IDEC Chip Design Contest

An Energy-Efficient Wireless Power and Data Transfer System

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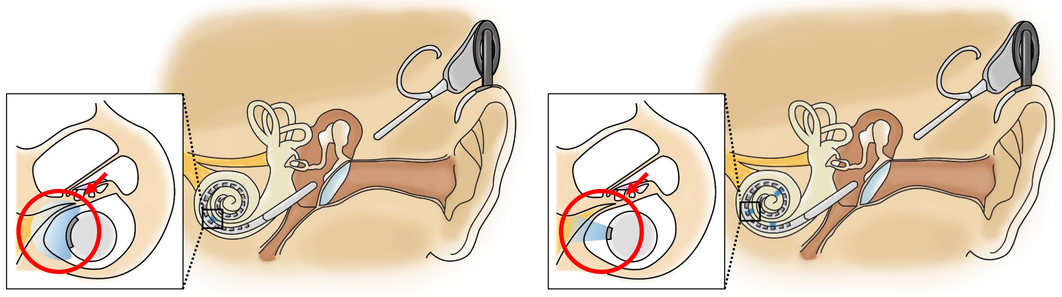
Introduction



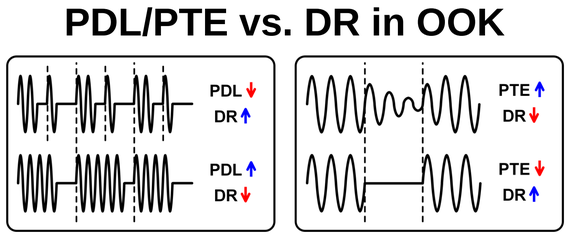
Electrical stimulation
→ Limited spatial resolution

Optogenetic Stimulation
→ Improved spatial resolution

- Neural prostheses: Providing a better life for patients with impairment
- Electrical neural stimulation: Limited spatial resolution due to the spread of stimulation current
- Optogenetic stimulation: An alternative to overcome the limitation
- Requirements of wireless power and data transfer system over a single link
  - ✓ Sufficient power delivered to the load (PDL) for stable operation
  - ✓ High power transfer efficiency (PTE) for extended battery time
  - ✓ High data rate (DR) for multi-channel stimulation

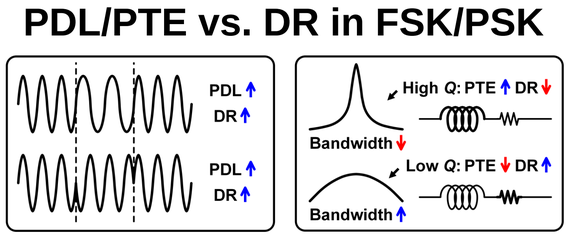
Fundamental Trade-Offs

PDL/PTE vs. DR in OOK



- OOK: Simplicity, discontinuous power transmission
- Trade-offs between PDL and DR, PTE and DR

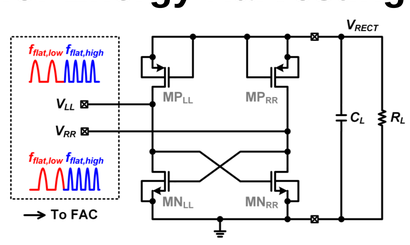
PDL/PTE vs. DR in FSK/PSK



- FSK/PSK: High DR with large PDL due to continuous power delivery
- Trade-off between PTE and DR

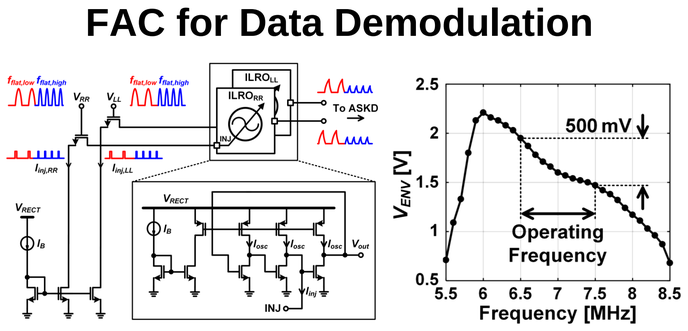
Key Building Blocks

Full-Wave Rectifier for Energy Harvesting



- AC-to-DC conversion
- 2-phase FM signal gen.

