Inter-service Interference (ISIX) Methodology Workshop

February 21, 2014

Workshop Agenda

1:00pm	**Opening remarks**
1:05pm	**Overview of Public Notice** **Introduction to Market Variation** **Presentation of an Inter-service Interference Methodology** • Predicting Coverage & Interference • Effects of Different Bandwidths Between Television and Wireless • Propagation Modeling Parameters, Including Clutter **Implementing the Methodology Using *TVStudy*** **Potential Application of the Methodology to Incentive Auction**
2:15pm	**Discussion and Moderated Q&A**
3:00pm	**Adjourn**

I. OVERVIEW OF PUBLIC NOTICE

Market Variation

- Ideally: Same spectrum repurposed in every market
- Realistically: In a voluntary auction, could be some variation and spectrum recovery; avoid “Least Common Denominator”
- Inter-service interference can result from wireless operations co- or adjacent-channel to a TV broadcast station operating in a nearby market, and vice-versa
- Objective: Develop a methodology that:
  - Protects broadcasters against harmful interference
  - Informs wireless bidders about spectrum environment
  - Ensures efficient use of the spectrum

- Some commenters suggested establishing a predefined separation distance – with distances ranging from 100 to 500 km
- OET developed more flexible methodology for managing inter-service interference that provides greater granularity in predicting possible interference
  - takes into account factors such as specific technical characteristics of TV stations, typical wireless systems, radio propagation factors, terrain variability, etc.
- Methodology presented is intended to yield greater spectral efficiency with less likelihood of leaving large geographic areas unavailable for wireless services

- PN released to expand record and solicit comment on the OET methodology
- OET staff is presenting a possible methodology for managing inter-service interference
- PN and today's presentation primarily focus on the technical aspects of the methodology—policy related issues remain outstanding and will be addressed later at the appropriate time

PN solicits comments on:

- whether methodology is more accurate than a generic separation distance or if other approaches should be considered
- whether assumptions and standards used in methodology are appropriate
- the use of specific clutter values
- the use of uniform distribution of wireless base stations for one of the interference scenarios
- projected interference threshold to DTV and use of proxy channels for analysis

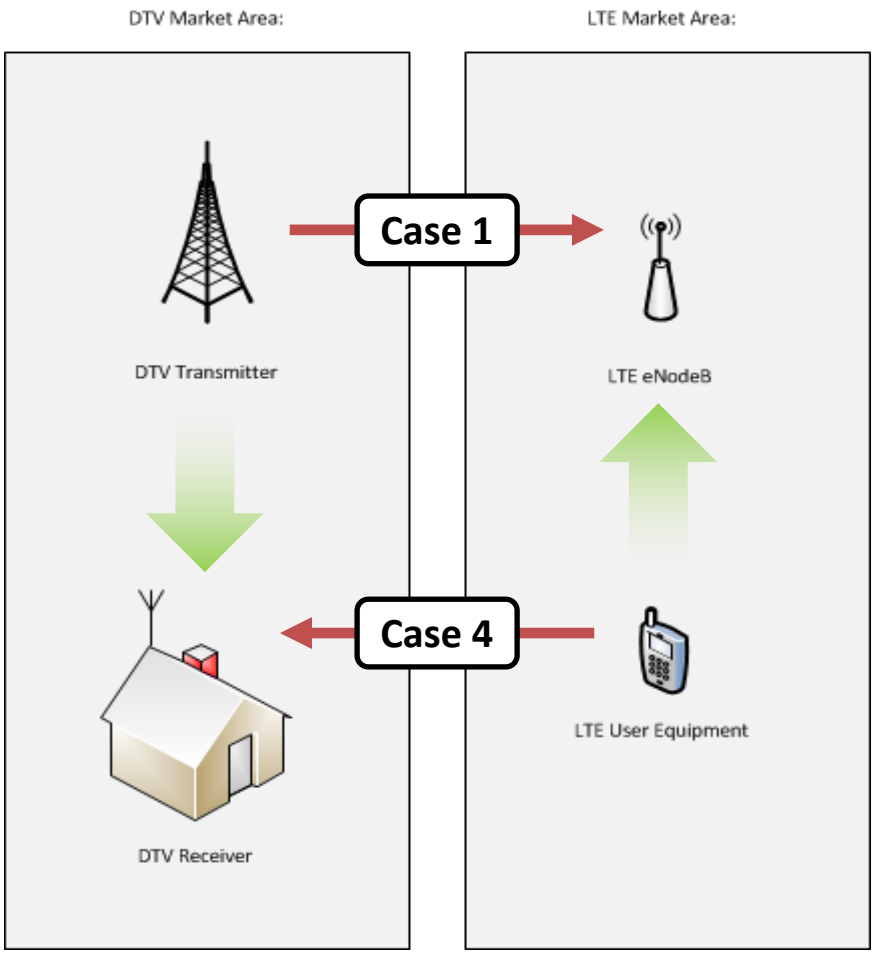
II. HOW MARKET VARIATION ARISES

Market Variation and Impairment

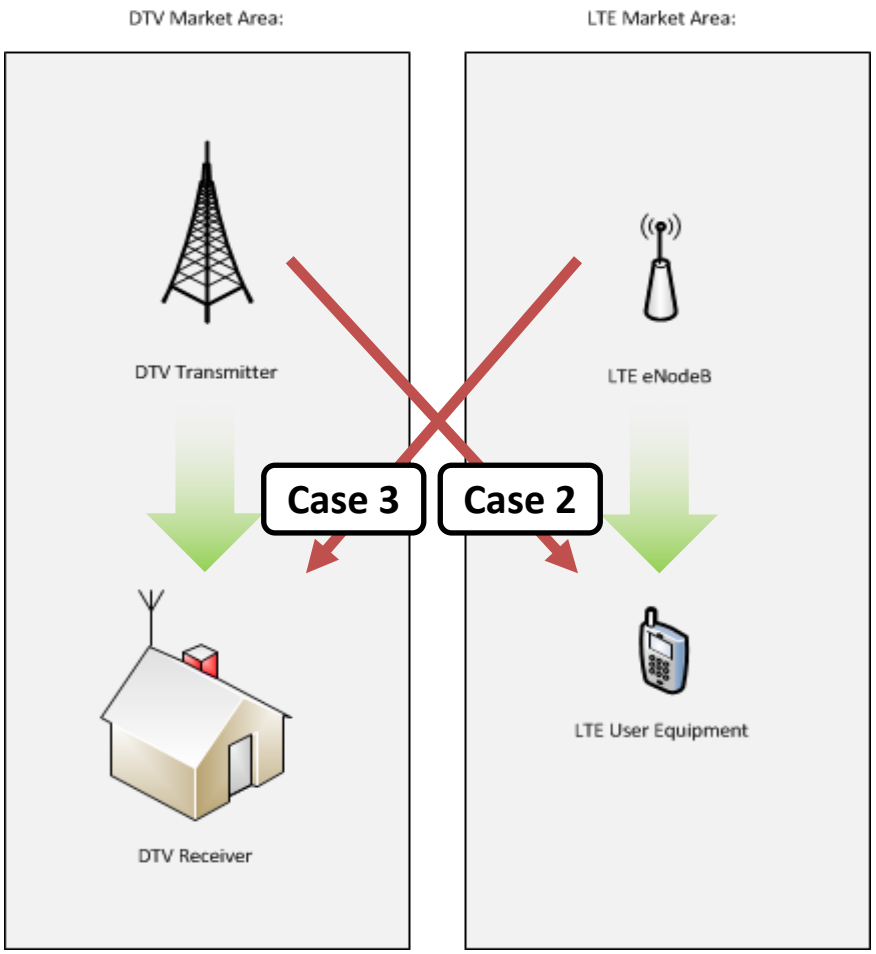
- Some frequencies have both TV and wireless
  - Must be geographically separated
  - IX areas will not align with license areas
- Amount of IX (area or population) can define "impaired" wireless market
  - Degree of impairment
  - Technology may help overcome impairments

