MichiganEngineering

Harvesting a Clock from a GSM Signal for the Wake-Up of a Wireless Sensor Network

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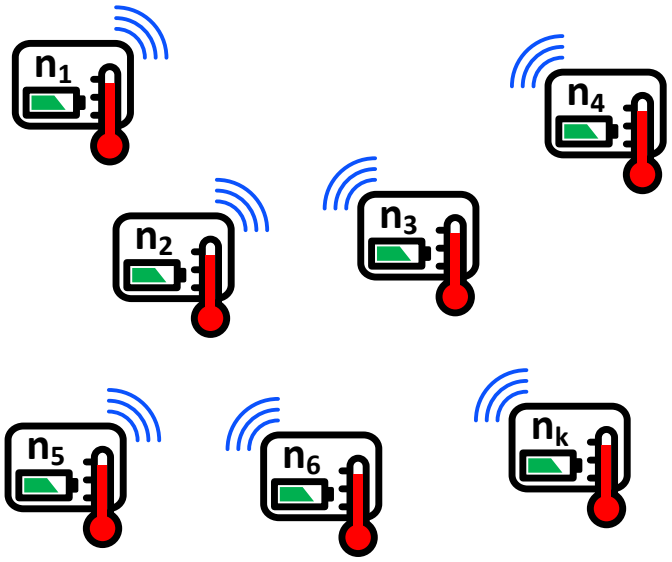
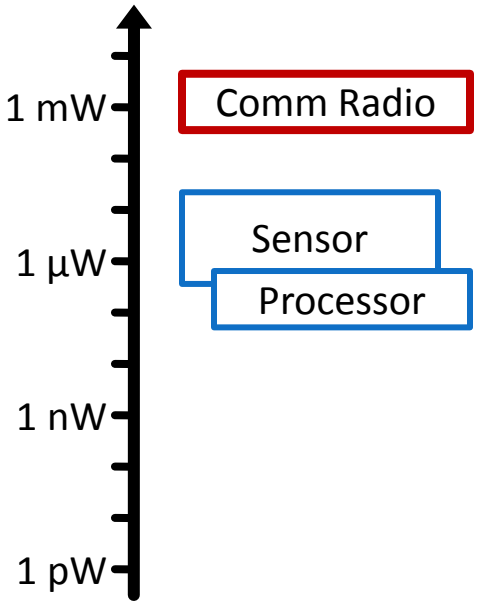
Wireless Sensor Networks (WSNs)

- Network of energy-constrained nodes
- Node functionality
  - Sense information
  - Communicate wirelessly
- Potential applications
  - Environmental sensing
  - Biomedical implants
  - Industrial monitoring
- Major design challenges
  - Small volume, low cost
  - Long lifetime → Low-power circuits



