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ON THE ISSUE OF SOLVING THE PROBLEM OF ELECTROMAGNETIC COMPATIBILITY OF THE WIRELESS TELECOMMUNICATION SYSTEMS

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The main condition for ensuring electromagnetic compatibility in mobile communication systems is an increase in the signal-to-noise ratio. To implement this, methods are used that combine the dynamic change in transmitter power, the organization of multiple access and the dynamic allocation of communication channels. It is shown that the most effective and promising direction for solving this problem is the use of noise-like signals.

Keywords: telecommunications, electromagnetic compatibility, noise-like signal, wireless communication, mobile device.

INTRODUCTION

The main purpose of wireless telecommunication systems (WTS) is the quality of service (QoS) of a large number of consumers. Trends in the development of the WTS demonstrate both the continuous growth of mobile traffic and the information capacity of the entire system as a whole. Ensuring high-quality joint operation of such a great number of devices is a difficult task. At the same time, an increase in the number of connected mobile devices entails an increase in the requirements for the medium of information transfer.

It is well known that the quality of services provided to the consumer is determined by the requirements of electromagnetic compatibility (EMC) of the WTS, in particular, by the signal-to-noise ratio (S/N) P_s / P_n. In a case when the bandwidth ΔF is given, a value of this ratio contributes to the quality of the services provided to the consumer and determines the throughput of the communication channel, irrespective of the way the information is transmitted, i.e.

$$C = \Delta F \cdot \log_2 \left(1 + \frac{P_s}{P_n} \right), \qquad (1)$$

where P_s is the power of the useful signal and P_n is the noise power. The value of C is customarily measured in bit per second.

The purpose of this paper is a determination of the conditions for ensuring EMC requirements in the WTS.

I. DESCRIPTION OF THE WAYS FOR INCREASING QOS

One of the ways to improve the criterion of the QoS is known to increase the power of the emitted signal while reducing the level of a noise (interference) and increasing the ratio S/N. However, as the power of the radiated signal increases in one of communication channels, the level of the noise in adjacent channels increases and, as a consequence, the ratio S/N decreases. On the other hand, as the signal power decreases, the information capacity of the WTS decreases and the number of consumers decreases. Moreover, to ensure high quality of the signal, it is necessary that the power of the received signal significantly exceeded background noise.

1. One of way to solve this problem is ***the method of dynamic change in transmitter power*** in the communication channel, depending on its state. Dynamic power control depends on the mobile device, and without considering the response of the base station, it continuously transmits the unmodulated pilot signal. This signal allows the mobile device to synchronize with the forward channel from the base station to the mobile device, which gives the reference phase for demodulation. It should also be used to monitor power. The mobile device monitors the power level of the received pilot signal and sets the transmitted power in the reverse channel from the mobile device to the base station, inversely proportional to the signal power. With this approach, the intensities of the signals in the forward and reverse communication channels are to be highly correlated. The circuit allows you to respond to fast signal intensity fluctuations. Such a fast response is required in the reverse link, where, with a random increase in the intensity of the received signal, all other signals can be suppressed at the base station. When controlling closed loop power, the signal strength in the reverse channel from the mobile device to the base station is equalized. This takes into account the characteristics of this reverse channel, such as the power level of the received signal, the signal-to-noise ratio or the frequency of the occurrence of erroneous bits in the received signal. The base station makes a power control decision and transmits the power control commands to the control channel of the mobile device. Closed-loop control is also used to equalize the power in the forward channel. In this case, the mobile device provides the base station with information about the quality of the received signal, and then the base station adjusts the transmitted power. In addition, the effects of reflection, diffraction and scattering can cause a rapid change in the levels of received

power, even at short distances. Due to different paths of propagation of radio waves (multipath propagation), interference of signals occurs, which creates a complex electromagnetic situation at the receiving site. The digital encoded signal comes in the form of several copies shifted in time. However, if the difference in the shift is greater than the duration of one pulse, the receiver is synchronized with the most powerful component of the received signal, while the rest are discarded. This ensures the resistance to multipath signal propagation.

2. An increase in the ratio S/N in the WTS is also possible due to the formation of the corresponding directivity diagrams of antenna systems [2]. Such an implementation is achieved by using ***the multiple access method***. For this, a request is made for the organization of a temporary communication channel. In this case, a circular pattern (CP) of the antenna system is used. Then the coordinates of the mobile device are determined. With the help of a digital antenna array (DAA), during a communication session, a highly directional CP is formed at the request source, increasing the ratio S/N by several orders of a magnitude. The conducted simulation showed the possibility of organizing with the help of the DAAs up to 8 simultaneously operating independent communication channels [3].

