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# Compatibility Challenges for Broadcast Networks and White Space Devices

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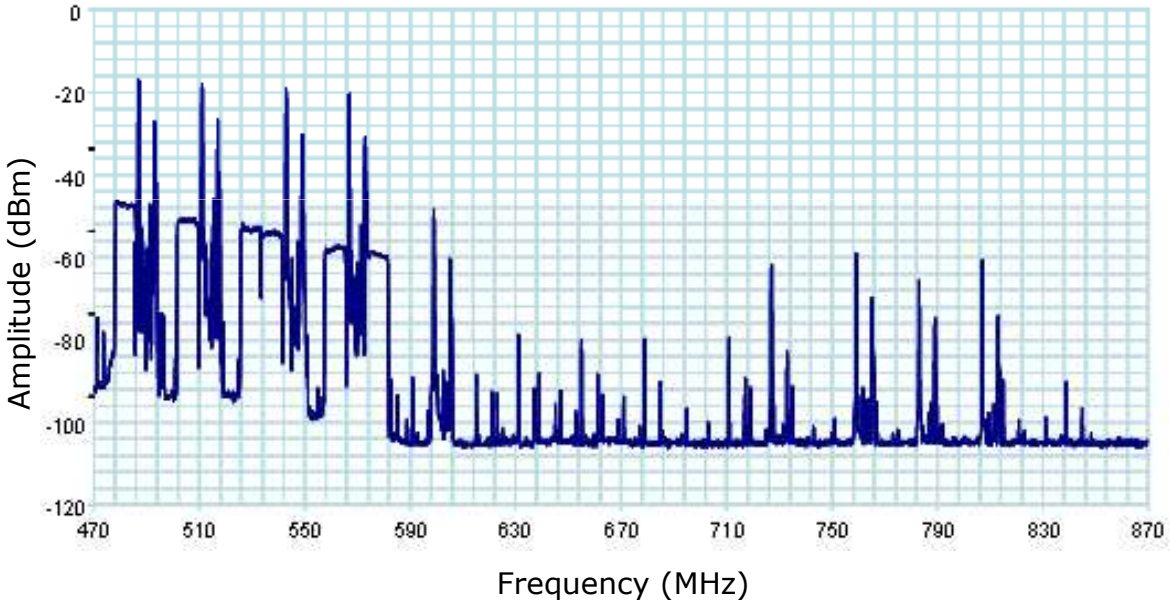
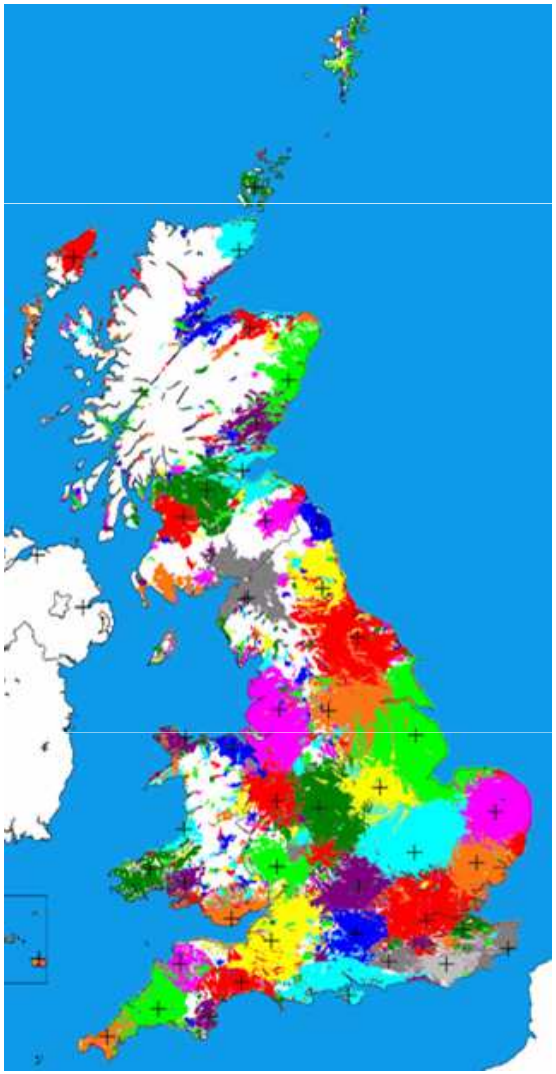
# Overview