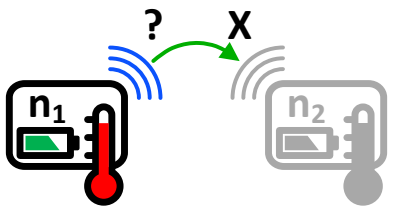
Motivation for Synchronization

- Relative power consumption of circuit components on a node

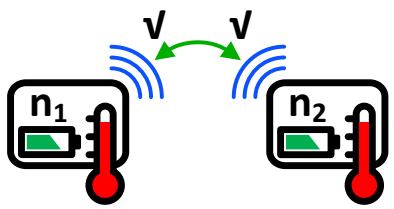


- Duty-cycled communication

Not synchronized

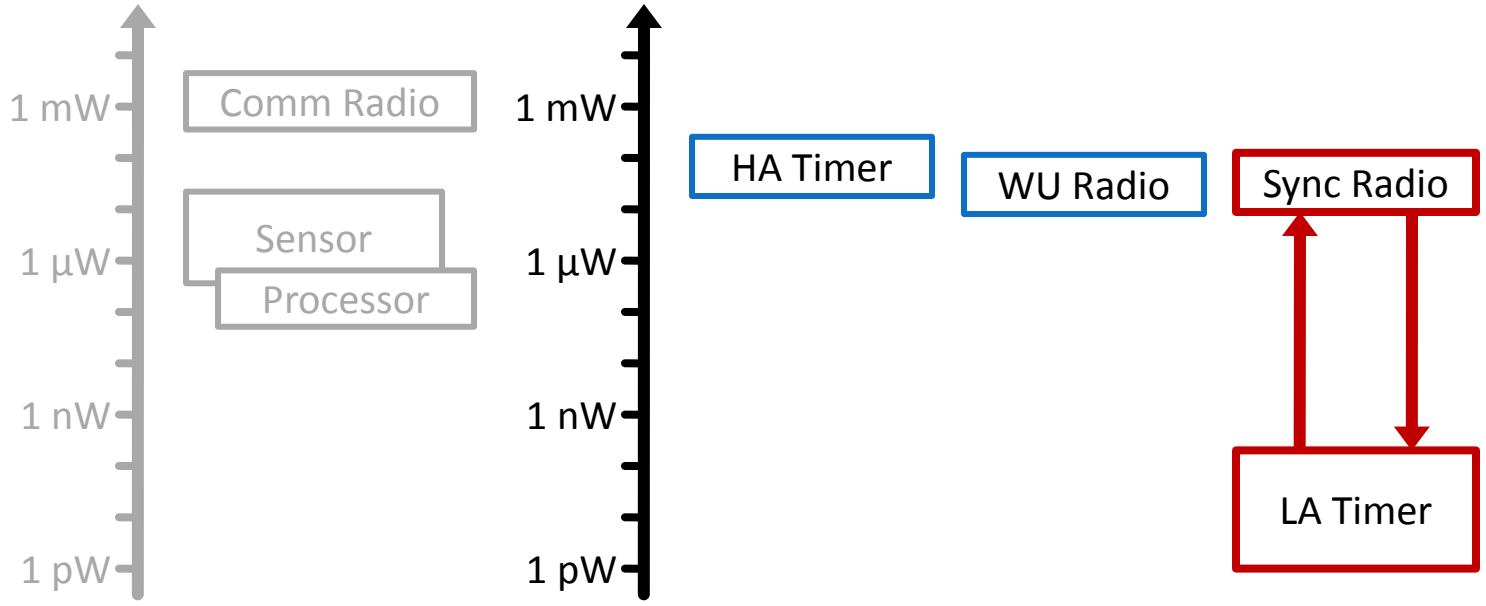


Synchronized



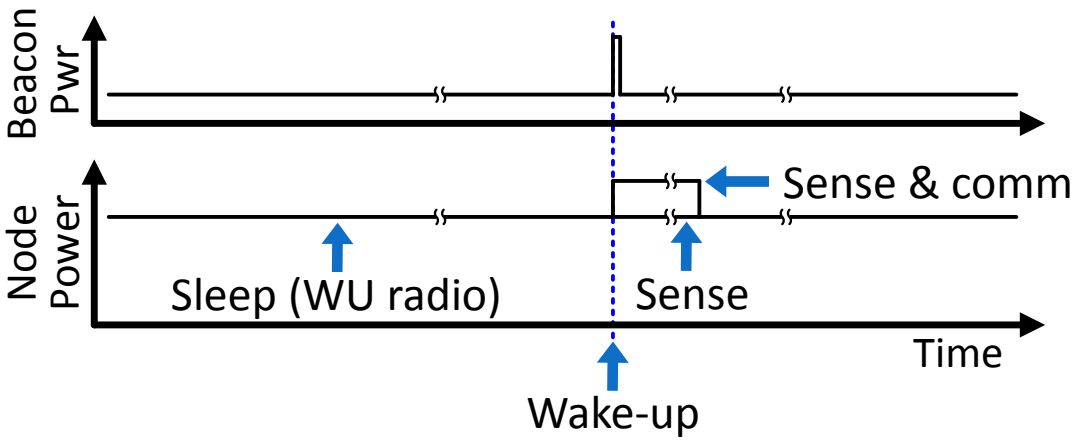
Motivation for Synchronization Radio

- Synchronization strategies
  - High-accuracy (high-power) timer
  - Wake-up radio
  - Low-accuracy (low-power) timer + synchronization radio
- Relative power for each synchronization strategy

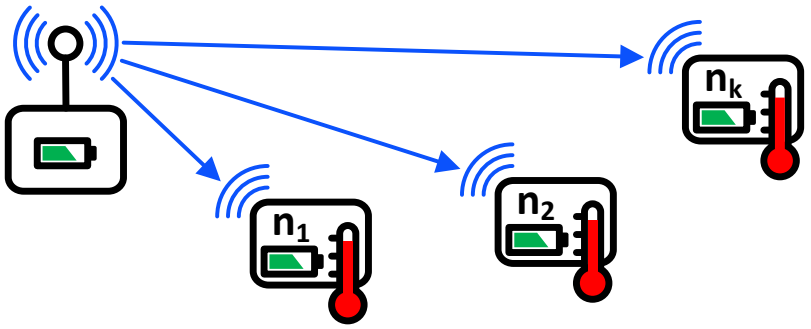


Motivation for Clock Harvesting

- Timing with a wake-up radio
  - Unknown time for wake-up signal
  - Wake-up radio on continuously