Potential Interference Cases

Uplink



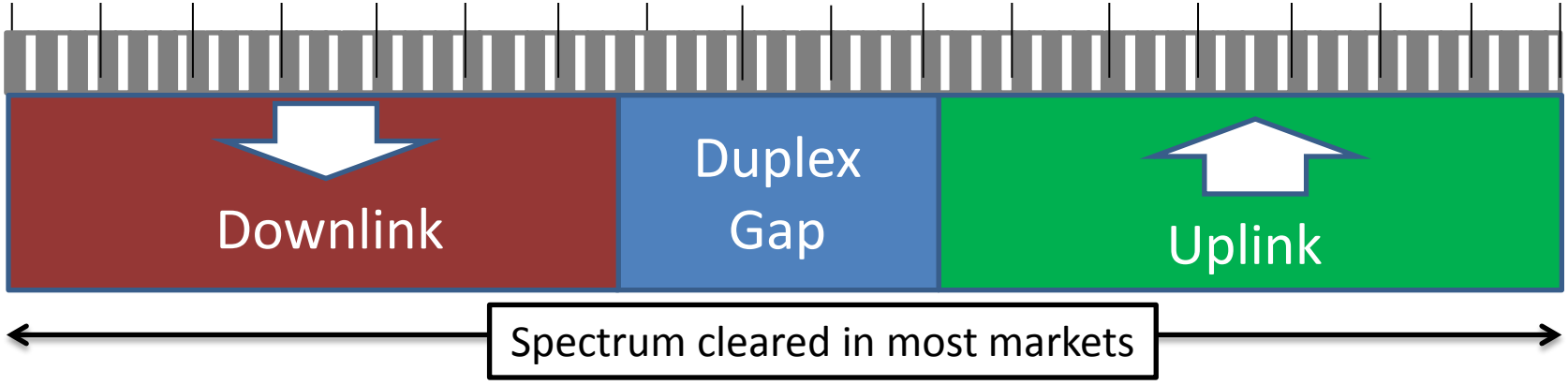
Downlink

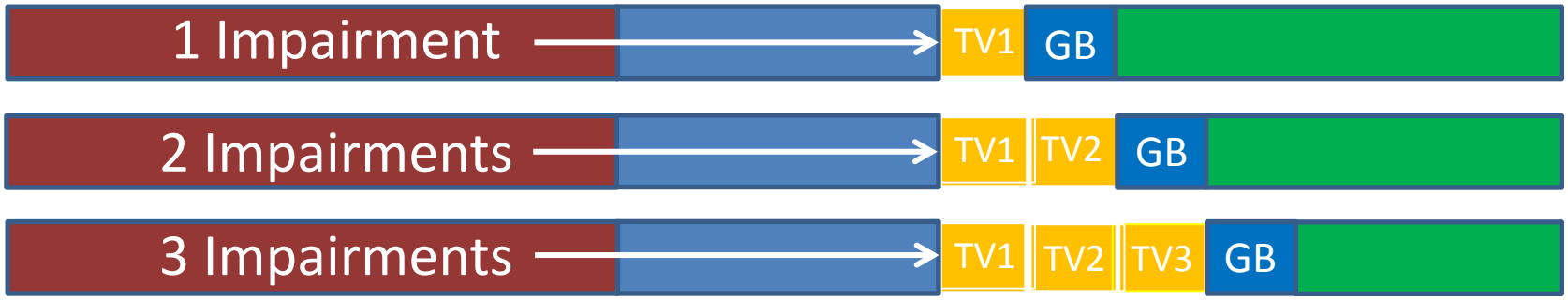


Geographic Variation

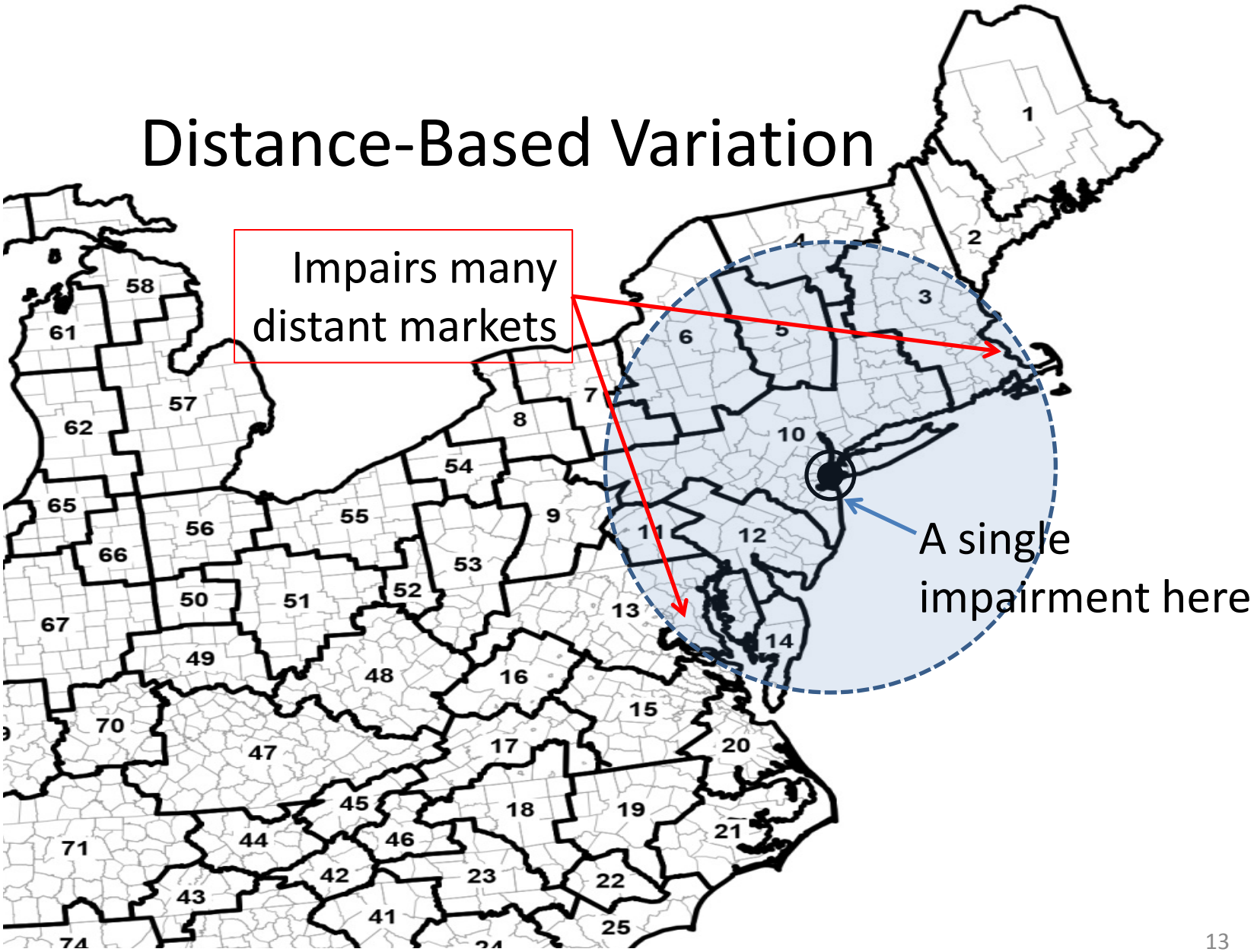
- Depending upon band plan adopted, could fix amount of downlink spectrum nationwide
  - Allows for uniform filters in all UE devices, reducing cost and promoting interoperability
  - Allows for variation in amount of uplink spectrum to accommodate different amounts of cleared spectrum
- Produces asymmetric uplink/downlink spectrum
  - Markets with less clearing have lower Uplink/Downlink spectrum ratio