Fig. 1 shows the results of modelling the 12-element antenna array. At the same time, the coordinates of the interference sources are determined and they form CP with the minimum antenna directivity factor, making the ratio S/N in the given direction minimal.

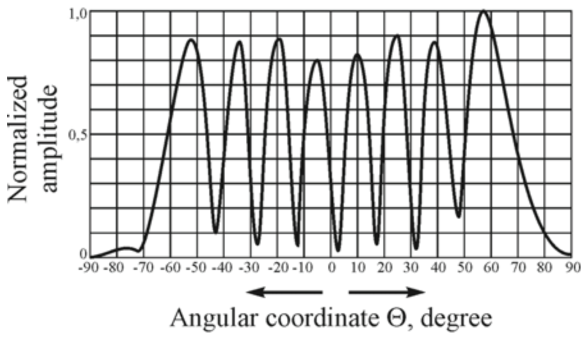

Fig. 1. Results of modelling

3. The air interface DECT (Digital European Cordless Telecommunications) is summoned to ensure the electromagnetic compatibility of equipment from different manufacturers. The base stations and subscriber terminals constantly scan all 120 available communication channels, while measuring the signal power in each of them. When establishing a new connection, the mobile device selects the channel with the lowest interference value. Thus, ***the method of dynamic channel allocation*** allows you to avoid frequency planning. Dynamic switching between channels is also possible during a communication session, since the mobile device continues to constantly analyze the level of noise (interference) in the available communication channels even when establishing a connection. Moreover, switching is possible both to another channel of the same base station and to another base station. An essential fact to ensure the requirements of EMC for the WTS is the low power of the emitted signal – from 10 to 250 mW. This allows you to locate the base stations in close proximity to one another, which allows you to achieve a record density of simultaneous connections (up to 10,000 Erl./km^2) with the most efficient use of the radio spectrum (500 Erl./MHz/km^2).

The physical limitations of the frequency resource and the need to improve the performance of communication channels in the transmission of information forces one to use complex signals that significantly improve the quality of information. Due to the fact that information is an ordered set of fixed symbols of an arbitrary nature, the theory of information should be considered as the mathematical basis of the theory of communication [3]. It is designed to address the challenges of improving the performance of communication systems. These are tasks of formalizing the description of information sources, their optimal coding, and also determining the maximum permissible bandwidth (1) of communication channels [4]. At the same time, information theory is designed to optimize communication systems as a whole by solving multicriterion problems taking into account mathematical models of various elements. Thus, it is possible to obtain high information transmission rates by creating superdense communication channels using signal-code structures for the transmission of information. They provide a data transfer rate close to the capacity of the communication channel (1).

4. One such practical solution is the use of ***noise-like (ultrawideband) signals***. These are signals in which the width of the spectrum is commensurable with the central frequency [5]. In this case, as it is shown in [6], the information is encoded by means of time-position-pulse modulation. The displacement of the pulse relative to its nominal position in the forward sequence sets "0", and backward "1". Moreover, the magnitude of the displacement should not exceed a quarter of the pulse duration. So, for example, in a sequence of pulses of 0.5 ns the duration with a pulse interval of 100 ns, the pulse that arrived 100 ps before is zero, and the one that arrives 100 ps later is a unit. One information bit is encoded by a sequence of many pulses, for example, 200 pulses per bit. As the encoding pulse, a Gaussian monocycle is used, which is described by the first derivative of the Gaussian distribution function

$$A(t) = A_0 \sqrt{2e}\,\frac{t}{\Delta t} e^{-(t/\Delta t)^2}, \qquad (2)$$

where Δt is the pulse duration and A_0 is the amplitude of the pulse. The general view of the Gauss monocycle is shown in Fig. 2.

The shape of the power spectrum of such a pulse is described by the relation

$$S(\omega) = A_0 \sqrt{2\pi e} \cdot \omega \cdot \Delta t^2 \cdot t \cdot e^{-\left(\frac{\omega^2 \cdot \Delta t^2}{2}\right)^2}, \qquad (3)$$

where ΔF is the width of the power spectrum of the pulse (Fig. 3). In this case, the base of the ultrashort pulse is $B = \Delta t \Delta F \approx 1$. So, for example, when using pulses of duration Δt from 2.0 ns to 0.1 ns, the bandwidth of the power spectrum is, respectively, from 500 MHz to 10 GHz, and the signal spectrum will occupy the frequency band from 0 to $\Delta F \approx 1/\Delta t$.

