
# Locally-Licensed Spectrum for Site-Specific Business & Industrial IoT Use

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# Outline

## Business & Economic Rationale

- Wireless IIoT as a business enabler
- Focus on site-specific scenarios

## Requirements & Spectrum Implications

- Business, Technical, Spectrum, Regulatory requirements
- Investment protection
- Today’s spectrum categories vs. business requirements
- Geographic status of locally-licensed spectrum
- Deployment models & architectures

## Frequencies & Site Density

- Low vs High frequencies
- How they match to business site density

## Conclusions

# Business & Economic Rationale

# Wireless 2.0

Major economic shift underway

- *Wireless as an enabler for important business & industrial processes, which will require clean spectrum for business-critical & deterministic applications*
- *Essential to innovation, competitiveness, economic productivity & growth*
- Broad range of business drivers & benefits
- Diverse & consequential uses: e.g., automation, IoT, Industrial IoT (IIoT), secure communications, flexible manufacturing, process monitoring & control, safety, ...

While there's benefit from leveraging consumer wireless technology ecosystems, there also are important differences from consumer wireless regarding:

- *Underlying business requirements & operational models*
- *Regulatory requirements for spectrum*

# Locally-Licensed Spectrum
## Business/Industrial/IIoT Use

**1. Focus here is on local, site-specific business & industrial use**

- Mostly indoor + limited outdoor coverage (property boundaries)
- Economically highly important category
- Beneficial overlap with government needs, and regarding compatible partners for future sharing of Govt/DoD spectrum
- Clear need for new business-appropriate spectrum regulations, not well served by today's rules
- Technically viable with appropriate technical & policy considerations

**2. Wider area outdoor use cases – not discussed here**

- Important differences w/ regard to RF coverage area
- Many cases addressable by traditional licensing, spectrum leasing &/or spectrum license disaggregation

# Requirements & Spectrum Implications

# Summary Spectrum Requirements for Business-Critical & Deterministic Wireless

| Aspects | What Businesses Want/Need | Unlicensed Spectrum | Traditional Licensed Spectrum |
|---|---|---|---|
| **Determinism** | **Require** guaranteed future capacity + no interference ✓ | No: Uncertainty re: future capacity & interference ✗ | Yes: Because it's licensed spectrum ✓ |
| **License Area** | **Business site-specific** ✓ | **N/A** ✗ | **Large** geographic regions ✗ |
| **Business Delivery Model** | **Flexible** Business can select model that best serves its needs ✓ | **Flexible** (multiple models) ✓ | **Only from license holder** ✗ |

This new category is called "locally-licensed spectrum", where businesses can obtain a spectrum license specific to their site(s)

# Business-Critical & Deterministic Wireless
## Business Drivers & Technical/Spectrum Requirements

| Categories | Drivers, Requirements & Examples |
|---|---|
| **Business Drivers**<br>Wireless as a enabler for business-critical applications and processes | Directly connects to business efficiency & competitivity<br>• Businesses need freedom & agility to select vendors & suppliers<br>• Investment protection: No tolerance for unexpected business impacts<br>Diverse use cases & business drivers:<br>• Cost, performance, local regulations/constraints, insurance req's, business-critical situations, safety, resiliency re: power outages, special equipment req's, … |
| **Diverse Technical Requirements**<br>Business flexibility is critical | Very broad, diverse needs:<br>• Access technologies (choice & variety), bandwidths, number of frequency carriers, duplexing flexibility, performance vs. cost tradeoffs, ...<br>• Diverse architectural req's: e.g., control loops spanning multiple access techs, etc.<br>• Business flexibility & control over all factors is essential |
| **Spectrum Requirements**<br>Investment protection | Zero tolerance for unreliability or future reductions in capacity or performance<br>• Clean spectrum = Reliable capacity, coverage, & latency = Determinism.<br>• Free of harmful interference, co-channel & adjacent-channel, now & in future<br>• Future performance & capacity guarantees<br>All about investment protection |