How Variation Might be Implemented

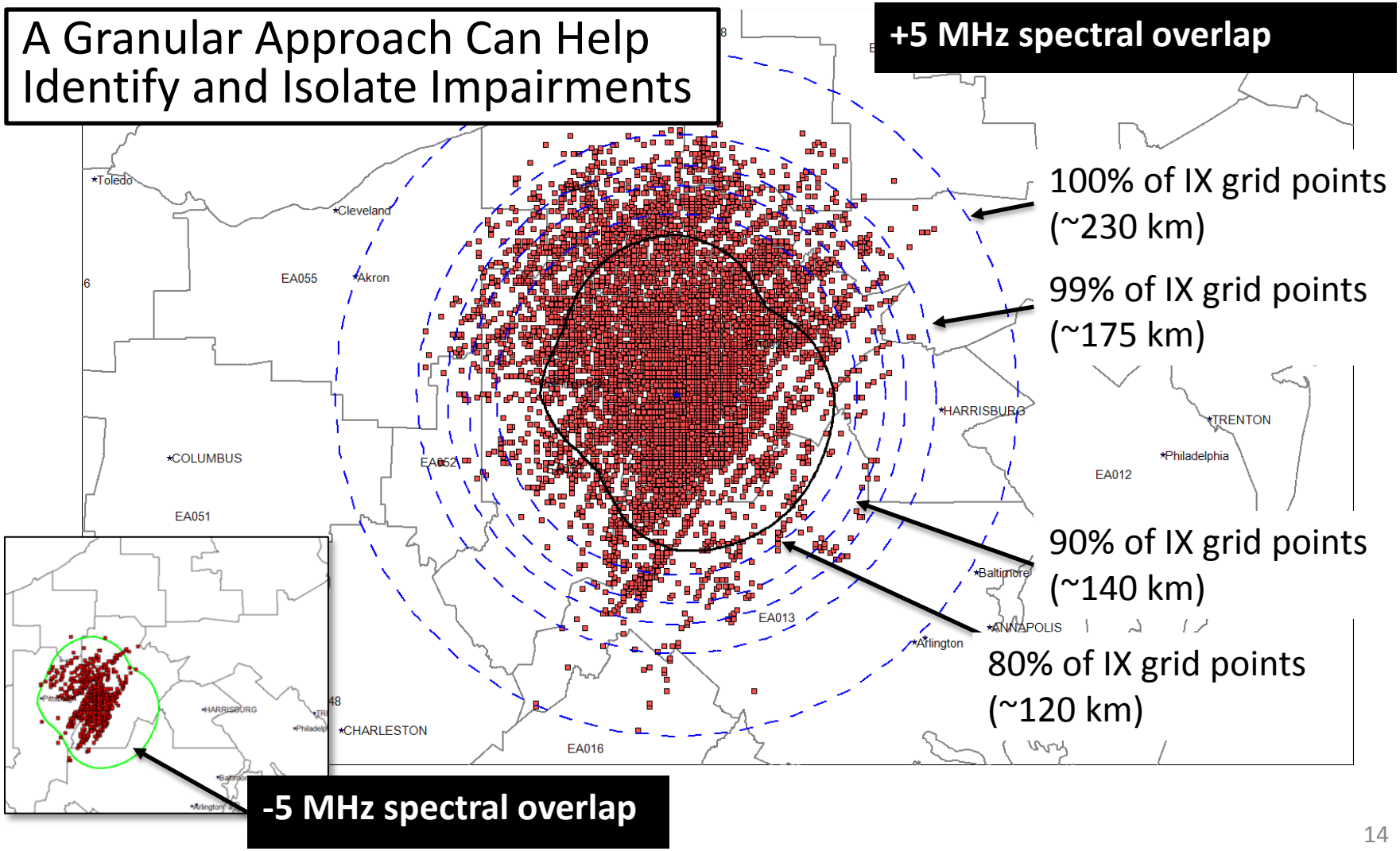




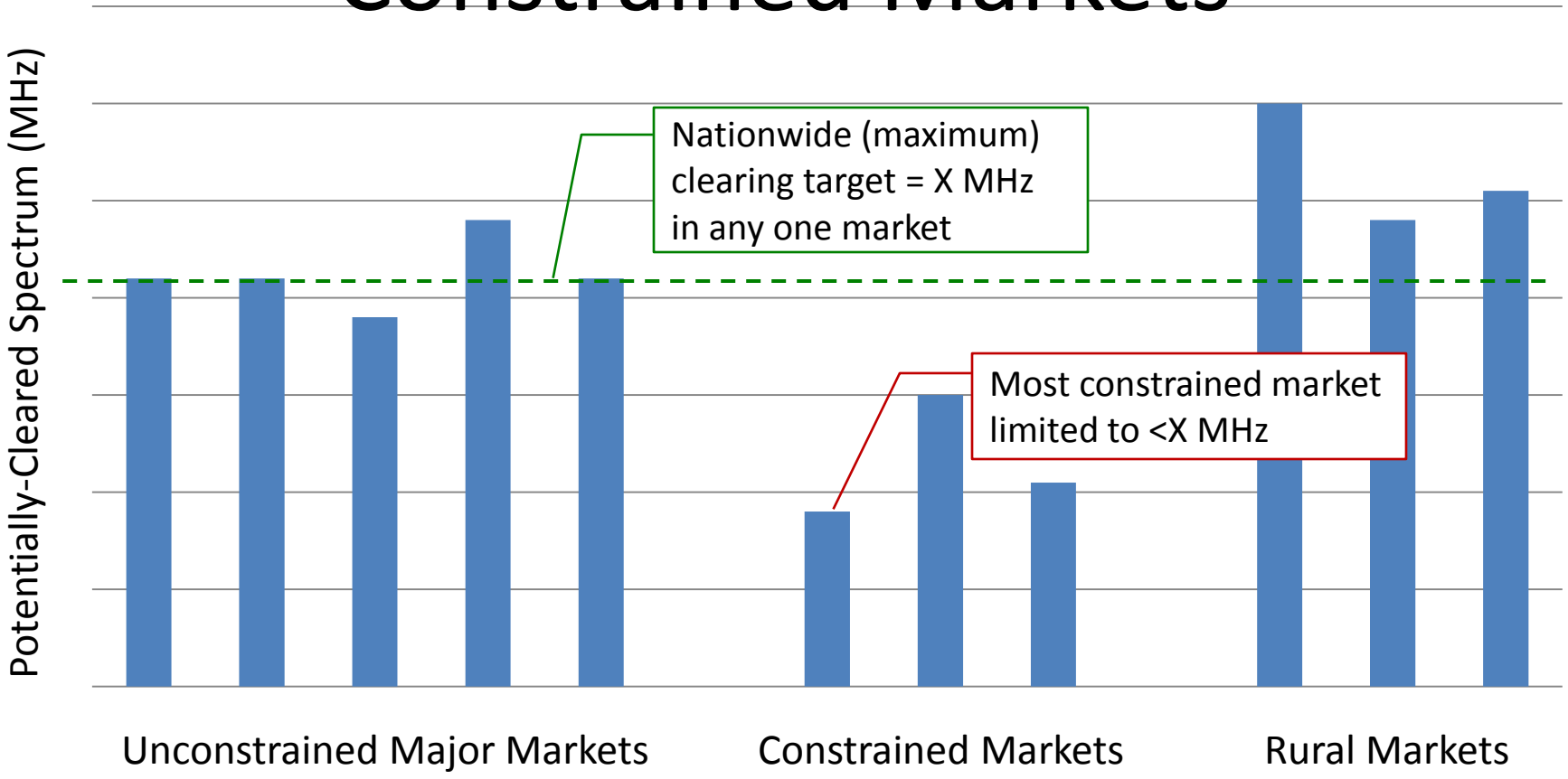
Distance-Based Variation



A Granular Approach Can Help Identify and Isolate Impairments



Spectrum Clearing Target *vs.* Constrained Markets

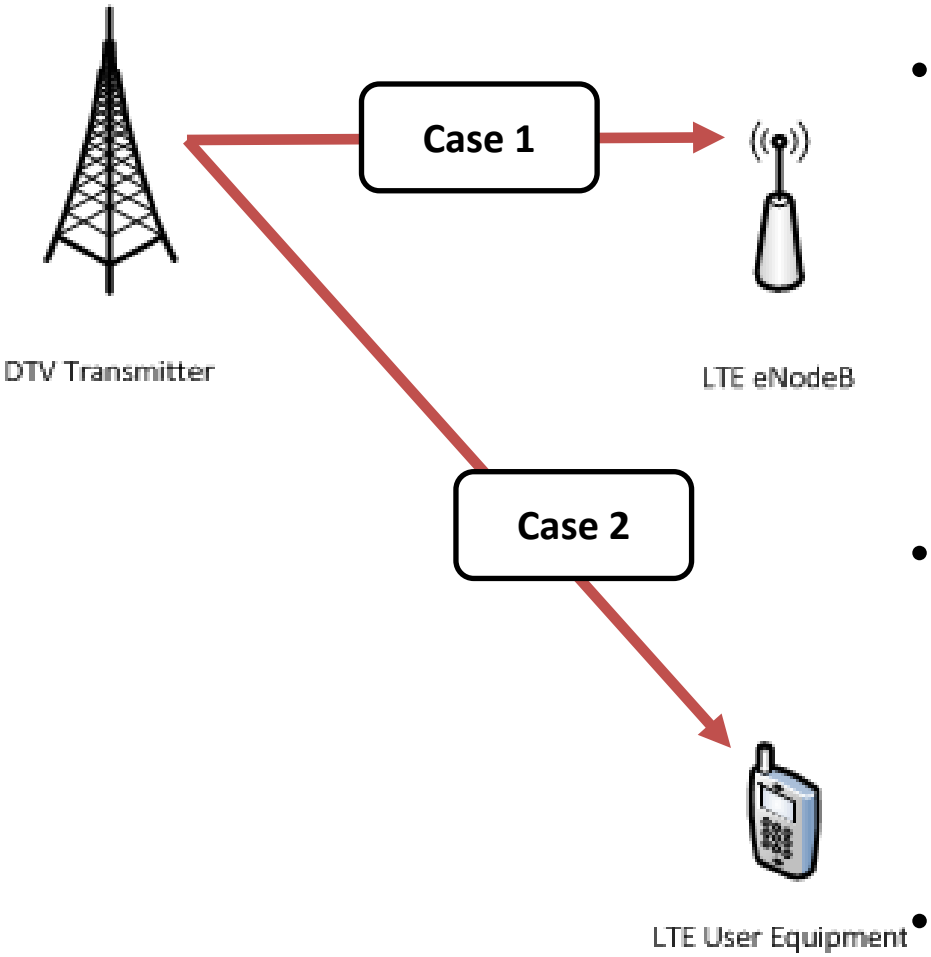


Truth Table Approach

- Cell-By-Cell *TVStudy* Results are very detailed
  - Typical full-power DTV station covers about 7,400 cells
- Cells having Zero population might be ignored
- Cells having “D” below a defined threshold can be ignored
- Not all cells need be considered
- The detailed results for relevant cells can be be simplified into an indexed truth table, where for each cell:
  - Interference-free Coverage = 1
  - Interference = 0
- An index is needed to provide location (county) and population references

III. OET ISIX METHODOLOGY OVERVIEW

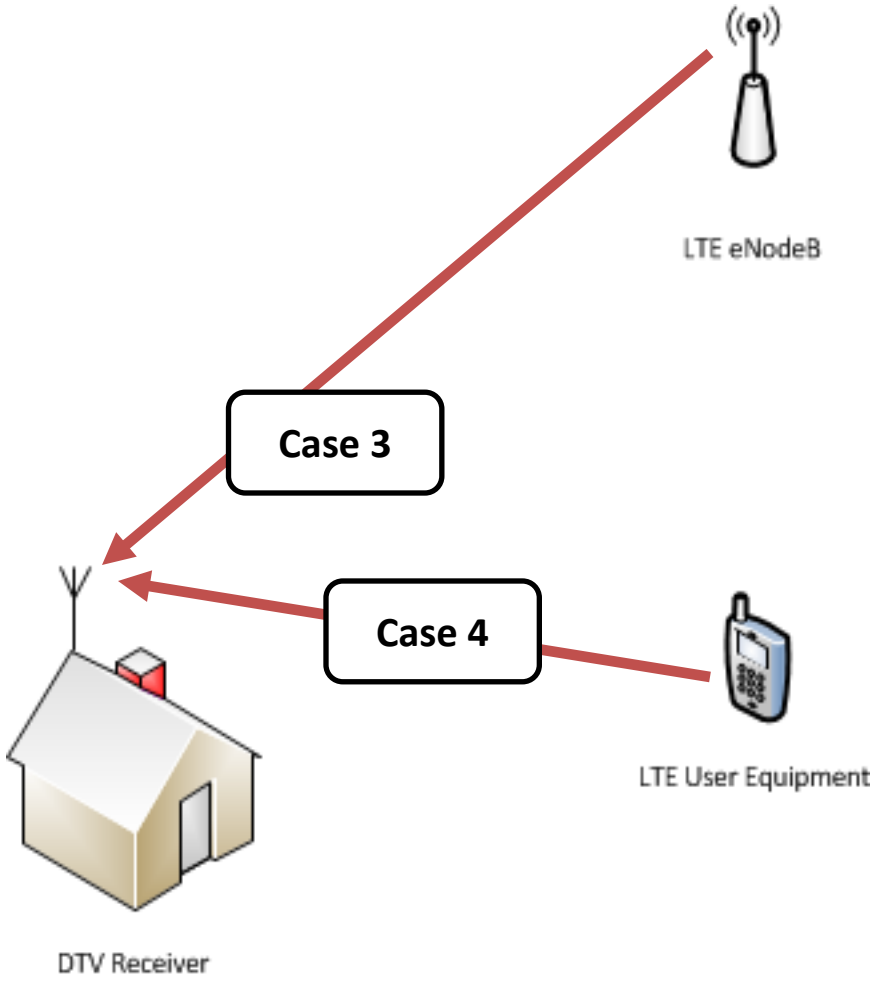
IX to Wireless



Cases 1 & 2: DTV TX into Wireless RX

- Longley-Rice Propagation Methodology
  - For large distances (100s of kilometers)
  - DTV transmitter specifications known
  - Terrain-specific path losses
  - Receiver heights can be adjusted
    - 30 meters for LTE eNodeB
    - 1.5 meters for UE
  - Consider clutter loss for Case 2 (UE)
- Statistical Analysis of DTV Path Losses
  - Consider a number of cases/paths
  - Vary by market and population
  - Identify repacked TV stations that contribute to post-auction market variation
- Same nationwide grid as DTV-to-DTV IX analysis

IX to DTV



Case 3: Wireless TX into DTV RX

- Longley-Rice Propagation Methodology
  - For large distances (100s of kilometers)
  - Future wireless TX specifications unknown
    - Uniform distribution (10 km) over market
    - Assume Part 27 power and OOBE limits
  - Terrain-specific path losses
  - DTV receiver height fixed at 30 feet
  - Consider clutter loss for both cases
- Statistical Analysis of Wireless Path Losses
  - Consider a number of cases/paths
  - Vary by market and population
  - Identify wireless license areas subject to post-auction market variation requirements
- Case 4 May Not Need to be Considered
  - Distances likely a few kilometers
  - IX distance subsumed by other cases

TX Specifications

- DTV
  - Operating data from FCC CDBS
    - Power, height, and antenna pattern
    - Geographic coordinates (NAD-27)
- Wireless
  - Assumed (typical) data taken from
    - 3GPP technical specifications
    - Manufacturer technical data
    - Locations distributed within license area

DTV station operating specifications

- Extracted from CDBS, or
- Inferred from OET Bulletin No. 69

Parameter	Value	Comment
Emission BW (MHz)	6	TV channel.
Effective Radiated Power (ERP)	(CDBS)	
Azimuth Relative Field Pattern	(CDBS)	
Elevation Relative Field Pattern	(OET-69/CDBS)	Pattern data from CDBS can be used when available.
Geographic Coordinates, NAD-27	(CDBS)	Coordinate datum must be consistent with terrain and other data.
HG(1) (m)	(CDBS)	Transmit antenna height above ground.

Wireless eNodeB Operating Specifications

Parameter	Value	Comment
Emission BW (MHz)	5	Wireless block.
ERP (W)	720	Assumes 1.2 kW ERP in 10 MHz channel plus 0.8 dB.* Assumes two 40 W power amplifiers, 15 dBi antenna gain, and 1 dB cable loss.
ERP (dBm)	58.6	= $10\log_{10}(\text{ERP}) + 30$.
G (dBd)	12.8	Assumes 15 dBi - 2.2 (approximate dipole gain).
L (dB)	1	Assumed line loss.
Az Relative Field Pattern	Omni	
Elv Relative Field Pattern	(OET-69)	Similar to many wireless antenna patterns
Geographic Coords, NAD-27	Uniform, 10 km grid	Hypothetical wireless base stations, distributed across each wireless license area. Note that *TVStudy* expects site coordinates in NAD-27.
HG(1) (m)	30	Transmit antenna height above ground.

* ERP of 720 W = 120 W/MHz x 6 MHz. This adds an additional 0.8 dB of interference power in the wireless block to simulate operations of wireless base stations transmitting across contiguous adjacent wireless blocks affecting one 6 MHz TV channel.

Wireless UE Operating Specifications

Parameter	Value	Comment
Emission BW (MHz)	5	Wireless block.
ERP (W)	0.12	EIRP = 200 mW; 0 dB loss + 0 dBi gain. *See* 3GPP TS 36.101, § 6.3.2.
ERP (dBm)	58.6	= $10\log_{10}$(ERP) + 30.
G (dBd)	-2.2	Assumes 0 dBi - 2.2 (approximate dipole gain).
L (dB)	0	Assumed line loss.
HG(1) (m)	1.5	Transmit antenna height above ground.

NOTE: Wireless user equipment transmitter assumptions may not necessarily be considered, since preliminary predictions involve distances of less than a few kilometers. The Longley-Rice propagation model may not be suitable for such short distances. See Daniel, W. and Wong, H., "Propagation in Suburban Areas at Distances less than Ten Miles," FCC/OET TM 91-1, Federal Communications Commission, Office of Engineering and Technology, January 25, 1991.

Receiver Performance

- Television
  - Taken from FCC and other sources
    - DTV planning factors
    - ATSC technical specifications
    - OET Bulletin No. 69 and FCC rules
- Wireless
  - Taken from
    - 3GPP technical specifications
    - Manufacturer technical data

DTV Planning Factors

Planning Factor	Symbol	Low VHF (2-6)	High VHF (7-13)	UHF (14-69)
Geometric Mean Frequency (MHz)	F	69	194	615
Dipole Factor (dBm-dBu)	K_d	111.8	120.8	130.8
Thermal Noise (dBm)	N_t	-106.2	-106.2	-106.2
Antenna Gain (dBd)	G	4 *	6 *	10 *
Antenna Front-to-back ratio (dB)	F/B	10	12	14
Downlead line loss	L	1	2	4
System noise figure (dB)	N_s	10	10	7
Required receiver S/N ratio (dB)	S/N	15.2**	15.2**	15.2**
Time variability factor (90% availability) (dB)	dT	0***	0***	0***
Location variability factor (50% availability) (dB)	dL	0	0	0

* Antenna placement is assumed outdoors at 10 meters (~30 feet).

** S/N value from *DTV Sixth Report and Order* and OET Bulleting No. 69 is 15 dB, which was rounded from 15.19 dB in Table 5.1 of FCC Advisory Committee on Advanced TV Service (ACATS) *Final Technical Report* (1995).

*** 90% Time variability is F(50,10) minus F(50,50), taken from § 73.699. This factor is a function of the distance between the transmitting and receiving antennas.

