Broadcast TV Coverage

ATSC 1.0, ATSC 3.0 and 5G Broadcast

Defining, Calculating, Measuring

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Presentation available at:
https://transmitter.com/tc2024/

Broadcast TV Coverage

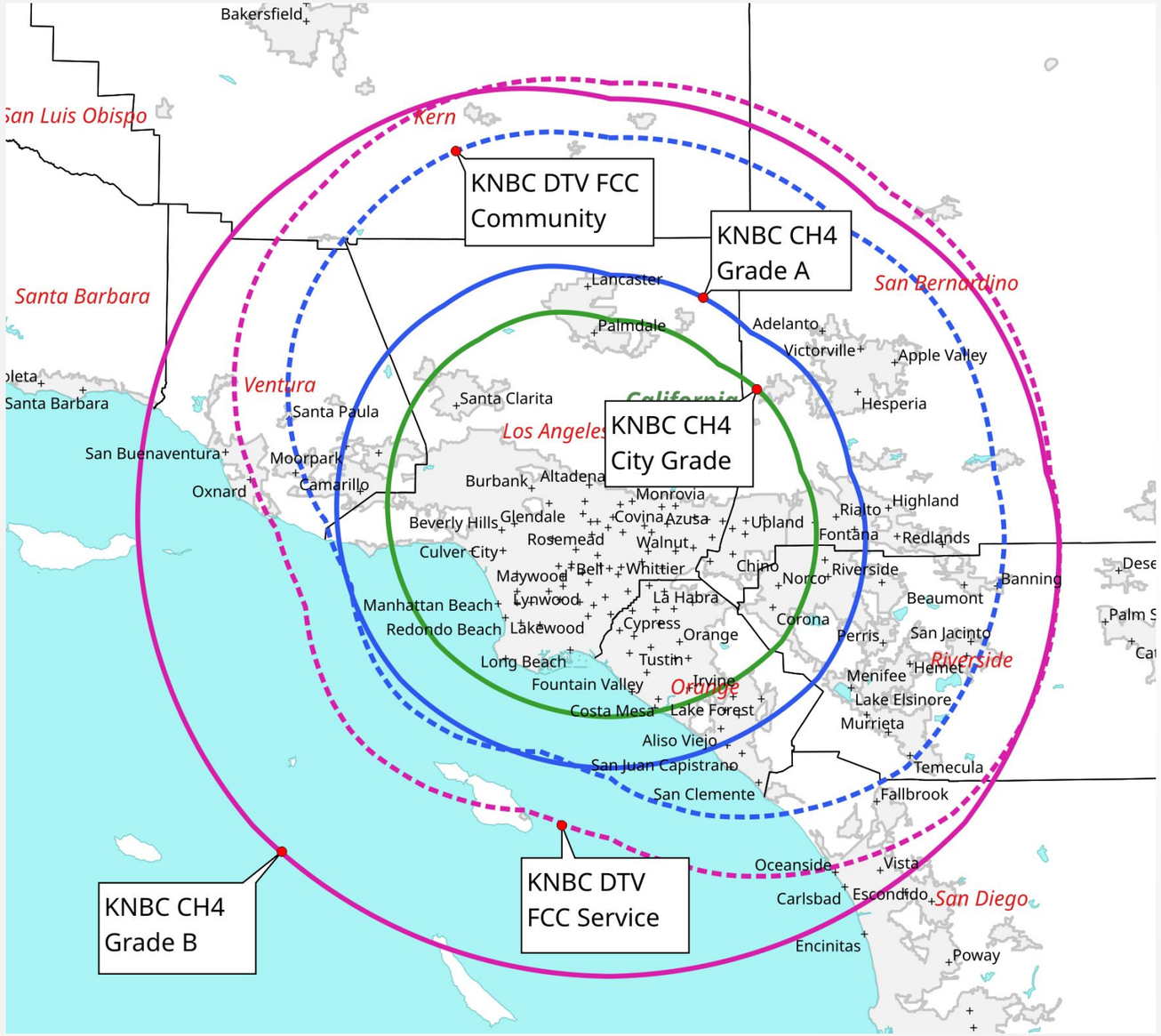
- **How do we define TV coverage? (Analog TV, ATSC 1.0, ATSC 3.0, 5G Broadcast)**
  - FCC coverage definitions
  - Coverage is defined by the distance to or areas predicted to receive the required field strength

- **Calculating TV Coverage – Required field strength**
  - Determine the required field strength for the receive environment
  - Adjust the required field strength for modulation and coding (ATSC 3.0 and 5G Broadcast)
  - Compare of required field strength and available data rate for different modulation and coding (ATSC 3.0 and 5G Broadcast)

