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REVIEWS - LETTERS - REPORTS

RADIO SIGNAL IN WLAN NETWORKS

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A lot of publications about WLAN (Wireless Local Area Network) have been released, some of them dealing with this network security, others describe the status of standardization development or offer various products from different prestigious producers. Only a few of them describe the structure of the physical — radio layer of this network. This paper describes the modulation schemes used in WLAN devices according to the most spread standard for WLAN, namely IEEE 802.11a/b/g made by the Institute of Electrical and Electronics Engineers.

According to IEEE 802.11a, WLAN networks operate in the frequency band marked as U-NII (Unlicensed National Information Infrastructure) which represents the bands 5.15−5.25 GHz; 5.25−5.35 GHz and 5.725−5.825 GHz and are able to offer 54 Mbit/s as the maximum bit rate. This standard specifies the physical layer for high bit rates, where the OFDM (Orthogonal Frequency Division Multiplexing) system is used as a basis. By means of this it is possible to create a WLAN network with communication capabilities of payload transmissions with data rates of 6, 9, 12, 18, 24, 36, 48 and 54 Mbit/s. The system uses 52 subcarriers that are modulated by Binary or Quadrature Phase Shift Keying (BPSK, QPSK), 16 or 64 state QAM — Quadrature Amplitude Modulation. For securing against transmission errors a convolution code is used with coding rate 1/2, 2/3 or 3/4.

Orthogonal Frequency Division Multiplexing is a multicarrier system, where the datastream is divided into several parallel carriers transmitted with a considerably lower symbol rate. The key of this system is that the distance between individual subcarriers equals to the integral multiple of the reciprocal symbol size. Thereby a state is achieved, where the individual subcarriers interfere neither with the main beam nor with the side bands, and at the top of the main beams all other components of the spectrum go through zero (Fig. 1). WLAN networks according to IEEE 802.11 use 48 subcarriers and 4 pilot signals, which gives 52 subcarriers together.

The aforementioned modulation schemes BPSK, QPSK, 16-QAM and 64-QAM are relatively well known and in practice often used methods of digital signal modulation. In the case of PSK the binary digits of the datastream sequence are transformed into a series of discrete phases of signal carrier. When using amplitude modulations, two individual symbols are transformed into two signal carriers. Representation of the mentioned modulation schemes in signal space — in IQ field is displayed in Fig. 2.

The required bit rate in WLAN network is achieved by using an appropriate combination of the code rate of the convolution code and modulation type, as displayed in Table 1, while the immediate configuration and thereby bit rate depend on the received signal quality and signal to noise ratio.

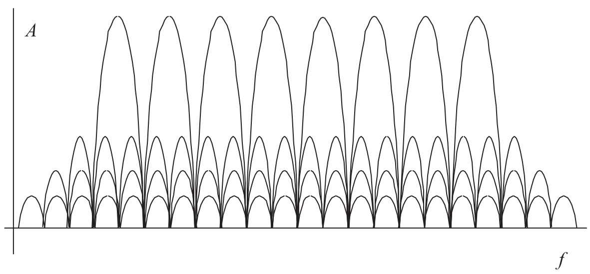

Fig. 1. OFDM spectrum

WLAN networks according to IEEE 802.11b operate in 2.4 GHz frequency band known as ISM (Industrial Scientific Medical). Using DSSS (Direct Sequence Spread Spectrum) as an access method, these networks offer a bite rate of 11 Mbit/s.

The purpose of DSSS is to spread the spectrum so that it is possible to operate with a low power signal level. The key of this system is replacing the signal in the baseband with an 11-chip PN code with 11 MHz frequency. The usage of DBPSK and DQPSK (Differential Binary-Quadrature Phase Shift Keying) as modulation schemes can achieve bit rates 1 Mbit/s and 2 Mbit/s. For higher bit rates, 8-chip CCK (Complementary Code Keying) is implanted into the modulation scheme, so 5.5 Mbit/s or 11 Mbit/s bit rate is achieved. This application of DSSS is also known as HR/DSSS (High Rate DSSS).

DBPSK and DQPSK modulations belong to a group of linear memory modulations and they do not come out of the absolute value of the phase of the carrier signal, but of the phase difference between the groups of symbols following in sequence. They are often used in practice and are well known.

For reduction of the CCK code words the following term is used. It is used for bit rates both 5.5 Mbit/s and 11 Mbit/s.

$$c = \{e^{j(\varphi_1+\varphi_2+\varphi_3+\varphi_4)}, e^{j(\varphi_1+\varphi_3+\varphi_4)}, e^{j(\varphi_1+\varphi_2+\varphi_4)}, -e^{j(\varphi_1+\varphi_4)}, e^{j(\varphi_1+\varphi_2+\varphi_3)}, e^{j(\varphi_1+\varphi_3)}, -e^{j(\varphi_1+\varphi_2)}, e^{j(\varphi_1)}\} \qquad (1)$$