DTV Receiver

Parameter	Value	Comment
Receive Power, P_r (dBm)	-84	$P_r = N_t + N_s + S/N$, where S/N = 15.2 dB. For UHF channels: P_r = -106.2 + 7 + 15.2 = -84.0 dBm.
Dipole factor, K_d (dBm-dBµV/m)	130.8	OET Bulletin No. 69, Table 3.
Antenna gain, G (dBd)	10	DTV Planning Factor.
Downlead loss, L (dB)	4	DTV Planning Factor.
Receiver BW (MHz)	6	TV channel.
Thermal noise, N_t (dBm)	-106.2	-174 (dBm/Hz) + $10\log_{10}$(6 MHz).
Receiver Noise Figure, N_s (dB)	7	DTV Planning Factor.
On-tune rejection, OTR (dB)	0	For wireless into DTV, OTR = 0 because the transmit signal bandwidth is assumed to be smaller than the receiver bandwidth.
Threshold field strength for service, FS_{th} (dBµV/m)	40.8	$FS_{th} = P_r + L + K_d - G$ = -84 + 4 + 130.8 – 10

Wireless Base Station Receiver

Parameter	Value	Comment
P_r (dBm)	-101.5	Ref sensitivity, per 3GPP Specification 36.104 § 7.2.
K_d (dBm-dBµV/m)	130.8	Dipole Factor, OET Bulletin No. 69, Table 3.
G (dBd)	13.8	G (dBd) = 12.8 dBd + G_{div} - G_{horiz}. G_{div} is receive antenna diversity gain, assumed to be 3 dB, and G_{horiz} is additional antenna discrimination due to downtilt below the radio horizon, assumed to be 2 dB.
L (dB)	1	Assumed line loss.
Receiver BW (MHz)	5	For bandwidths (BWs) ≥ 5 MHz, the reference sensitivity level is measured in accord with the 3GPP Technical Specification 36.104 using 25 consecutive resource blocks, corresponding to a channel bandwidth of 4.5 MHz.
Thermal noise, N_t (dBm)	-107.5	= -174 (dBm/Hz) + $10\log_{10}$(4.5 MHz).
N_e (dB)	6	Effective noise figure (derived).
OTR (dB)	0.8	For TV into wireless, OTR = $10\log_{10}(6/5)$ = 0.8 dB. Using typical 3 dB transmit signal bandwidths, $10\log_{10}(5.38/4.5)$ is also approximately 0.8 dB.
Minimum field strength for service, MFS (dBµV/m)	17.3	MFS = P_r + L + K_d - G + OTR = -101.5 dBm + 1 + 130.8 - 13.8 + 0.8 = 17.3 dBµV/m.

Wireless User Equipment Receiver

Parameter	Value	Comment
P_r (dBm)	-100	Ref sensitivity level, per 3GPP Specification 36.101 § 7.3.
K_d (dBm-dBµV/m)	130.8	Dipole Factor, OET Bulletin No. 69, Table 3.
G (dBd)	-2.2	Assumes 0 dBi - 2.2 (approximate dipole gain).
L (dB)	0	Assumed line loss.
Receiver BW (MHz)	5	For bandwidths (BWs) ≥ 5 MHz, the reference sensitivity level is measured in accord with the 3GPP Technical Specification 36.104 using 25 consecutive resource blocks, corresponding to a channel bandwidth of 4.5 MHz.
Thermal noise, N_t (dBm)	-107.5	= -174 (dBm/Hz) + $10\log_{10}$(4.5 MHz).
N_e (dB)	7.5	Effective noise figure (derived).
OTR (dB)	0.8	For TV into wireless, OTR = $10\log_{10}(6/5)$ = 0.8 dB. Using typical 3 dB transmit signal bandwidths, $10\log_{10}(5.38/4.5)$ is also approximately 0.8 dB.
Minimum field strength to receive service, MFS (dBµV/m)	33.8	MFS = P_r + L + K_d - G + OTR = -100 dBm + 0 + 130.8 - (-2.2) + 0.8 = dBµV/m.

Off-Frequency Rejection (OFR)

- TV channels and wireless blocks will not align
- OFR added to threshold field strength as spectral overlap decreases from co-channel condition
- Incremental decrease in sensitivity accounts for roll-off of both transmit and receive filters to adjacent-channel values
- Amount of “noise” in the pass-band of the victim receiver

Gaussian Noise Equivalence

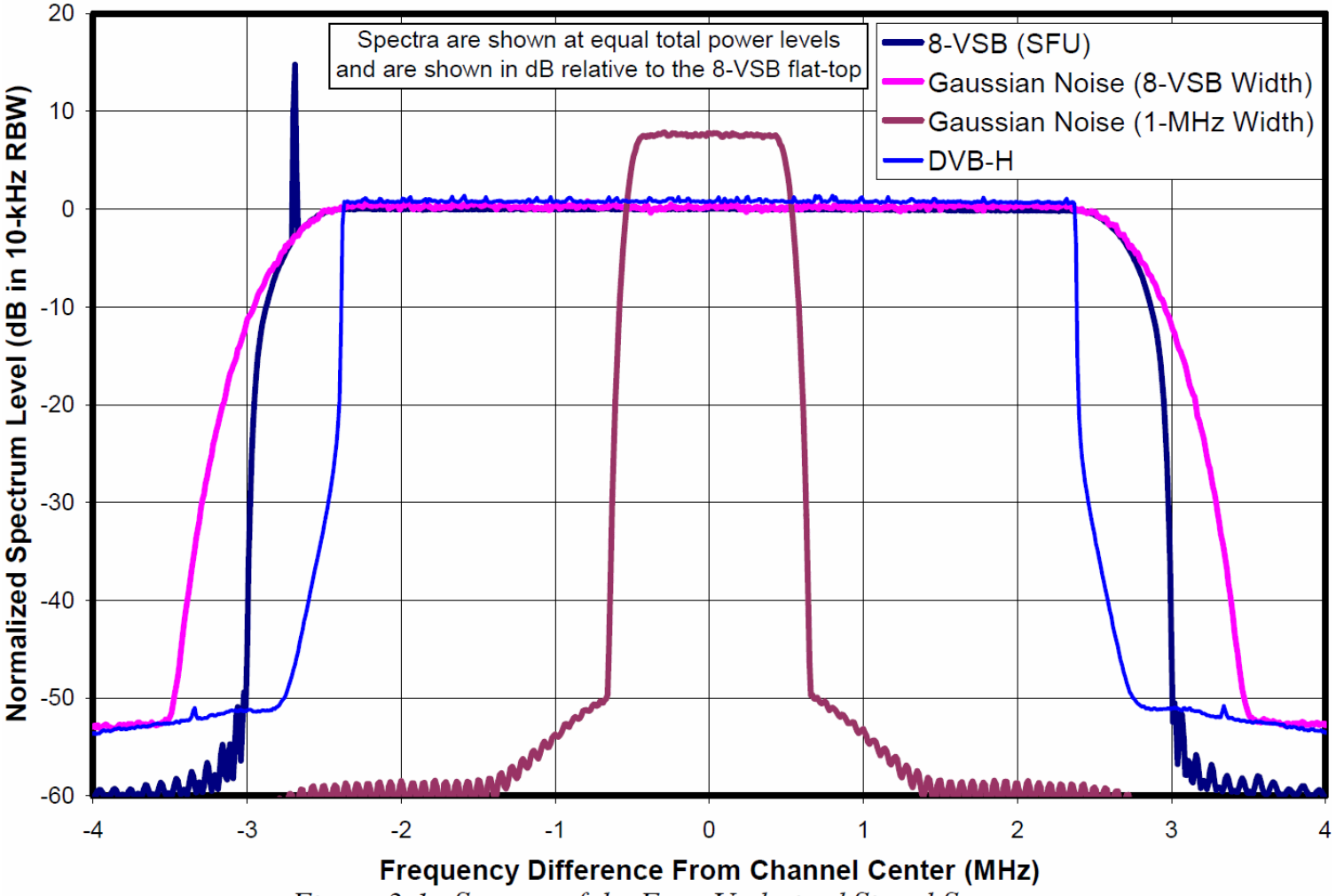
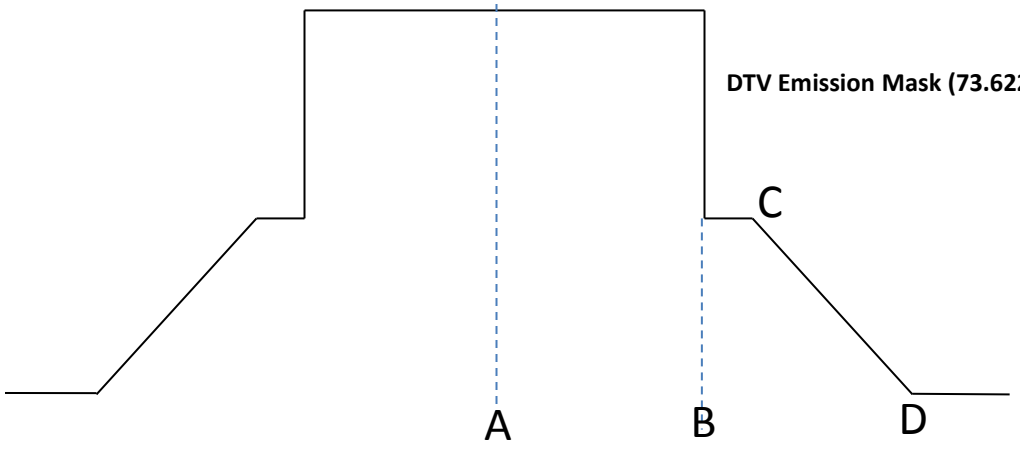


Figure 2-1. Spectra of the Four Undesired Signal Sources

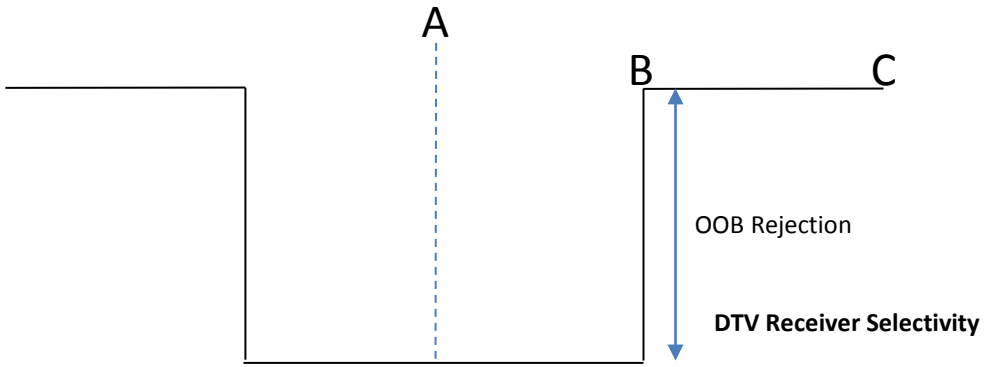
Source: Stephen R. Martin, "Interference Rejection Thresholds of Consumer Digital Television Receivers Available in 2005 and 2006," FCC/OET Report 07-TR-1003, March 30, 2007.

