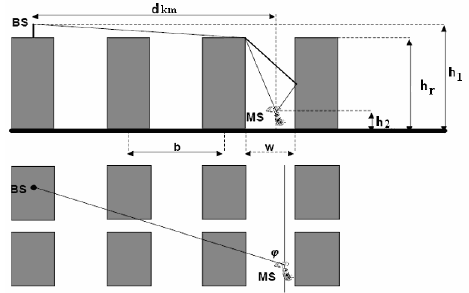


Figure 2.1. Radio signal gear geometry and Walfish - Ikegami model parameters

here *h 1* , *h 2* – height of TS and AS antennas respectively , m;

*d km* - horizontal base air and mobile distance between stations , km; *h r* – the average height of the building , m;

*b* – average damage of the building , m;

*w* – average width of the street , m;

ϕ- angle along the street relative to the base station , degree ( from 0 °d to 90 °).

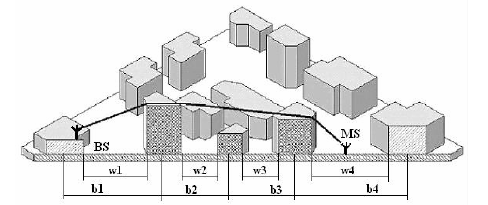


Figure 2.2 . Determination of Walfish-Ikegami model parameters for non-permanent structures

components included in ( 2.1) are listed below is determined based on expressions .

1. Propagation losses across the open field

( 2.2)

B) Signal propagation losses due to diffraction phenomenon under the roof of the building:

, (2.3)

where *L ori* is the loss due to signal propagation and cross-direction of streets,

, (2.4)

(Note: when φ = 28.25°, the value is *L ori*= 0.)

C) Losses during the reflection of multiple signals along the walls of the building:

, (2.5)

in which, *L bsh* – the component that takes into account the reduction of losses in cases where TS is located above the roof of the building,

, (2.6)

*k a* – *d km* the coefficient representing the effect of distance *L msd on losses* (sota radius) ,

, (2.7)

*kd* is the coefficient representing the effect of TS antennas moving up and down from the roof of the building on losses *L msd ,*

, (2.8)

*k f is* the coefficient expressing the effect of signal frequency and construction characteristics on losses *L msd ,*

, (2.9)

1. Within the Walfisch-Ikegami model, the line-of-sight (WIM-LOS) model applies when the TC antennas are located above the roof of a building and are spread out over a street or other open area.

In this case, the following expression is used ,

. (2.10)

(2.2) and (2.10), it can be seen that

, (2.11)

Or, taking into account the approximation,

, (2.12)

here *d m* – distance between TS and AS in meters .

to (2.11- 2.12) , *d m* = At 20m , Walfish-Ikegami model and is equivalent to the model of propagation over an open area (2.2). *d m* In increments, this model is 6dB per decade along the distance , i.e separates more fades than the open field model .

According to the calculations, when the structures are not permanent, the placement of the TS antenna below the roof of the building Walfish-Ikegami reveals numerous flaws in the model . Since the model is designed for the flat planes of the city, it cannot be used in urban conditions with a relief consisting of sharp unevennesses .

**4. The task of keeping accounts**

1. Formation of a set of initial parameters for the Walfish-Ikegami model based on real construction parameters in the districts of Tashkent city.

*d km* and *f* frequency based on the selected parameters for conditions where there are no direct views .

3. Compare the determined expression with (2.2) and (2.10) by calculating the attenuation based on all three formulas for the values of 5..7 of *d km .* It is necessary to take into account that *φ = 1800 MHz.*

**5. Structural structure of the report**

1. Present the results of experimental calculations of the TS coverage area based on the Walfish-Ikegami model together with the proposed initial data.
2. The map of Tashkent city shows the calculated TS for the cases where direct views of districts are available and where they are not. ( Examples of Tashkent city maps are in Appendix 2 ) cited ).
3. **Control questions**

1. Walvis Bay-Ikegami What conditions is the model designed for ?

2. How are the parameters of the Walfish-Ikegami model designed for non-permanent constructions determined ?

3. What are the components of a WIM expression in cases where there are no direct representations ?

4. Give an expression for the losses associated with the propagation of a signal through an open area.

5. How do WIM-LOS losses differ from the value obtained based on free dispersion across the field?

6. What is the general structure of the boundaries of the radio coverage area of TS?

## PRACTICAL WORK №3

**Calculation of the signal loss load on one triangular (cline) track using the diffraction model**

1. **Purpose of work**

* diffraction for the calculation of losses in the path of a mobile communication network learning model n .​
* Formation of skills on the structural profile of the signal propagation route based on the local map .

1. **Task**
2. Diffraction accounting for path losses with a wedge-shaped barrier study the model and the basics of the structural profile of the signal propagation route based on the local map .
3. Diffraction using the proposed initial data conducting an experimental calculation of losses based on the model and forming a profile of the distribution route based on the local map provided by professors and the base points of TS and AS .
4. Preparing a report on the work carried out .

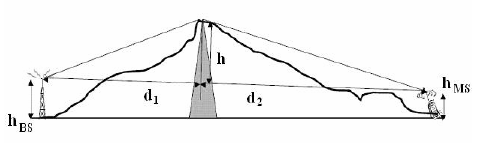
**3 . Brief theoretical information**

3.1 . Single-cline diffraction model

Diffraction models are used to account for signal losses traveling through obstacles that block the line - of-sight (LOS) between the TS and AS antennas . Among such barriers, one can include obstacles ranging from high reliefs located along the signal propagation route to high-rise buildings located separately. The geometry of the diffraction model consisting of one wedge-shaped barriers on the track and its parameters are shown in Figure 3.1.