- Background
  - White space definition
  - UK digital switch over plan
  - Available white space spectrum
- White Space Applications
  - Existing licensed
  - Proposed licence-exempt (LE)
- Access Techniques - Cognitive Radio
  - Spectrum sensing
  - Geolocation
  - Beacons
- Technical Challenges
  - Spectrum sensing and the hidden node problem
  - ACI management
- Conclusions

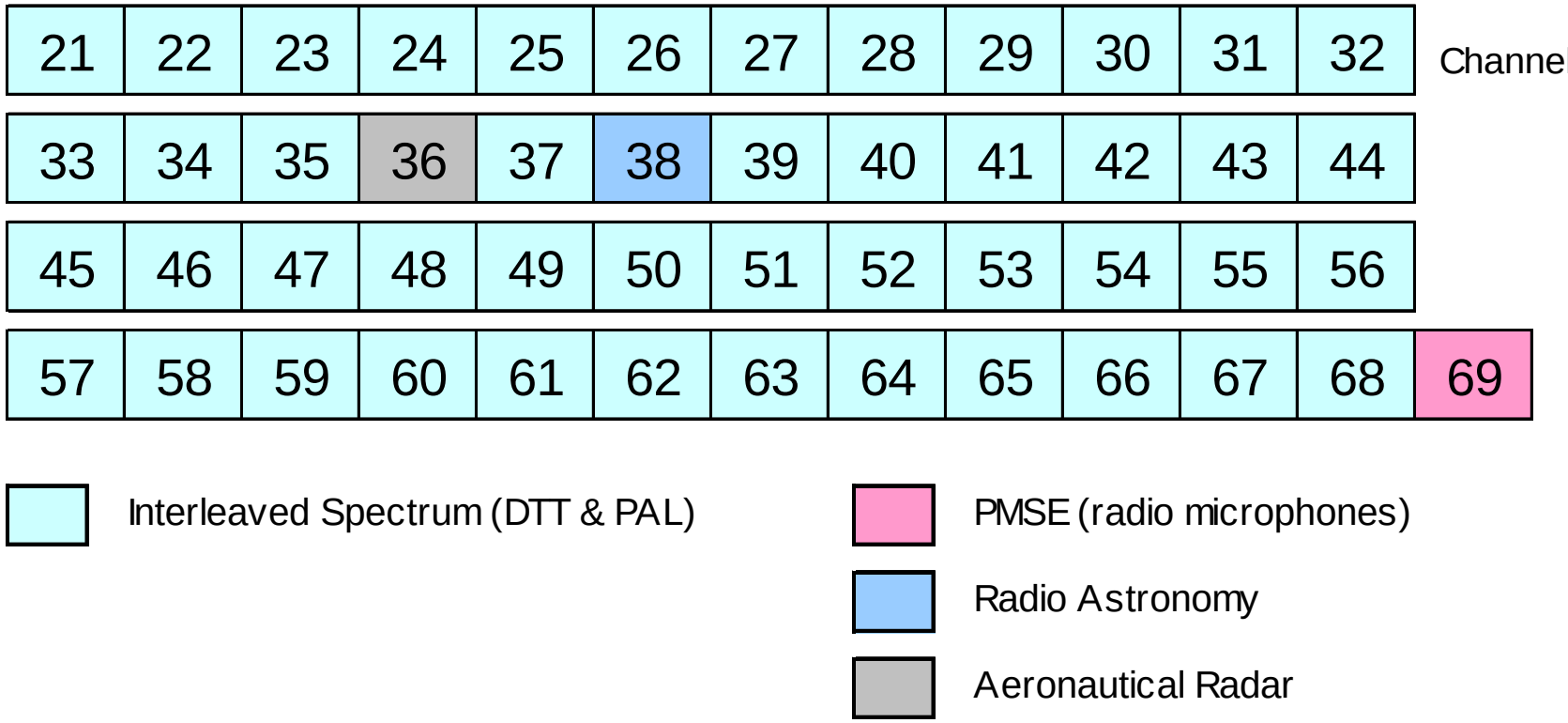
# What is White Space?