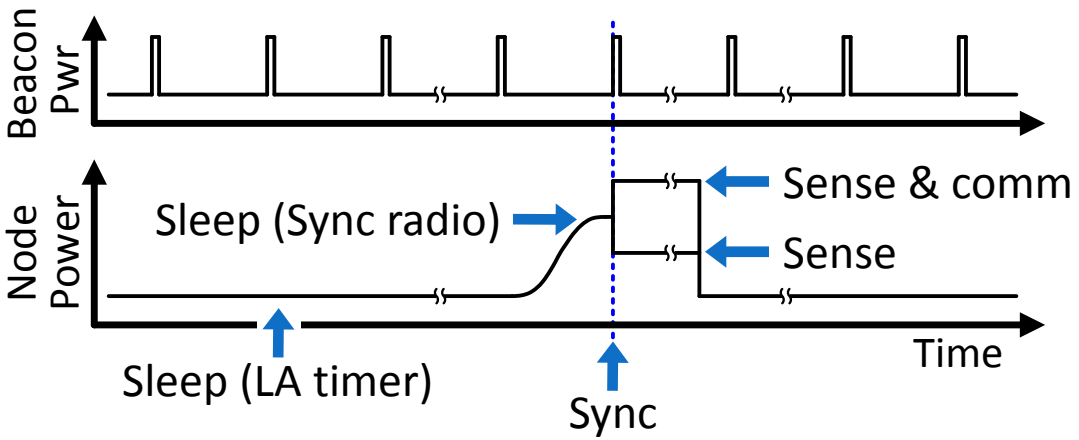


- Beacon strategy
  - Generate within network
    - Requires network power to generate it
    - Requires custom infrastructure

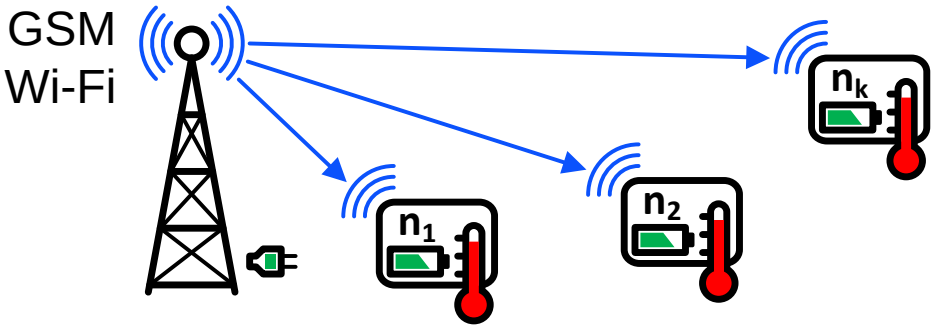


Motivation for Clock Harvesting

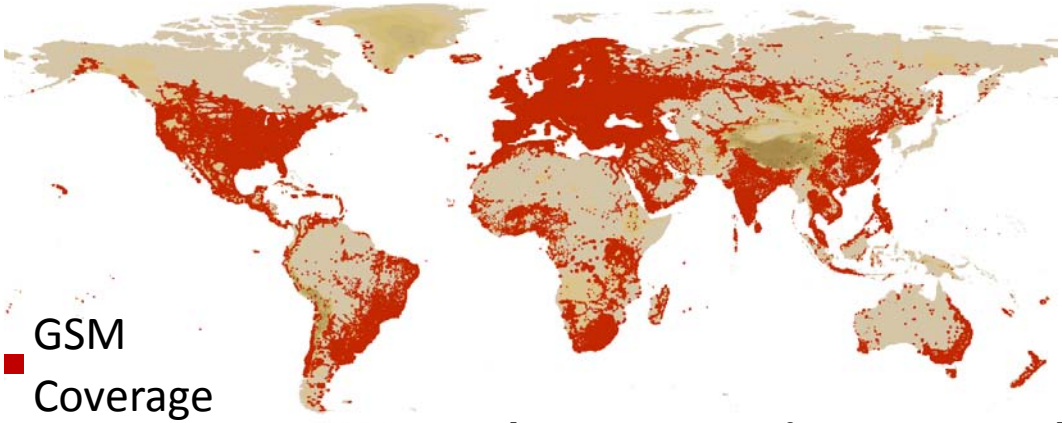
- Timing with a synchronization radio
  - Known time for sync signal
  - Sync radio on intermittently



- Beacon strategy
  - Generate within network
  - Harvest existing signal
    - Doesn't require network power to generate it



Motivation for GSM-Based Clock



[Image Courtesy of GSM Association]

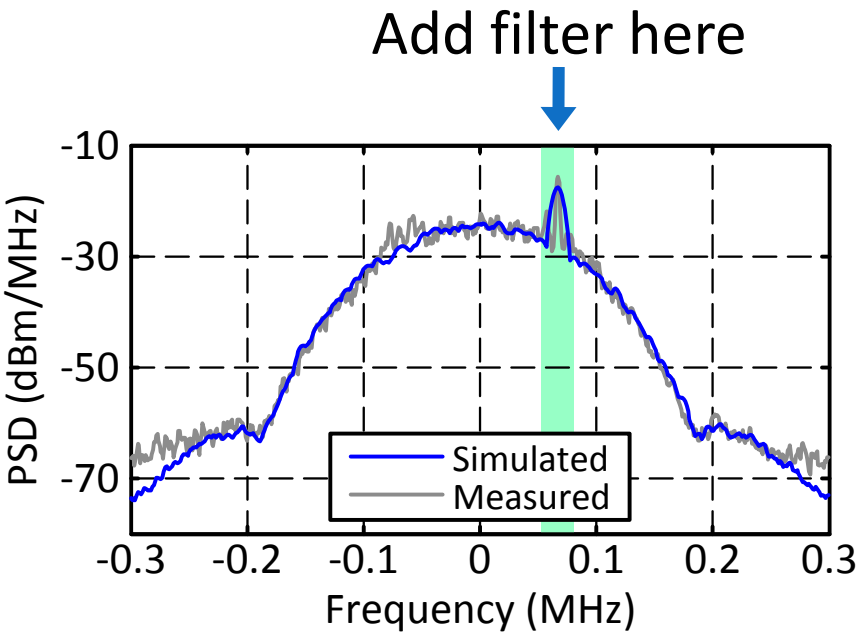
- Provides worldwide coverage
- Broadcasts high-power signals
- Contains an embedded clock
  - Low-frequency
  - Simple to extract (i.e. low-power)

