Use of logical predistortion for the purpose of decreasing digital signal intersymbol interference

O.R. Nikitin[1], **P.A. Polushin**[1]

[1]Vladimir State University named by Aleksandr Grigorievich and Nikolaj Grigorievch Stoletov (VlGU), Gorky Street, 87, Vladimir, Russia, 600000

Abstract. Method of decreasing of negative influence of intersymbol interference in digital signals is described. Method consists of carrying in transmitted signal logical predistortion. Copy of received signal after channel with intersymbol interference is nearer to initial informational signal that transmitted signal without predistortion.

Keywords: intersymbol interference, predistortion, digital signals.

1. Introduction

One of the trends of signal transmission progress nowdays is increasing of signal transmission rate and as the effect using wide frequency band. In using of various types of channels (troposphere, ionosphere and so on) even narrow banded channels are damaged by fadings of signal level because of non-stationary parametres of channel. When signal frequency band are wider than frequency correlation band then additional signal distortions appear [1]. They are caused by non-equality of transmission coefficient $K_T(f)$ in different frequencies and form of frequency characteristic changes every time. Such frequency selected fadings (FSF) make intersymbol interference (ISI) of digital signals. They are caused by interference of neighbour symbols of transmitted sequence.

2. Description of the method

Various methods of decreasing of negative consequences of ISI are known [2]. Some of them use knowledge of channel frequency characteristic in order to correct partly signal spectrum distortion. Here is used information that is obtained by periodical test seances, though non-test methods using measurement of some symbol sequence characteristics are known [3].

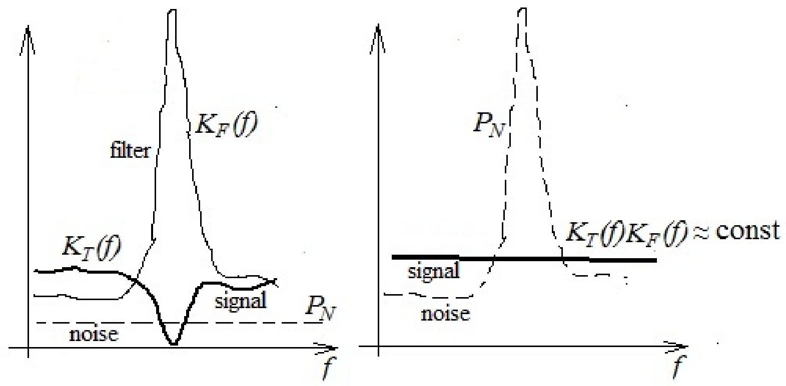
In receiver such methods of frequency correction can be realized variously but all of them come to additional signal spectrum distortion. Distortion are based on signal passing through filter with changing frequency characteristic $K_F(f)$ that is approximately equal to $1/K_T(f)$. So, form of characteristic become approximately uniform and negative effects of ISI diminish.

Distortion of transmitted signals can also be carried in transmitter. It can be accomplished in double-sided transmission systems when information about current channel characteristics is translated from receiver backwards to transmitter. Distortions are carryed in spectrum of transmitted signal. The operation consists of signal passing through the filter with frequency characteristic near to $1/K_T(f)$, so that after passing the channel the form of summing frequency characteristic begin to be near to uniform. Such steps reduce negative consequences of ISI but results may be small or may be absent because other negative factors may increase.

Firstly let us examine method of putting distortions in receiver. (It is illustrated by figures 1a and 1b). Let initial transmitted signal spectrum is near to uniform, then after influence of fadings it will change to $K_T(f)$ (figure 1a). After the filter with inverse characteristic it will be corrected (figure 1b). However, if before correction noise power had uniform spectrum characteristic, then after correction some places where channel characteristic gaps are situated noise power may increase greatly. Such important parameter as error probability depends on noise level and worsening of this parameter owing to noise may prevail on its improving because of decreasing ISI.

Then let us examine method of putting distortions in transmitter. (It is illustrated by figures 2a and 2b). Figure 2a is corresponded to absence of distortions. Practically all technical possibilities of transmitter are used, so signal has maximal power P_{MAX} of last cascades, it provides maximal signal/noise ratio in receiver and minimal error probability. So, we can think that power $P(t)$ of transmitted signal (for example with BPSK modulation) is constant and is near to its middle power P_{CP} and is equal to maximum transmitter power. In this case pic-factor of signal has its minimal level.

Figure 2b corresponds to using distortion in transmitter. The form of every symbol changes after passing through distortion filter. (For example in BPSK modulation before filter it was uniform but after filter it acquire complicated form that depends on current frequency characteristic of the filter.)



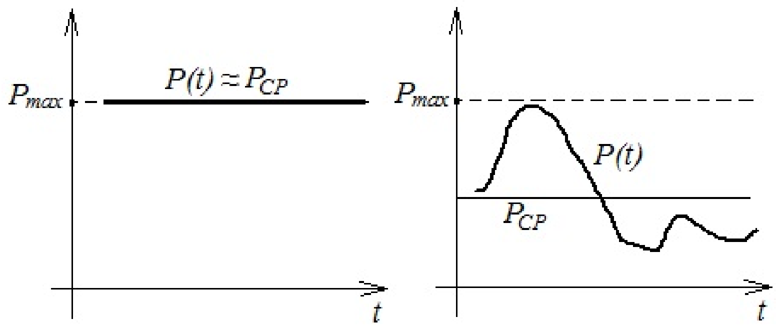
a) b)

Figure 1. Putting predistortions in receiver.