- Digital TV Planned as MFN
  - Derived from analogue plan
  - 84 main sites, ~1000 relay sites
- Typical channel re-use every 100km
- Relatively sparse use of UHF spectrum



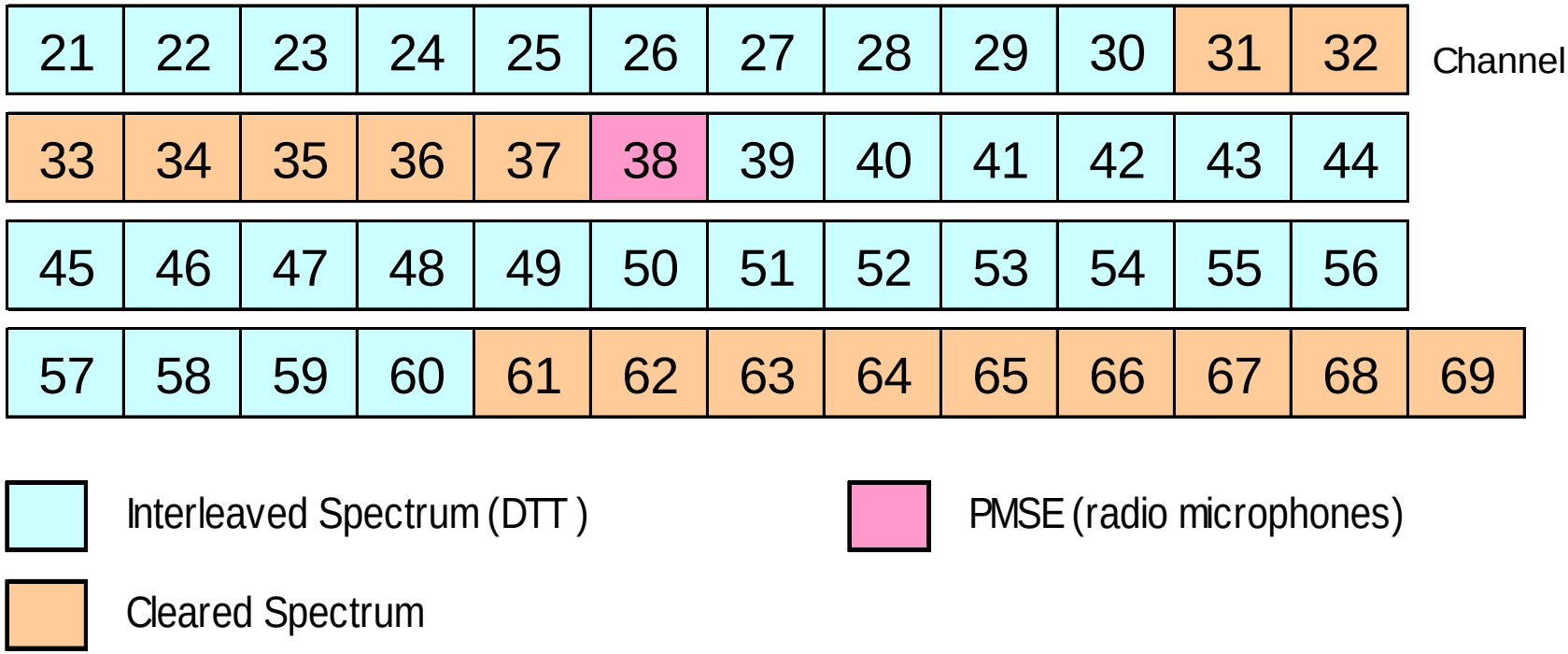



# UK TV Spectrum 2009




- MFN using 46 UHF channels (368MHz total)
- 11 MFN TV Services (5xPAL + 6xDTT multiplexes)
- Licensed interleaved PMSE access (radio microphones)

