2.4GHz vs. Sub-GHz
Markets, Applications & Key Decisions
Overview

Many customers are trying to decide between 2.4 GHz or sub-GHz

- This presentation will define the key factors impacting a customer’s choice
- Goals
  - Clarify the 2.4 GHz market segment
  - Help you sell Silicon Labs sub-GHz radios against 2.4 GHz

Key customer decision factors

- Worldwide deployment
- Interoperability = “standard”
- Range
- Power consumption
- Antenna size

Focus is on proprietary 2.4 GHz and 802.15.4

- Most likely competitors you will encounter versus sub-GHz
We are not focusing this presentation on BT or WiFi®
- Few applications where you can sell sub-GHz against BT or WiFi®

Bluetooth
- Predominantly focused on high volume, consumer space
  - Cell phone accessories, PC accessories, etc.
- Highly integrated, system solutions for these applications
  - Example: Single chip solutions for Bluetooth headsets
- Mostly orthogonal to sub-GHz markets

Ultra low power Bluetooth (WiBree)
- New addition to Bluetooth standard for low power, end nodes
- Target market: cell phone accessories
- Highly integrated system solutions mostly orthogonal to sub-GHz

WiFi
- Target applications: high data rate communication products
- High data rate not a target for sub-GHz products
2.4GHz market numbers include 802.15.4/ZigBee

Sub-GHz 2008 TAM: 492Mu

2.4GHz 2008 TAM: 174Mu
- Proprietary: 154Mu
- 802.15.4: 20Mu
Frequency and Application Trends

- 2.4 GHz and sub-GHz each have unique advantages
- Certain markets have consolidated with one solution
  - 2.4 GHz—Wireless game controllers
  - Sub-GHz—Automotive remote keyless entry (RKE)
- Other markets mixed
  - Automated meter reading (AMR):
    - Sub-GHz—long range wireless backhaul network
    - 2.4 GHz—meter to home communication
  - Home security:
    - Sub-GHz—low data rate sensors (glass break, PIR, etc)
    - 2.4 GHz—high data rate video cameras
- Some markets are undecided
  - Home automation:
    - Sub-GHz—existing systems use sub-GHz almost exclusively
    - 2.4 GHz—customers considering 2.4GHz/ZigBee™ for future systems
2.4 GHz Radio Overview

- **Strengths and weaknesses of 2.4 GHz radios**
  - **Strengths:**
    - *Worldwide deployment* — one device for all major markets
    - *Small antenna size* — 2.4 GHz antenna is 1/3 the size of 900 MHz
    - *High data-rates* — larger than 1 Mbps
  - **Weaknesses:**
    - *Reduced range* — environmental losses at 2.4 GHz are ~9 dB more than at 900 MHz
    - *Increased power consumption* — due to reduced circuit efficiencies
    - *Polluted spectrum* — WIFI, Bluetooth, microwave ovens

- **Short range consumer electronics** — predominantly 2.4 GHz
  - Global frequency allocation: big advantage
  - Range and power consumption are lower concerns
    - Couch to TV range
    - Months long battery life acceptable

- **Example applications**
  - Game controller, audio headsets, keyboards/mice

*For 2.4GHz to achieve similar performance to sub-GHz requires much higher current consumption. In reality 2.4GHz does not target high performance.*
Sub-GHz Radio Overview

- Strengths and weaknesses of sub-GHz radios
  - Strengths:
    - **Communication range** — kilometer ranges easily achieved
    - **Reduced power consumption** — multi-year battery life
    - **Narrowband operation** — allows long range communication
    - **Low interference** — bands mostly used for proprietary low duty cycle links
  - Weaknesses:
    - **Antenna size** — optimal antenna size up to 7” @ 433 MHz
    - **Lower data rates** — due to limited bandwidth channels
    - **Worldwide deployment** — “almost” worldwide frequency allocations

- Long range and battery life—predominantly sub-GHz
  - Maximum range, multi-year battery life

