Hidden Node Problem Discussions

Presentation to
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Federal Communications Commission
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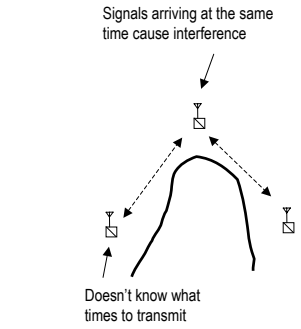
Shared Spectrum Company
703-761-2818
mmchenry@sharedspectrum.com

Agenda

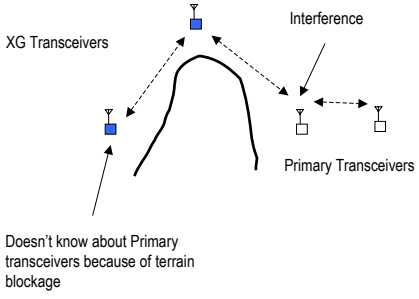
- What is the Hidden Node problem?
- Hidden node issues with different spectrum access methods
  - Listen-Before Talk
    - “TDMA” spectrum
    - Broadcast spectrum
  - Probe
  - Geo-location/database

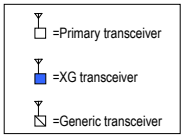
"Hidden Node Problem" Has Several Definitions

Generic Networking Definition



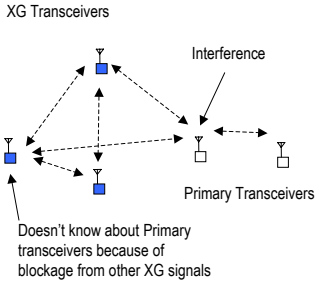
Spectrum Sharing Definition – Terrain Blockage Case



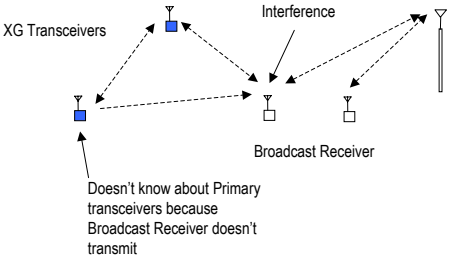


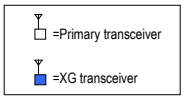
"Hidden Node Problem" Has Several Definitions (Continued)

Spectrum Sharing Definition – Signal Blockage Case



Spectrum Sharing Definition – Broadcast Case



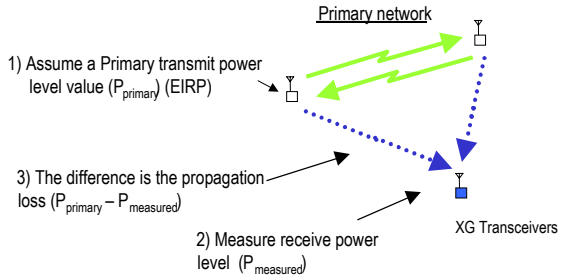


Spectrum Access Methods

- Non-cooperative Primary user methods
  - No connection between XG and Primary transceivers
  - Method depends on Primary user system architecture
    - Listen-Before Talk
      - "TDMA" spectrum
      - Broadcast spectrum
    - Probe
    - Geo-location/database
  - XG focus
- Cooperative Primary user methods
  - Uses electronic feedback from Primary transceivers
  - Not being worked by SSC