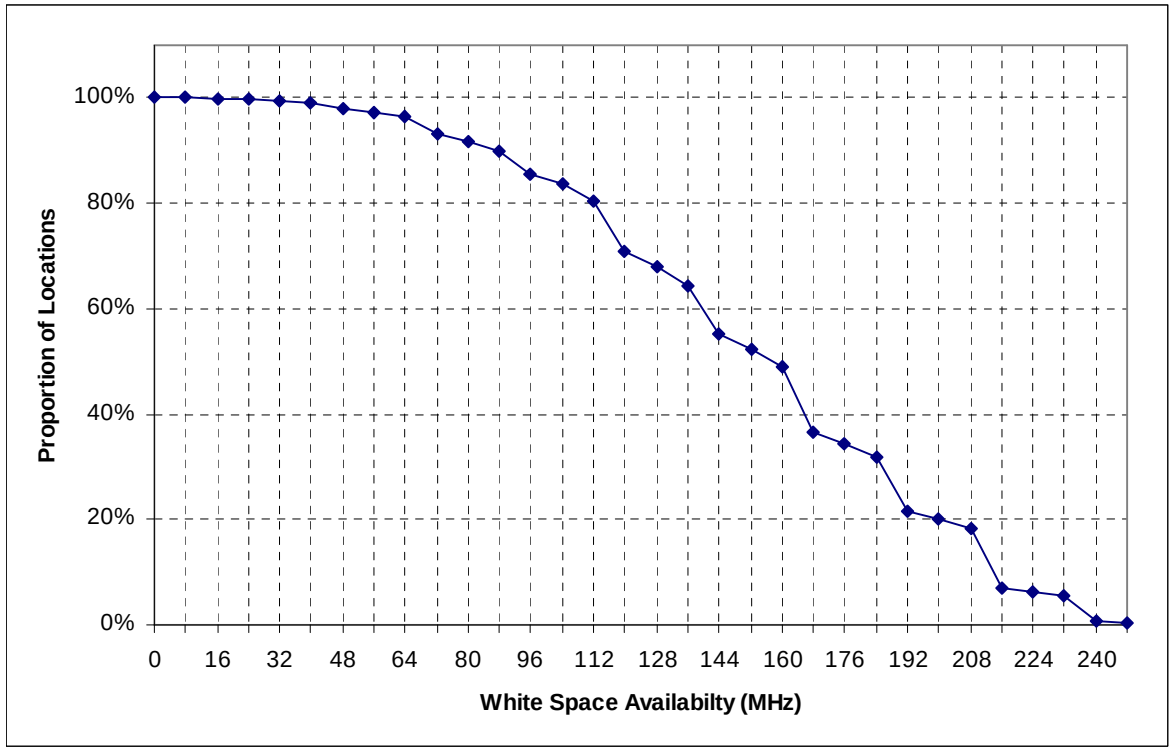
# UK TV Spectrum 2012




- 16 channels (128MHz) cleared for auction
  - Upper cleared (9 channels) for UMTS-800 (LTE)
  - Lower cleared (7 channels) use to be determined
- 32 channels (256MHz) retained for 6 x DTT multiplexes and interleaved whitespace (PMSE + WSDs)

# White Space Availability

- Naively, 256MHz DTT spectrum for 6 Multiplexes (48MHz)
- Increased use for  TV Relays and at MFN boundaries
- Typically 50% of UK coverage area will have >150MHz White Space spectrum



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# A Word of Caution….

- 50% of coverage area not necessarily 50% of population
- Bottlenecks in densely populated areas where TV relay requirement is highest (e.g. London)
- Adjacent channel use of white space is restricted
  - ACI and OOB issues

# Existing White Space Applications

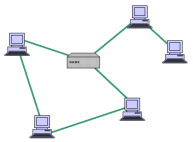
Programme Making and Special Events (PMSE)

- Radio microphones (10 - 50mW EIRP)
- TV Studios, ENG ,Theatres
- Typically licensed by a band manager (JFMG in the UK)

# New White Space Applications

- Broadband Wireless Access
  - Rural Area Networks (IEEE 802.22)
    - "ADSL-like" broadband networks operated by an ISP
    - Up to 4W EIRP (802.22 Draft)
    - Lower power RAN variant may suit denser TV network in Europe

