Research of the methods of an equalizing with using OFDM signals for communication systems

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***Abstract* – The article discusses recommendations about a choice of the valuation method of transfer function of the radio propagation channel by using pilot subcarriers. The distances between pilot subcarriers in case of which the high data transmission rate will remain for standard models of the channel propagation are selected. Process of an estimation of transfer function of the radio propagation channel by using pilot subcarriers is modeled. Bit error rate for each of the offered methods is estimated.**

Key words – channel estimation**,** equalization, methods of interpolation, bit error rate.

I. Introduction

The fourth-generation of mobile networks actively developed in our time. For estimation of radio propagation channel in such networks are used methods based on using pilot signals, are known in the transmitter and the receiver. The technology of using pilot signals assumes partition of an information signal on elements, which include from one to several pilot signals, providing the necessary accuracy of the estimation of the transfer function. After the formation of all evaluations, equalizer removes the distortion caused by the channel, in the simplest case by dividing the received signal on the estimation of transfer function channel.

II. Algorithms of an estimation of transfer function

Most often in modern communication systems using channel estimation of pilot subcarriers, the following methods for estimating the transfer function are implemented:

*Assessment by one pilot***.** Phase and amplitude distortions of information subcarriers within one element are evaluated on one pilot signal, Eq.1:

$$\hat{H} = P, \qquad (1)$$

where $\hat{H}$ – data subcarriers, P – pilot subcarriers.

Algorithm of averaging. This algorithm uses mean value of pilot subcarriers for an assessment of transfer function, Eq.2:

$$\hat{H} = (P_1 + P_2 + ... + P_N)/N, \qquad (2)$$

This algorithm is the simplest valuation method of the radio propagation channel and is used in WIMAX systems [1]. It effectively reduces influence of noise and is suitable for a case of slow fading of the signal level when passing through the channel.

The linear interpolation. Other widely used algorithm – the linear interpolation [2]. is calculated by one-dimensional linear interpolation Eq.3.

$$\hat{H} = k_i x + b_i, \qquad (3)$$

$$k_i = \frac{y_1 - y_0}{x_1 - x_0},\; b_i = y_0 - kx_0,$$

Interpolation of a parabola. This method uses three pilot subcarriers and is brought together to finding of coefficients of the parabola passing through them [2]. Coefficients of a parabola are respectively equal, Eq.4.

$$\hat{H} = a_i x^2 + b_i x + c_i, \qquad (4)$$

$$a_i = \frac{y_3 - \dfrac{x_3(y_2 - y_1) + x_2 y_1 - x_1 y_2}{x_2 - x_1}}{x_3(x_3 - x_1 - x_2) + x_1 x_2},$$

$$b_i = \frac{y_2 - y_1}{x_2 - x_1} - a_i(x_1 + x_2),$$

$$c_i = \frac{x_2 y_1 - x_1 y_2}{x_2 - x_1} + a_i x_1 x_2,$$

Spline interpolation. This algorithm interpolates function value by using cubic splines. The cubic interpolation spline corresponding to this function *f(x)* and these x_i nodes, function *S(x)*, satisfying the following conditions [2] is called:

1. At each interval [x_i - 1, x_i], i = 1, 2, ..., N is a polynomial function of third degree.
2. Function and its first and second derivatives are continuous on the interval [a, b].
3. i = 0, 1, ..., N.

III. Modeling

Comparison of methods for estimation of the transfer function of the channel PPB was carried out by numerical modeling in the environment of Matlab. Used for channel estimation pilot subcarriers arranged in steps 40, 60 and 80 kHz. By each method formed an assessment of tranfer function of the channel, then it was compared to the true and the estimation root mean square error was calculated. The number of implementations equaled 15000, number of subcarriers – 480. The distance between subcarriers equaled 10 kHz. For calculation of probability of a bit error rate was used an OFDM signal with two indexes of modulation: QAM-4 and QAM-16.