In any case level of signal pic-factor increases and signal middle level will be considerably smaller then signal maximum level. To compensate ISI we must transmit signal with proper changed form after filter. So long as maximum signal level is determined by maximum transmitter power then middle signal level is considerably smaller in comparison of situation without correcting filter. It causes decrease of middle signal/noise ratio in receiver and increase of error probability.

So, examined situations show that use of such «physical» distortions for ISI diminishing in many situations does not give positive effect. Another method of predistortion of transmitted signal can be proposed using not «physical» but logical predistortions (distortions of logical form of transmitted digital signal before modulation).

Let us examine essence of proposed method in general. Let us designate some N digital symbol sequence as a vector $\mathbf{x}_i$, where i is a number of variant of such sequence. (In all may be 2^N variants of sequence.) Order of variant numeration is not essential, so index of number 1 will correspond to practically transmitted variant of digital sequence in communication system.



a) b)

Figure 2. Changing pic-factor in transmitter.

Symbols are transmitted through communication channel after coming from source of information and after modulation. In channel they are undergone ISI then they are demodulated in receiver and form received sequence described by vector $\mathbf{y}_i$. In general all these transformations can be described by some operation M, that is $\mathbf{y}_i = M\{\mathbf{x}_i\}$.

If noise and ISI are absent then $\mathbf{y}_i = \mathbf{x}_i$. Influence of ISI results in non-coincidence of sequences $\mathbf{y}_i$ and $\mathbf{x}_i$. Measure of their difference is equal to Hamming distance and characterizes negative influence of ISI. This fact is illustrated by figure 3. All amount of possible sequence variants may be describe by some discret space L that contains 2^N elements. Transmitted signal vector $\mathbf{x}_1$ disposes in the space as an element. By operation M it is transformed into other element $\mathbf{y}_1$ that also is disposed somewhere in this space. By operation M other possible variants of sequence (elements $\mathbf{x}_i$, $\mathbf{x}_j$, $\mathbf{x}_k$,…) are transformed into according elements $\mathbf{y}_i$, $\mathbf{y}_j$, $\mathbf{y}_k$, … Metrics of such a space is Hamming distance.

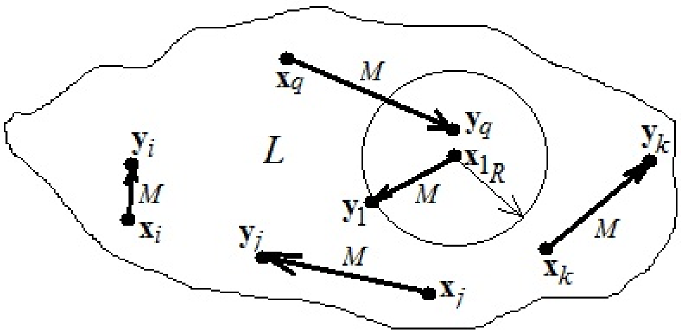


Figure 3. Space of variants of transmitted and received sequences.

Let Hamming distance between $\mathbf{x}_1$ and $\mathbf{y}_1$ is equal to R. We shall examine sphere of radius R around element $\mathbf{x}_1$. This sphere contains some elements of the space. Let $\mathbf{y}_q$ is one of these elements. Element $\mathbf{x}_q$ is its initial element. (It may dispose in the sphere or out of it.) It means that after transmitting sequence $\mathbf{x}_q$ instead of sequence $\mathbf{x}_1$ through channel with ISI the result of demodulation in receiver will be nearer to the initial sequence of information source than $\mathbf{y}_1$. So, negative influence of ISI will be partly corrected «automatically».

Number of elements same as $\mathbf{y}_q$ may be not one inside the sphere with radius equal R. The nearer element $\mathbf{y}_q$ to $\mathbf{x}_1$, the better will be eliminate negative influence of ISI. So long as logical sequence $\mathbf{x}_q$ differs with logical sequence $\mathbf{x}_1$ then translation $\mathbf{x}_q$ instead of $\mathbf{x}_1$ may be considered as carrying logical predistortions in sequence $\mathbf{x}_1$. Task of the method is search of best variants of such sequences.

Effectiveness of the method depends on current state of communication channel. In general number of elements $\mathbf{y}_i$ is smaller then 2^N, so as middle Hamming distance between neighbour elements is bigger then one. However space L is packed by elements $\mathbf{x}_i$ closely. Ties between elements $\mathbf{x}$ and $\mathbf{y}$ may be analyzed in «inverse» direction. Every element $\mathbf{y}_q$ coincides with some element $\mathbf{x}_i$. Hence if sequence $\mathbf{x}_i$ was transmitted then using described method (transmitting sequence $\mathbf{x}_q$ instead of $\mathbf{x}_i$)

influence of ISI can be eliminated. Using translation of sequence $\mathbf{x}_q$ instead of nearest "neighbours" of element $\mathbf{x}_i$ (those do not coincide with any elements $\mathbf{y}_q$), also we succeed to decrease negative influence of ISI. Thus, at the average described method allows to increase essentially steadiness of communication to intersymbol interference.

3. References

[1] Polushin, P.A. Redundancy of signals in radio communications / Polushin P.A., Samoylov A.G. – M.: Radio engineering, 2007. – 256 p.
[2] Prokis, J. Digital communication / J. Prokis. – M.: Radio and communication, 2000. – 800 p.
[3] Polushin, P.A. Methods to combat intersymbol interference / P.A. Polushin, D.A. Martyshevskaja. – Saarbrucken, Germany: Palmarum Academic Publishing, 2016. – 144 p.