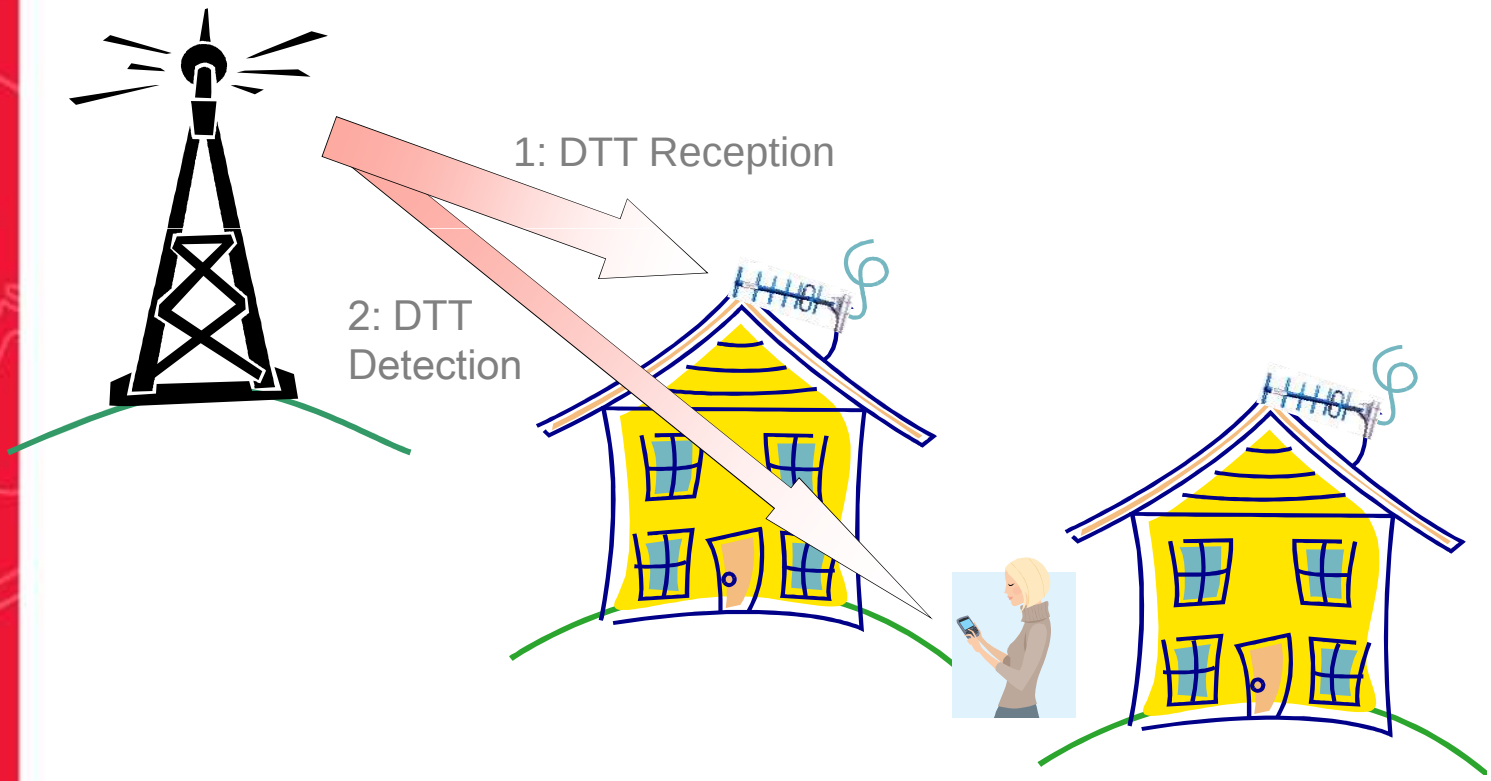
- In Home Networks
  - Improved WiFi (range & throughput)
  - Multimedia streaming and VOD
  - Internet sharing (e.g. FON model)
    - Helping to meet universal broadband objectives