- **Calculating TV Coverage – Propagation models and software**
  - Empirical models
  - Deterministic models
  - Compare models
  - Coverage study and mapping examples

- **Measuring Coverage**

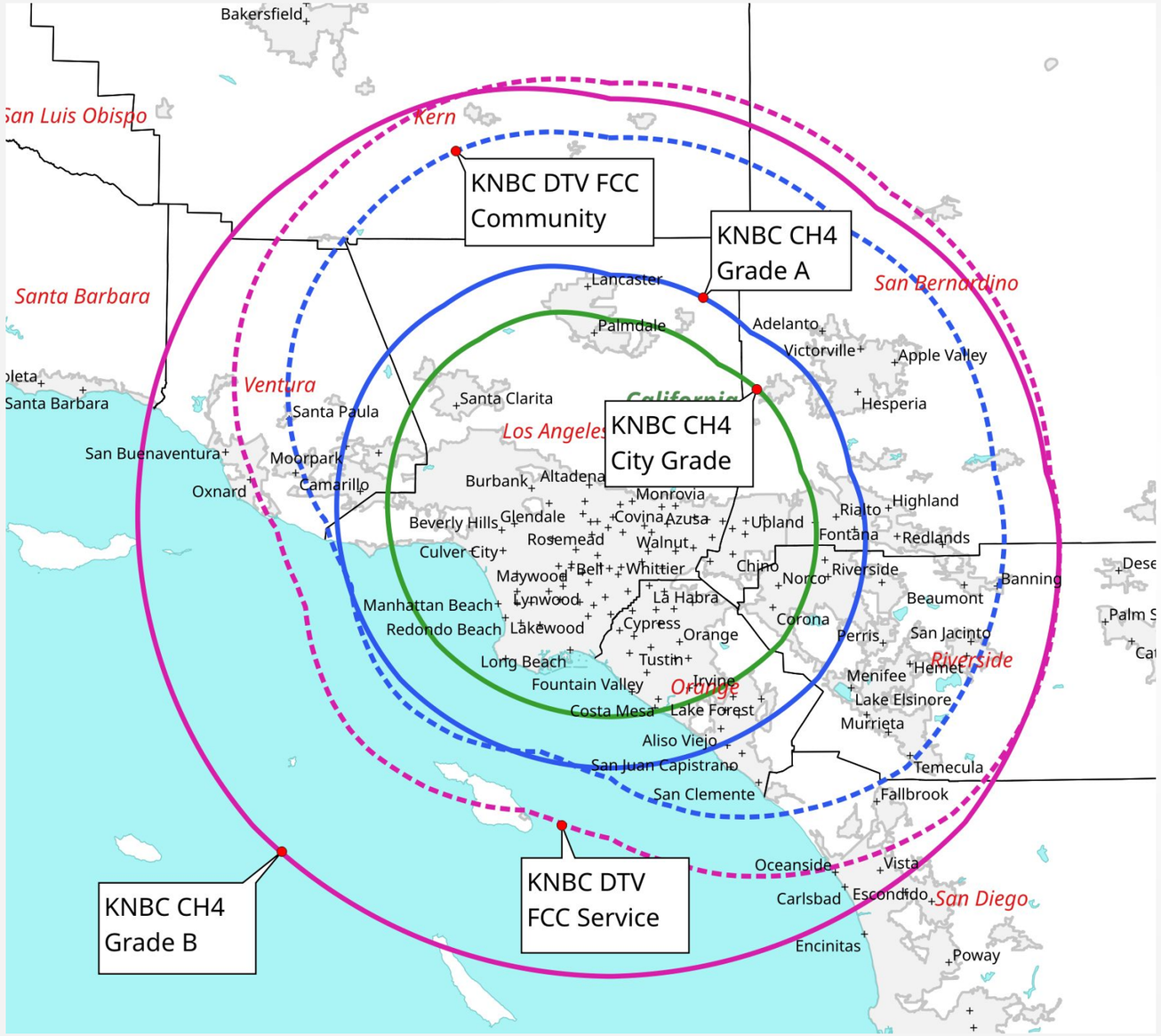
FCC Contours – Traditional Coverage



- **FCC Coverage Contours**
  - Define the FCC protected coverage
  - Simplest way to show coverage
  - Sales people love these
- **FCC Analog contours (example shown)**
  - City Grade = 74 dBµV/m
  - Grade A = 68 dBµV/m
  - Grade B = 47 dBµV/m
- **FCC DTV contours (ATSC 1.0 or ATSC 3.0)**
  - *Noise-Limited Service area*
    - 28 dBµV/m (channels 2-6)
    - 36 dBµV/m (channels 7-13)
    - 41 dBµV/m (UHF before adjustment: *41 - 20 log[615/(frequency in MHz)]*)
  - *Community Grade*
    - 35 dBµV/m (channels 2-6)
    - 43 dBµV/m (channels 7-13)
    - 48 dBµV/m (channels 14-36)

Are contours still relevant?