- Example applications
  - Automated meter reading—maximum range and 20 year battery life
  - Home security—whole house coverage, multi-year sensor battery life
  - RKE/garage door openers—100m+ range, multi-year battery life
Range is significantly better at sub-GHz due to:

- **Path loss—Friis Equation**
  - Path loss at 2.4G is 8.5dB higher than 900M
  - A theoretical range improvement of 2.67X

- **Greater interference at 2.4 GHz due to Wifi and Bluetooth**

- **Greater range degradation at 2.4 G due to moisture**

- **XTAL ppm accuracy forces larger channel bandwidths**
  - 20ppm@2.4G > 20 ppm @ 900 M
  - A wider channel BW degrades sensitivity
Key Factors—Antenna

➢ Size (1/4 wavelength)
  ▪ 433 MHz ~ 17.3 cm (6.8”)
  ▪ 915 MHz ~ 8.2 cm (3.2”)
  ▪ 2.4 GHz ~ 3 cm (1.2”)

➢ Size vs. efficiency
  ▪ In space constrained projects:
    • 2.4 GHz has the advantage of being naturally smaller
    • Making larger antenna smaller can easily result in inefficiencies
      • Dissipated as heat instead of radiation into space
      • Increased parasitics

\[ \text{Length(cm)} = \frac{7500}{\text{freq(Hz)}} \]
Key Factors—Worldwide Deployment

- World wide ISM allocation
  - 433 MHz, 2.4 GHz
- Regional ISM Frequencies
  - 315, 470, 868, 915, 950 (MHz)
Key Factors—Worldwide Deployment

- The 2.4 GHz band is a global spectrum
- Each country may have different regulations
  - Can force customers to choose specific countries to certify – reduces worldwide deployment

Some country-specific examples:

- **France:**
  - (3a and 6a) Outdoor use limited to 10mW EIRP between 2454 – 2483.5 MHz
  - (11a) Max EIRP = 500mW

- **Italy:**
  - (3a) If used outside of own premises general authorization is required

- **Luxembourg:**
  - (3a) General authorization required for public use

- **Norway:**
  - (4a) Only 2447, 2448.5, 2450, 2451.5 and 2453 MHz allowed

- **Poland:**
  - (4a) Limited to 100mW

- **Romania:**
  - (1l) Individual licenses required

- **Slovak Republic:**
  - (3a) Military Band & Max 10mW EIRP

- **Sweden:**
  - (4a) Licences Required
  - (11a) Limited to 25mW EIRP
Key Factors—Compliance

Real life Illustration: Hardware & Firmware

Restrictions at 2.4 GHz actually require ‘worldwide’ products to have regional SKUs

- Linksys WAP54G Wireless Router

FCC Radiation Exposure Statement

This equipment complies with FCC radiation exposure limits set forth for an uncontrolled environment. This equipment should be installed and operated with minimum distance 20cm between the radiator and your body.

This transmitter must not be co-located or operating in conjunction with any other antenna or transmitter. IEEE 802.11b or 802.11g operation of this product in the USA is firmware-limited to channels 1 through 11.

Industry Canada Statement

This Class B digital apparatus complies with Canadian ICES-003 and RSS210.

Operation is subject to the following two conditions:
1. This device may not cause interference and
2. This device must accept any interference, including interference that may cause undesired operation of the device. This device has been designed to operate with an antenna having a maximum gain of 2dBi. Antenna having a higher gain is strictly prohibited per regulations of Industry Canada. The required antenna impedance is 50 ohms.
Key Factors—Interoperability

- Drives a standards based radio solution
- Not limited to a particular frequency

### Sub-GHz Standards

<table>
<thead>
<tr>
<th>Standard</th>
<th>Modem</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZigBee™</td>
<td>One-Net</td>
</tr>
<tr>
<td>EnOcean</td>
<td>Insteon</td>
</tr>
<tr>
<td>IOHomecontrol</td>
<td>Z-Wave</td>
</tr>
</tbody>
</table>