Major Themes: Investment protection & business control

# Business-Critical & Deterministic Wireless
## Business Model & Regulatory Requirements

| Categories | Requirements & Examples |
|---|---|
| **Business Model Requirements**<br>Business control, flexibility & agility | Business freedom to determine:<br>• Network owner: e.g., own, lease, as a service, …<br>• Network operations: Self-operate, or contract all/part to external Service Providers, system integrators, vertical-specific companies, etc.<br>• Select/change vendors/operator as need, without impacting assets, infrastructure, operations.<br>Example: How businesses utilize cloud services today<br>• Frequently migrate data/apps across/between own DC + multiple cloud providers due to cost, performance, other factors. Businesses will seek same flexibility re: wireless services. |
| **Regulatory Focus**<br>Focus on minimal requisites for RF isolation & high spatial reuse between sites, consistent with business needs & flexibility | Minimal requisites<br>• RF isolation: Restrict to low Tx power, consistent w/ achievable building material & separation.<br>• Outdoor use using high Tx powers should be placed in different spectrum, to avoid interference<br>• Leave business owner to address on premise details re: coexistence & interference<br>• Use higher frequencies for denser environs, where material penetration & propagation losses are higher – thus enabling high spatial reuse & RF isolation |
| **Technology Agnosticism**<br>Business select technology(ies) based on their needs | No explicit or implicit technology constraints, such as:<br>• Technology type or standards family restrictions<br>• Bandwidth or channelization req's that reject relevant technologies<br>• Frame structure, synchronization, duplexing constraints |

Taken together, these requirements provide the motivation for locally licensed spectrum

# Countries With Locally-Licensed Spectrum

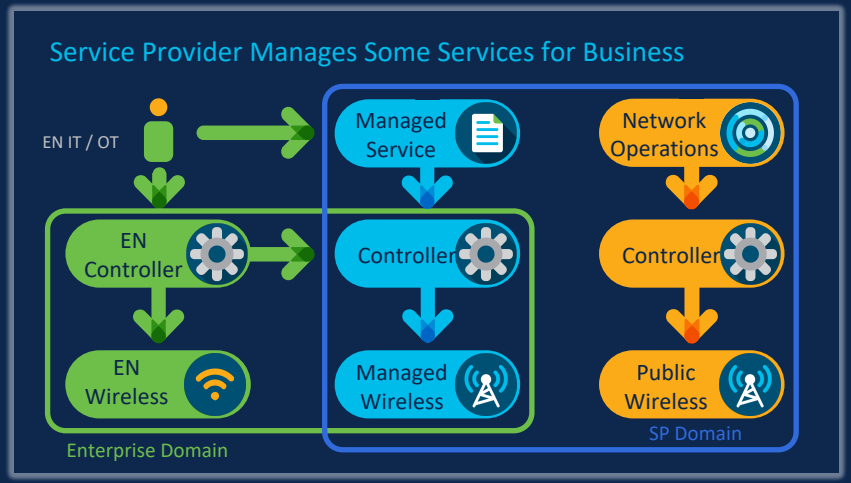
## Countries with locally licensable spectrum (now or near future)

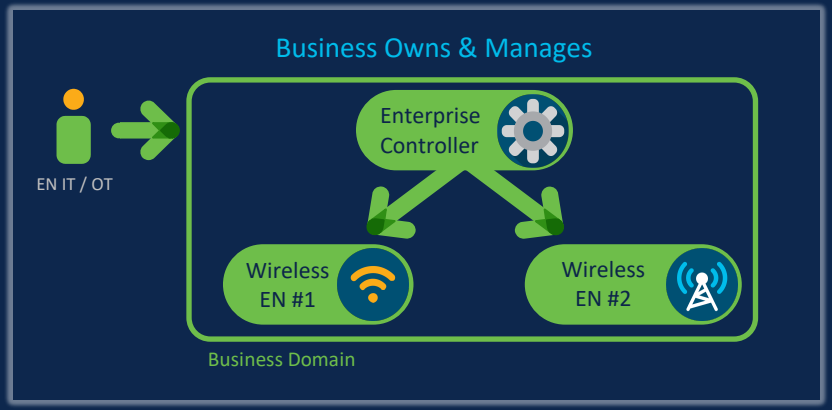
- Germany (100MHz at 3.7GHz)
- Japan (100MHz at 28.2GHz, also considering parts of 28.3-29.1GHz & 4.6-4.8GHz)
- UK (100MHz within 3.8-4.2GHz; also 24.25-26.5 GHz for indoor)
- France (40MHz at 2.6GHz)
- Sweden (80-100MHz at 3.7GHz)
- Major businesses are using these bands

