

## Wireless Mobile Communication Systems without Pilot Signals

MICHAEL BANK, MOTI HARIDIM Holon Institute of Technology, Israel,

BORIS HILL, MIRIAM BANK

**Abstract — In this article, I propose an innovative method of multiple access, known as Frequency Bank Signal (FBS). FBS combines the phase shift compensation used in the PAL-TV system, the OFDMA principle and the spread spectrum concept with Walsh functions.**

**The main advantage of using an FBS is that the error probability is almost non-sensitive to the Doppler Effect, separate signals delay and to the influence of fading. In addition, the FBS signal is free of special pilot, synchronization or equalization signals.**

**Index Terms — Mobile communication, OFDM, Doppler shift, delay, fading.**

### I. INTRODUCTION

Many in the mobile/wireless community believe that the future of such systems as the 3G cellular lies in OFDM-based systems. The OFDM method provides greater frequency efficiency and a decreasing Multi-Path Propagation (MPP) influence. However, it is difficult to achieve good parameters in the mobile communication field using an OFDM system. This is due to Doppler shift, which is the cause of prolonged selective fading and Delay changing influence. It is necessary to use various additional signals to deal with these problems that is to decrease frequency efficiency.

For example, OFDM systems used in the field of Terrestrial Digital Video Broadcasting (DVB-T) may use pilot signals on the same additional carriers. These problems are particularly apparent in the case of the OFDMA method, where each signal may be comprised of a different speed and delay. In OFDM systems, pilot signals may be used on the same additional carriers as in Terrestrial Digital Video Broadcasting (DVB-T) systems. However, this may prove difficult to implement in OFDMA systems, where various sources use various carriers.

The goal of new Frequency Bank Signal (FBS) method is increasing frequency efficiency and acquiring signals not affected by the presence of

Doppler frequency shift and non-synchronized signals (below “delay”).

### II. FBS METHOD USING MPSK MODULATION

FBS combines the phase shift compensation used in the PAL-TV system, together with the OFDMA principle and spread spectrum concept with Walsh functions using the Walsh-Hadamard matrix.

In PAL –TV systems, prior to transmitting a color signal, the system’s phase sign is changed every second line. In decoders, the phase sign is returned and summed together with phases of neighboring lines. As a result, phase deviations in channel  $\phi$  are compensated for [2].

The first version of the FBS method (FBS-1) [2] can be illustrated by transforming an OFDMA system with eight one-carrier MPSK modulation signals to an FBS-1 system with the same eight signals on the same eight carriers (see Fig. 1). Here, by using the FBS method, each signal phase is transmitted eight times with a varying phase sign corresponding to one of the eight Walsh-Hadamard matrix lines.

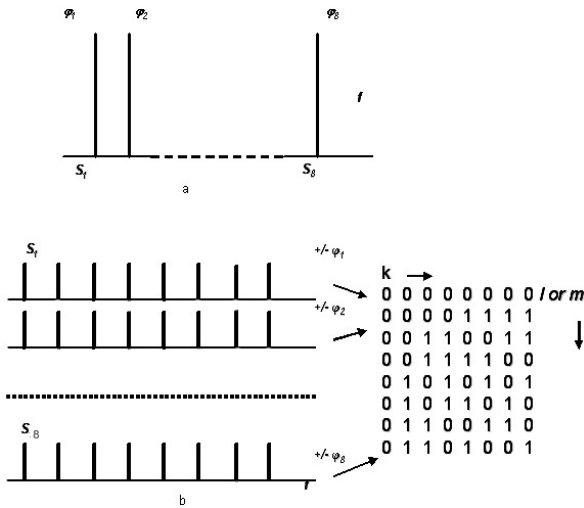


Fig. 1. Transition from OFDM (a) to FBS-1 (b)

The formula (1) is an FBS-1 signal mathematical notation.

$$S_{(kl),FBS-1} = E_l \sum_{k=0}^{N-1} e^{j[2\pi f_k t + (-1)^{W_{kl}} (\theta_l + \beta_l)]}, \quad (1)$$

where

$E_l$  - component magnitude,  $l = 0, \dots, N - 1$  or Walsh-Hadamard matrix lines

$\theta_l$  - initial phase, chosen for certain signals. For example,  $45^\circ$  or other phase,

$\beta_l$  - information symbol of the  $l$  st FBS signal (BPSK or QPSK representation),

$f_k = f_0 + k\Delta f$  - FBS carrier frequencies,  $k = 0, \dots, N - 1$  or Walsh-Hadamard matrix columns

$W_{kl}$  - sequence of phases of the  $l$  st FBS carrier pattern.