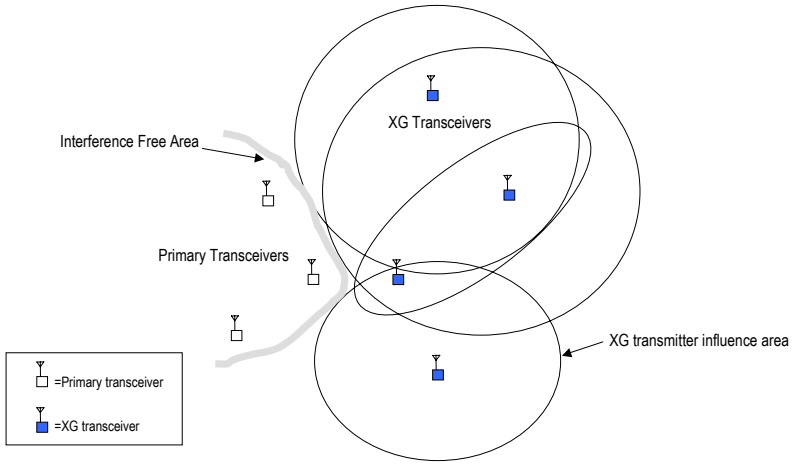
Listen-Before-Talk Spectrum Access Method

$$P_{max\,TX} = P_{allowable\,interference} + P_{primary} - P_{measured}$$



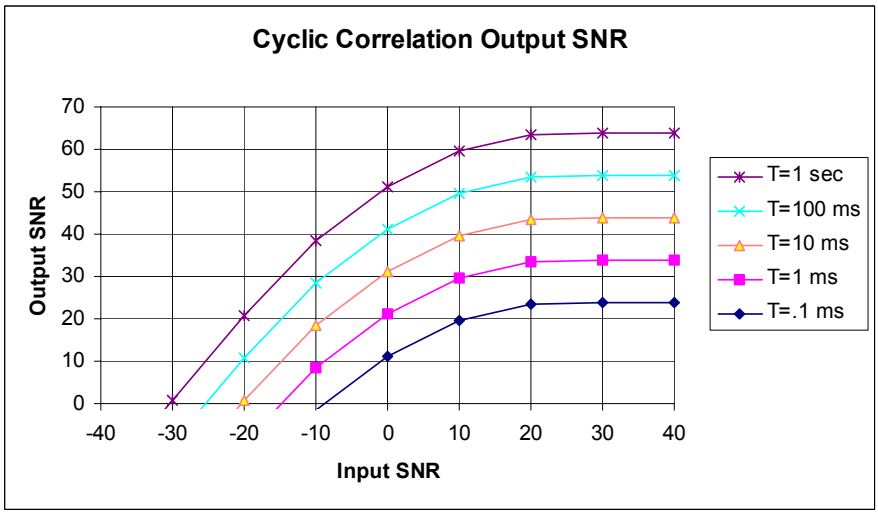
- $P_{max\,TX} = 10*\log10(k * T_i * B) + P_{Primary} - P_{measured}$ - Protection Ratio
  - Protection Ratio = 10 to 20 dB, required for cummulative effects, rapid propagation changes, false alarm minimization
  - T_i – Interference Noise Temperature, in K
  - B = signal bandwidth, in Hz

XG Coverage “Morphs” To Fit Primary Users

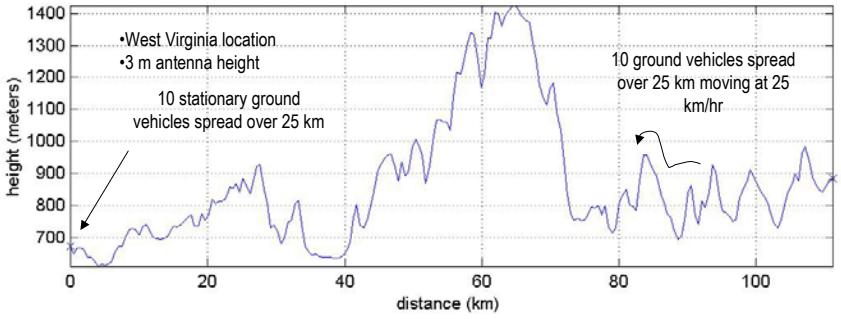


Hidden-node problem overcome by each XG transceiver listening to all Primary users within range