The model can be used correctly under the following conditions: *h>> l* ; *h<<d 1 ,d 2* ; the flat height of the wedge does not exceed 1/20 of the distance between TS and AS.

In the model shown in Figure 3.1, deviations (krivizny) of the Earth's surface are not taken into account. After all, the distance between TS and AS in the sota usually does not exceed 5 km . Caution is required in such distances, consisting of deviations on the surface of the earth ( curvizn a) .



3.1 . - picture . Single-cline diffraction model geometry and parameters .​​​​

Here : *ҳ BS , ҳ MS* – sometimes and mobile elevation height of station antennas ;

*yes* - directly - the height of the wedge in relation to the line of sight , m;

*d 1* – horizontal distance from the base station to the wedge , m;

*d 2* – a bonent from klin horizontal distance to the station , m.

The median signal power loss in single-cline route propagation is defined as :

, (3.1)

here *L 0* – losses in open field propagation ( see problem #2 ), *L D(n)* – diffraction losses .

In turn, diffraction losses are determined based on the following expression :

, (3.2)

where ***n*** are Fresnel-Kirchhoff diffraction parameters defined as follows

, (3.3)

***ν*** near-zero diffraction losses at the shadow boundary

 (3.4)

Diffraction When using the model , the salinity profile of the radio signal propagation route is required .

**4.2. Propagation track profile structures based on local map**

the radio signal propagation path profile is based on the local map, height isolines - horizontal ones based on input . Horizontal height certain to zero relatively in meters expressed as b , in which , for example, the level of the Baltic Sea in Europe is accepted . The teacher distributes a map on a scale of 1:10,000 with a step of 2.5 m , a scale of 1:25,000 with a step of 5 m , and a map of 1:50,000 with a step of 10 m . It is necessary to pay attention to the fact that , in addition to multi-pointed horizontals , half-step dotted horizontals moving along the height are also found on the map .

When creating a track profile, the following steps should be taken :

* a profile line from the starting point A to the final point B of the route ( 1:25000 in the example of a local map for distances up to 10 km shown in Figure 3.2 scale ) ;
* it is graphed ( razgraflennoy )​​​ Attach a sheet of paper and mark the points where the horizontals meet the profile lines ( horizontal protrusions ) using short lines on its edge ;
* razgraflennoy​​​ on the left side of the sheet of paper , depict the heights corresponding to the horizontal heights on the map , conditionally accepting the intervals between these lines in height ;
* along all the lines ( horizontal exits ) to the intersections, lowering the parallel lines perpendicular to the signs and marking the defined intersection points ;
* Connecting free curve points representing the route profile .

A of the resulting profile , a TS mast, conditionally no higher than 20-30 m high, is depicted . From its top to point B , a straight line is drawn ( in a simplified form, it is represented by *х МС* = 0m). In areas with large obstacles, the wedge height *is* is measured based on the profile . After that, diffraction using the map *d 1* required for models and *d 2* distances are determined .

Walfish-Ikegami model and diffraction Using mathematical expressions of the models , it is possible to determine the signal level in the cells of mobile communication systems and the effective radius of the cells . For this , 6…10 beams are directed in different directions from the location of the TS . With the help of these beams, all important parameters are determined based on the selected model , in particular, the distance at which the base station can capture the detection threshold of the subscriber station. The determined points are combined using all beams and the deviation limit corresponding to the radio coverage area of the existing TS is obtained.

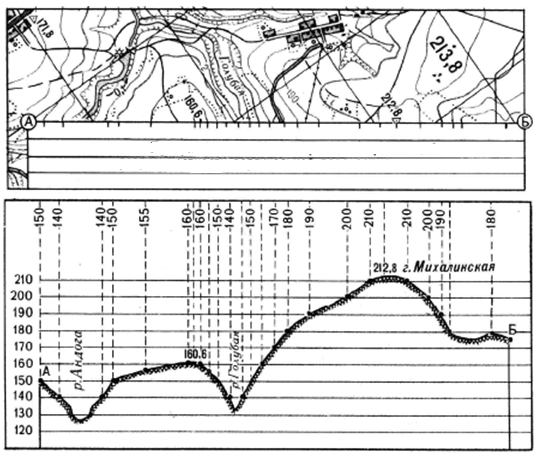


Figure 3.2 . Trass a profile structure

1. **A task for the account**
2. Diffraction of losses in paths with a wedge-shaped (wedge) barrier to determine on the basis of models .
3. Determination of the distribution route profile based on the local map distributed by the teacher and the given location points of TS and AS .

**5 . Structure of the report**

1. Diffraction​ the results of calculation of losses on roads with single-clinic barriers based on the initial data obtained for roads under different conditions on the basis of models .
2. Presenting a distribution route profile constructed independently based on the local map obtained from the teacher and the location point of TS and AS . ( The local map is presented in Appendix 3 ).

**6 . Control questions**

1. Single-cline diffraction under what conditions is the model used ?
2. parameters affect the value (magnitude) of diffraction losses in the shadow area ?
3. How to create a signal propagation path profile based on a local map ?

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