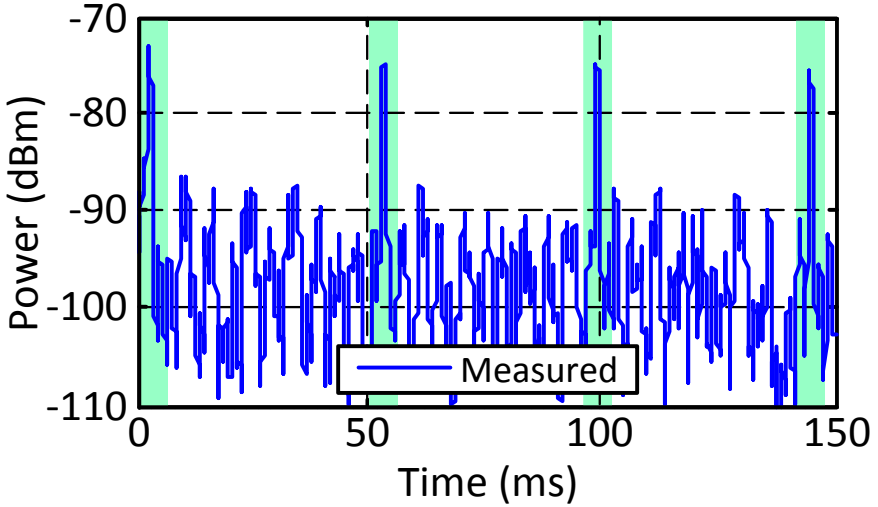
Characteristics of GSM Standard

- 4 major frequency bands worldwide
  - 850 MHz, 900 MHz, 1800 MHz, 1900 MHz
- 200-kHz bandwidth physical channels
- Basic services (BCCH carrier)
  - Includes…
    - Frequency correction (FCCH)
    - Broadcast control (BCCH)
  - Exist on all GSM, GPRS, and EGDE networks
- Channel properties
  - Gaussian minimum shift keying (GMSK) spectrum
  - Constant envelope

Proposed GSM-Based Clock

- Frequency correction burst (FB)
  - Generates tone 67.7 kHz above center freq of BCCH carrier
  - Repeats at rate of approx 21 Hz

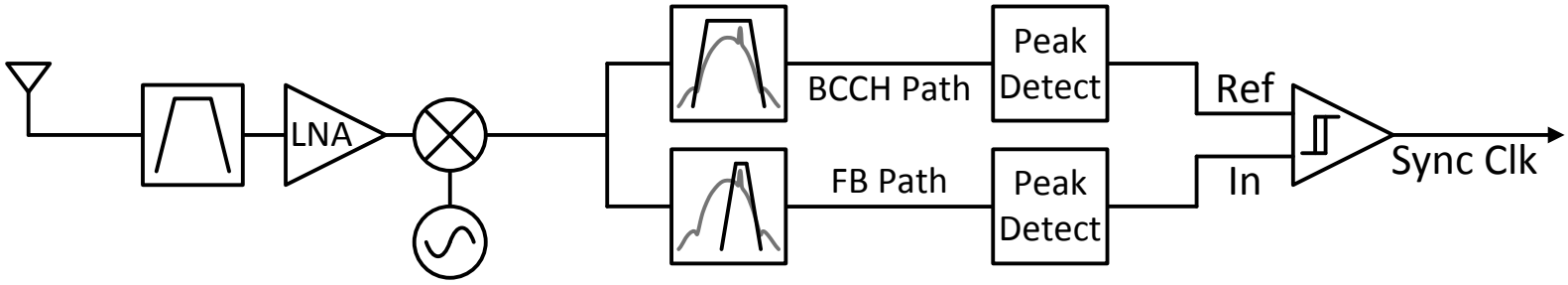




Looks like a clock

Proposed Receiver Architecture

- Measures power of BCCH carrier and at FB offset freq
- Uses periodicity of FB as a clock for synchronization