DTV TX and RX Assumptions



Normalized DTV Tx Mask

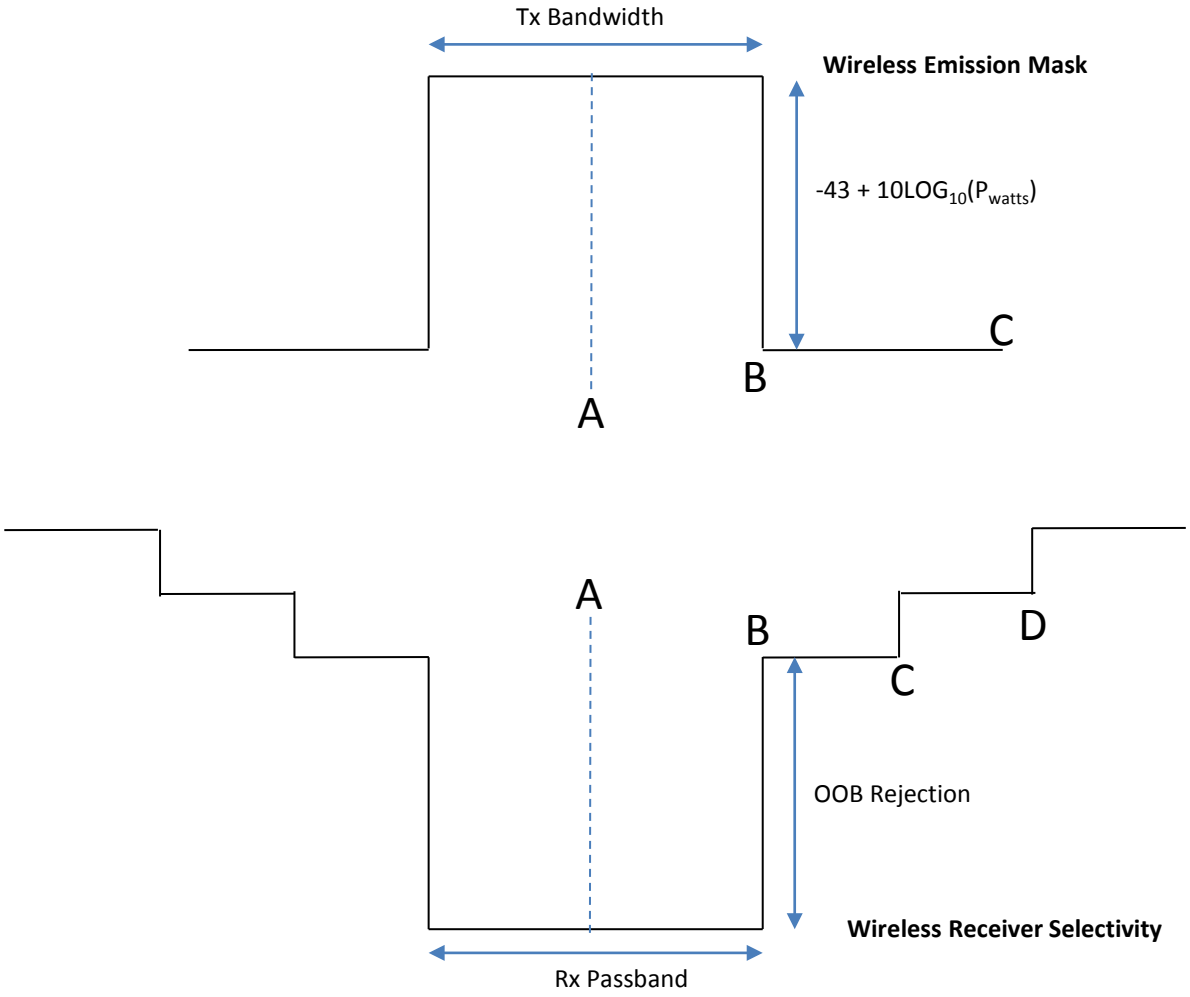
	KHz offset	Attenuation (dB)
A	0	0
B	3000	0
B	3100	-47
C	3500	-47
	3600	-48.3
	8900	-109.3
D	9000	-110.4
D	43000	-110.4



DTV Rx Selectivity

	KHz offset	Rejection (dB)
A	0	0
B	3000	0
B	3100	33
C	9000	33
C	43000	33

LTE Assumptions



Normalized BS Tx Mask

	KHz offset	Attenuation (dB)
A	0	0
B	2500	0
B	2600	-76
C	42500	-76

Normalized UE Tx Mask

	KHz offset	Attenuation (dB)
A	0	0
B	2500	0
B	2600	-36
C	42500	-36

BS Rx

	KHz offset	Rejection (dB)
A	0	0
B	2500	0
B	2600	43.5
C	7500	43.5
C	7600	52.5
	42500	52.5

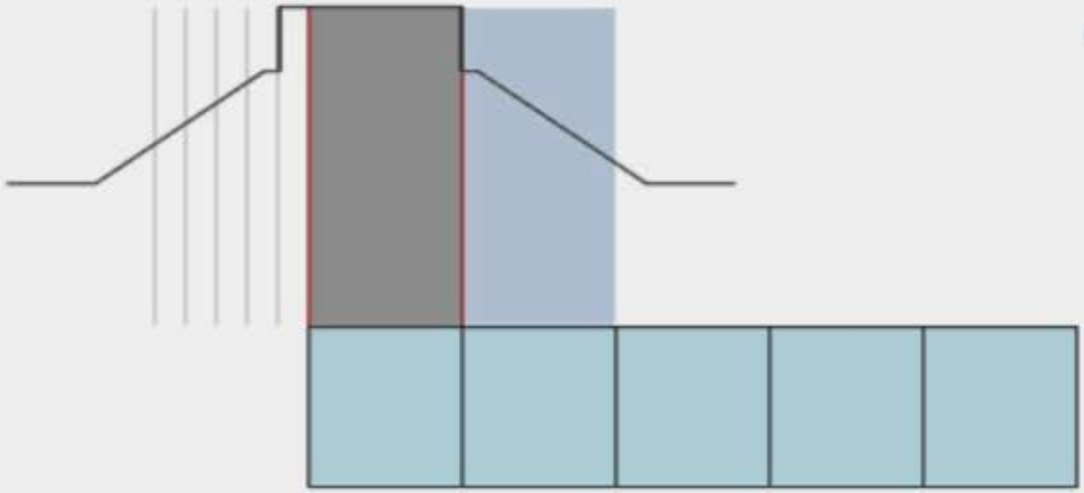
UE Rx

	KHz offset	Rejection (dB)
A	0	0
B	2500	0
B	2600	31.5
C	7500	31.5
C	7600	38
D	17400	38
D	17500	50
	42500	50

Off-Frequency Rejection (OFR)

- Use NTIA's MSAM Suite for Spectrum Management
  - Frequency Dependent Rejection (FDR) program
  - http://ntiacsd.ntia.doc.gov/msam/
- Example:

  DTV → Wireless
- Start with co-channel minimum field strength threshold value for BS receiver (see slide 27)



Spectral Overlap (MHz)	5	4	3	2	1	0	-1	-2	-3	-4	-5
DTV Field Strength into Wireless Uplink (dBμV/m)	17.3	18.2	19.5	21.2	24.0	34.4	61.4	62.5	63.7	65.5	68.6

Off-Frequency Rejection (OFR)

- DTV → Wireless

Overlap in MHz	5	4	3	2	1	0	-1	-2	-3	-4	-5
DTV into Uplink	0	0.9	2.2	3.9	6.7	17.1	44.1	45.2	46.4	48.2	51.3
DTV into Downlink	0	0.9	2.2	3.8	6.6	16.9	32	32.8	33.8	35.1	37

- Wireless → DTV

Overlap in MHz	5	4	3	2	1	0	-1	-2	-3	-4	-5
Downlink into DTV	0	0.9	2.2	3.9	6.7	17.0	33	33	33	33	33
Uplink into DTV	0	0.9	2.2	3.8	6.6	16.9	31	31	31	31	31

Off-Frequency Rejection (OFR)

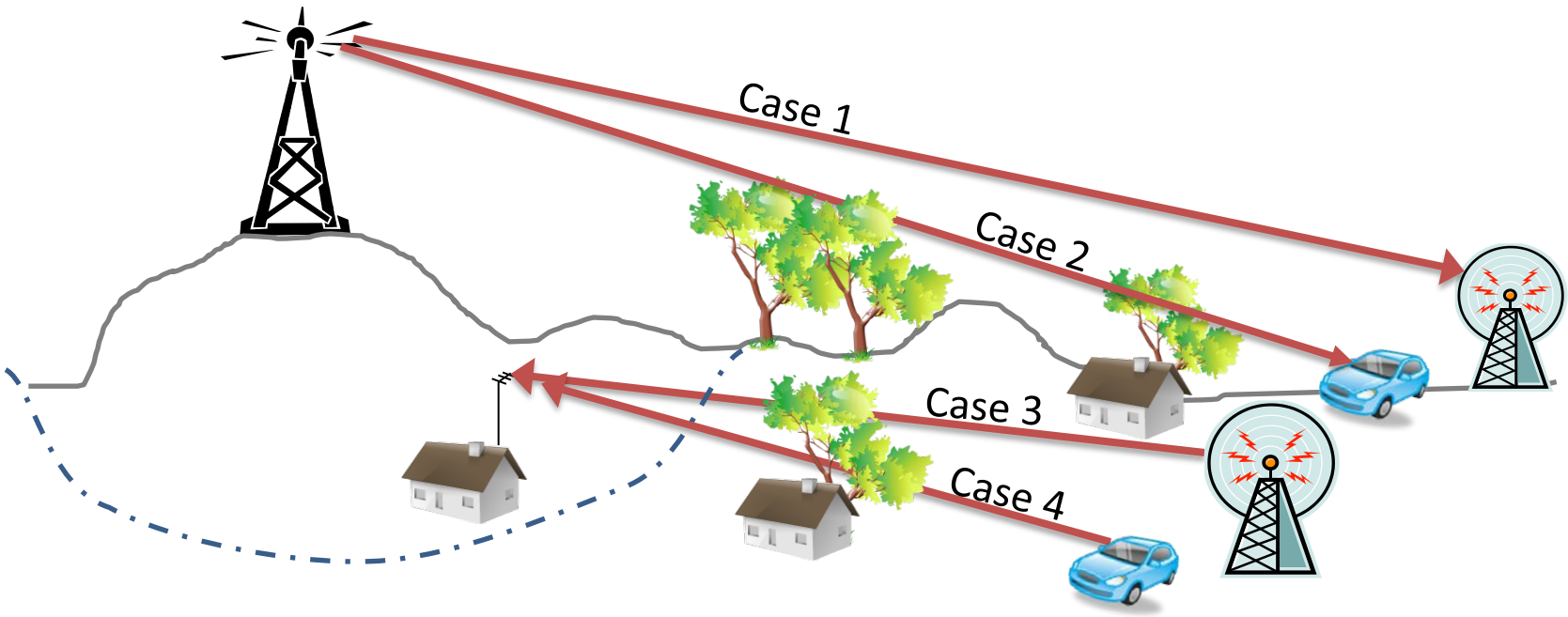
- Minimum Field Strength, DTV → Wireless

Overlap in MHz	5	4	3	2	1	0	-1	-2	-3	-4	-5
DTV into Uplink	17.3	18.2	19.5	21.2	24.0	34.4	61.4	62.5	63.7	65.5	68.6
DTV into Downlink	33.8	34.7	36.0	37.6	40.4	50.7	65.8	66.6	67.6	68.9	70.8

- Minimum D/U Ratio, Wireless → DTV

Overlap in MHz	5	4	3	2	1	0	-1 to -5
Downlink into DTV	15.0 + α	14.1 + α	12.8 + α	11.1 + α	8.3 + α	-2.0 + α	-18 + α
Uplink into DTV	15.0 + α	14.1 + α	12.8 + α	11.2 + α	8.4 + α	-1.9 + α	-16 + α
α = 10log10[1.0/(1.0 - 10-x/10)], where x = S/N - 15.19 dB. *See* 47 C.F.R. § 73.623.							

ISIX Scenarios versus Clutter



Interference Case	*Transmitter Antenna Height (m)*	*Receive Antenna Height (m, AGL)*	*Apply Clutter?*
Case 1: TV into Uplink:	Value from CDBS (AMSL)	30	No
Case 2: TV into Downlink:	Value from CDBS (AMSL)	1.5	Yes
Case 3: Downlink into TV:	30 (AGL)	10	Yes, only for undesired path
Case 4: Uplink into TV:	1.5 (AGL)	10	Yes, only for undesired path

Derivation of Clutter Factors

Case 3 Factors: eNodeB to DTV

Clutter Category	Clutter Category Description	Clutter Loss (dB) (to be subtracted from calculated field strength) Channels 14-36	Channels 38-51
1	Open land	4	5
2	Agricultural	5	6
3	Rangeland	3	6
4	Water	0	0
5	Forest land	5	8
6	Wetland	0	0
7	Residential	5	7
8	Mixed Urban / Buildings	6	6
9	Commercial / Industrial	5	6
10	Snow and Ice	0	0

Taken from OET Bulletin No. 73 "*The ILLR Computer Program for Predicting Digital Television Signal Strengths at Individual Locations*"

Case 2 and Case 4 Factors: Cases involving UE

Clutter Category	Clutter Category Description	Clutter Loss (dB) (to be subtracted from calculated field strength) Channels 14-36	Channels 38-51
1	Open land	6	7
2	Agricultural	5	6
3	Rangeland	3	6
4	Water	0	0
5	Forest land	10	13
6	Wetland	0	0
7	Residential	11	13
8	Mixed Urban / Buildings	13	13
9	Commercial / Industrial	12	13
10	Snow and Ice	0	0

Calculated clutter factor based on ITU P.452 height gain equations normalized to OET-73 factors

Clutter Category Mapping

TVStudy allows for the definition of 10 clutter categories while the NLCD database has 16 categories

