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SUCCESSIVE INTERFERENCE CANCELLATION IN TREE ALGORITHMS OF RANDOM MULTIPLE ACCESS



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Abstract — Nowadays Wireless Broadband Networks (WBN) are dynamically developed sphere of science and technology. The given work is devoted to analysis of Random Multiple Access method called Successive Interference Cancellation (SIC), which is widely used in IEEE 802.16 standard. The direction of research is rather up-to-date and its importance is very high. We only use the Kalman filtering techniques to reduce distortion, which has a positive effect on the main index of the tree algorithms — the speed of conflict resolution.

After analysis it is clear that among the various methods of random multiple access to the highest potential speed of conflict resolution have a tree algorithms using SIC. Potential SIC algorithms properties can be implemented in condition of the adjacent slots signal structure identity, one hundred is achieved by selecting amplitude — phase equalizers. An efficient algorithm for the amplitude and phase equalizer can be obtained, if taken into account the statistical structure of the received signals, taking into account the correlation of these signals on adjacent slots, the degree of coherence of the received signals, which directly determines the magnitude of the sampling step for transmitting a reference signal and the number of taps of the delay line.

Анотація — Ця робота присвячена аналізу методу випадкового множинного доступу SIC, який широко використовується в IEEE 802.16. Запропонований метод базується на використанні інтегровано-степенного полінома Вольтерра 1-го роду для моделювання багатопроменевого каналу розповсюдження радіосигналу і фільтра Калмана-Б'юсі при реалізації алгоритму амплітудно-фазового вирівнювача.

Аннотация — Данная работа посвящена анализу метода случайного множественного доступа называемого последовательным подавлением помех (SIC), который широко используется в IEEE 802.16. В предлагаемый метод базируется на использовании интегро-степенного полинома Вольтерра 1-го рода для моделирования многолучевого канала распространения радиосигнала и фильтра Калмана-Бьюси при реализации алгоритма амплитудно-фазового выравнивателя.

Introduction

Among the various methods of multiple (multistation) access in wireless communication most popular are methods of random multiple access (RMA). There are a lot of RMA methods including ALOHA, Binary Exponential Backoff), tree algorithms [1]. The most important characteristic of these methods is the collision resolution interval (CRI). Collision happens when two or more subscribers at the same time pretend to base station or repeater resource. An indicator of CRI speed is the ratio [2]:

$$V = \frac{k}{T_k},$$

where k — collision multiplicity, T_k — collision resolution interval (CRI).

The first was ALOHA algorithm, which is used with various modifications to the present. This algorithm is not widely used nowadays because of (из-за) random delay se-

lection mechanism which is too (очень) extensive and in modern broadband wireless systems such as WiMax, LTE, instead of these algorithms it is recommended to use BEB and tree algorithms, wherein CRI is largely determined, and the CRI speed reaches 0,3—0,4. With additional measures, using a consistent noise compensation (Successive Interference Cancellation — SIC), this rate can reach 0.6 or more [2]. Let us consider in detail the procedure for the tree algorithm and evaluate the possibility of its effective use.

I. The functioning of tree algorithms

For successful work methods such as RMA BEB and tree algorithms in a wireless communication system require tight synchronization of all subscriber stations (SS) and the BS. Another important limitation is that by the end of the subscriber information transfer BS has to give feedback information about transmission success or failure. All further actions in the system depend on the chosen method of RMA.

With traditional tree algorithms in the presence of conflict in the BS is the identification of conflicting SS. After a conflict is detected BS authorizes to transmit a packet one of the speakers in the next slot. The rest of the conflicting packets (or packet) is transmitted in the third slot (fig. 1).

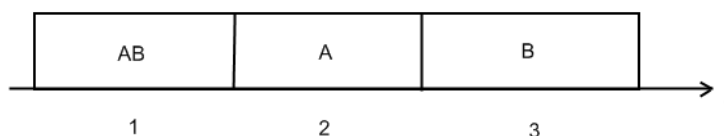


Fig. 1. Structure of packet A and B conflict in the first slot.

The feature of SIC algorithm, applied to the situation in fig. 1, is that in the third slot there is no need to pass the packet. This packet can be obtained (calculated) from the signals of the conflicting packets $A + B$, by subtracting the (compensation) of this amount, a signal relating to A packet, adopted in the second slot. Obviously, to perform these operations you must fulfill a number of conditions:

- all information that was received in the 1st slot should be kept in memory until the end of the conflict;
- noise is not expected to significantly distort the structure of the received signals, i.e. S/N ratio should provide reliable reception with error probability $P_e \leq 10^{-5} \dots 10^{-6}$;
- amplitude-phase structure of the signals A, taken in the 1st and 2nd slots must be identical.