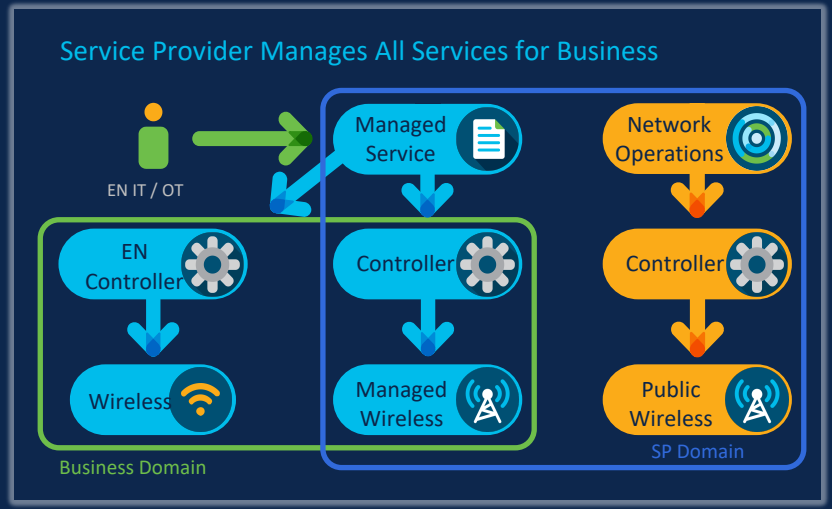
## What are the potential economic impacts?

- Higher productivity from business investments
- Incent businesses to build/expand new factories/warehouses/industrial facilities
- May place other countries at a competitive disadvantage

# Deployment Models & Architectures




Multiple architectural variants, including

- RF, user-plane (UP) & control-plane (CP) all on premises
- RF & UP on prem, CP in Cloud/SP domain
- RF on prem, rest in Cloud/SP domain
- Network slices

A business might have multiple models &/or architectures for different use cases

# How Frequency Relates to High Spatial Reuse

# Outdoor vs. Indoor Wireless

## Relevant Factors & Frequency Ranges for Future Business/Industrial Networks

*Low-$f$ characteristics favor longer range & outdoor deployments*

Outdoor

Long range, best for wide area outdoor use

Diffracts well for ubiquitous coverage

Good match to larger “macro” cells

Reduced outdoor range

Diffracts poorly, severe outdoor shadow fading

Beam tracking challenge for high mobility situations

**Lower frequencies: $f$<~6GHz**

*Densely utilized spectrum, hard to obtain wide BWs*

**Higher frequencies: $f$> 6GHz (e.g., mmW)**

*Less densely utilized, larger BWs available*

Indoor-outdoor interference leakage

Need large spatial separation for isolating nearby networks

Limited spatial reuse for nearby networks

End result: Narrow BWs, lower capacity per site

Propagation benefits by reflecting from walls/ceilings/floors

High penetration loss → good indoor-outdoor isolation

Easier to isolate nearby networks

High spatial reuse possible for nearby networks

High BWs & capacities possible for dense IIoT networks

Indoor

*High-$f$ characteristics favor dense &/or indoor deployments*

# Business & Industrial Locations
## Rural/Suburban vs. Dense/Urban Sites

### Business sites with surrounding land

- Losses from propagation + building penetration → reduce RF interference
- Lower interference + Higher spatial reuse = Determinism & Capacity
- Low or high frequencies can both serve the needs

### Dense business/industrial districts

- Multi-story buildings to Multi-tenant start-ups
- Short distances → RF isolation challenges for deterministic use
- High frequencies best serve the needs
  - Intrinsic isolation benefits & higher spatial reuse for determinism & capacity
  - Indoors, reflections from walls/floors/ceilings fill in shadow fades

**With appropriate frequencies + regulatory framework, both are addressable**

**Providing deterministic spectrum for business/industry/IIoT networks**

# Example mmW Regulatory Framework

## Based Upon 37.0-37.6 GHz Band

### Restrict to on-premise business/industrial/government use

- Site-specific licenses supporting high spatial reuse
- No rogue interference from consumer devices
- Not an avenue for “new entrant” consumer-oriented operators to emerge

### High frequency benefits

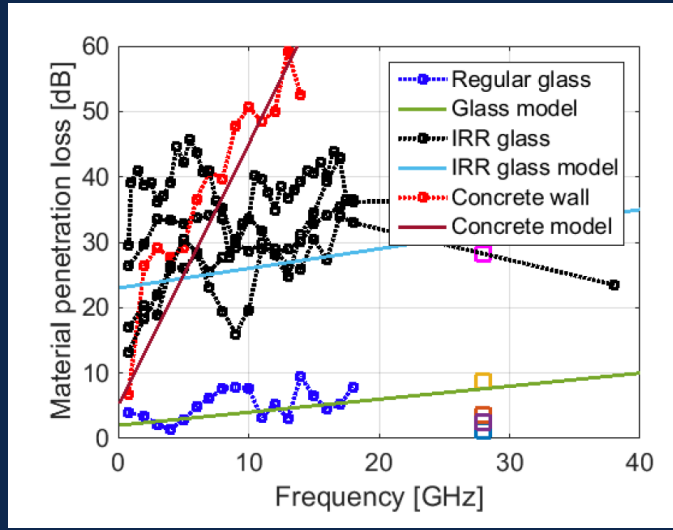
- High building penetration loss (concrete, steel, IRR glass, …)
- Low-cost isolation materials (mesh, carbonized foam, aluminized mylar, …)
- Most indoor surfaces reflect well; Reduced range for leakage outdoors

