IEEE 802.11
Wireless Access Method and Physical Layer Specification

Title: **Infrared Modulation Method: 16 Pulse Position Modulation (PPM)**

Authors: Adriano J. C. Moreira, Rui T. Valadas, A. M. de Oliveira Duarte

Integrated Broadband Communications Group
Dept. of Electronics and Telecommunications
University of Aveiro
3800 AVEIRO
PORTUGAL

Tel: +351 34 381937
Fax: +351 34 381941
Email: adriano@ci.ua.pt

Summary

A modulation scheme (16 PPM) for wireless infrared transmission is proposed, following the format suggested in the IEEE P802.11-93/123 document.
In addition, some remarks are made to the aspects to be considered in the comparison of the several modulation methods.
This work is being carried out as part of the ESPRIT.6892 - POWER (Portable Workstation for Education in Europe) project commissioned by the CEC.

1. Estimated cost (Manchester = 1.0).

The PPM transceiver complexity is a bit higher than that of a Manchester system (threshold detector plus encoder/decoder). However, in view of essential requirements for mobile applications such as high degree of integration, a low power consumption and space occupied by the transceiver circuitry, both systems must be implemented by resorting to VLSI technologies. In this case, both systems can be reduced to a single chip. Moreover, the PPM detection process can go digital immediately after the optical front-end, making that chip all digital. From this point of view (complexity ≠ cost), we can rate the cost of the PPM system at 1.5.

2. Support of multiple data rates?

Yes. Data rate can be detected during the preamble using simple correlation techniques to estimate the distance between consecutive pulses.

3. Bit error rate versus signal to noise ratio curve (at 1 and 4 Mbps).

See document IEEE P802.11-93/79. In this document, curves for the bit error rate versus irradiance (power per unit area) are presented for NRZ, Manchester and PPM (several orders) at 1 Mbps.
For 16 PPM, the receiver sensitivity for a BER of 10^{-9} is **-54.6** dBm/cm2 at 1 Mbps and **-49.4** dBm/cm2 at 4 Mbps.

Comment: the bit error rate curve should be presented as a function of the optical power density and not signal to noise ratio. The former allows the optical power budget to be easily determined from the cell area.
We believe that it is essential to define a common reference model for the purpose of comparing the different modulation methods, including the same noise model and levels. We propose to adopt the reference model presented in document IEEE P802.11-93/79. In addition it will be highly desirable to have experimental data to confirm the theoretical calculations.

4. Multipath sensitivity (at 1 and 4 Mbps).

The optical power penalty due to multipath dispersion is to be determined. However, no more than 50 ns of dispersion are expected for most of the practical rooms (see IEEE P802.11-93/78 and 142). The pulse width at 1

Mbps is 250 ns but can be made narrower to accommodate the 50 ns pulse spread, reducing the penalty to a negligible level.
At 4 Mbps, the power penalty due to multipath dispersion may have to be considered if no equalisation is used. However the same is also true for Manchester whose pulse width is 125 ns at 4 Mbps. More work have to be done in this area.

5. Support multiple co-located IR channels?

No. Since baseband is used, wavelength division multiplexing is the only possible solution and that is not cost effective at this time.

6. Power consumption (Manchester = 1.0).

Power consumption of the IR transceiver (PHY only) is obviously dependent on the modulation method (sensitivity of the receiver) but also, and more drastically, on the electro-optical conversion efficiency of the emitting device (most probably LEDs), average data traffic and cell area. The electrical power the transceiver drains from the power supply unit (or batteries) is different depending on the state of the transceiver: while transmitting, receiving or in idle (sleep) mode. It is meaning less to consider only the format of the transmitted signal when comparing the power consumption associated to the different modulation methods. It is even probable that the average power consumption will be determined by the consumption of the transceiver while in receiving or idle mode. An accurate comparison of the average power consumption requires the specification of the data traffic and cell area.

Power consumption of the 16 PPM transceiver, compared to the Manchester transceiver:

- Idle mode: 1.0 (only the carrier sense function is required in both transceivers).
- Receiving mode: 1.5 (the modulator/demodulator is more complex).
- Transmitting mode: 0.14. While in transmitting mode, the power consumption is highly dependent on the receiver sensitivity. Since the sensitivity of the PPM receiver is about 8.5 dB better than that of the Manchester receiver for the same cell area, the PPM system requires the transmitter to emit only 14% of the optical power required by the Manchester system.

As an example, we consider the following conditions to estimate the average power consumption:

- electro-optical conversion efficiency: 10%
- percentage of time in mode (idle, receiving, transmitting): (50%, 25%, 25%)
- Power consumption (Manchester transceiver):
  - Idle mode: 100mW
  - Receiving mode: 500mW
  - Transmitting mode: 2W (200mw optical / 10% conversion efficiency)

Total average power consumption:

- Manchester: $P = 0.5 \times 100mW + 0.25 \times 500mW + 0.25 \times 2000mW = 675mW$
- PPM: $P = 0.5 \times \mathbf{1.0} \times 100mW + 0.25 \times \mathbf{1.5} \times 500mW + 0.25 \times \mathbf{0.14} \times 2000mW = 307.5mW$

7. Stress on the IR LEDs (Manchester = 1.0).

Since the transmit duty-cycle of the LEDs is 1/16 in average, higher (16 times) current levels can be used to drive the LEDs. The maximum current on the LED is however limited by the electro-optical conversion efficiency which is lower at high current levels and by the destructive levels.

8. Preamble length.

Several actions have to be performed during the preamble period: signal level detection (or/and carrier sense), data rate detection and clock recovery. In order to provide enough time for all those actions, a preamble consisting of 7 octets is desirable.