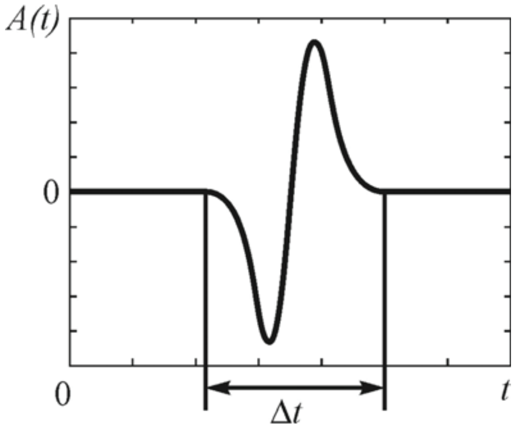

Fig. 2. Gauss monocycle shape

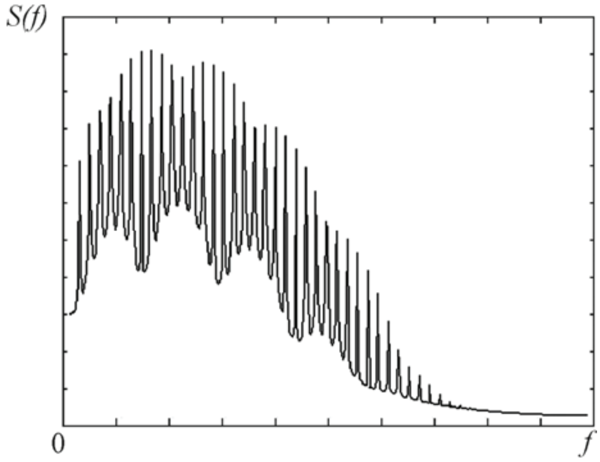

Fig. 3. Spectrum of the Gauss monocycle

To encode an information symbol, it is not single ultrashort pulse that is used, but their sequence. When using a sequence of ultrashort pulses, the signal base increases in proportion to their number. However, a regular sequence of such pulses does not carry any information. Its spectrum has a pronounced comb nature. Thus, such a signal can interfere with other radio engineering systems. To eliminate interference and organize independent channels in one frequency band, the position of each pulse is shifted by the time proportional to the current value of some pseudo-random sequence. In this case, the shift time is one or two orders of magnitude higher than the time shifting. As a result, the signal spectrum is substantially smoothed out, becomes noise-like and no longer interferes with other devices operating in the same band. Using a system of orthogonal codes to control the time delays of pulses, there are up to a thousand voice independent communication channels per base station created in one band without the use of special algorithms for digital signal processing [7]. Using orthogonal pseudorandom sequences-special codes for identifying connections form separate communication channels protected from interference are formed. Due to the fact that all channels are located in a singlewide frequency range, the signal becomes noise-like. To isolate from the general cacophony of radio signals, the part that is intended for the given receiver, it is necessary to assign a separate numerical code for each user. All other signals will be perceived as noise. Thus, in a single frequency band, several transceivers that do not interfere with each other can operate. Due to the broadband signal, its power is reduced with a very long base, below the white noise level. Logical channels are formed by spreading the signal spectrum with Walsh sequences. Each of these sequences is one of the rows of the Hadamard matrix. Their main property is that all rows of the matrix and their inversion are mutually orthogonal [7, 8]. For example, the Hadamard matrix of the second order has the form

$$A_2 = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix},$$

but of the fourth order

$$A_4 = \begin{bmatrix} A_2 & A_2 \\ A_2 & -A_2 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix}.$$

For example, to extend the information flow, we use a 64-bit Walsh sequence. As a result, each information bit of the source stream corresponds to 128 output sequence chips. The gain in relation to s/i for the extended and original signal is 10 log 128 = 21 dB. Taking into account that the s/i ratio of 3 dB is acceptable at the receiver input, the transmission of information signals can be carried out at a signal level 18 dB below the level of interference disturbance.

Being synchronized with the transmitter and knowing the pseudo-random channel sequence, the correlator determines the deviation of the received pulses, forming at the output +1, if the signal, for example, came to 100 ps before the end of the interpulse interval, and -1 if it came to 100 ps is later and 0 otherwise. These values are accumulated in the integrator. As a result, narrowband interference from a transmitter with a continuous carrier or a signal from another impulse transmitter can prevent the reception of individual pulses, but not an information bit as a whole. The accumulated value of the correlator from random interference is 0. This allows you to avoid the interference of the signal that occurs when building communication within the premises and the conditions of complex terrain. The reflected signal enters the correlator with a delay and is perceived as a random interference, without affecting the direct signal in any way. Moreover, due to the broadband signal, its attenuation in various media is rather small. Short pulses easily pass through various obstacles, since signal suppression does not occur throughout the entire range.

