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CONTENTS

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System free of channel problems inherent in changing mobile communication systems

M. Bank

A proposal is put forward for an innovative method of multiple access, termed frequency Bank signal (FBS). The major advantage of FBS is that the error probability is almost non-sensitive to, either, the Doppler effect, separate signal delay or to the negative effect of reflected signals. In addition, FBS signals do not require special pilot or equalisation signals.

Introduction: **.**Mobile communication system problems such as Multipath Propagation (MPP) and Doppler Effect (DE) have deteriorated in effectiveness in recent times. This deterioration can be seen today in the increase of frequency by up to 10 GHz, and in vehicle speeds of up to 300 km/h. The OFDMA method combined with MPP offers slight improvement, but creates new difficulties consisting of orthogonality disturbance and channel changing during a long symbol. To date, these problems are dealt with through help channel estimations, pilot signals transmitting and through help effective Error Correction Codes. However, these methods significantly reduce system frequency efficiency, sometimes even doubling the reduction in efficiency.

Below is a proposal for an innovative mobile communication system. This informational transmitting signal system includes data about changing channel conditions without the use of redundancy. Variation in channel signals is compensated during the decoding process. Only regular synch signals (header) in the beginning of a long frame are transmitted, but channel estimation signals or pilot signals are not transmitted.

In [1], the author proposed a new method called the Frequency Bank Signal (FBS-I) method, which is a modification of the OFDM method combined with MPSK modulation. FBS-I employs a precoding scheme based on the Walsh sequence, to enhance the performance of OFDM-MPSK signaling. In this article, the FBS-I method is extended to allow for the application of the precoding method in MQAM-OFDM signaling [2]. This new method is named the FBS-II method.

FBS-II Method Theory: Assuming a single carrier MPSK or MQAM modulated signal, which transmits at the symbol rate R_S, one can transmit this signal on N sub-carriers using the OFDM method. On each sub-signal symbol, the rate will be R_S/N. The frequency difference between carriers will be $1/T_S$, where T_S is the symbol duration on each sub-carrier.

Let us assume the first symbol of first sub-signal *x(t)* to be:

$$x(t) = A\sin(\omega t + \varphi) \qquad (1)$$

We can break down this signal by orthogonal components I and Q, as follows:

$$I = A\sin\varphi \quad and \quad Q = A\cos\varphi \qquad (2)$$

We can transmit I and Q values on N sub-carriers corresponding to one Walsh function pair selected from a N×N Walsh-Hadamard matrix. For example, for one of N = 8 pair: 1 -1 -1 1 -1 1 1 -1 and 1 -1 1 -1 1 -1 1 -1

the following I and Q values will be transmitted, in reality:

I –I –I I –I I I –I
Q –Q Q –Q Q –Q Q –Q

For receiving transmitted sub-signals we must conduct opposite processing with the aid of the same pair of Walsh functions. The sum of all values in the first line is 8I and the sum of all values in the second line is 8Q. Using values for I and Q we can find values for A and φ. On the same N carriers we can transmit N/2 signals without mutual influences due to orthogonality of the Walsh function. For transmitting the same value of information on the same number of sub-carriers in OFDM and in FBS-II, we must double M in the case of FBS-II. For example, instead of QPSK in OFDM, we use 16QAM in FBS-II.

It is known that a change from QPSK to 16QAM must correspond with an increase of power by 4dB. Subsequently, the frequency band becomes twice as narrow. In our case, the frequency band remains at the same frequency since we have made use of the same sub-carriers. The signal to noise ratio also does not change. Actually, the same information is transmitted on N sub-carriers. Essential information (I and Q) is summed using an arithmetical method. However, noise components are summed using a root-mean-square method. As a result, the desired power in OFDM – QPSK and in FBS – 16QAM will be approximately the same.

The signal and apparatus: The sign of I or Q can be written as $I\cdot(-1)^{k_l}$ or $Q\cdot(-1)^{k_m}$, where k is 0 or 1. Let us transmit i^{th} symbol with amplitude $A_{i,j}$ and phase $\varphi_{i,j}$ of the j^{th} signal, where j is from 1 up to $N/2$. This symbol can be presented as a sum of two following orthogonal components:

$$I_{i,j} = A_{i,j}\sin(\varphi_{i,j}+\theta_j),\quad Q_{i,j} = A_{i,j}\cos(\varphi_{i,j}+\theta_j)$$

where θ_j is the initial phase, chosen for the j^{th} signal. θ_j eliminates possible mutual compensation of two components on one sub-carrier if these components have the same amplitudes and opposite phases.

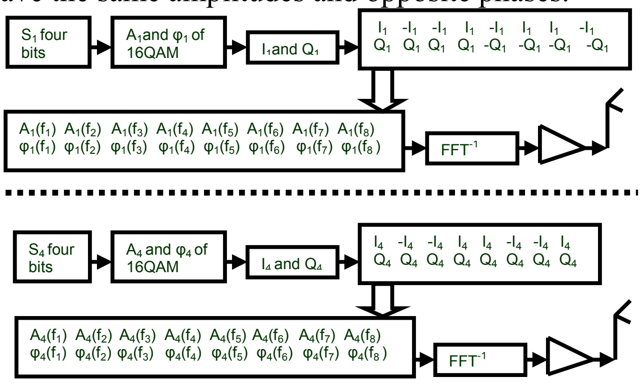

Fig. 1. Transmitter block diagram.