The first requirement can be satisfied by using the appropriate components. The second limitation is related to the presence of external and internal thermal noise. There are a number of methods, e.g. those based on cryogenics, able to solve the problem of minimizing internal noise. The subject of a more detailed discussion is the third limitation discussed below.

II. Adjacent slots signal structure identity ensuring methods

Structural differences of signals in adjacent slots are due to the influence of medium randomness and multipath propagation. In the presence of random parameters changes of Gaussian nature in the distribution channel, these differences are inversely proportional to the correlation levels of these processes on the adjacent slots. However, in real radio lines these differences always occur, and they correspondingly reduce compensation algorithms quality of SIC. In this case, to equalize the structures of the signals a constructive approach is proposed where at each regular slot this structure will be compared and adjusted with respect to some reference signal, transmitted along with the information signal.

III. Propagation channel model

In many practical problems it is necessary to obtain the output signal of a radio-electronic device of a given structure. The deviation of the actual received signal from a given structure can occur, for example, by the distortion, the presence of additive and multiplicative noise in the communication line. Thus, in conditions of multipath propagation in the line of radio pulse shape information spreads, the amplitude and phase are distorted. The model of the distorted signal general case can be written as an integro-power polynomial Volterra of the first kind [3]:

$$y(t) = \sum_{m=1}^N \int_0^t \dots \int_0^t K_m(S_1, S_2, \dots, S_m) \prod_{i=1}^m x(t - S_i) dS_i, \quad t \in [0, T], \quad (2)$$

where K_m – Volterra kernels for the stationary case are symmetric in all variables. The block diagram that implements the procedure (1) is shown in fig. 2.

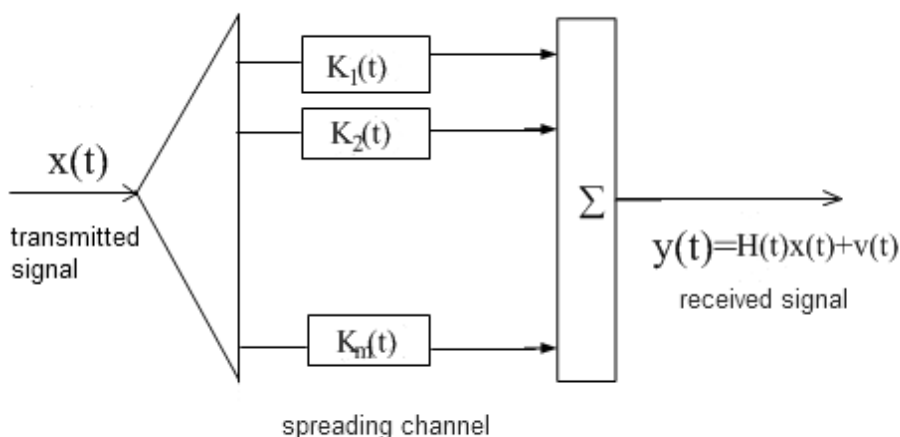


Fig. 2. Equivalent structural diagram of signal transmission system through a multipath channel (2).

Multipath signal components are represented as:

$$y_i(t) = \int_0^t K_i(t, S_i) x(S_i) dS_i, \quad i = 1, 2, \dots, N, \quad (3)$$

where $K_i(t, S_i)$ – are complex functions in general. Thus, each kernel provides the corresponding changes in amplitude and phase of the partial signal. A model of the communication channel depends on the amplitude variation range and resulting signal phase. For example, representation of a signal through the quadrature components is often used in communication theory

$$y(t) = \sum_{i=1}^N y_i(t) = A(t) \cos(\omega t + \varphi(t)) = \\ = A(t) \sin(\varphi) \sin(\omega t) - A(t) \cos(\varphi) \cos(\omega t) A_s(t) \sin(\omega t) + A_c(t) \cos(\omega t) \quad (4)$$

where $A_s(t)$ and $A_c(t)$ – are sine and cosine quadrature, respectively.