NLCD Classification Number	NLCD Classification Description	TVStudy Clutter Category Mapping	TVStudy Clutter Category Description
11	Water	4	Water
12	Perennial Ice Snow	10	Snow and Ice
21	Developed, Open Space	7	Residential
22	Developed, low intensity	7	Residential
23	Developed, Medium Intensity	9	Commercial / Industrial
24	Developed High Intensity	8	Mixed urban / buildings
31	Bare Rock / Sand / Clay	1	Open Land
41	Deciduous Forest	5	Forest Land
42	Evergreen Forest	5	Forest Land
43	Mixed Forest	5	Forest Land
52	Shrub/Scrub	3	Rangeland
71	Grasslands/Herbaceous	3	Rangeland
81	Pasture/Hay	2	Agricultural
82	Row Crops	2	Agricultural
90	Woody Wetlands	5	Forest land
95	Emergent Herbaceous Wetlands	6	Wetland

IV: Using *TVStudy* for Inter-Service Interference Studies

Analysis Steps

- Baseline of TV Noise Limited Service Contours
- Set up *TVStudy* for ISIX runs
  - Create study and set study parameters
  - Create xml scenario (Appendix I of *TVStudy* manual)
- Run *TVStudy* to obtain detailed cell-level output
  - tvstudy.cel, points.csv, contours.shp
- Extract pertinent detail from output
- Post-process data into format for use in constraint file generation

Baseline Noise-Limited Service Contours: contours.shp output

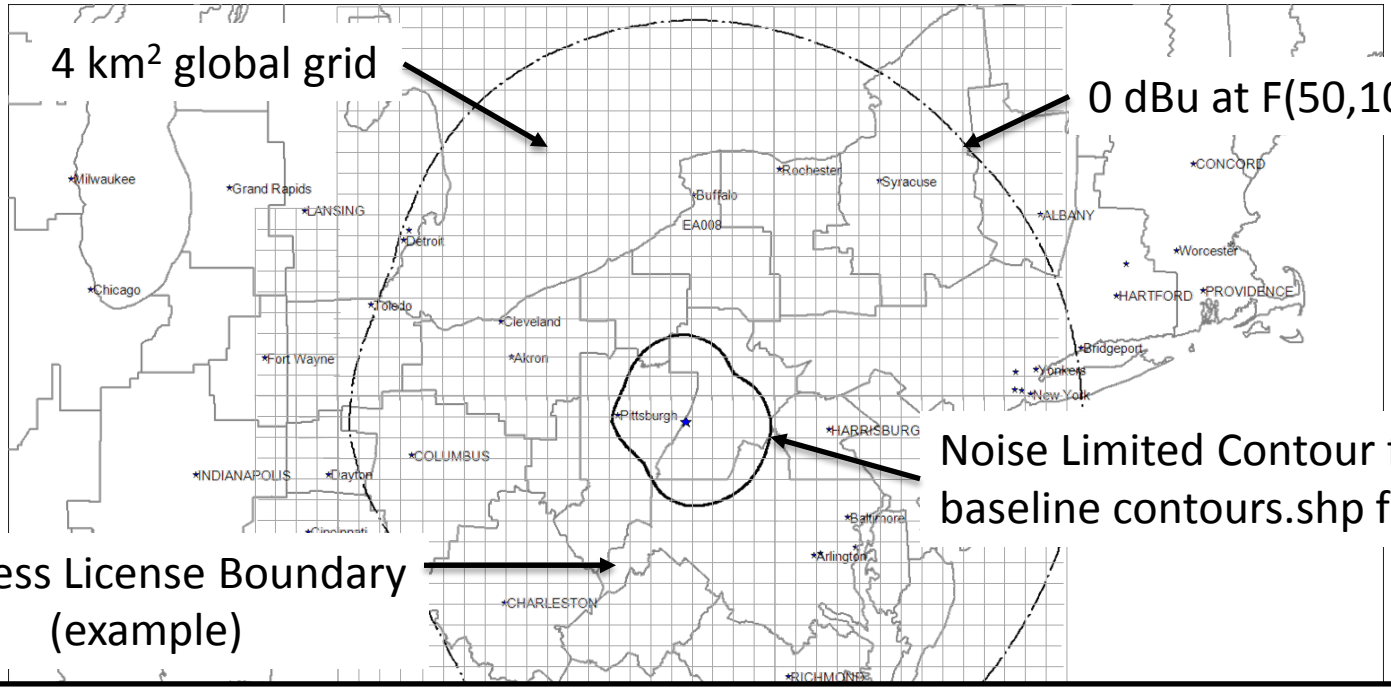
- In *TVStudy*, create a study using the "default" template
- Create a scenario by importing applicable TV stations from CDBS database
  - Set all stations as "desired only"
- Run study and save "contours.shp" file
  - This file shows the baseline noise limited contours for all TV stations

DTV → Wireless: Scenario Creation

- Export XML scenario used to create baseline contours
- Edit xml scenario:
  - If final channel assignments are unknown, replicate all stations on a single "proxy" channel (*e.g.*, channel 36)
  - Run all stations as "Desired" only. Although in this case the TV signal is "undesired" we are only interested in the field strength from the TV at each grid cell

```
<SCENARIO NAME="AllStations">
<DESCRIPTION>Case 1 and 2 Scenario</DESCRIPTION>
<SOURCE DESIRED="true" UNDESIRED="false" LOCKED="true" REPLICATE="36" CDBS_ID="1541281"/>
<SOURCE DESIRED="true" UNDESIRED="false" LOCKED="true" REPLICATE="36" CDBS_ID="1499825"/>
<SOURCE DESIRED="true" UNDESIRED="false" LOCKED="true" REPLICATE="36" CDBS_ID="1414833"/>
<SOURCE DESIRED="true" UNDESIRED="false" LOCKED="true" REPLICATE="36" CDBS_ID="1504605"/>
<SOURCE DESIRED="true" UNDESIRED="false" LOCKED="true" REPLICATE="36" CDBS_ID="1333036"/>
<SOURCE DESIRED="true" UNDESIRED="false" LOCKED="true" REPLICATE="36" CDBS_ID="1561877"/>
.
.
.
</SCENARIO>
```

DTV → Wireless: Calculation Contour



Cases 1 and 2 require *TVStudy* contours large enough to ensure that all locations are considered where DTV field strength reaches the wireless co-channel interference thresholds, which are lower than the DTV service thresholds in OET Bulletin 69, Table 2

DTV -> Wireless: Setup of Study *TVStudy* Parameters for Cases 1 & 2

- Contour
  - 0 dBu
  - F(50,10)
- Receive Antenna Pattern
  - Front-to-Back ratio = 0 dB (omni-directional antenna)
- Clutter
  - Turn on clutter but set all categories to 0 dB.
- Pathloss Calculations
  - Ignore Longley-Rice errors
    - Use pathloss as returned by model
  - Sample profile at 10 pts per kilometer
  - Receive Antenna height
    - 30 m Case 1
    - 1.5 m Case 2
  - F(50,50) propagation statistics, broadcast mode

DTV → Wireless: Processing the Data Detailed tvstudy.cel output

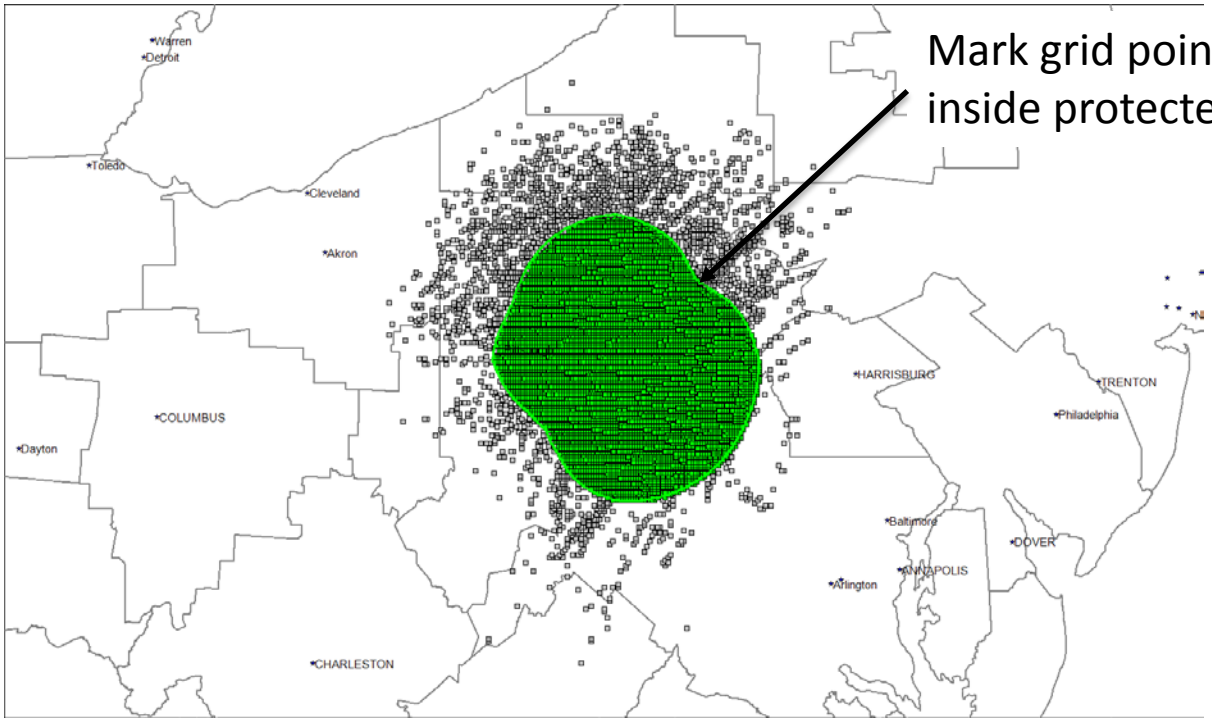
[sources]
<SourceKey>, <DesFlag>, <UndFlag>, <CountryKey>, <ServiceType>, <Channel>,
<ServiceLevel>,.....
[endsources]
[grid]
<LatIdxSouth>, <LonIdxEast>, <LatIdxNorth>, <LonIdxWest>
[cell]
<LatIdx>, <LonIdx>
"P", <ptCountryKey>, <ptLat>, <ptLon>, <ptArea>, <ptPop>, <ptClutterCategory>
"D", <DSrcKey>, <DFieldStrength>, <Bearing>, <KWXFlg>,<ServiceFlg>
.
.
.
[endcell]
[endgrid]
[endscenario]

- Read tvstudy.cel file line-by-line to "flatten" the grid cell information into simple CSV with one line for every grid point vs TV station
- For Case 2: Adjust "D" field strength for clutter based on Clutter Category at receive location
  - If final channel assignment is unknown, use "low UHF" values