To receive one of these signals, for example signal number 2, the following algorithm must be implemented: the  $S_2$  receiver receives all signals together, makes FFT, obtains eight spectral components with thy amplitudes and phases, changes phase signs of components 5, 6, 7 and 8 (see second line in Walsh-Hadamard matrix in Fig.1.) . The result will be equal to the phase sum divided by eight. The phase sum of the other seven signals should be equal to zero [2]. Fig. 2 explains the main advantage of using the FBS-1 method.

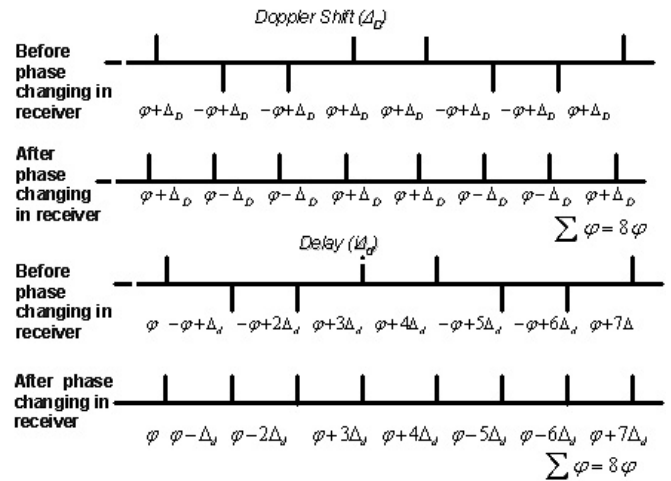


Fig. 2. Phase shift compensation after decoding FBS-1

In the case of symmetrical Walsh function, for example, 0 1 1 0 0 1 0 0, the Doppler Shift and Delay have no influence on FBS-1 reception. If the Walsh function is nonsymmetrical, (for example 0 0 1 1 0 0 1 1), there will be an additional phase shift, which is independent of phase information and which can be compensated for.

### III. FBS METHOD USING MPSK OR MQAM MODULATION

During the phase compensation process, there is usually a certain level of data loss in the amplitude.. Therefore, it is possible to implement modulation only by phase, by using for example MPSK [2]. In dealing with these difficulties we therefore present a FBS-2 system. In this upgraded version, one can implement other modulation methods, such as MQAM. For transmitting  $N/2$  sub-signals in system FBS-2 we use  $N$  orthogonal sub-carriers  $f_1, f_2, \dots, f_m$  and Walsh-Hadamard matrix of order  $N$ . For each symbol of each sub-signal:

$$x(t) = A \sin(\omega t + \varphi) \quad (2)$$

we present as

$$I = A \sin \varphi \quad \text{and} \quad Q = A \cos \varphi \quad (3)$$

$I$  and  $Q$  values when transmitted separately on  $N$  sub-carriers correspond to one of the pair of Walsh functions selected from an  $N \times N$  Walsh-

Hadamard matrix. For example, for one of N = 8 pair:

$$\begin{matrix} 0 & 1 & 1 & 0 & 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 \end{matrix}$$

the following I and Q values are transmitted:

$$\begin{matrix} I & -I & -I & I & -I & I & I & -I \\ Q & -Q & Q & -Q & Q & -Q & Q & -Q \end{matrix}$$

When receiving a transmitted sub-signal, it is necessary to implement the opposite process with the help 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. By knowing the values for I and Q, we can find A and φ.

$$A = \sqrt{I^2 + Q^2}; \quad \varphi = \arctg \frac{I}{Q} \quad (4)$$

The I and Q sums of other signals will be equal to zero.