### 2.4GHz Standards

<table>
<thead>
<tr>
<th>Standard</th>
<th>Modem</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.4 (PHY/MAC)</td>
<td>6loPAN</td>
</tr>
<tr>
<td>ZigBee</td>
<td>RF4CE</td>
</tr>
<tr>
<td>Bluetooth</td>
<td>WiFi</td>
</tr>
</tbody>
</table>

- Standards based solutions tend to add cost:
  - ZigBee radio node: $2.0 and 128 kB stack
  - Sub-GHz radio node: $1.2 and 4 kB EZMacPRO stack

- Many markets remain proprietary due to cost
  - Home automation, PC peripherals

- Most user applications are node to node—not a network

- Few applications require vendor interoperability
  - Home automation, CE are potential exceptions
802.15.4 / ZigBee Market Overview

- 802.15.4 radios can implement a wide range of protocols
  - ZigBee, RF4CE, 6loPan, WirelessHART, proprietary

- Market for 802.15.4 is emerging (2009 TAM 15 Mu)
  - ZigBee dominated by smart energy (AMR) ~ 5 Mu TAM in 2009

- ZigBee optimized for high node count systems
  - Low TX power can be overcome by meshing in high node count systems
    - Increases complexity and power consumption
  - Large stack size (can be >128 kB) limits usage in simple, low cost systems
  - Few applications due to high cost, limited range, and lack of adoption

- Low cost systems will use optimized stacks built on 802.15.4
  - RF4CE optimized for consumer remote control applications
    - Smaller stack size, reduced system cost and complexity
Proprietary 2.4 GHz Market Overview

- **Dominated by Nordic semi**
  - 2009 Nordic 2.4 GHz volume approx 150MU
  - Dominated by PC peripherals, sports and gaming

- **Advantages of proprietary**
  - Lower cost—smaller die sizes, reduced MCU memory footprint
  - Reduced power—with more efficient radio usage
  - Reduced software complexity—Bluetooth, ZigBee® stacks are heavy (128 Kb+)
  - Optimized designs for very low cost systems

- **Risk that the large proprietary markets will migrate to standards**
  - Ultra low power Bluetooth—addresses some proprietary advantages
  - 802.15.4—targeted stacks can approach proprietary memory footprint
# Key Factors Summary

<table>
<thead>
<tr>
<th>Key Factor</th>
<th>Strength</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>Sub-GHz</td>
<td>Higher regulatory output power, reduced absorption, less spectral pollution, narrowband operation</td>
</tr>
<tr>
<td>Power consumption</td>
<td>Sub-GHz</td>
<td>Better circuit efficiency, improved propagation at sub-GHz. 2.4GHz chips performance much lower</td>
</tr>
<tr>
<td>SW cost</td>
<td>Proprietary</td>
<td>Small stack sizes, targeted applications</td>
</tr>
<tr>
<td>Multi-vendor</td>
<td>Sub-GHz</td>
<td>Most standards are at 2.4GHz (due to global frequency); Many sub-GHz standards are also available</td>
</tr>
<tr>
<td>Worldwide deployment</td>
<td>2.4 GHz</td>
<td>2.4GHz has an advantage, 433MHz can be used in most of world except Japan. Same 868MHz/915MHz designs for most of world.</td>
</tr>
<tr>
<td>Antenna size</td>
<td>2.4 GHz</td>
<td>Smaller antennas optimal with 2.4GHz; however very small designs can be achieved in sub-GHz</td>
</tr>
<tr>
<td>Data rate</td>
<td>2.4 GHz</td>
<td>Much higher throughput can be achieved</td>
</tr>
</tbody>
</table>

- High data rate, worldwide → 2.4 GHz
- Long range, low-power → sub-GHz
- Low-cost, single vendor → proprietary
Application frequency trends

2.4GHz
- Game Controllers
- PC Peripherals
- Bluetooth™
- WiFi™
- Cordless Phones
- Meters (Home Display)
- STB
- Sports Equip.
- Consumer Medical
- RFID
- Security
- Home Automation
- Toys

SubGHz
- Meters
- GDO
- Aftermarket RKE
- Automotive
  - TPMS
  - RKE
**Game controllers**

- The majority of wireless game controllers are 2.4GHz
  - What factors push this product into the 2.4GHz space?