The 3 models of channels are selected for researching[3]:

Channel No. 1 – Expanded model 3GPP of a radio channel of cellular systems for the normal city;

Channel No. 2 – Expanded model 3GPP of a radio channel of cellular systems for the pedestrian;

Channel No. 3 – Expanded model 3GPP of a radio channel of cellular systems for the vehicle.

The parameters of the channels are shown in Tables 1-3.

TABLE 1

CHANNEL MODEL FOR URBAN 1

№ Beam	Delay, ns	Power, dB
1	0	0
2	200	-0.9
3	800	-4.9
4	1200	-8.0
5	2300	7.8
6	3700	-23.9

TABLE 2

MODEL OF CHANNELS OF RADIO PROPAGATION 2

№ Beam	Delay, ns	Power, dB
1	0	0.0
2	30	-1.0
3	70	-2.0
4	90	-3.0
5	110	-8.0
6	190	-17.2
7	410	-20.8

TABLE 3

MODEL OF CHANNEL OF RADIO PROPAGATION 3

№ Beam	Delay, ns	Power, dB
1	0	0.0
2	30	-1.5
3	150	-1.4
4	310	-3.6
5	370	-0.6
6	710	-9.1
7	1090	-7.0
8	1730	-12.0
9	2510	-16.9

Example of implementation of transfer function of these channels are figured in a Fig. 1.

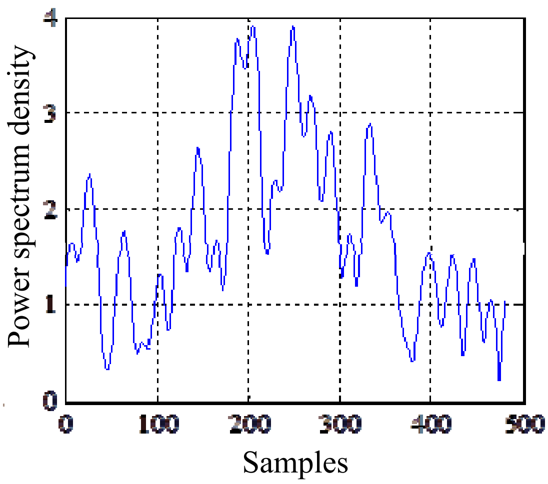


Fig. 1. Example of channel transfer function

In Fig. 2 is shown the example of an assessment of transfer function of the channel is provided by different methods.

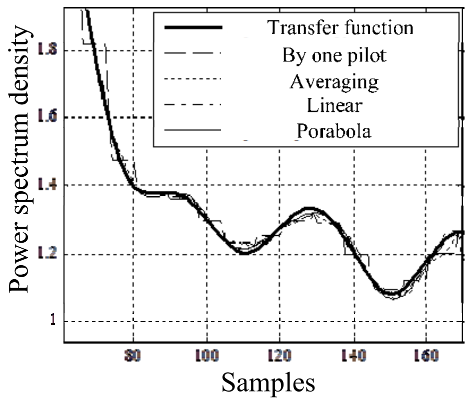
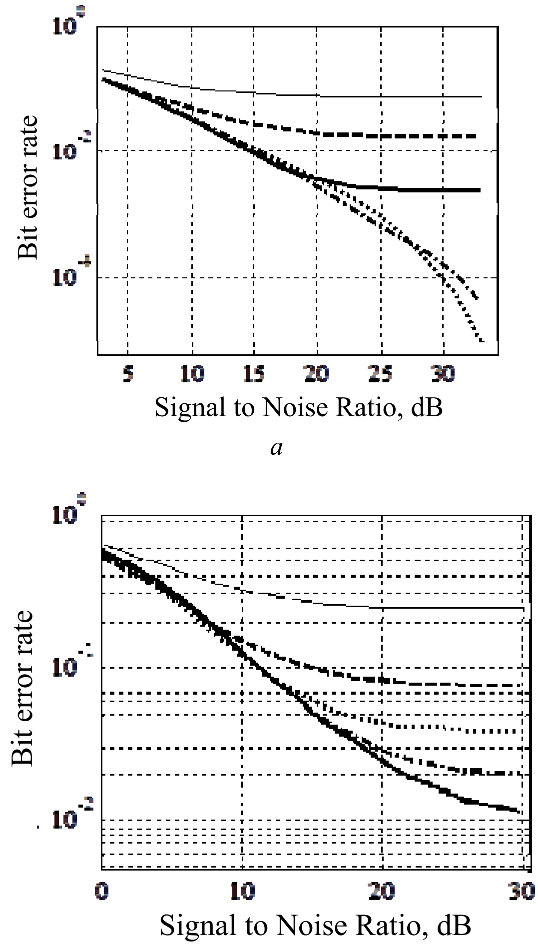