Thus, the Rayleigh distribution corresponds case when the mean values of $A_s(t)$ and $A_c(t)$ quadratures are equal to zero, dispersion are the same ($\sigma_s^2 = \sigma_c^2$), while quadratures themselves are independent. Phase of the signal

$$\varphi(t) = \operatorname{arctg} \frac{A_s(t)}{A_c(t)}$$

is equally distributed on interval $t \in [0, T]$.

To correct gained distortions in channel inverse transformation must be done (3). Such transformation is possible in view of the nuclei symmetry. This problem can be solved by ensuring conditions for the distortions effects observability. For this we usually use periodic test signals transmission, whose structure is known in advance. In this case, the difference of the signal with the reference

$$\Delta y(t) = y(t) - y_e(t). \quad (5)$$

The problem of corresponding coefficients management can be solved in order to minimize the difference (5). There is a problem of management supervision [4] based on the discrepancy.

IV. Choice justification of received signals correction device structure

During selection of a correction device structure raises there emerged the problem of limitations within which an optimization problem of distortion level minimization $\Delta y(t)$ can be solved. The important factor is the selection of required number of correlation branches N . Obviously, there must be done the condition $N \geq 2$, that the appropriate choice of the amplitudes and phases of the weights in the branches of the correction will provide mutual compensation of distortion. By $N = 2$ distortions reflect the situation with a flat phase front in the elements of the spatial signal $x_i(t)$. If $N = 3$, you can display non-linear parabolic form of the phase front. If the receiver is implemented in the form N – element antenna array, the size of the aperture D must be compared with the radius of spatial correlation ρ . Obviously, if $D \ll \rho$, when all the spatial structure of the signal $x_i(t)$

phase front will be perceived as flat. At the same time using only one receiving antenna, a model of the statistical structure of the multipath signal should be selected on the basis of the above representations.

Another limitation of choice is the repetition period of the test signals. This option should be compared with the interval of correlation or random changes in the signal. Obviously in order to compensate random changes, repetition period must be such that during this time there was no noticeable change of nuclear functions. The experience of practical usage of similar algorithms shows that the results are valid if the period are chosen from the conditions

$$T_T = \frac{\tau_K}{10}, \quad (6)$$

If the correlation falls in the interval of about 100 Sampling of values, the results are good enough, less than 1% of distortion remain uncompensated.

Ranges of changes controls for amplitude and phase signal compensation usually agree with the statistics of the channel (Rayleigh, Rice, etc.) and the regulators themselves are made with the use of quadrature expansion, which allows you to stay within the linear control algorithms procedures.

V. Synthesis of received signals distortion compensation device in multipath channel

Weighting factors, ensuring compensation of the distortions created by the nuclear functions — form a vector and represent a random process. The differential equation of state can be used as mathematical models of these processes [4]:

$$\frac{dw(t)}{dt} = F(t)w(t) + G(t)\xi(t), \quad (7)$$

where $F(t)$ and $G(t)$ are the state and generation matrices, $F(t)$ matrix elements are the values α_{ij} the inverse correlation intervals of the multidimensional process $w(t)$, $\xi(t)$ — generating a Gaussian white noise (GBSH) with the spectral power density.

For a digital implementation of commonly used procedures for evaluation and management (7) takes the form:

$$w(k+1) = \Phi(k+1, k)w(k) + G(k)\xi(k), \quad (8)$$

where $\Phi(k+1, k) = \exp\{-\alpha\Delta t\}$, $\alpha = \frac{1}{\tau_k}$, $\Delta t = T_T$ — recursive procedure sampling step (8),

$$G(k) = \sqrt{\sigma_w^2(1 - \exp\{-\alpha\Delta t\})}.$$

To obtain an optimal weight vector (WV) $\hat{w}(k)$ we use the Kalman-Bucy procedure [4]:

$$\hat{w}(k+1) = \Phi(k+1, k)\hat{w}(k) + M(k)[y(k) - y_e(k)], \quad (9)$$

where $y(k) = \hat{w}(k)x(k) + v(k)$, – observation equation of the desired signal to background GBSH $v(k)$ with the spectral power density N_v . Fig. 3 shows a block diagram of the device receiving the correction signal.

Coefficient $M(k)$ – is an analog of the constant close proximity to the Widrow-Hoff procedure, which is optimal for the situation, where $K_i(k)$ – random processes, in accordance with FKB:

$$K(k) = P(k)Y^T(k)N_0^{-1}, \quad (10)$$

where $Y(k)$ – vector of the received signal at the output of the delay line (DL), where the taps of DL follow in time intervals $\tau_i, i = 1, 2, 3, \dots, N$. Here $\sum_{i=1}^N \Delta\tau_i = \tau_k$ – coherence interval of multipath signal received.