Each selected pair of Walsh functions may be added to make a symmetric form. For example, the following three pairs of Walsh functions give a symmetrical form (Table 1.)

Table 1. Walsh functions choosing examples for getting symmetrical form.

	First couple	Second couple	Third couple
I	0 1 1 0 1 0 0 1	0 0 1 1 1 1 0 0	0 0 0 0 1 1 1 1
Q	0 1 0 1 0 1 0 1	0 1 0 1 1 0 1 0	0 0 1 1 0 0 1 1
	+ + - - - + +	+ - - + + - - +	+ + - - - + +

One of the FBS-2 signals with *l*-line of the Walsh-Hadamard matrix for I and *m*-line of the Walsh-Hadamard matrix for Q, can be presented as follows:

$$S_{(l,m),FBS-2} = E_{l,m} \sum_{k=1}^N \left\{ \begin{matrix} \sin[2\pi f_k + (-1)^{W_{kl}} (\theta_{l,m} + \beta_{l,m})] + \\ \cos[2\pi f_k + (-1)^{W_{km}} (\theta_{l,m} + \beta_{l,m})] \end{matrix} \right\} \quad (5)$$

For comparison purposes, we will use the example where the FBS-1 uses N carriers for transmitting N signals. Since FBS-2 utilizes only I carriers and Q carriers, N/2 signals may be transmitted on the same allocated channels. Nevertheless, the QAM modulation technique (used in FBS-2), allows transmitting twice as much data as the PSK modulation technique (used

in FBS-1), for the same allocated channels.

It is well known, that for a transmitting signal with 16QAM instead of QPSK, the signal should be greater by at least 4dB. In the case of FBS-2, there is an increasing effective power of the detector signal. This is due to the fact that N/2 signals are transmitted here, and not N signals as is usually transmitted using OFDM. The summing powers in OFDM and in FBS-2 are approximately equal.

After FBS demodulation (after compensation) we obtain the phase, whose average value is approximately φ. It can be shown using simple trigonometric arguments that the phase error between transmitting and receiving value of φ, denoted E(Δ<sub>v</sub>), for FBS with N = 4 is:

$$E(\Delta_v) = \left| \arctan \left( \tan \frac{\Delta_v}{2} \cdot \tan \Delta_v \cdot \tan \frac{5\Delta_v}{2} \right) \right| \quad (6)$$

Hence, for Δ<sub>v</sub> = π/8 we have for FBS method, E(Δ<sub>v</sub>) = 7°. For the same conditions and OFDM modulation the resulted phase shift on four sub-carrier will be close to 90°.

#### IV. SIMULATION RESULTS

A typical situation involving a cellular system was implemented in order to make a comparison between OFDMA and the FBS systems. A receiver was placed in the center of a 10 km diameter zone (cell). The receiver acquired signals from three transmitters located along the border of the zone. The first transmitter was brought nearer and then was moved away from the transmitter at the speed of 120 km per hour. Presuming that the reflected signal with maximal delay has 5 km additional way, that is maximal delay equals τ<sub>max</sub> = 10 μs. Let us choose a symbol duration of T = 100 μs. Therefore, the frequency difference between sub carriers will be Δf = 1/T = 10 kHz. The motion of the first transmitter results in a phase shift and Doppler shift. Let the central carrier frequency be 10<sup>9</sup> Hz. Therefore, the phase shift per each symbol time due to delay will be 3.9°. Under these conditions, the Doppler shift can be 1% of Δf (See Fig. 3). Each signal is transmitted in OFDMA on two sub-carriers with QPSK, and in FBS on eight sub-carrier with 16QAM.

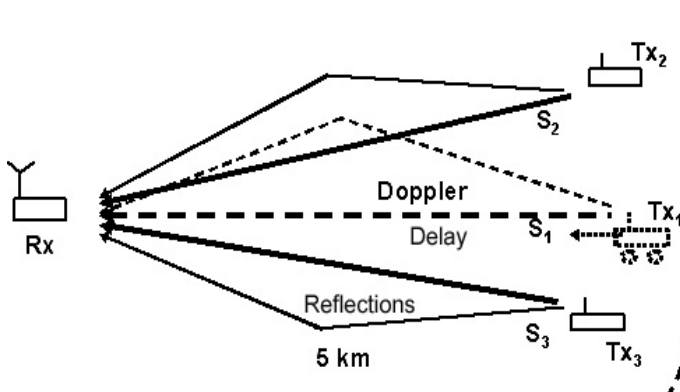


Fig. 3. Simulations scenario for OFDM and FBS comparison.