Using the line l of the Walsh-Hadamard matrix for I_j and the line m of the Walsh-Hadamard matrix for Q_j, we can present a FBS signal for transmitting this symbol as follows:

$$S_{i,j} = \sum_{k=1}^{N}\left\{I_{i,j}(-1)^{W_{l,k}}\cos 2\pi f_k t - Q_{i,j}(-1)^{W_{m,k}}\sin 2\pi f_k t\right\} \qquad (3)$$

where $W_{l,k}$ is the k^{th} value in line l of the Walsh-Hadamard matrix, $W_{m,k}$ is the k^{th} value in line m of the Walsh-Hadamard matrix.

Fig. 1 shows a FBS-II transmitter block diagram for transmitting four signals on 8 sub-carriers.

The FBS receiver block diagram (where one signal is received out of four transmitted signals) can be seen in Fig. 2.

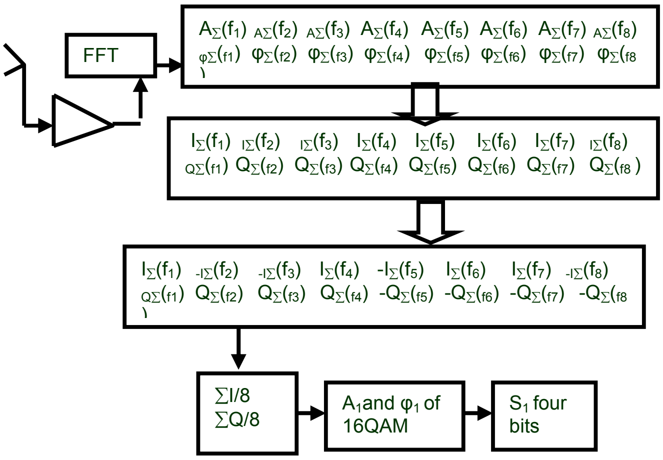

Fig. 2. Receiver block diagram.

FBS advantage: In the event of transmitting or receiving signals in mobile situations, the receiving signal parameters can be significantly changed. Out of all the elements of the signal, the phase of the signal changes the most, (see the example in the following section). Although, the signal amplitude does not change noticeably during a single frame, the Amplifier Gain Control in the receiver compensates for the change in amplitude.

In FBS-II systems, phase shift leads to increasing or decreasing I and Q values on all sub-carriers. The next example illustrates that when N = 8, after an opposite sign changing in the receiver has been performed, the result is that the phase shift disappears.

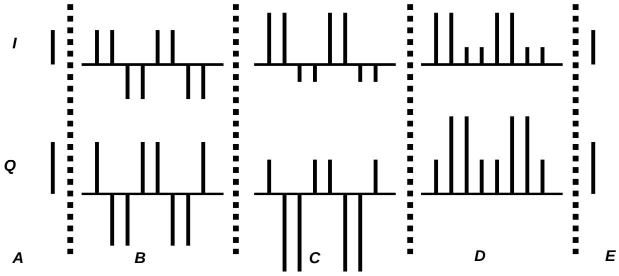

Fig 3. Illustration of I and Q values changing mutual compensation.

In Fig 3 one can see I and Q transmitting values – part A. In part B there are values of I and Q after sign changing which correspond to the correct Walsh function. In part C one can see a possibility of change in the channel. In part D there are I and Q values after performing opposite sign changing in the receiver. In part E we have mean values of I and Q, which equal to values in part A. It is evident in [2], that in the case of optimal distribution of Walsh functions for all I and Q channel influence compensation, the even phase shift is proportional to the frequency.

One of simulations results: A receiver is situated in the center of a 10 km diameter zone (cell). The receiver acquires signals from four transmitters located on the zone border. All transmitters can move with a speed of 120 km per hour. Let us assume that the reflected signal with maximal delay has 5 km additional way, i.e. maximal delay equals $T = 10$ μs. Let us choose a symbol duration of 100 μs. Therefore, the frequency difference between sub carriers will be $\Delta f = 1/T = 10$ kHz. A moving transmitter causes a phase shift and Doppler shift. Let the central carrier frequency be 10^9 Hz. The phase shift per one symbol time due to delay will be 3.9^0. The Doppler shift under these conditions can be 1% of Δf. OFDMA modulation is QPSK, and FBS modulation is 16QAM. In both cases, the bit-rate, frequency band and power are the same. There are pilot signals where OFDMA is used. Pilot signals are powered by using an extra 3 dB more than the power used in information signals.

One can see simulation results on Fig. 4. In the case of OFDMA frequency, efficiency is reduced by double. In the case of FBS, the channel has no influence on the receiving quality.

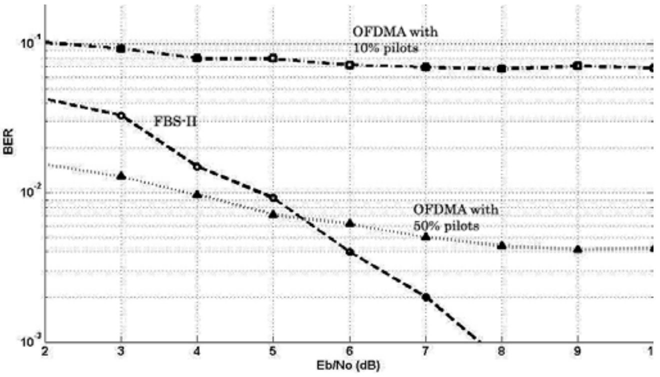

Fig 4. Simulation results.

Conclusion: By using the FBS method one can almost completely eliminate channel influence in mobile communication systems. This can be achieved without having to increase the power or the frequency band.

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