Wireless Communication Systems for Bio-sensors

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Abstract

- Technical focus
  - Application of reliable medical devices enable numerous important diagnostic and therapeutic applications. Among these, a class of devices that require large amounts of data processing are emerging, such as neural prosthetics and植入式implants. For these devices to be clinically valuable, the current transcutaneous wireless connections, which are prone sources of failure and infection, need to be alleviated. Developing very low-power, high-bandwidth wireless data and power links to replace the wired connections for micro-scale implanted medical devices is a key research challenge, and the main focus of this talk.

- Results
  - Two major steps were given to achieve the task goal. The HermesD discrete transmitter was successfully built on an actual silicon foundry. This system supports the simultaneous transmission of 32 channels of broadband data at 30 ksamples/s and 100 MHz, using FSK modulation on a 3.3 GHz carrier. By a link range of over 10 m. More recently, the IC design of the future HermesE version was completed (in manufacturing). This transmitter is a very low-power (<1 mW) and low size (6x6x0.7 mm) UWB transceiver capable of transmitting 96 channels of neural data.

HermesD: High-rate, multi-channel transmitter

- Supports the transmission of 32 channels of broadband data
- 30 ksamples/s
- 12 bit DACs
- Operating frequency of 3.3 GHz, FSK Modulation, 24 Mbit/s
- Reconfigurable digital control and data framing for easy modification (such as changing the nr. of channels)
- Communication range: > 10 m
- Total power budget: 150 mW
- 2 days of operation time

HermesE UWB transmitter UWB architecture

- All transmitter parameters programmable:
  - Pulse center frequency (Pulse1) by controlling the LED delay (delay = 1 ms delay control bits)
  - Pulse width controlled by the on-chip driver
  - Pulse shape control by the on-chip driver
  - Pulse delay control by the on-chip driver
  - Output capacitor (Ctune)

Simulation Results: pulse waveforms

- Design example:
  - Fcenter = 4 GHz
  - BW = 1 GHz, FSK modulation
  - Cell delay = 1 ms
- Energy performance (rectangular pulse):
  - DC Power: 15.5 mW
  - RF Power peak: 160 mW
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HermeS ECHIP Test board

- Chip-on-board assembly
- Test board includes commercial UWB antenna
- Alternative antenna: L-shaped circular disk monopole (LCDM) antenna
- Simulation results:
  - Radiation pattern at 5 GHz
  - Return loss

HermeS E chip layout

- 65 nm 19PM 1.0 V process
- Die area: 1.0 x 0.7 mm²

Hermes Project

- Neural prosthesis research: high data-rate biological application
- Neural signals are measured using arrays of electrodes implanted in various brain areas
- Data is transmitted wirelessly
- Neural signals are transmitted with arbitrarily timed bursts
- Neural spike times are extracted for each neuron (spike sorting)
- Control signals are generated to guide prosthesis activity for instance

Hermes B and C: Current versions

- Two channels recorded out of the 96 available
- Battery and memory autonomy are both limited to 18 hours
- Data rate is 360 kbit/channels
- 16 ksamples/s per channel
- 10 bits/sample
- Wireless capability introduced in HermesC
- 3.3 MHz old band, FSK modulation
- One channel transmitted at 14 ksamples/s, 10 bits/sample
- Max. communication range: 4 m
- Power consuming: 50 mW

UWB transmitter design goals for HermesE

- Pulse based UWB
- Frequency range: 4 – 8 GHz
- Data rates in excess of 40 Mbit/s
- DC Power < 1 mW
- Range to cover > 3 m
- Programmable pulse envelope and duration (spectrum control)
- Good transmitter energy efficiency (> 20%)

Energy efficiency vs antenna driver voltage

- Driver weight vector: W = [7 7 7 7 7 7 7 7]
- RF energy/pulse: 1.7 pJ
- Scrambler on/off: Scrambler on

Summary

- 2008-2009 contributions
  - Development, implementation and test of a 24 MHz wireless transmitter to support 32 channels of broadband data for the Hermes system
  - UWB transmitters and software of a very low-power and high-rate integrated UWB Transmitter for neuro-implants (HermesE)
  - Hermes antenna; simulation and lab measurements

Related references