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Wireless LANs

Proposal for 2.4 GHz High Speed FH PHY

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Abstract

A high speed Frequency Hopping 2.4 GHz PHY is proposed. The proposal stresses compatibility, in several respects, with the regular 802.11 FH PHY. In particular, it is based on 1 MHz symbol rate; it may use same preamble and header structure, and then switch to higher rate. The proposed modulation format is constant envelope and it is FM based, and in that respect fits perfectly into implementation architectures for 802.11 FH radios.

The modulation method utilizes the fact that although regulatory requirements for a FH signal spectrum are to drop to -20 dBc (when measured in 100 KHz bandwidth) within +/-0.5 MHz, there is no requirement for it to drop any further at larger frequency offsets. The baseband waveform can be shaped prior to FSK modulation so that the spectral density of the resulting signal drops sharply to below -20 dBc and stays at that level for +/-5 MHz around the carier, and then drops.

The proposed baseband modulation resembles multicarrier modulation, with the difference that properly timed and phased MSK waveforms are summed (according to an idea described in Bingham's book). The subcarriers are at symbol rate of 1 MHz, which enables to use a common clock derived during preamble acquisition. The multicarrier baseband signal is preemphasized to achieve the desired spectral shaping and for maintaining the sensitivity of the different subcarriers in the colored discriminator noise.

On the negative side of the proposal, the receiver requires a new wider IF filter in order to capture the energy in the wide -20 dBc sidebands. In addition, the new modulation method disturbs larger number of adjacent channels and is disturbed by a larger number of such channels, so smaller number of APs can coexist in same area - a price which may be expected in view of the significantly increased throughput.

The regulatory aspects of the new signal require careful examination. The new signal may encounter regulatory difficulties when the carrier approaches the edges of the ISM band, so new hopping sequences may be required.

Modulation Method Proposal for 2.4 GHz High Speed FH PHY

Modulation Format

The modulation is based on FM (Frequency Modulation) by a baseband signal defined as:

$$s_{FM}(t) = h_{FM} s(t) * h_{preemphasis}(t)$$
$$s(t) = \sum_{k=1}^{K} \sum_{n=0}^{N} a_{k,n} p_{(k \bmod 2),n}(t - kT_S)$$

where

$a_{k,n}$	is the (e.g. binary) value of *n*-th component of the *k*-th symbol
T_S	is symbol period, equal to 1 microsecond.
$p_{k,n}(t)$	is the pulse shape of n-th component, dependent whether k is even or odd.
N	number of multicarrier components
$h_{preemphasis}(t)$	is the impulse response of a preemphasis filter
h_{FM}	FM modulation index

The pulse shapes are defined as :

$$p_{0,0}(t) = \cos(\pi t / 2T_S) \qquad |t| < T_S$$
$$p_{0,n}(t) = \cos(\pi t / 2T_S)\sqrt{2}\sin(n\pi t / T_S) \qquad |t| < T_S \quad n \text{ odd}$$
$$p_{0,n}(t) = \cos(\pi t / 2T_S)\sqrt{2}\cos(n\pi t / T_S) \qquad |t| < T_S \quad n \text{ even}$$
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$$p_{1,n}(t) = \cos(\pi t / 2T_S)\sqrt{2}\sin(n\pi t / T_S) \qquad |t| < T_S \quad n \text{ even}$$

The waveforms of the set are illustrated in Figure 1 at the end of the document.

The values a_k may accept are +/-1. Note that the $p_{1,0}(t)$ does not exist (is zero), therefore odd symbols carry N bits, while even symbols carry $N+1$ bits, i.e. each couple of symbols carries $2N+1$ bits. Note that for n-th component the half-cosine pulse shapes modulate alternately sine or cosine component of a subcarrier centered around $f_c = n / 2T_S$, therefore the stream of *n*-th components (*n*>0) is an MSK waveform. Therefore the combined baseband waveform $s(t)$ may be viewed as a multicarrier modulation combined of multiple MSK carriers. All the pulse shapes $p_{k,n}(t)$ involved are orthogonal (the proof of orthogonality is left as an exercise to the reader (or look in Bingham's book)), therefore passing the received baseband (after discriminator and demphasis) waveform through a set of matched filters will reconstruct ISI-free values $a_{k,n}$ from which the data may be derived.

The proposed number of subcarriers is N=8. Therefore each two intervals carry 17 bits. It is proposed that one of the bits (e.g. the one which corresponds to $p_{0,0}(t)$) will be a parity bit over the rest 16 bits.

The preemphasis filter $h_{preemphasis}(t)$ addresses two needs: to produce a signal with a table-like shape after FM modulation and to cope with colored noise after discriminator in the receiver. The preemphasis is 20 dB/decade, with corner frequency to be chosen. The value of h_{FM} chosen so that the sidelobe level of -22 dBc (regulatory -20 dBc with some margin) is achieved. The resulting spectral shape of the transmitted signal, simulated with the 100 KHz resolution bandwidth (as per FCC measurement procedure) is illustrated in Figure 2.

Receiver structure

On the receive side the signal is filtered with 10 MHz wide IF filter, detected by a discriminator and then it is correlated with multiple templates (MSK demodulators) in order to extract the bits. The bit timing is common to all the streams and initially it is derived from the 1 MHz preamble. The carrier phase and the amplitude of each of the MSK streams may vary due to multipath, so those need to be estimated. For this purpose a wideband preamble is proposed (described later).

The extra parity bit may be used not only for error detection but also for error correction, for example using Wagner's Rule (if parity is wrong, invert the least reliable bit). Even a simple error correction like this can do miracles to overall robustness of a modulation scheme.