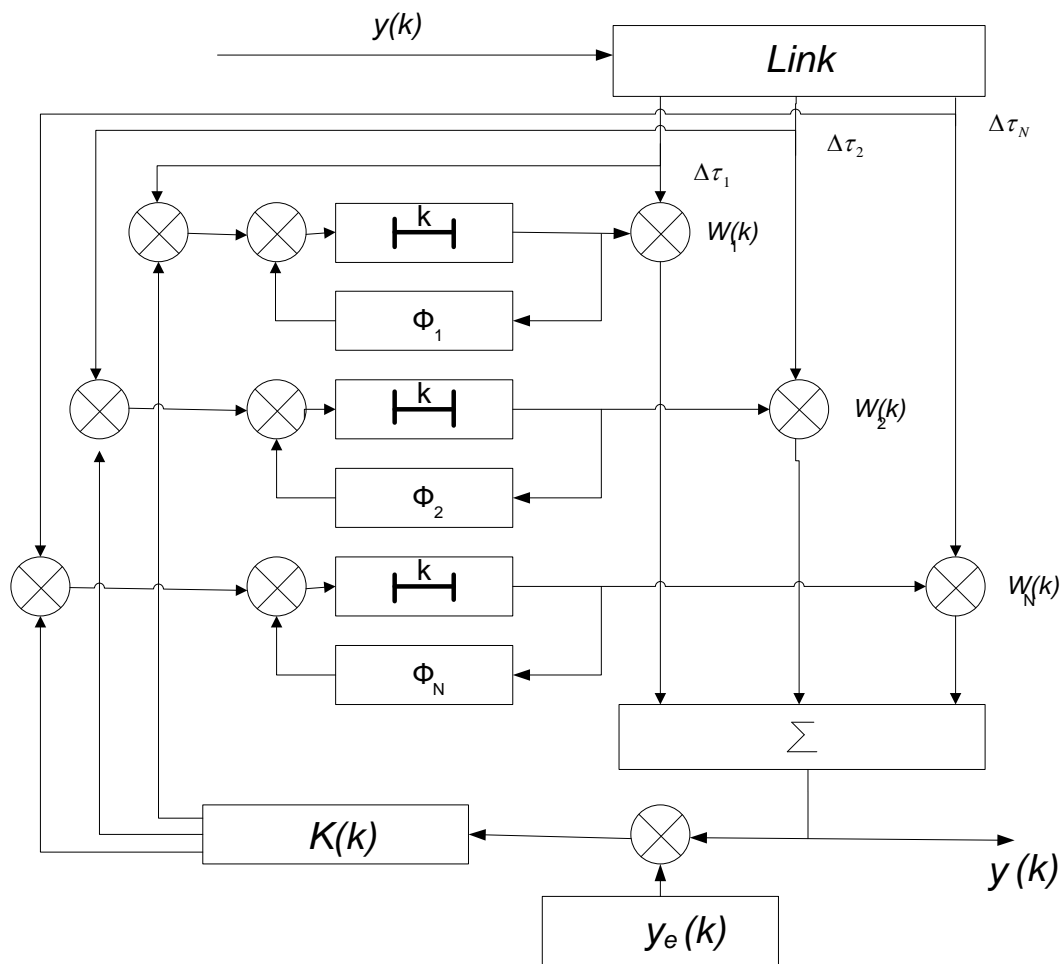


Fig. 3. Block diagram of received signals correction device

Conclusion

Among the various methods of random multiple access tree algorithms using SIC has the highest potential speed of conflict resolution have. Potential SIC algorithms properties can be implemented in condition of the adjacent slots signal structure identity, one hundred is achieved by selecting amplitude-phase equalizers.

An efficient algorithm for the amplitude and phase equalizer can be obtained, if taken into account the statistical structure of the received signals, taking into account the correlation of these signals on adjacent slots, the degree of coherence of the received signals, which directly determines the magnitude of the sampling step for transmitting a reference signal and the number of taps of the delay line

A good mathematical model of multipath signal propagation channel can be an integro-power polynomial Volterra of the first kind with which adequately both linear and nonlinear situations can be displayed.

The optimal procedure for the implementation of the algorithm of amplitude-phase equalizer is the Kalman-Bucy filter.

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