Goal is to harvest a clock, not extract GMSK-modulated data

Proposed Receiver Architecture

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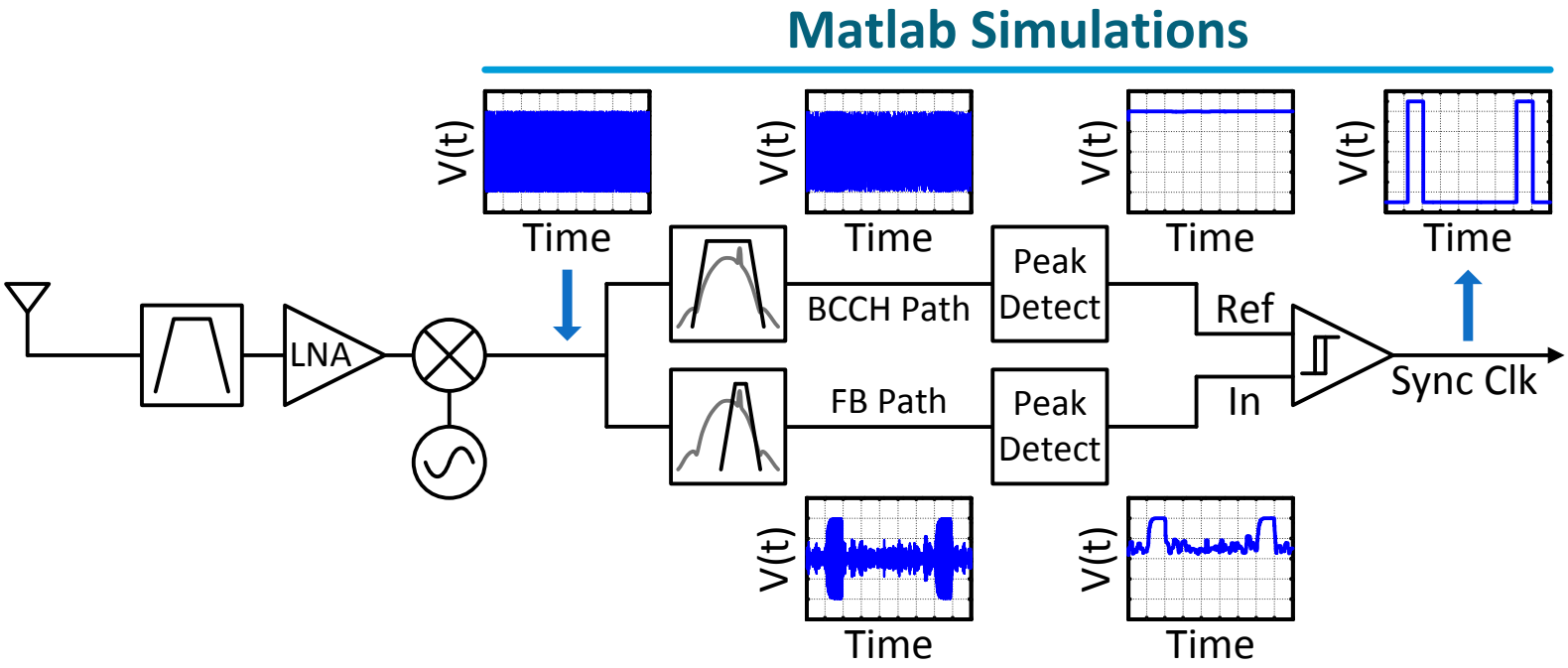

Desire signal at output of FB filter **only** during freq bursts; otherwise, AWGN

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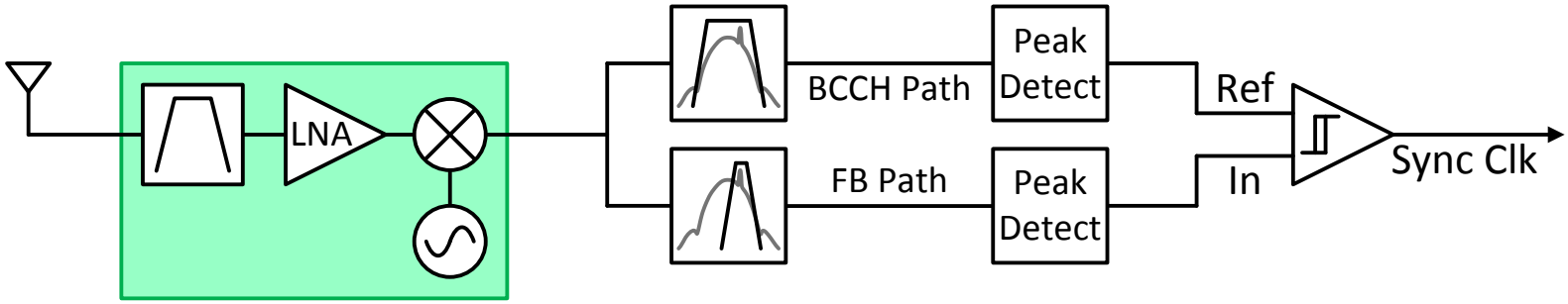