# White Space Access Techniques (UHF Cognitive Radio)

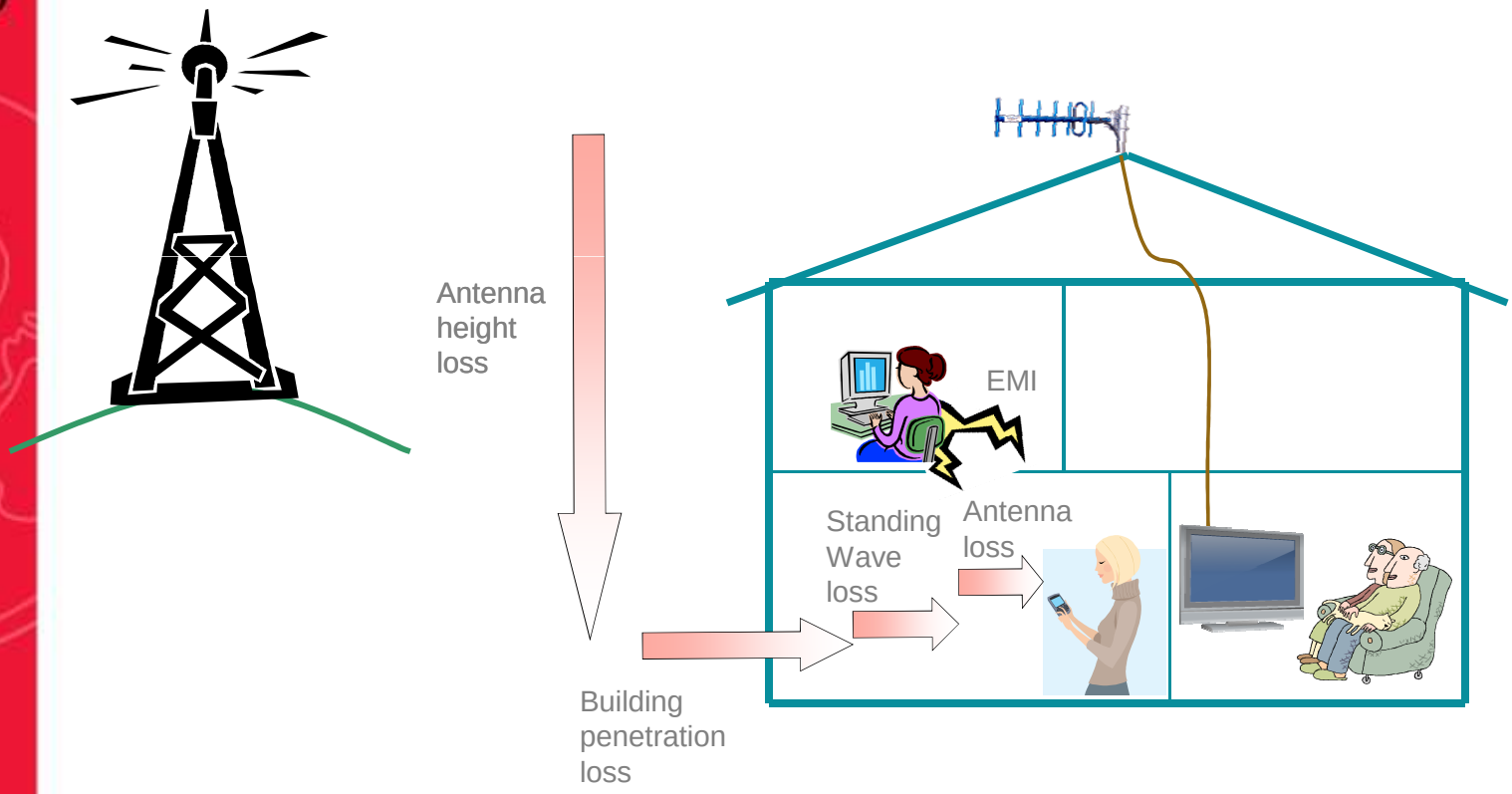
- Spectrum sensing
  - Avoid incumbent TV or PMSE
    - Energy detection
    - Feature detection & correlation
- Geolocation
  - Location aware (GPS)
  - Internet database of channels and EIRP limits
- Beacons
  - Independent network to signal white space availability or
  - Keep out areas for PMSE

# Spectrum Sensing – Hidden Node Problem




- Detection path loss much higher than for fixed reception
  - Hidden node margin (path 2 – path 1)
  - Resulting C/N for detection small

# Hidden Node Components




- Height Loss
- Building Penetration Loss
- Standing Waves
- Antenna Loss
- EMI

# DTT Detection C/N Estimation

| | |
|---|---|
| Required DTT CNR for QEF (64QAM rate 2/3) | 19 dB |
| Planning Margin | 8 dB |

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| WSD Antenna gain | -10 | dBi |
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| Height loss | 12 | | dB |
| Building penetration loss | 7 | | dB |
| Location variation (95%) | 14 | | dB |
| C/N losses due to location | | -33 | dB |