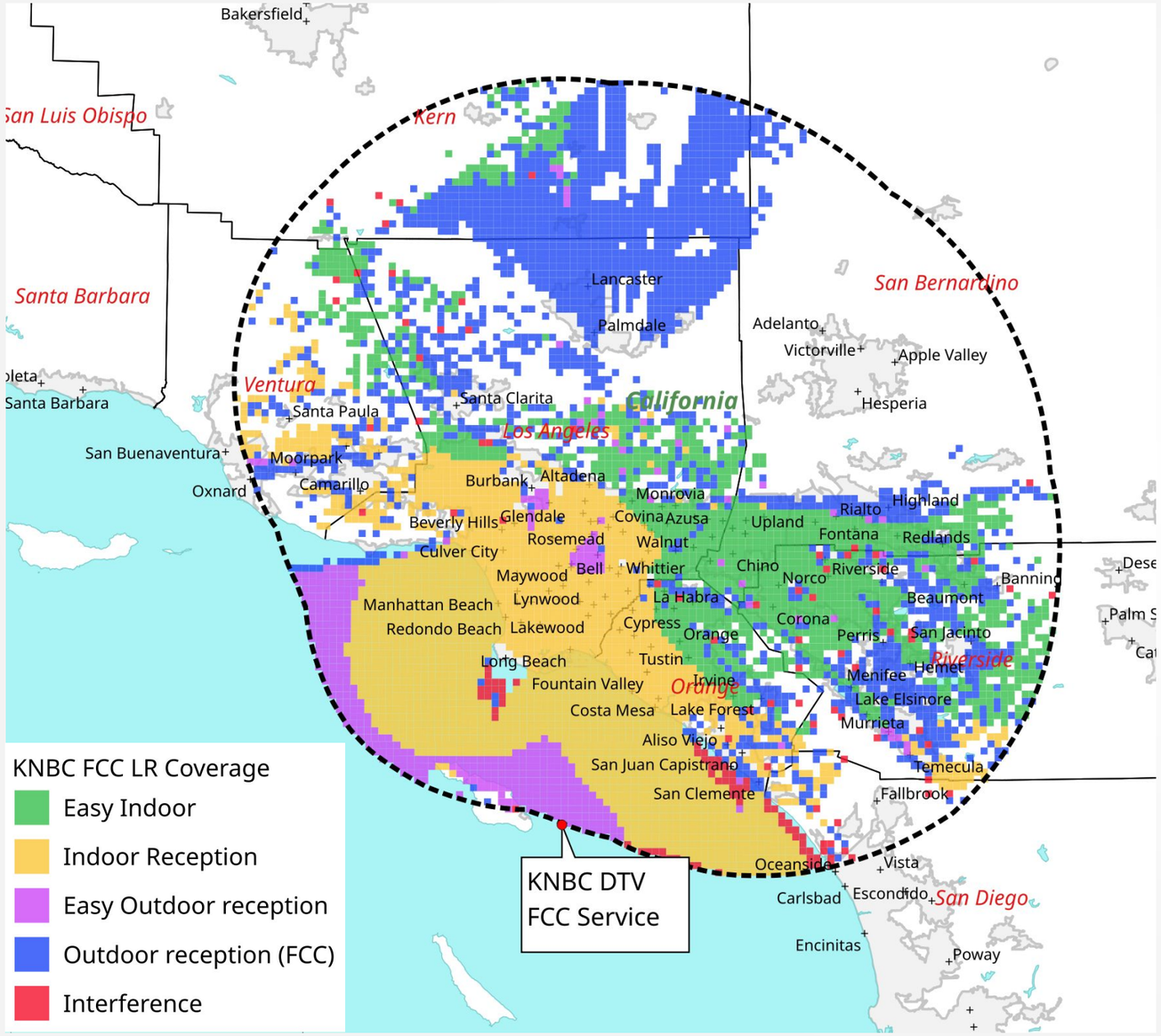
FCC Contours (2)



- **FCC contours seldom reflect real coverage**
  - Terrain and buildings impact coverage
  - FCC antenna data may not reflect the signal on the ground
- **More dBµV/m = Easier Reception**
  - Analog contours had three field strength levels
    - 27 dB difference between City Grade and Grade B at Channel 4
  - FCC DTV coverage has only two field strength levels – Noise-limited and Community grade
    - ~ 7 dB difference between DTV noise limited and community grade contours at UHF
  - FCC DTV coverage based on outdoor antenna 30 feet high
  - More signal is needed for today's antennas

How do we more accurately predict coverage?