Expected power similar to wake-up radios previously reported

Proposed Receiver Architecture

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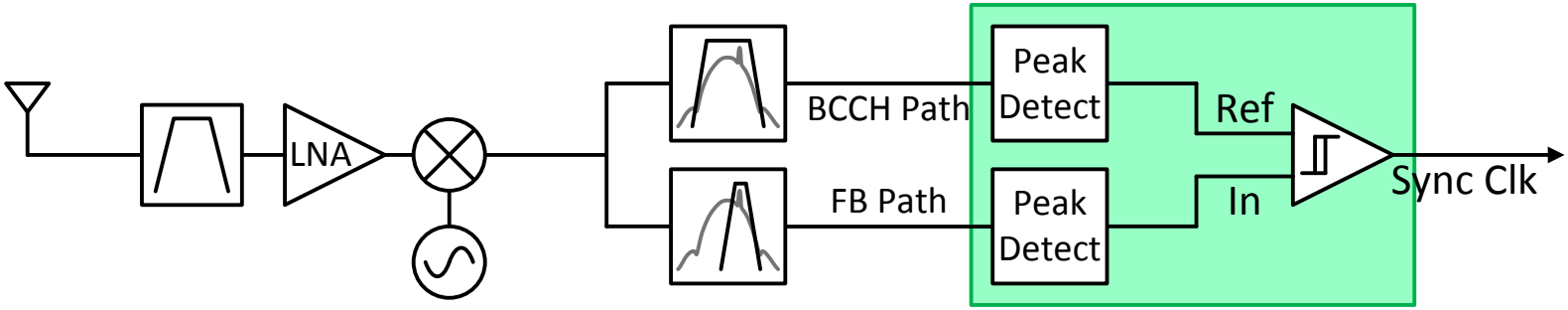

Requires some design, but relatively little power at IF

Proposed Receiver Architecture

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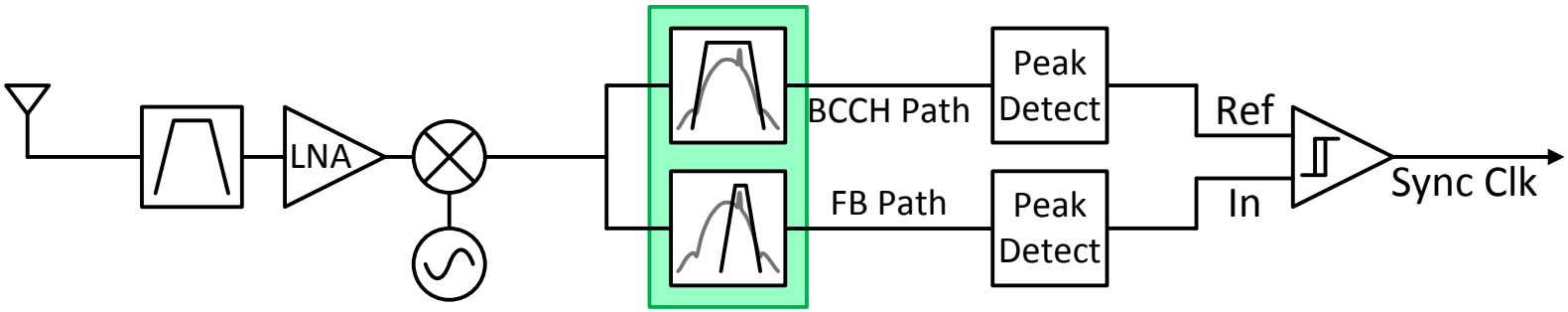
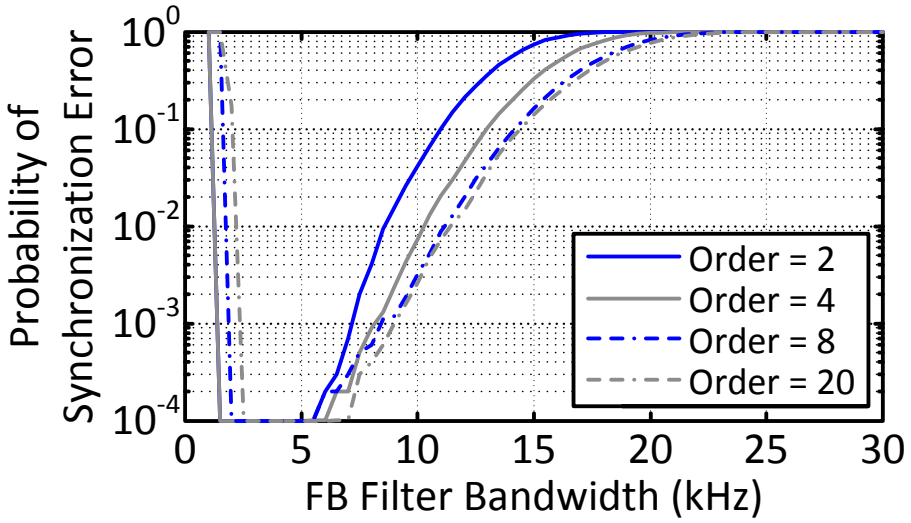


Potentially high power because potentially high-Q, especially narrowband FB filter