High Sensitivity Receiver Performance

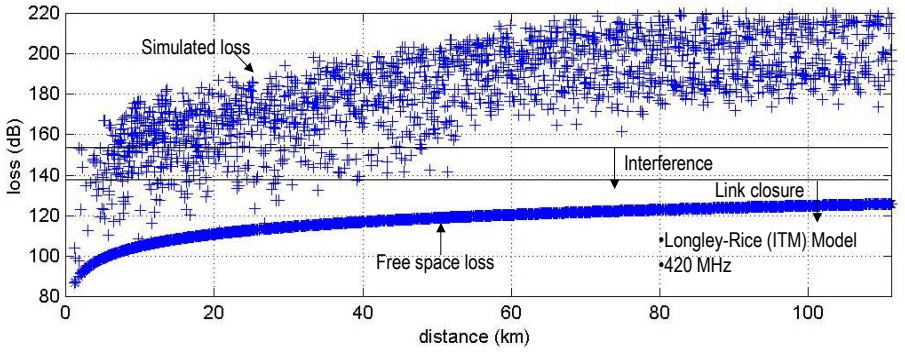


Simulation Example

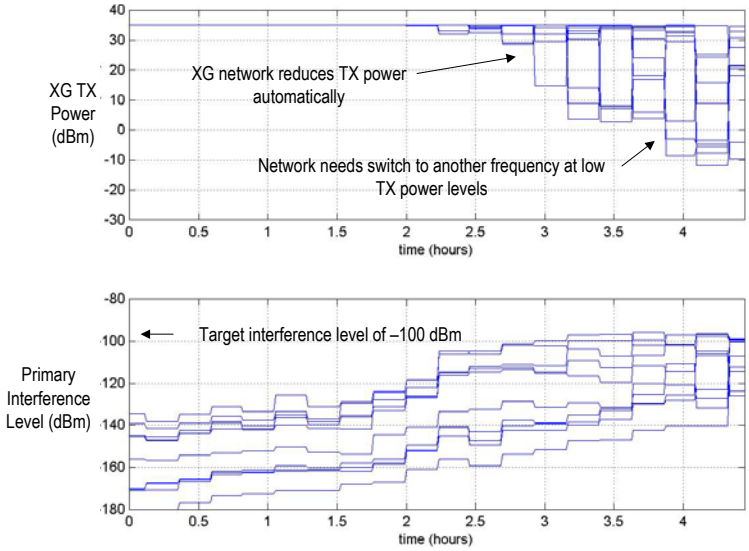


- Primary users are stationary
- XG users are mobile
- Omni-directional antennas
- 420 MHz signal frequency

Propagation Losses



TX Power and Interference



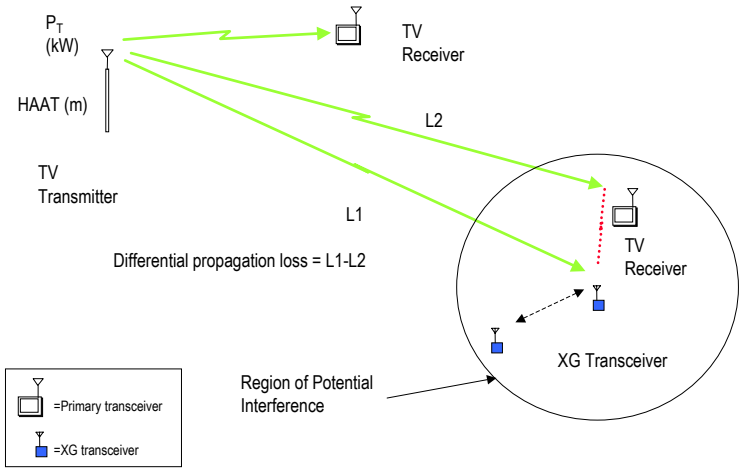
Interference Temperature Limits Should Be A Statistical Quantity

