Towards a **True** ULP PHY

Overview

- IEEE 802.15 has a TG exploring an ultra-low power PHY (ULP)
- What is ULP for 802.15.4?
- What are the ways to reduce PHY power?
- Possible true low power solutions
- Conclusions

What is ULP?

- The current state of the art in radios is already well below 10 mW
- Bluetooth low energy (BLE) is already < 5 mW with 1 Mb/s
- 15 mW goal in PAR is too loose.
- We should trying for 10 mW peak power for 100 kB/s at 100 m.
- Also should reduce energy to less than 10 μW/bit

System considerations

- In lower TX power radios, the receiver accounts for most of the actual battery usage
- The reason is that the receiver is on longer
- The best way to save power is to transmit quickly and turn off the radio ASAP.

Where is the power in the radio?

- Reference frequency
- Synthesized LO
- Baseband (coding, DAC, etc.)
- PA
- RX processing (usually the most)

RF frequency

- Don't require an accurate RF frequency
  - No synthesizer required or it can be turned off during transmission
- Methods:
  - ASK (no synthesizer required)
  - FSK allowing the frequency to drift (e.g., Bluetooth)

Symbol timing

- Timing recover requires an accurate reference and power
- To save power, don't require accurate timing
- Methods:
  - Manchester coding
    - 100% overhead, but instandaneous
  - 8b/10b coding
    - Widely used, low power and well understood

Power amplifier

- For high TX power applications, the PA may be a significant contribution to the power
- Complex modulations can require operation at inefficient power levels
- Methods:
  - Select modulation that can operate at Psat, e.g., FSK or BPSK (QPSK sometimes)
  - Use ASK and turn off the PA
    - Need to worry about “splatter”

Baseband

- The digital baseband complexity adds to power usage
- This tends to hit the receiver more than the transmitter, but that is more important than transmitter power for ULP devices
- Methods
  - Don't use FEC, it doesn't help in interference environments (i.e., real environments)
  - Use a simple coding (e.g., FSK and ASK) in which the bits can be applied directly to the analog portions of the radio.

So, what is a ULP radio?

- ASK, 2 level, Manchester encoding, 1% frequency accuracy for RF and symbol rate.
  - Can turn PA and LO on and off
  - No synthesizer required
  - Timing recovery is easy
  - Direct modulation possible

Another ULP

- 2-FSK
  - Allow frequency drift so synthesizer can be turned off before transmission
  - Easy Direct modulation allowed because loop is turned off
  - TX chain is VCO and PA only
  - 8b/10 coding for timing recovery

What not to do

- Combine frequency and ASK
  - Current TASK has none of the advantages of either BPSK/FSK and ASK
  - LO must stay locked because phase coherency is required
  - Only PA can be turned off, but for a ULP device, the PA is a small portion of the power.
- Use complex coding methods
  - Burns power on TX and complicates the receiver
  - Doesn't help performance because we are not SNR limited by interference limited
  - Even in SNR limited environments, the gain only happens at the far edge of coverage, close in, there is no advatage

What do we do?

- Vote no on the letter ballot and submit comments
  - Change the PHY to a real ULP solution
  - Use two-level coding, not ternary
  - No FEC, it wastes power and provides no advantage in an interference environment.
  - Relax frequency and timing requirements
  - Use a well known, simple encoding (Manchester or 8b/10b) for timing recovery