Characterization of the FB Filter

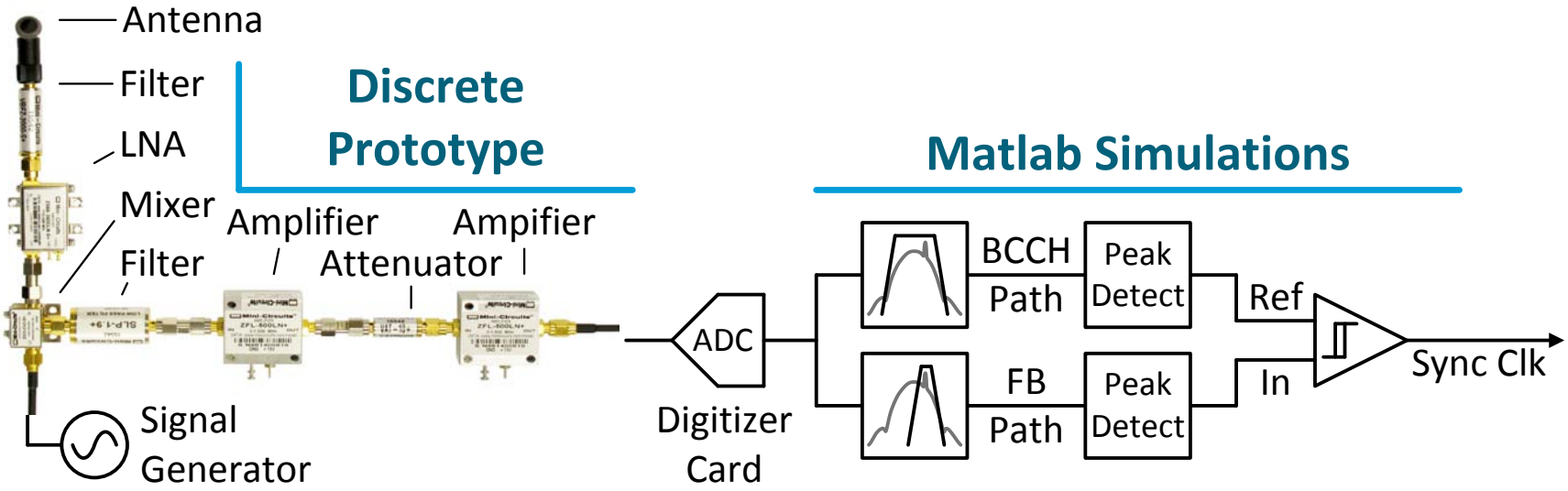
- Generated GMSK-modulated FBs and PR bursts
- Set BCCH filter to…
  - 200 kHz bandwidth | 2nd-order bandpass
- Swept FB filter bandwidth and order
  - Generated 10^4 FB intervals (>10^8 GMSK symbols)
- Counted number of synchronization errors



- Set FB filter to…
  - 7 kHz bandwidth
  - 4th-order bandpass

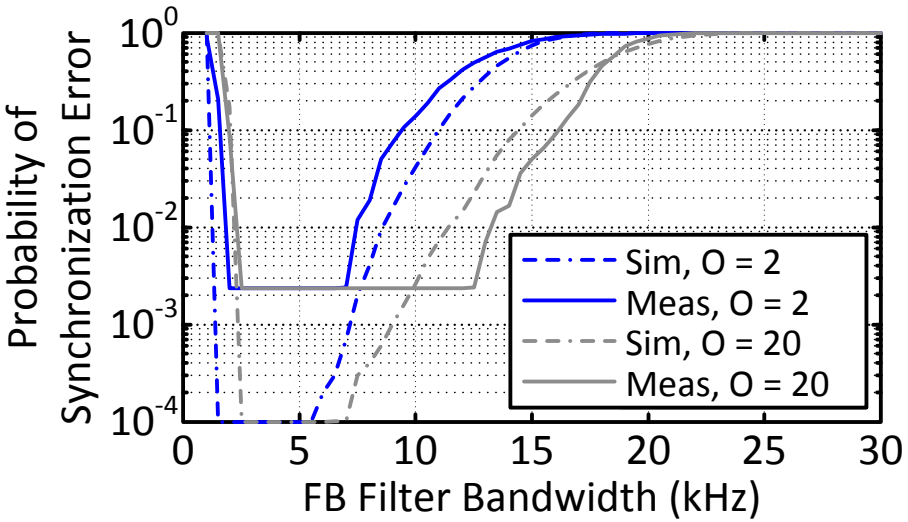
Prototype Receiver for Proof-of-Concept

- Set IF to 275 kHz
- Digitized real GSM data
- Used measured data as input to simulated baseband



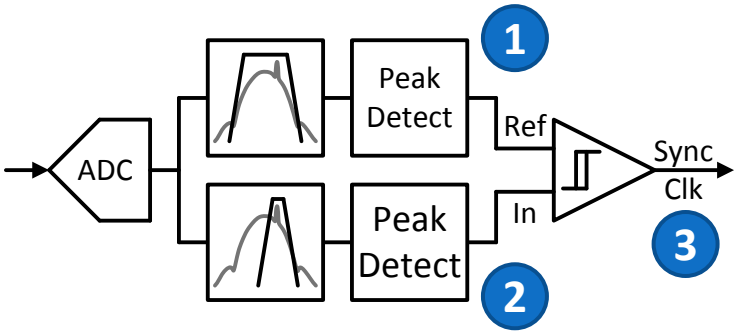
Extraction of Real GSM-Based Clock

- Counted number of synchronization errors
- Compared simulated and measured results