- Levels and duty cycles consistent with true noise condition
- Specific to Primary antenna height, antenna gain pattern
- Values depend on Primary system characteristics

Notional Interference Temperature Limits

Fraction of Receiver Locations	Intermittent Interference			Continuous Interference	
	90%			5%	5%
Interference Noise Temperature Level	Maximum Duration (seconds)	Maximum Occurrences Per Hour in any One Primary Channel	Maximum Occurrences Per Hour Per Band	Maximum Duration (seconds)	Maximum Duration (seconds)
<5 dB	Unlimited	Unlimited	Unlimited		
5 dB to 25 dB	0.1 second	10	50	Unlimited	
5 dB to 25 dB	1 second	5	25		
25 dB to 40 dB	0.1 second	5	25		Unlimited
25 dB to 40 dB	1 second	2	10		

Listen-Only Method in the Broadcast Bands



Transmit Power Rule For Broadcast Band

$P_{max\ TX}$ = Po (low value) if Primary signal is not detected

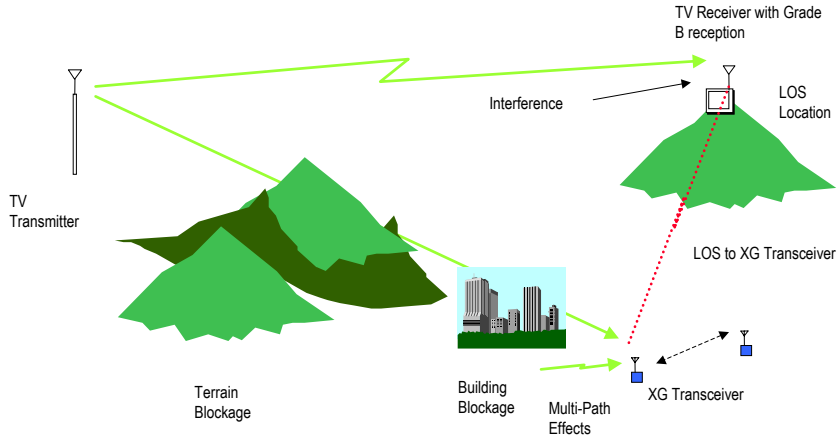
Transmission prohibited[1] if Primary signal is detected

where, $P_{max\ TX}$ = Frequency XG transmitter power level, in dBm

Po = specified power value, in dBm

Note 1: Could use a reduced power instead no transmission

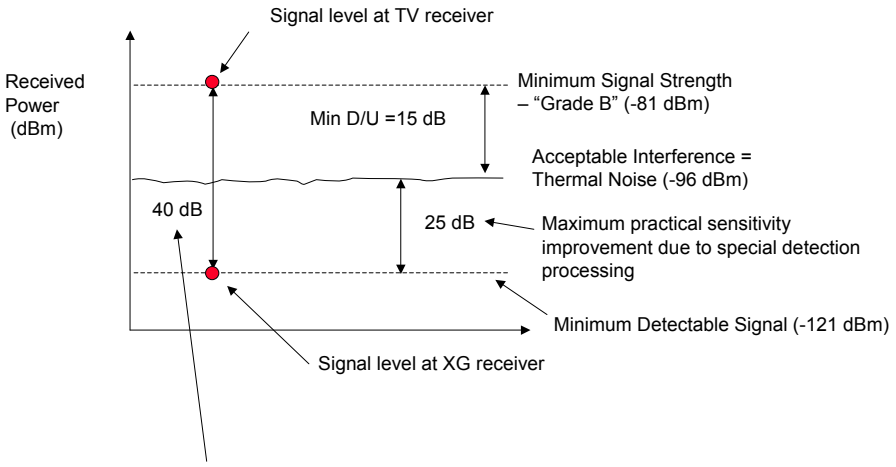
Minimal Interference



- Joint probability of three conditions
  - –XG doesn't detect TV signal
  - –Primary user receives TV signal
  - –D/U < 15 dB