To evaluate noise immunity, the notion of increased processing should be used. In spread spectrum systems, processing gain is defined as the ratio of the channel bandwidth to the bandwidth of the information signal. Thus, for systems of spreading the spectrum by the method of direct sequence with a channel width of 5 MHz and an information signal of 10 kHz, the gain is 27 dB. For the same signal transmitted by a 2 GHz bandwidth, the gain is 53 dB. Thus, because of the high effective amplification of signals in noise-like systems, they can operate with a very low average transmitter power (50 mcW – 2 mW). Therefore, they do not interfere with existing radio systems, working with them in the same frequency range.

One of the most important elements for implementing noise-like technologies are powerful pulse keys. They must have commutation fronts with a duration of about 10-100 ps with a megahertz repetition rate and very high stability. In this case, the commutated voltage is measured in hundreds and thousands of volts. To implement the method, it is required to create generators capable of generating ultrashort pulses of nano- and picosecond duration and a repetition rate of up to tens of megahertz. Moreover, the temporal position of these pulses should be determined with an accuracy of at least 10 ps.

II. ANALYSIS

The analysis shows that at low power noise-like systems are able to transmit data inside buildings and objects with complex architectures. A characteristic feature inherent in communication systems based on ultra wideband (UWB) signals is the high electromagnetic compatibility of existing communication systems. Small signal levels, use of coding and noise-like structure of UWB systems practically do not interfere with other devices, which allows in most cases to work on a license-free basis. Expansion of the communication channel band and transition to channels with an ultra-wide band allows practically unlimited increase in the number of communication channels. While signals between subscribers, their frequencies and types of modulation being distributed beforehand, communication is realized between subscribers without mutual listening and mutual interference. At the same time, multi-channel but time-separated communication does not require an increase in transmitter power, while simultaneous transmission of different information to several subscribers requires an increase in this power or a reduction in the information transfer rate. Another advantage of this system in comparison with conventional narrow-band systems is their weak sensitivity to the distortions in conditions of multipath propagation of radio waves. For transmission in UWB systems, very short pulses are used, so there are no intersymbol distortions, since the energy of the received pulse practically always has time to completely die out before the next copy arrives. The most important criterion, characterizing the efficiency of wireless communication systems, is the high potential specific density of data transmission. It is defined as the value of the achievable total data transfer rate per square meter of the work area and has the dimension "bit/s/m^2", and according to the results obtained, the UWB systems have the highest value of this indicator today – about 1 Mbit/s/m^2.

III. CONCLUSIONS

Thus, the main way to ensure the requirements of electromagnetic compatibility in mobile communication systems is to increase the ratio S/N. The implementation of this direction is carried out through the use of methods of dynamic change in transmitter power, organization of multiple access and dynamic distribution of communication channels. However, the most effective and promising direction is the use of noise-like signals.

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К вопросу решения проблемы электромагнитной совместимости беспроводных телекоммуникационных систем / А.А. Серков, Г.И. Чурюмов // Прикладная радиоэлектроника: науч. – техн. журнал. – 2017. – Том 16, № 3, 4. – С. 117 – 121.

Основным путем обеспечения требований электромагнитной совместимости в системах мобильной связи является повышение соотношения сигнал / шум. Реализация этого направления осуществляется за счет использования методов динамического изменения мощности передатчиков, организации множественного доступа и динамического распределения каналов связи. Показано, что наиболее эффективным и перспективным направлением является использование шумоподобных сигналов.

Ключевые слова: телекоммуникации, электромагнитная совместимость, шумоподобный сигнал, беспроводная связь, мобильное устройство.

Рис.: 3. Библиогр.: 8 назв.

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До питання вирішення проблеми електромагнітної сумісності бездротових телекомунікаційних систем / О.А. Сєрков, Г.І. Чурюмов // Прикладна радіоелектроніка: наук. – техн. журнал. – 2017. – Том 16, № 3, 4. – С. 117 – 121.

Основним шляхом забезпечення вимог електромагнітної сумісності в системах мобільного зв'язку є підвищення співвідношення сигнал / шум. Реалізація цього напрямку здійснюється за рахунок використання методів динамічної зміни потужності передавачів, організації множинного доступу і динамічного розподілу каналів зв'язку. Показано, що найбільш ефективним і перспективним напрямком є використання шумоподібних сигналів.

Ключові слова: телекомунікації, електромагнітна сумісність, шумоподібний сигнал, бездротовий зв'язок, мобільний пристрій.

Іл.: 3. Бібліогр.: 8 найм.