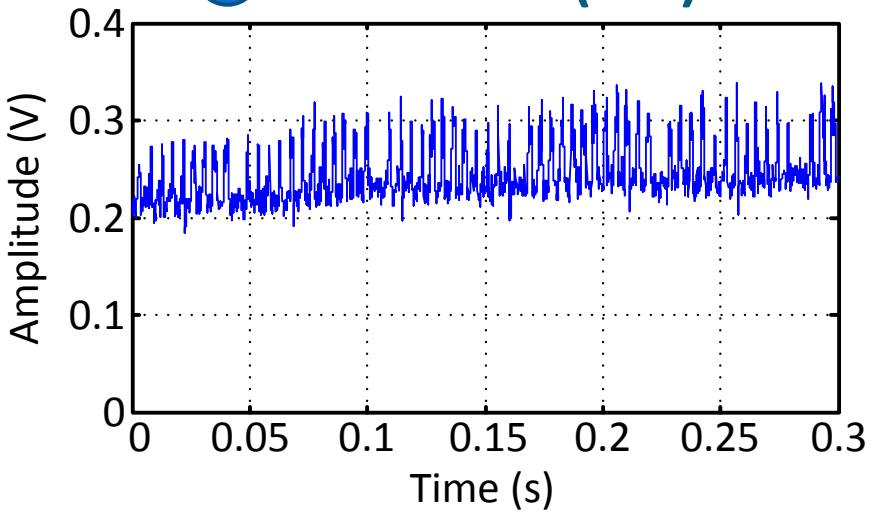


Similar trends…with discrepancies

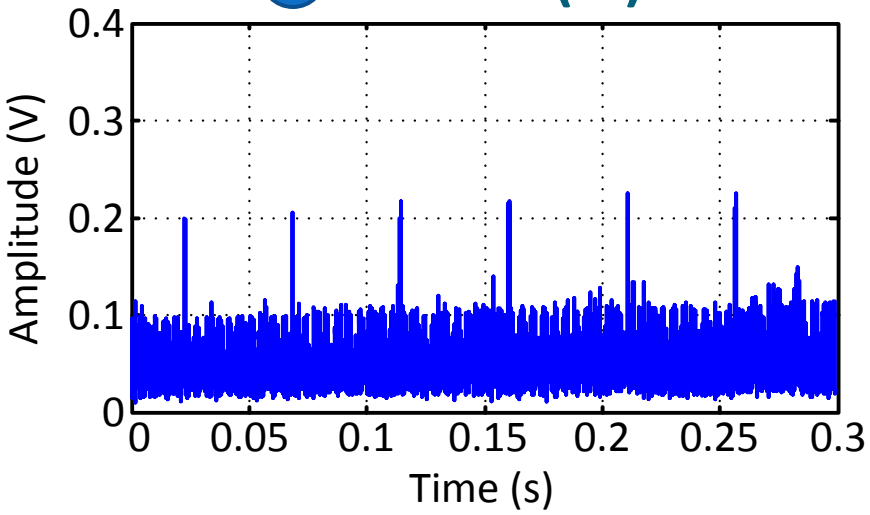
Extraction of Real GSM-Based Clock



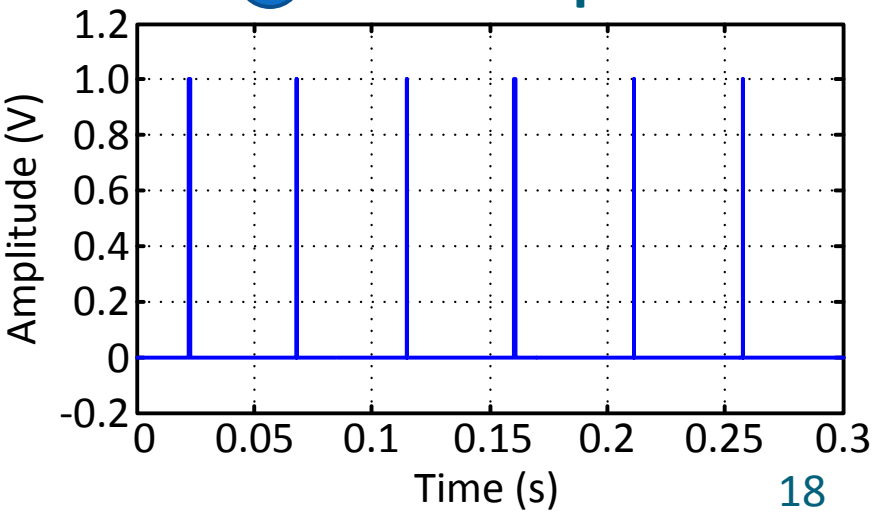
1 BCCH Path (Ref)



2 FB Path (In)



3 Clock Output



Summary / Conclusions

- Introduced technique of clock harvesting
  - Synchronizes network with existing signal
  - Conserves energy in sensor network
- Identified embedded clock in GSM standard
- Proposed radio architecture for synchronization
  - Amenable to low-power design
  - Characterized probability of synchronization error
- Verified functionality with prototype
- Harvested clock from real GSM signal