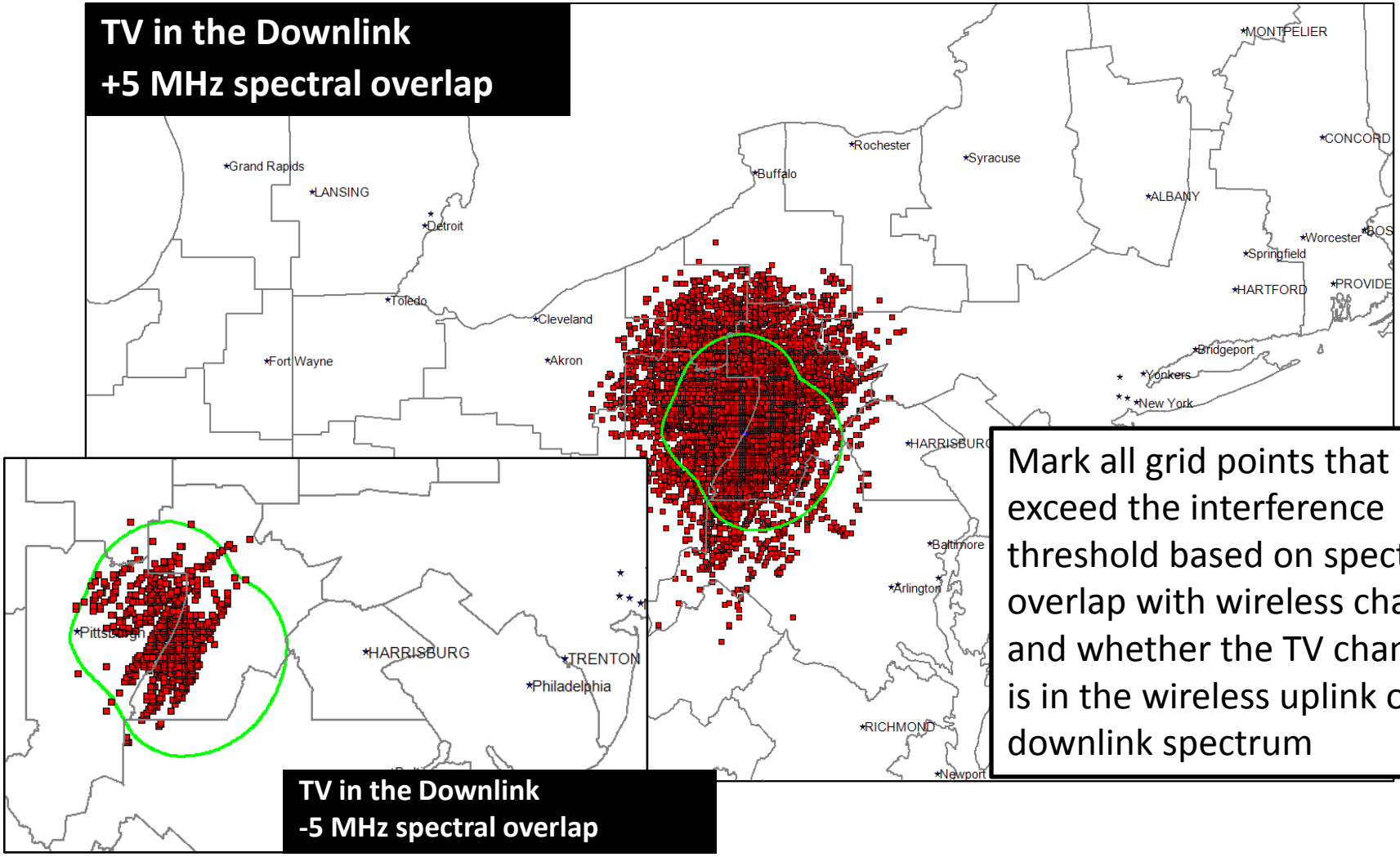
DTV → Wireless: Processing the Data
Detailed points.csv output

- This file is not the same "points.csv" file created when pair-wise studies are run (but it's similar)
  - LatIdx, LonIdx, ptCountryKey, **ptKey**, ptLat, ptLon, ptElev, ptArea, ptPop, ptClutterCategory
- This file is used to obtain the unique "point key" (ptKey) for each grid cell on the global
  4 km^2 grid
  - Provides a simple way to reference a grid cell without listing LatIdx + LonIdx + ptCountryKey

DTV → Wireless: Processing the Data
Compare points.csv *vs* contours.shp

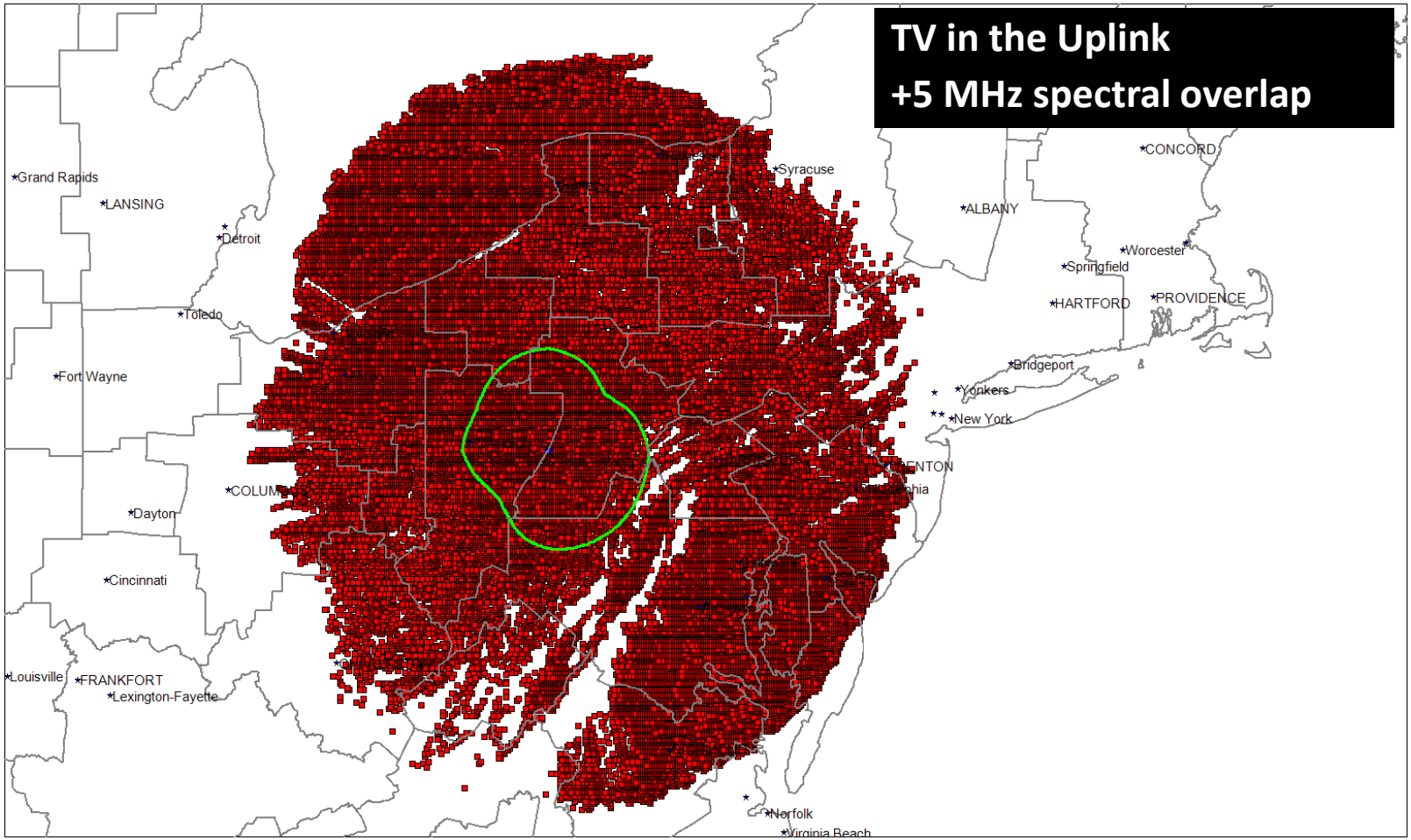


DTV → Wireless: Analyze Data for Each Spectral Overlap IX Threshold



Mark all grid points that exceed the interference threshold based on spectral overlap with wireless channel and whether the TV channel is in the wireless uplink or downlink spectrum

DTV → Wireless: Analyze Data for each Spectral Overlap IX Threshold

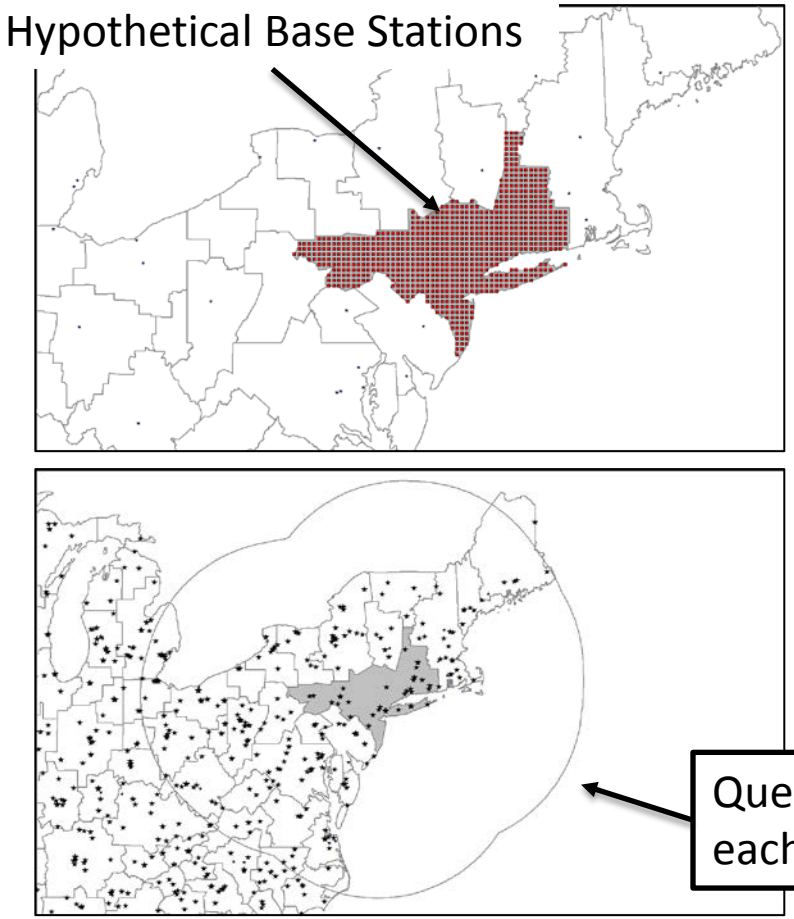


DTV → Wireless: Data used for Constraint Generation

COL 1	COL 2	COL 3	COL 4	COL 5	COL 6
FACID	OL	UL_DL	InCon	IX	ptKey

- FACID: facility ID for TV station
- OL: Spectral Overlap
- UL_DL: “U” for Case 1 and “D” for Case 2
- InCon: 0 if grid cell falls outside protected contour and 1 if grid cell falls inside
- IX: 0 if field strength from TV station is less than interference threshold; 1 if field strength is greater than interference threshold
- ptKey: unique identifier for grid cell point

Wireless → DTV: Scenario Creation



- Create xml scenario with
  - "hypothetical" base stations spaced uniformly every 10 km
  - Include TV stations within 500 km of edge of each wireless market boundary

Wireless → DTV: Example Scenario

```
<SCENARIO NAME="EA010">
<DESCRIPTION>Case 3 for EA010</DESCRIPTION>
<SOURCE DESIRED="FALSE" UNDESIRED="TRUE" LOCKED="FALSE" CDBS_ID="1" ID="1" SERVICE="DT" COUNTRY="US" CHANNEL="36"
 CALL_SIGN="eNB-1" CITY="EA010" STATE="EA" STATUS="LIC" FILE_NUMBER="FCCFileNo_1" LATITUDE="41.2342" LONGITUDE="78.0777"
  HAMSL="-999" HAAT="30" ERP="0.72" HAS_APAT="FALSE" HAS_EPAT="FALSE" EPAT_ETILT="0" EPAT_MTILT="0" EPAT_ORIENT="0"
   HAS_MPAT="FALSE" USE_GENERIC="TRUE">
</SOURCE>
<SOURCE DESIRED="FALSE" UNDESIRED="TRUE" LOCKED="FALSE" CDBS_ID="2" ID="2" SERVICE="DT" COUNTRY="US" CHANNEL="36"
 CALL_SIGN="eNB-2" CITY="EA010" STATE="EA" STATUS="LIC" FILE_NUMBER="FCCFileNo_2" LATITUDE="41.414" LONGITUDE="77.9652"
  HAMSL="-999" HAAT="30" ERP="0.72" HAS_APAT="FALSE" HAS_EPAT="FALSE" EPAT_ETILT="0" EPAT_MTILT="0" EPAT_ORIENT="0"
   HAS_MPAT="FALSE" USE_GENERIC="TRUE">
</SOURCE>
<SOURCE DESIRED="FALSE" UNDESIRED="TRUE" LOCKED="FALSE" CDBS_ID="3" ID="3" SERVICE="DT" COUNTRY="US" CHANNEL="36"
 CALL_SIGN="eNB-3" CITY="EA010" STATE="EA" STATUS="LIC" FILE_NUMBER="FCCFileNo_3" LATITUDE="41.3241" LONGITUDE="77.9652"
  HAMSL="-999" HAAT="30" ERP="0.72" HAS_APAT="FALSE" HAS_EPAT="FALSE" EPAT_ETILT="0" EPAT_MTILT="0" EPAT_ORIENT="0"
  HAS_MPAT="FALSE" USE_GENERIC="TRUE">
</SOURCE>
.
.
.
<SOURCE DESIRED="true" UNDESIRED="false" LOCKED="true" REPLICATE="36" CDBS_ID="2001362"/>
<SOURCE DESIRED="true" UNDESIRED="false" LOCKED="true" REPLICATE="36" CDBS_ID="2001363"/>
<SOURCE DESIRED="true" UNDESIRED="false" LOCKED="true" REPLICATE="36" CDBS_ID="2001364"/>
<SOURCE DESIRED="true" UNDESIRED="false" LOCKED="true" REPLICATE="36" CDBS_ID="2001365"/>
<SOURCE DESIRED="true" UNDESIRED="false" LOCKED="true" REPLICATE="36" CDBS_ID="2001366"/>
<SOURCE DESIRED="true" UNDESIRED="false" LOCKED="true" REPLICATE="36" CDBS_ID="2001367"/>
<SOURCE DESIRED="true" UNDESIRED="false" LOCKED="true" REPLICATE="36" CDBS_ID="2001368"/>
<SOURCE DESIRED="true" UNDESIRED="false" LOCKED="true" REPLICATE="36" CDBS_ID="2001633"/>
<SOURCE DESIRED="true" UNDESIRED="false" LOCKED="true" REPLICATE="36" CDBS_ID="2001647"/>
                                                                                  001648"/>
                                                                                  001652"/>
```