Fig.2 Example of an Assessment of Transfer Function of the Channel by different methods

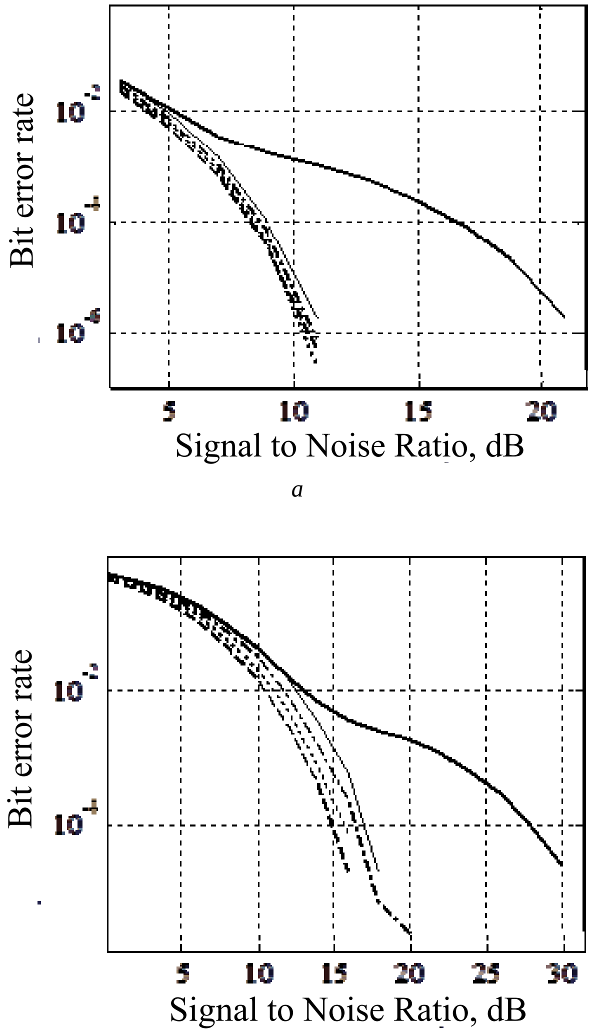
In the following figure are shown the results of calculation of probability of a bit error rate for each of channels in case of two indexes of modulation: QAM-4 and QAM-16.