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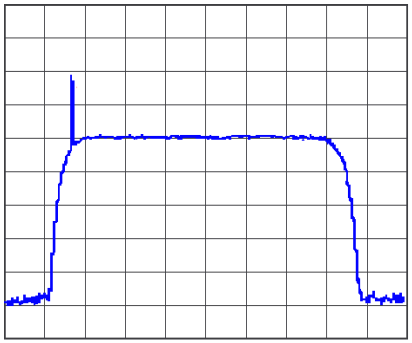
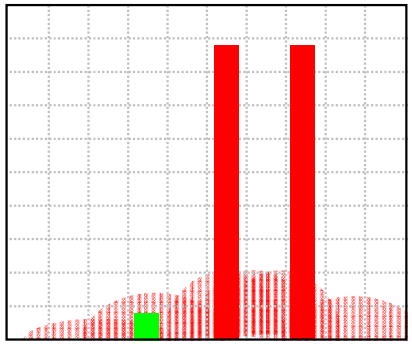
| Location variation (95%) | 14 | dB |
| C/N losses due to location | | -33 dB |
| Degradation due to man made noise | | -8 dB |
| C/N at Cognitive receiver | | -36 dB |

Source: "The Chester 1997 Multilateral Coordination Agreement"

# Sensing Issues

- DTT typically buried in noise
- Detection very difficult
  - DVB-T sensing requires correlation over all modes
  - ATSC sensing easier using fixed pilot
  - Linearity issues
- Geolocation favoured over sensing for co-channel interference protection
  - Greater control of the White Space with ability to tune parameters





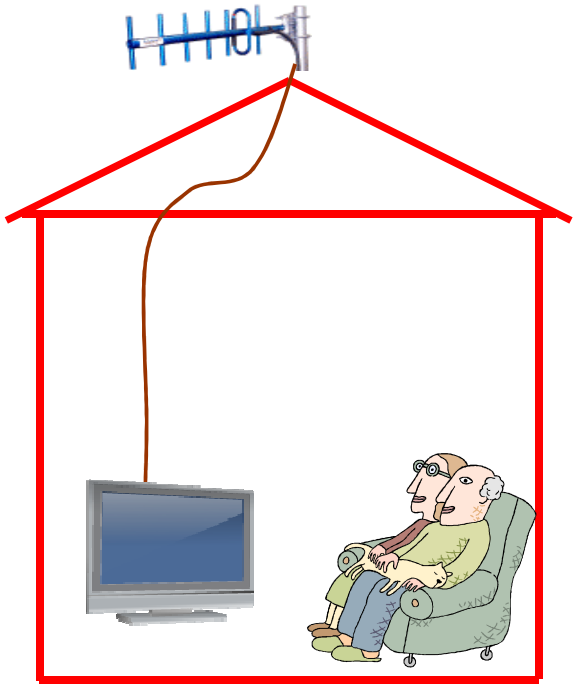
# Adjacent Channel Interference (ACI) protection

- Adjacent and non adjacent devices can still interfere with DTT
- Need EIRP limits
  - Potentially location dependent using geolocation techniques to maximize WSD performance