Could reduce interference probability using joint detection (both XG's must not detect TV signal)

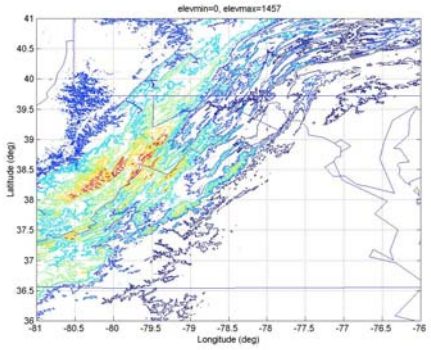
Maximum Differential Propagation Value

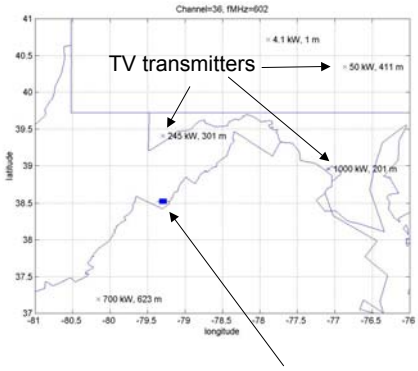


Maximum differential propagation value = 40 dB

Simulation of Differential Propagation

Scenario – Mid-Atlantic Region
Elevation contours

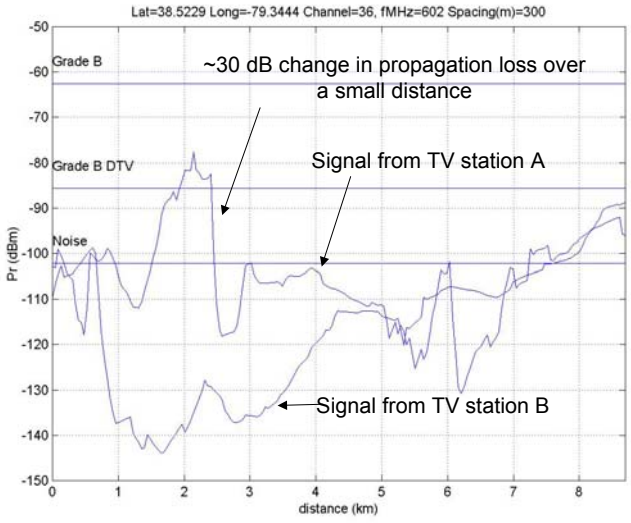




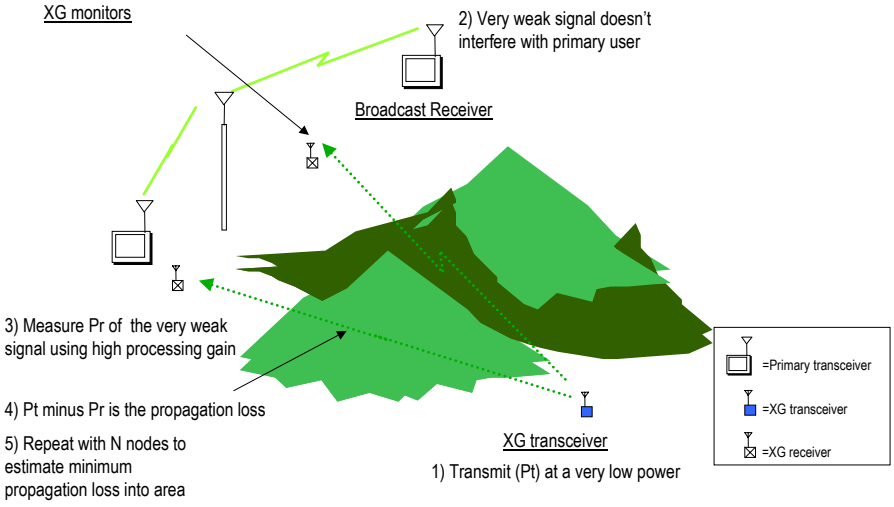
Test reception points along a ~ 8 km path