The performance of the proposed scheme is currently under investigation.

Wideband preamble

The original 1 MHz preamble does not contain enough information about the whole 10 MHz in which the received signal is contained. Therefore an 8 symbol long preamble is proposed for estimating the propagation conditions over the signal bandwidth and applying this information for phase tracking and bit prioritization for Wagner decoding.

Summary

The proposed modulation method fits well within -20 dB bandwidth regulatory requirements. The effect of a wider spectral skirt on operation near the edges of a band needs further investigation. Further details and initial performance estimates are expected in January.

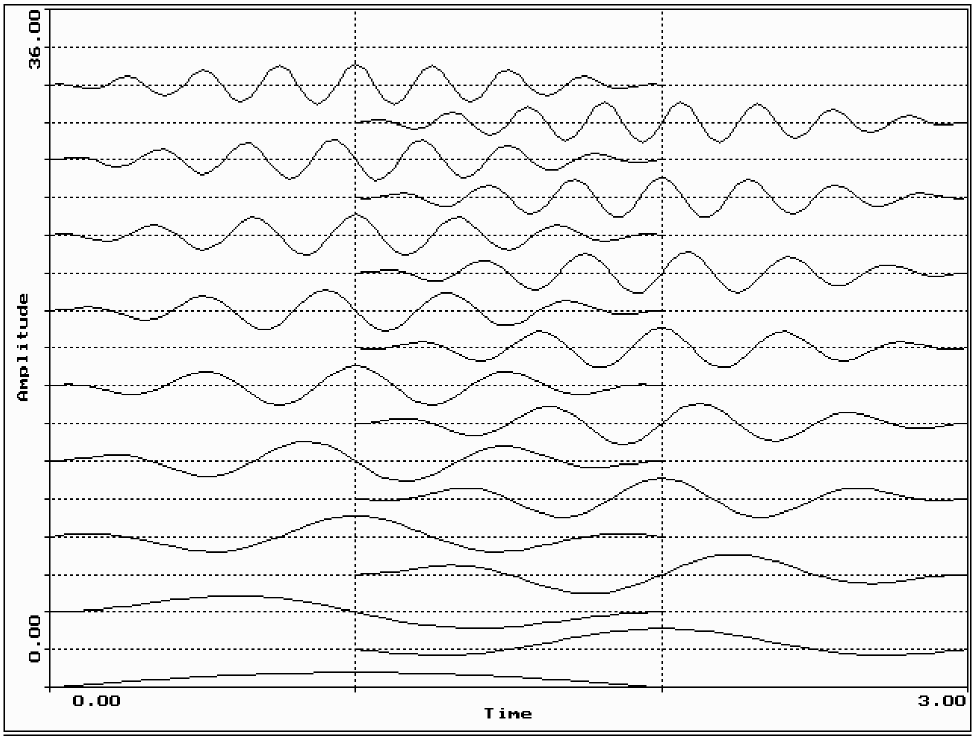

Figure 1: Illustration of orthogonal waveform set

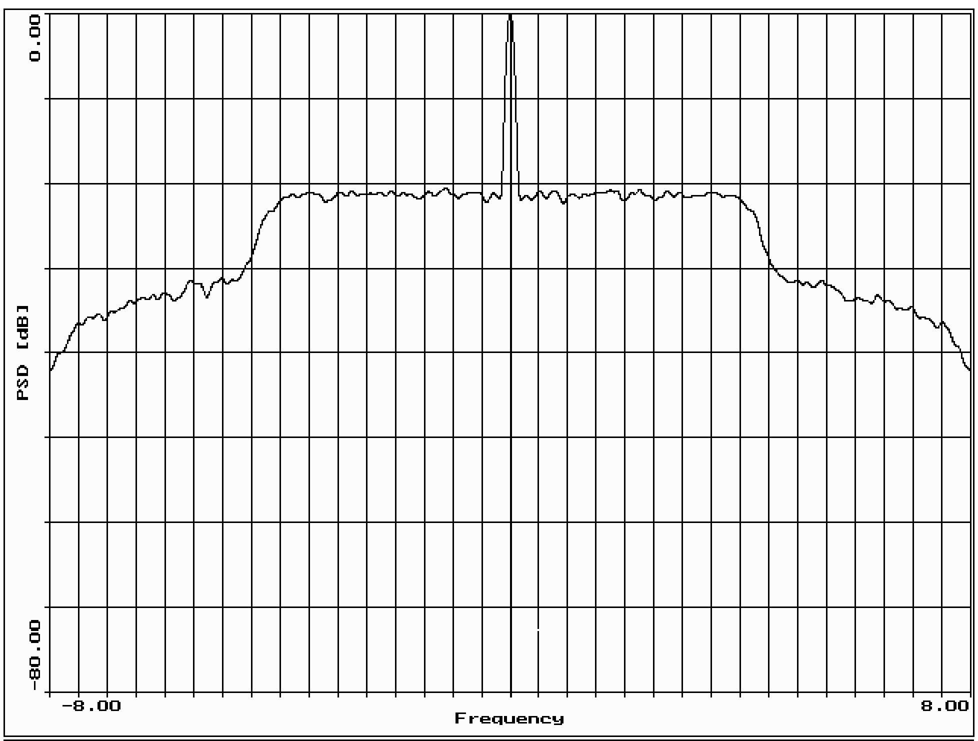

Figure 2: PSD of the proposed signal, simulated with 100 KHz RBW