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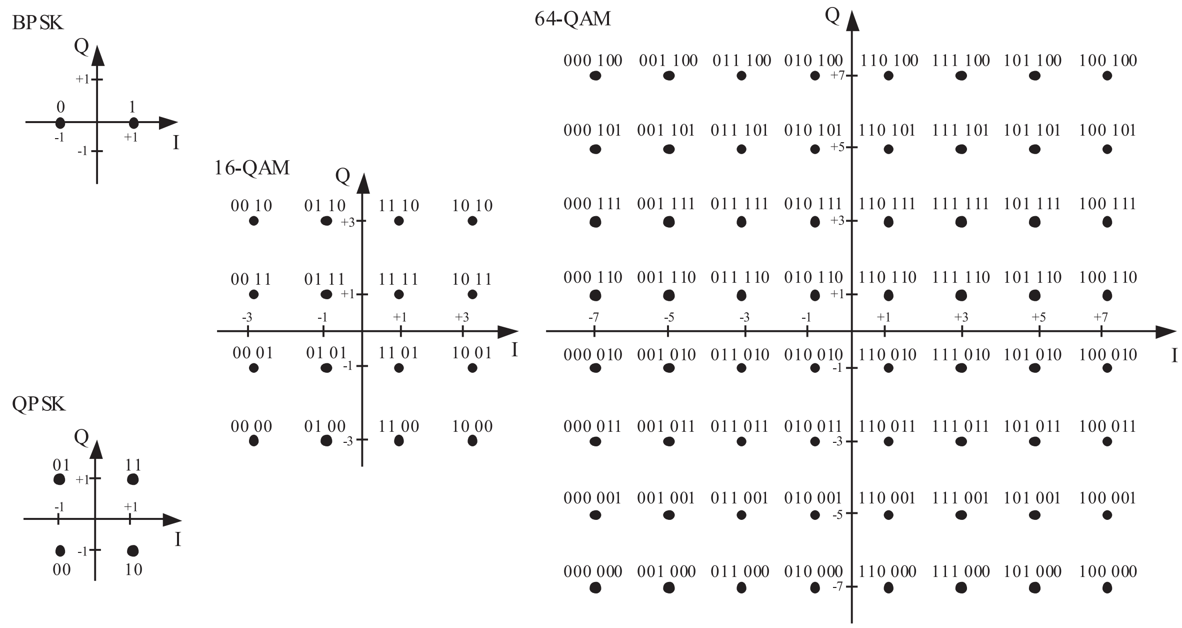

Fig. 2. Representation of BPSK, QPSK, 16-QAM and 64-QAM in signal space

Here φ_1, φ_2, φ_3 and φ_4 and are defined separately for rates 5.5 Mbit/s and 11 Mbit/s. By using this form we get 8 complex chips $c = \left(c_0, c_1, \dots, c_7\right)$. This is a form of generalized Hadamard transform encoding, where φ_1 is added to all code chips, φ_2 is added to all odd code chips, φ_3 is added to all odd pairs of code chips and φ_4 is added to all odd quads of code chips. Depending on the bit rate, by 5.5 Mbit/s 4 bits are transmitted per symbol and by 11 Mbit/s 8 bits are transmitted per symbol.

Table 1. Rate dependent parameters

Bit rate Mbit/s	Modulation	Coding rate	Coded bits per sub-carrier	Coded bits per OFDM symbol	Data bits per OFDM symbol
6	BPSK	1/2	1	48	24
9	BPSK	3/4	1	48	36
12	QPSK	1/2	2	96	48
18	QPSK	3/4	2	96	72
24	16-QAM	1/2	4	192	96
36	16-QAM	3/4	4	192	144
48	64-QAM	2/3	6	288	192
54	64-QAM	3/4	6	288	216

Standard IEEE 802.11g is an enhancement of IEEE 802.11b. WLAN networks according to this standard operate in 2.4 GHz ISM band, and IEEE 802.11g devices are usually retrocompatible with IEEE 802.11b devices. The main difference is the maximum bit rate, IEEE 802.211g networks offer 54 Mbit/s. The basic system offering physical layer bit rates 1 Mbit/s, 2 Mbit/s, 5.5 Mbit/s and 11 Mbit/s operate on DSSS, CCK principles or optional PBCC (Packet Binary Convolutional Coding). The physical layer bit rate extension lies in using the of DSSS-OFDM system, which is a hybrid modulation applying DSSS on header and OFDM on payload data, achieving bit rates 6, 9, 12, 18, 24, 36, 48 and 54 Mbit/s, or ERP-PBCC (Extended Rate Phy PBCC) system, which is a modulation scheme with a single carrier encoding payload data using 256 state binary packet convolution code, achieving bit rates 22 and 33 Mbit/s. The immediate bit rate of both systems depends on the received signal quality and signal to noise ratio.

WLAN networks are very popular present days among ordinary users and various network or Internet providers. Their great advantage is very simple and quite inexpensive realization. Indisputable disadvantages of these networks are often occurring interferences, because ISM and U-NII frequency bands are unlicensed, therefore even various noise resistant modulation schemes need not be able to guarantee the maximal bit rate of the system.

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