Large Change in Propagation Loss over a Short Distance is Rare

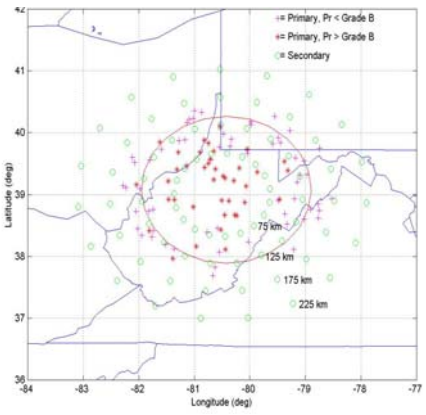
- Simulation using TIREM model
  - Neglects small spatial variations
- Minimal "differential" propagation measurements in the literature

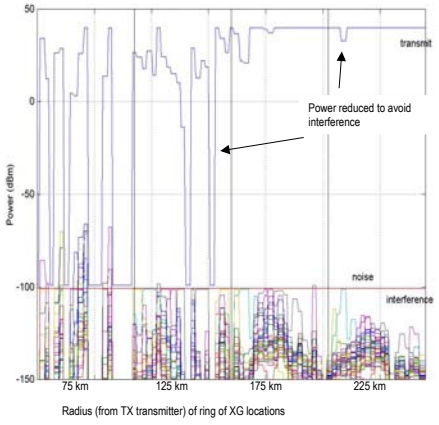


Spectrum Probing Method



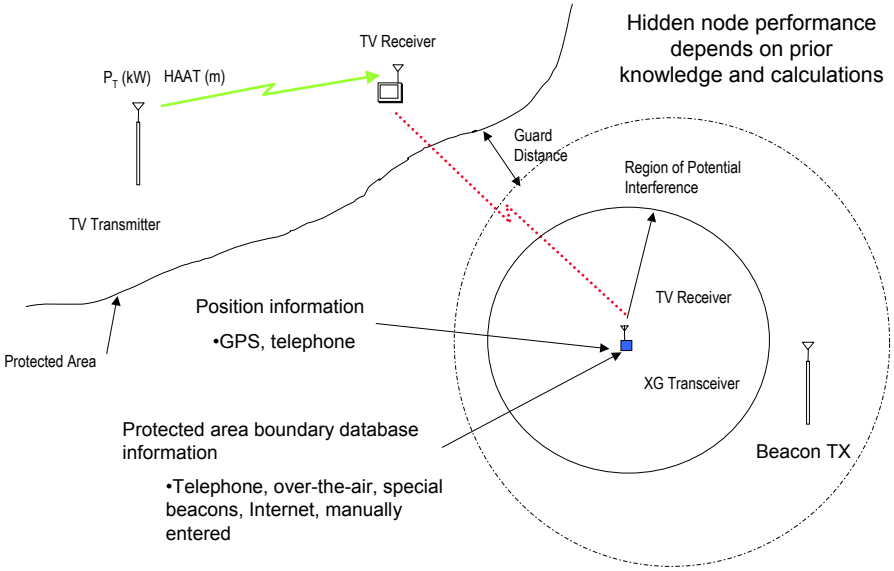
Simulation of Probing Method





- 6 monitors surrounding Grade B region
- 100 randomly located TV receivers
- Negligible interference (eliminate hidden node problem) > 125 km from TV TX
- Closer distances require more monitors

Geo-Location Method



Summary

- Multiple definitions of Hidden Node Problem
- Multiple, robust spectrum access methods
  - Listen-Before Talk
    - "TDMA" spectrum
    - Broadcast spectrum
  - Probe
  - Geo-location/database
- Hidden Node Problem
  - Overcome in many access methods