### Example rules for good isolation & high spatial reuse

- EIRP ≤ ~1W (reduces interference)
- -77 dB(W/m2) PFD @ site boundary ⇒ Consistent w/ above & ~40dB BPL
- Ensures interference is 6dB below thermal noise
- Suitable constraints on out-of-band interference to/from adjacent bands

### Suitable sharing mechanism

- E.g., shared database to protect any incumbents



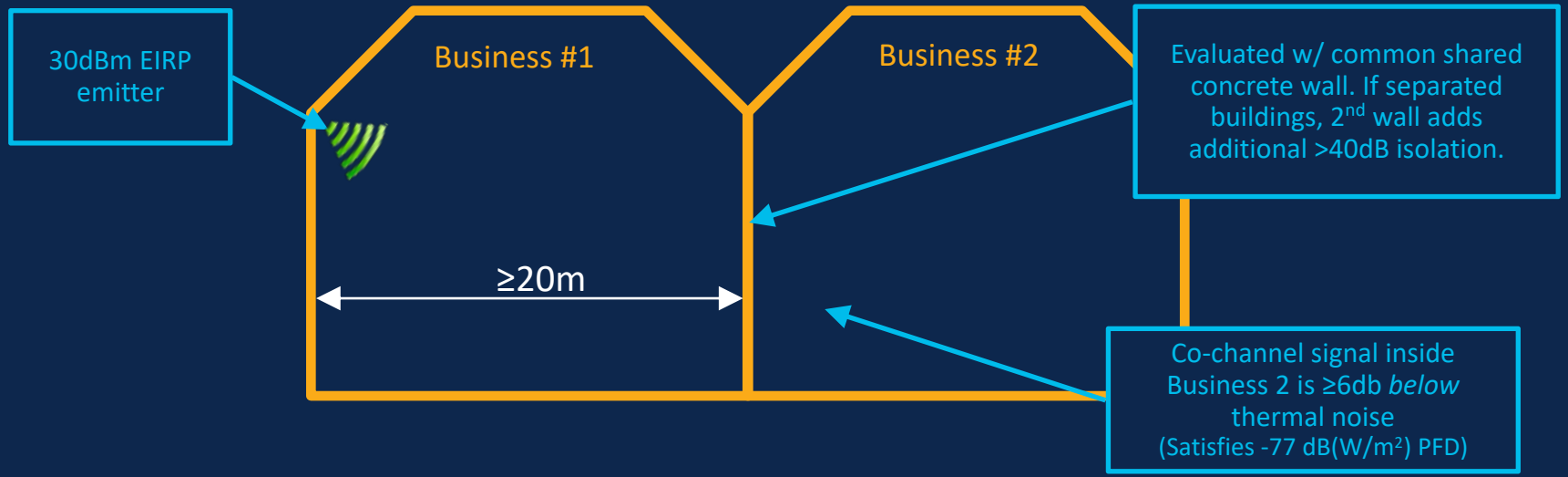

*From “5G Channel Model for bands up to 100 GHz” (Oct 2016)*
*http://www.5gworkshops.com/5GCM.html*

*BPL: building penetration loss*
*PFD: power flux density*

# Dense Spatial Reuse Example

## Adjacent Buildings with Shared Concrete Wall

- 37GHz calculation, 30dBm EIRP in 100MHz occupied bandwidth
- Common wall (or common floor/ceiling) w/ ≥40dB BPL (1-2” of concrete)
- Free space pathloss, no clutter considered (conservative)



# Summary

- Wireless is now enabling critical business & industrial processes.
- Businesses need local-licensable spectrum options for business-critical and deterministic use cases (e.g., IIoT). Those without may face future competitive disadvantage relative to international competitors.
- IIoT & businesses present new critical requirements re: investment protection, flexibility on business & operational models, etc.
- Dense scenarios are best served by higher frequencies, which provide propagation advantages (shorter range, high isolation, …) for determinism and high spatial reuse.
- The right spectrum regulatory framework can address these requirements.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