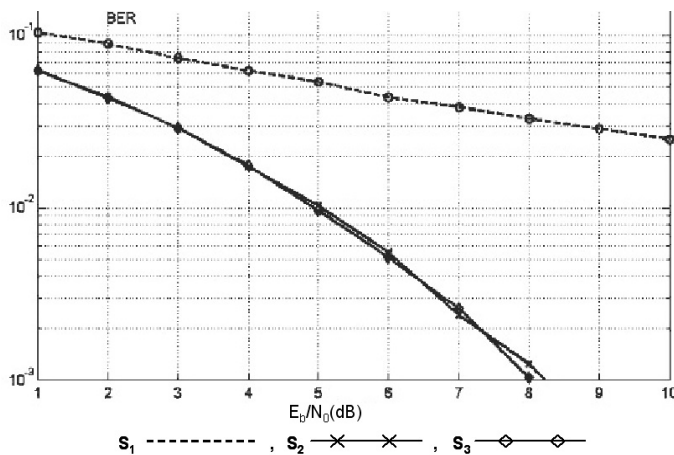


Fig. 4. BER calculations in case of OFDM with pilot signals

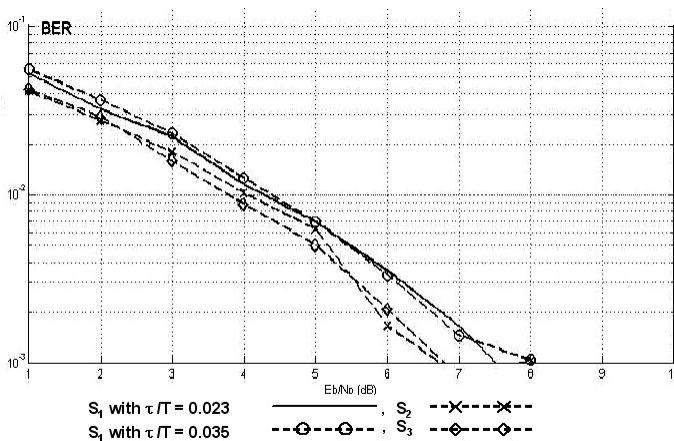


Fig. 5. BER calculations in case of FBS-2 without pilot signals

In the case of OFDMA, a pilot signal with  $E_b/N_0 = 16\text{dB}$  is transmitted after every 20 symbols. Simulation results are shown in Fig. 4 (OFDMA) and Fig. 5 (FBS-2).

The above practical example illustrates that the OFDMA method cannot operate without increasing the redundancy of the pilot signals till 100%.

The main restrictions for FBS system design as for OFDM systems is the  $T > \tau_{max}$  signal part bandwidth with FBS transformation, which should be smaller than a coherence bandwidth  $B_c$  [3] or  $\Delta F \times N < B_c$  when the receiver has a Amplifier Gain Control (AGC).

### V. CONCLUSIONS

The FBS system can be implemented in all forms of wireless communications including broadcasting systems, personal telephone systems, military systems etc. The main advantages are:

- A significant decrease in the Doppler shift, as well as in delays, reflections and the influence of fading.
  - It is unnecessary to conduct tests or to use either pilot signals or an equalizing process,
  - Eliminating prolonged selective fading by means of randomly shifting sub-carriers frequencies.
- All these can now be achieved without a frequency band or by having to increase system power.

### REFERENCES

[1] R. van Nee, and R. Prasad, "OFDM for wireless multimedia communications", Artech House 2000.  
 [2] M. Bank, "On increasing OFDM method frequency efficiency opportunity", IEEE Transactions on Broadcasting, 50(2), 2004 (165-171).  
 [3] William C. Y. Lee, "Mobile Cellular Telecommunications", McGraw-Hill, Inc., 1995.