a

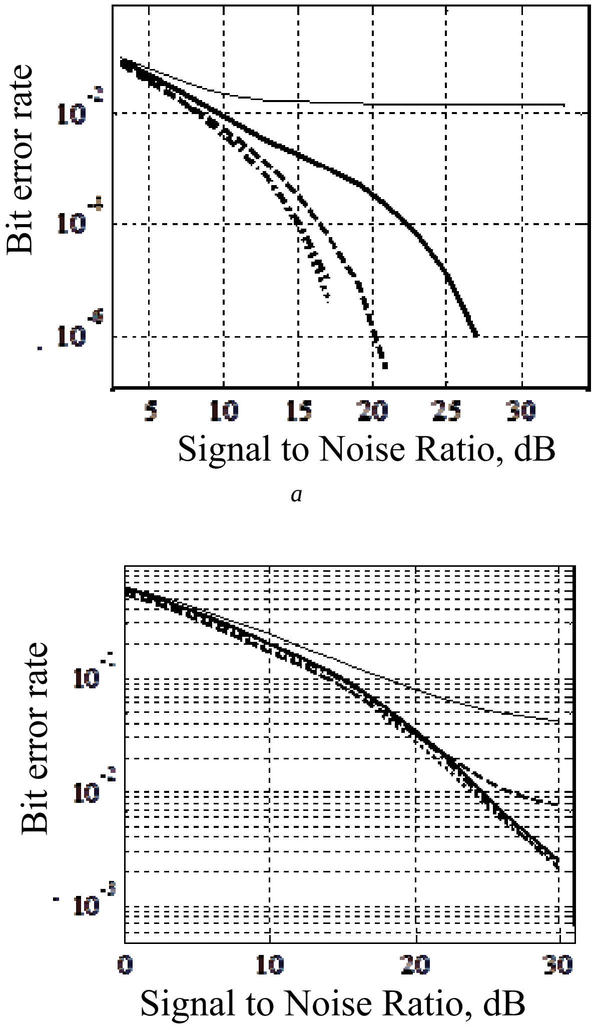
b

Fig. 3. The dependence of the bit error rate of the signal-noise ratio for different interpolation methods for modulating *a*) QPSK, *b*) QAM16, for channel No. 1



b

Fig. 4. The dependence of the bit error rate of the signal-noise ratio for different interpolation methods for modulating *a*) QPSK, *b*) QAM16, for channel No. 2



b

Fig. 5. The dependence of the bit error rate of the signal-noise ratio for different interpolation methods for modulating *a*) QPSK, *b*) QAM16, for channel No. 3

From a Fig. 3 follows that in case of the low relations signal/noise the smallest error of estimation provides an averaging method. In case of increase the relation of signal/noise the assessment accuracy an averaging method increases, but more slowly, than assessment accuracy an interpolation method. If a step of location of pilot subcarriers relatively small, an averaging method it is expedient to use to the relations of signal/noise 30 dB. In case of the relation signal/noise higher than 30 dB it is necessary to select a method of interpolation by a cubic spline. In case of a step of pilot subcarriers, equal 60 kHz, it is favorable to already use interpolation in case of the relation signal/noise of 25 dB.

The analysis of results of simulation for the channel No. 1 showed that in case of the high relation of signal/noise, the best algorithm of an assessment of transfer function is an interpolation by a spline. In case of low values of the relation of signal/noise, the results of simulation of different algorithms differ less than for one percent.

The analysis of results of simulation for the channel No. 2 showed obvious advantage of a method of averaging. For all almost significant relations of signal/noise, it shows the smallest SKO of estimation of transfer function and the best probability of a bit error rate. However in case of the high relations of signal/noise, the accuracy of an assessment of transfer function of the channel for all of the other methods increases, and the difference between SKO of an assessment of transfer function doesn't exceed 0,2%.

The analysis of results of simulation for the channel No. 3 showed that in case of the minimum step of location of pilot subcarriers and the relations signal/noise less than 35 dB the averaging method provides the minimum root mean square errors of estimation. In case of the big relations signal/noise, it is expedient to use a method of interpolation by a spline or the linear interpolation. In case of the increased step of location of pilot subcarriers, it is convenient to already use the interpolation by a spline in 27-30 dB of the relation signal/noise.

Conclusion

Results of numerical modeling showed that for different types of radio propagation channels it is expedient to use different methods of estimation of transfer function Guidelines for using the test methods for the development of the fourth-generation communications networks are summarized in Table 4.

TABLE 4

RECOMMENDATIONS ABOUT A CHOICE OF PARAMETERS OF A COMMUNICATION SYSTEM FOR EACH CHANNEL TYPE

Chanel number	The recommended distance between pilots, kHz	Recommended algorithm within the relation signal/noise of 0-30 dB	Recommended algorithm within the relation signal/noise of 30-50 dB
1	2	3	4
Channel No. 1	40	Algorithm of averaging	the interpolation by a spline
Channel No. 2	80	Algorithm of averaging	Algorithm of averaging
Channel No. 3	60	Algorithm of averaging	the interpolation by a spline

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