Hypothetical sites

CDBS sites

When final TV Channel assignments are unknown, all Channels are set to Channel 36

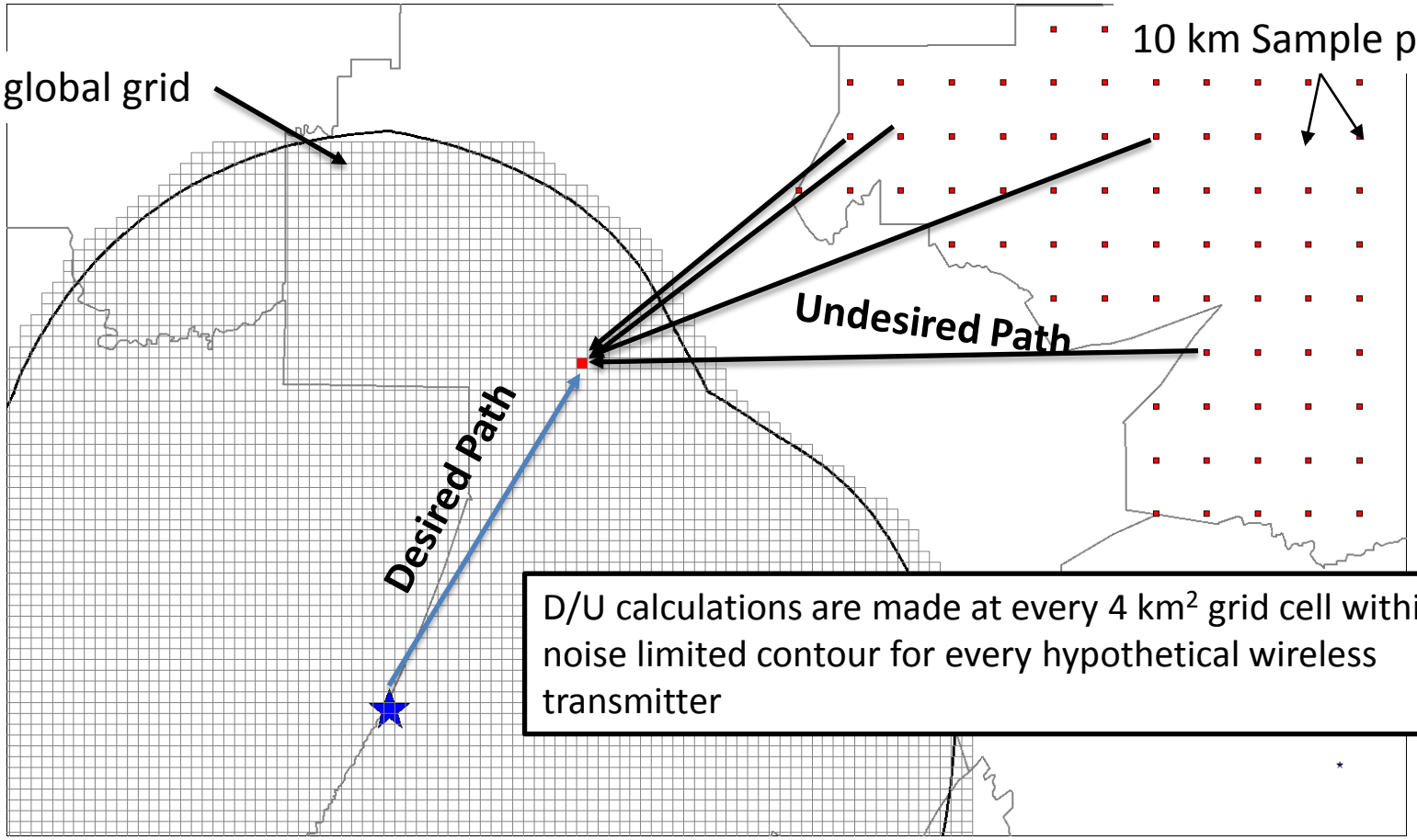
Wireless → DTV: Example Scenario

- When LOCKED="FALSE" in xml scenario
  - CDBS_ID and ID can be any number because the "hypothetical" site will not need to be referenced to actual site in the CDBS
  - STATE is any 2-character value
  - FILE_NUMBER is any character value
  - LATITUDE/LONGITUDE are NAD-27 values and can be in either DD MM SS H or decimal degrees
  - HAAT is 30 m for Case 3 and 1.5 m for Case 4
  - HAMSL set to -999 will cause *TVStudy* to calculate this value
  - ERP is to appropriate value for Case 3 or Case 4
  - USE_GENERIC ="TRUE" uses OET-69 generic antenna

Wireless → DTV: Running *TVStudy* *TVStudy* Settings Case 3 & 4

- Contour
  - Use OET Bulletin No. 69 values
- TX antenna pattern
  - Use Generic elevation pattern
  - Mirror generic patterns = TRUE
- Clutter
  - Turn on clutter but set all categories to 0 dB
- Pathloss Calculations
  - Ignore Longley-Rice error code
    - Use pathloss as returned by code
  - Receiver Antenna height
    - 10 m AGL Case 3 & 4
  - Minimum transmitter height = 1.5m (for Case 4)
  - F(50,90) propagation for desired signal (default)
  - F(50,10) propagation for undesired signal (default)

Wireless → DTV: Calculations

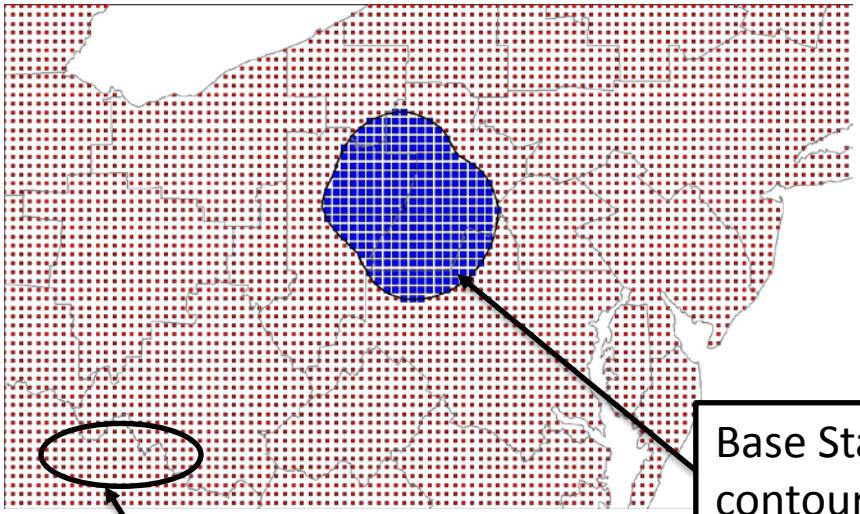


Wireless → DTV: Processing the Data Detailed tvstudy.cel output

[grid]
.
[cell]
<LatIdx>, <LonIdx>
"P", <ptCountryKey>, <ptLat>, <ptLon>, <ptArea>, <ptPop>, <ptClutterCategory>
"D", <DSrcKey>, <DFieldStrength>, <Bearing>, <KWXFlg>, <ServiceFlg>
"U", <USrcKey>, <UFieldStrength>, <Bearing>, <RxPatternAdj>, <KWXFlg>, <IXFlg>
"DU", <DUratio>, <DUThreshold>, <DUadjustment>
"U", <USrcKey>, <UFieldStrength>, <Bearing>, <RxPatternAdj>, <KWXFlg>, <IXFlg>
"DU", <DUratio>, <DUThreshold>, <DUadjustment>
.
.
.
[endcell]
[cell]
.
.
.
[endcell]
[endgrid]
[endscenario]

- Read tvstudy.cel file line-by-line to "flatten" the grid cell information into simple CSV with one line for every grid point vs TV station
  - Each line includes DU ratio, DU Threshold for TV station, and clutter category
- Adjust "DU" ratio for clutter value on the "U" path
  - If final channel assignment is unknown use "low UHF" values

Wireless → DTV: Processing the Data Detailed tvstudy.cel output

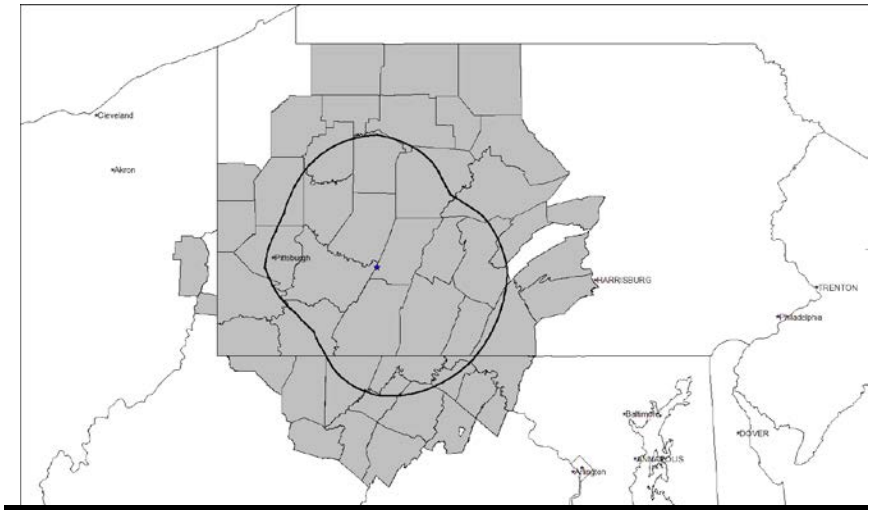


- Compare location of each Hypothetical Base station to the TV station baseline contour to determine if Base Station Location is inside or outside contour

Base Station Points inside baseline contour are noted

Hypothetical Base Stations spaced every 10 km across entire Continental US

Wireless → DTV: Analyze Data



TV in the Downlink
+5 MHz spectral overlap

- Grey areas are marked because:
  - Hypothetical Base Station causes IX inside the Baseline contour
    - OR -
  - Hypothetical Base Station is inside Baseline contour

Wireless → DTV: Data Provided for Constraint Generation

COL 1	COL 2	COL 3	COL 4	COL 5	COL 6	COL 7
FACID	OL	UL_DL	InCon2	IX	ptKey	*<BndryID>*

- FACID: facility ID for TV station
- OL: Spectral Overlap
- UL_DL: “D” for Case 3
- InCon2: 0 if Base Station falls outside protected contour and 1 if Base Station falls inside
- IX: 0 if D/U ratio is greater than threshold, else 1
- ptKey: unique identifier for grid cell point
- <*BndryID*>: A boundary identifier (e.g. County FIPS code) Used to specify “restricted” boundary

V: Potential Application to the Incentive Auction

Presenters

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