# Calculation of EIRP limits – ACI protection

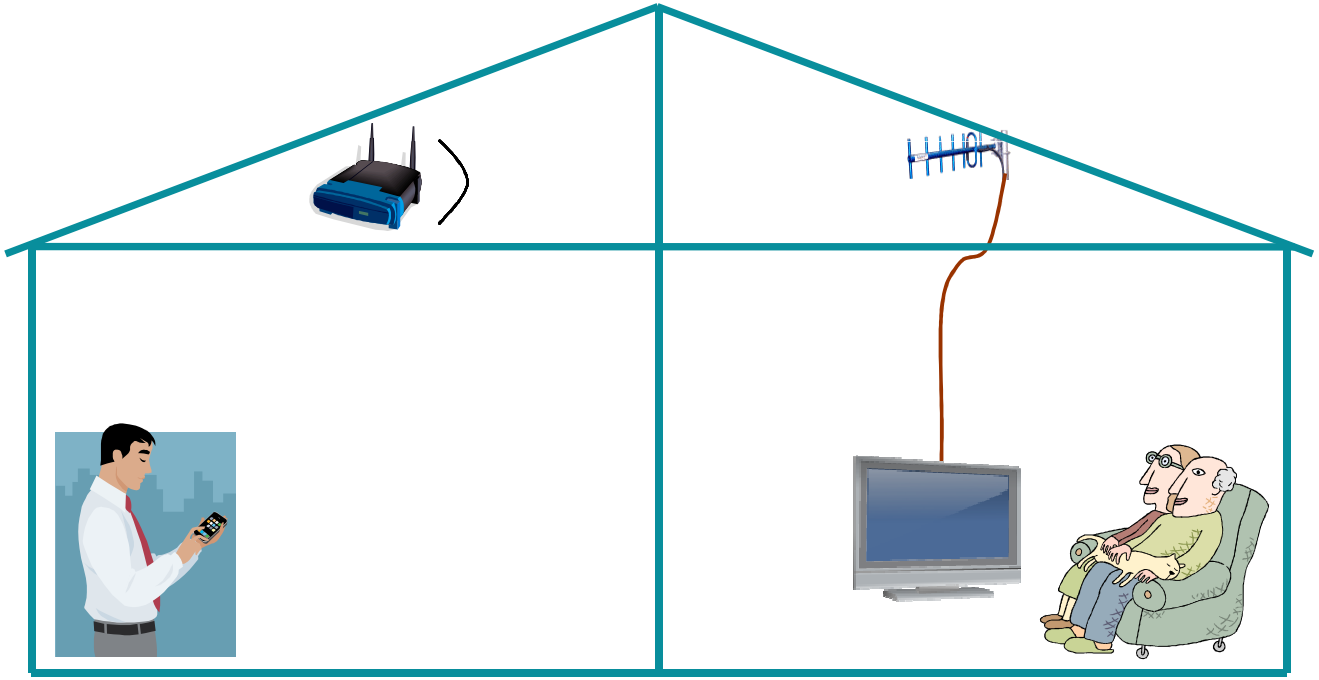
- Consider C/I performance of receiver and planned DTT signal level to define maximum possible WSD interference level
- Calculate path loss from WSD to DTT receiver for a given scenario
- Infer maximum WSD EIRP

# Interference Scenario 1: WSD ground floor to fixed DTT



- Path loss at 500MHz, 48dB
- DTT @ -72dBm
- Receiver C/I: -27dB adjacent (-38dB alternate)
  - Maximum EIRP: +3dBm (+14dBm alternate)

# Interference Scenario 2: Loft mounted WSD to loft DTT



- Path loss at 500MHz, 37dB
- DTT @ -79dBm (7dB shielding)
- Receiver C/I: -27dB adjacent (-38dB alternate)
  - Maximum EIRP: -15dBm (!) (-4dBm alternate)

# Comparison of required EIRP limits with Regulator Proposals

| Scenario | EIRP Protection requirement | |
|---|---|---|
| | Outdoor | Loft |
| Adjacent Channel Use | +3dBm | -15dBm |
| Non Adjacent Channel Use | +14dBm | -4dBm |

# Comparison of required EIRP limits with Regulator Proposals

| Scenario | EIRP Protection requirement | | FCC-8-260 14/11/08 | |
|---|---|---|---|---|
| | Outdoor | Loft | Mobile | Fixed |
| Adjacent Channel Use | +3dBm | -15dBm | +16dBm | - |
| Non Adjacent Channel Use | +14dBm | -4dBm | +20dBm | +36dBm |

# Comparison of required EIRP limits with Regulator Proposals

| Scenario | EIRP Protection requirement | | FCC-8-260 14/11/08 | | Ofcom 1/7/09 |
|---|---|---|---|---|---|
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| Adjacent Channel Use | +3dBm | -15dBm | +16dBm | - | +4dBm |
| Non Adjacent Channel Use | +14dBm | -4dBm | +20dBm | +36dBm | +17dBm |

- ACI issues with the current proposals
- Loft antenna and portable DTT reception unprotected

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# Conclusions

- White Space Devices can potentially enable new applications
  - Mobile broadband, home networks & RANs
- Sensing very difficult to engineer
- Geolocation emerging as preferred access solution for CCI prevention
  - Parameters can be tuned over time to manage interference
- Beacons useful to define keep out areas for PMSE

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# Conclusions

- Adjacent and non-adjacent channel interference risks
- Regulator EIRP proposals do not protect current receivers
- Particular problems
  - At edge of DTT coverage area
  - Loft reception with indoor WSDs
  - Portable reception (unprotected)


Thank you !

- Questions ?