<table>
<thead>
<tr>
<th>Priority</th>
<th>Key Factor</th>
<th>Comment</th>
<th>Sub-GHz</th>
<th>2.4GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Range</td>
<td>Couch to TV range (not multi-room)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Battery life</td>
<td>Months</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Bandwidth</td>
<td>Low data rates only needed</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>High</td>
<td>Small antenna</td>
<td>Sub-GHz antenna can fit</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Global compliance</td>
<td>Must ship to all countries</td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>
Wireless water meter

The majority of wireless water meters are sub-GHz

- What factors push this product into the sub-GHz space?

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<tr>
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<th>Key Factor</th>
<th>Comment</th>
<th>Sub-GHz</th>
<th>2.4 GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Antenna</td>
<td>Meter allows for larger antennas</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td></td>
<td>Global compliance</td>
<td>Only needs to work domestically</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td></td>
<td>Bandwidth</td>
<td>Low data rate</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>High</td>
<td>Range</td>
<td>100s of meters, hostile environments</td>
<td>√</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Battery life</td>
<td>Years not months</td>
<td>√</td>
<td>X</td>
</tr>
</tbody>
</table>
Application Example—‘Undecided’

Consumer remote (used in STB, TV, AV)
- Today the consumer remote space is mixed between IR and sub-GHz
- There is discussion for future designs to migrate to 2.4 GHz (RF4CE)
  - What factors are impacting this decision?

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</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Bandwidth</td>
<td>Optimized for low speeds</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>High</td>
<td>Global compliance</td>
<td>IR designs today are global</td>
<td>?</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Small antenna</td>
<td>Must fit in in remote</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Unclear</td>
<td>Range</td>
<td>Single room (TV) or multi-room (STB)</td>
<td>✓</td>
<td>?</td>
</tr>
<tr>
<td></td>
<td>Battery life</td>
<td>Charging cradle, LCD?</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>
Key Questions to Ask a Customer

- How to influence customer’s sub-GHz vs. 2.4 GHz decision

- What countries will the product be sold to?
  - 433 MHz is a viable 2.4 GHz alternative in most of the world
  - 868 MHz and 915 MHz for USA/Europe with a single design

- What range is required?
  - Applications with multi-room range is a strong sub-GHz candidate
  - Sub-GHz can achieve multi-km range, 2.4 GHz requires meshing

- What is the overall radio system cost?
  - Sub-GHz or 2.4 GHz proprietary target lowest system cost
  - Sub-GHz, one-way link for lowest possible cost (with Si4010 family)

- What is the battery lifetime requirement?
  - Sub-GHz systems can easily achieve multi-year battery life

- What is the data rate?
  - Low data rate apps (longer range, longer battery life) = sub-GHz
Call-to-Action

- **Win all applications inherently in the sub-GHz space**
  - Long range, battery life, small memory footprint = sub-GHz
  - EZRadioPRO® is the world’s highest performance sub-GHz radio
  - Si4010 offers cost sensitive one-way link sub-GHz solution
  - EZMac®/PRO offers small memory footprint, proprietary networking stack

- **Understand what is driving a customer’s frequency decision**
  - Look for opportunities to highlight sub-GHz advantages

- **Push evaluation of sub-GHz by customers ‘on the fence’**
  - Many customers assume their only option is 2.4 GHz

- **Help identify high-volume 2.4 GHz customers**
  - 2.4 GHz is a Silicon Labs roadmap item
  - Need to identify key customers to help define product vector