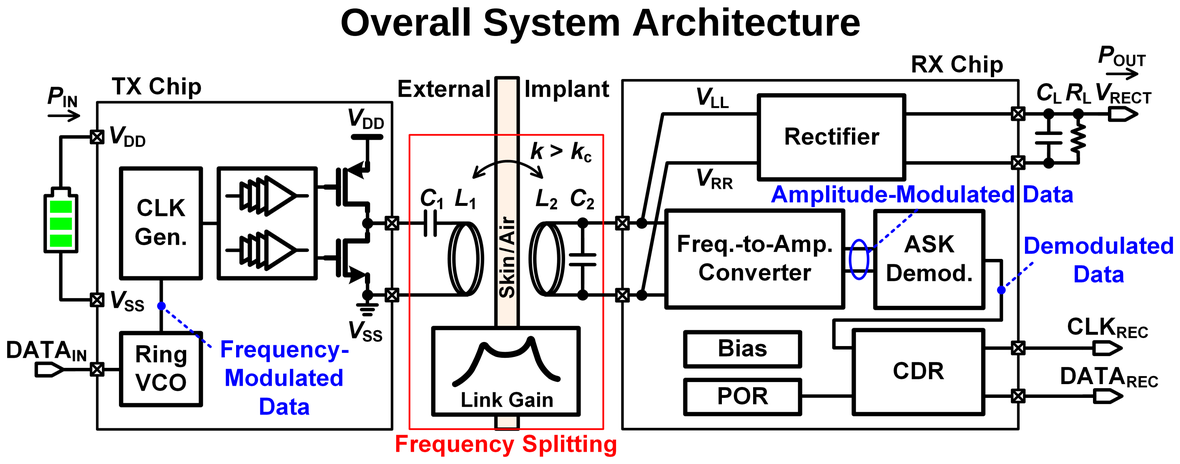
FAC for Data Demodulation



- 2-phase ILROs used for high DR
- High sensitivity (500 mV/1 MHz)

System Implementation

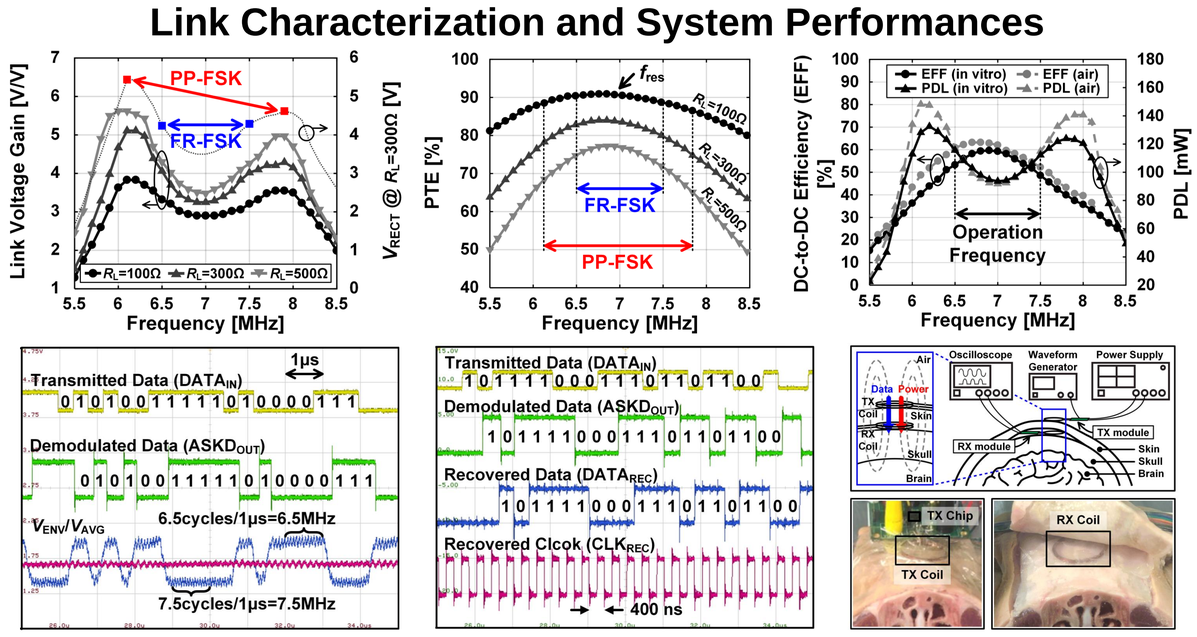
Overall System Architecture



- FSK (High DR with large PDL) and frequency-splitting phenomenon (Wide bandwidth without degrading PTE) employed
- High-sensitivity frequency-to-amplitude converter (FAC) to enable high-DR communication over relatively narrow bandwidth compared to the previous work
- ASK demodulator to demodulate the amplitude-modulated signal generated by the FAC circuit
- Reference-less clock and data recovery (CDR) circuit for synchronized data communication with the frequency-modulated carrier

Measurement Results

Link Characterization and System Performances



- Smaller link gain variations, lower drops of PTE, and Higher DC-to-DC efficiency for the proposed flat-region FSK (FR-FSK) compared to those of the conventional peak-point FSK (PP-FSK)
- Frequency-to-amplitude conversion observed from the ripples at 6.5 MHz (High) and 7.5 MHz (Low)
- Data demodulation and CDR operation verified at the DR of 2.5 Mb/s in both through-air condition and in-vitro setup

Conclusion

- Frequency-splitting-based wireless power and data transmission IC employing a proposed flat-region FSK scheme presented
- Trade-offs between PDL and DR, as well as PTE and DR overcome altogether
- High-sensitivity frequency-to-amplitude converter based on 2-phase ILROs developed for high-DR demodulation
- 2.5-Mb/s DR, 115-mW PDL, and 89.6% PTE achieved simultaneously

Acknowledgement

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