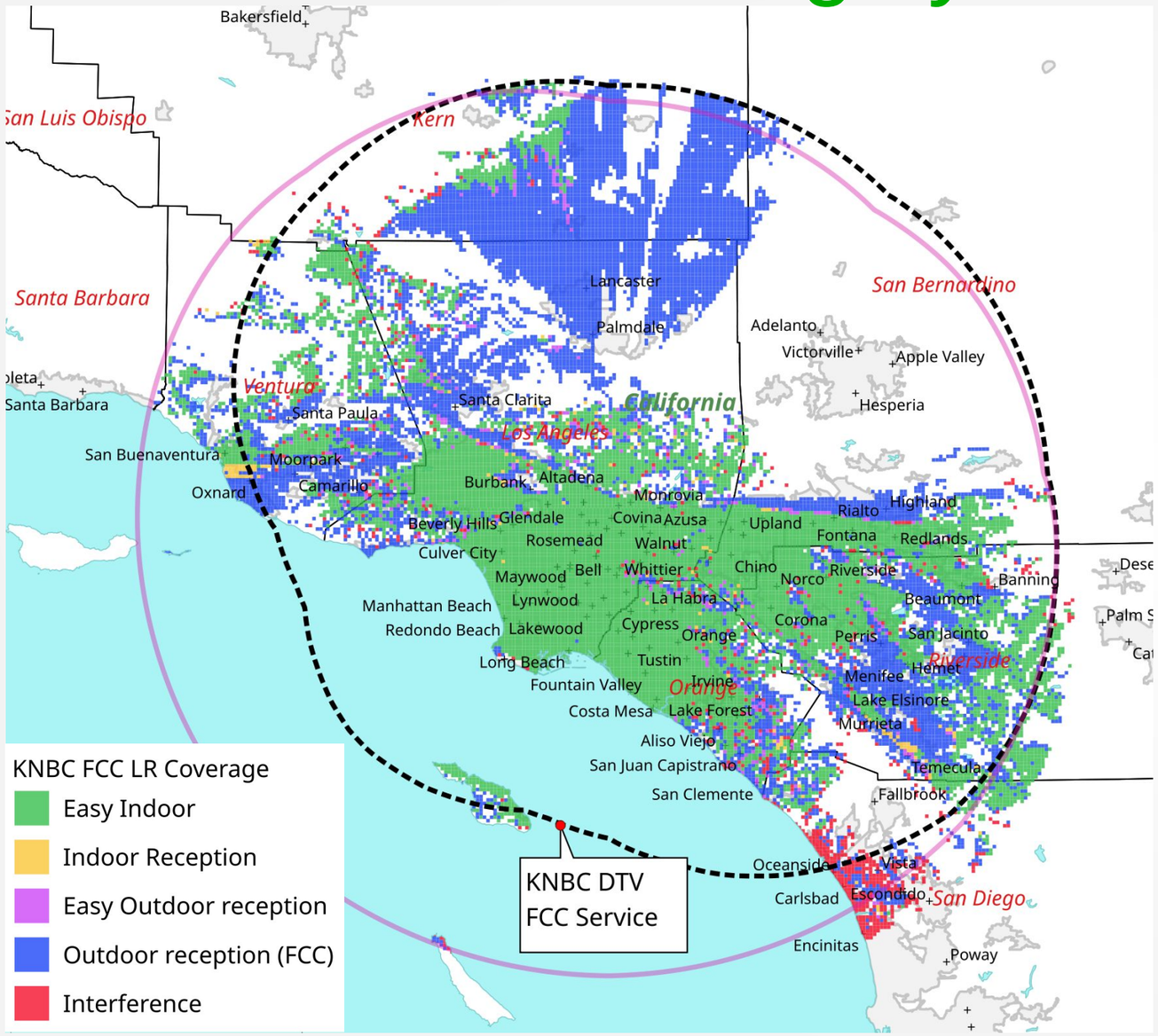
FCC Terrain Sensitive Coverage



- **FCC Longley-Rice ITM Coverage (OET-69)**
  - Field strength is calculated at individual cells (2 km to 500 m spacing) considering terrain between the transmitting antenna and the cell
  - OET-69 defines study methodology
    - Directional outdoor antenna at 30 feet
    - Interference levels between stations
    - Longley-Rice parameters
  - Required for all applications for new and modified TV broadcast facilities
- **Limitations**
  - Viewers may not have outdoor antennas
  - FCC treatment of Longley-Rice errors codes can show coverage where none exists
  - FCC database does not include complete (3-D) antenna patterns for most stations

What happens with more accurate antenna data?

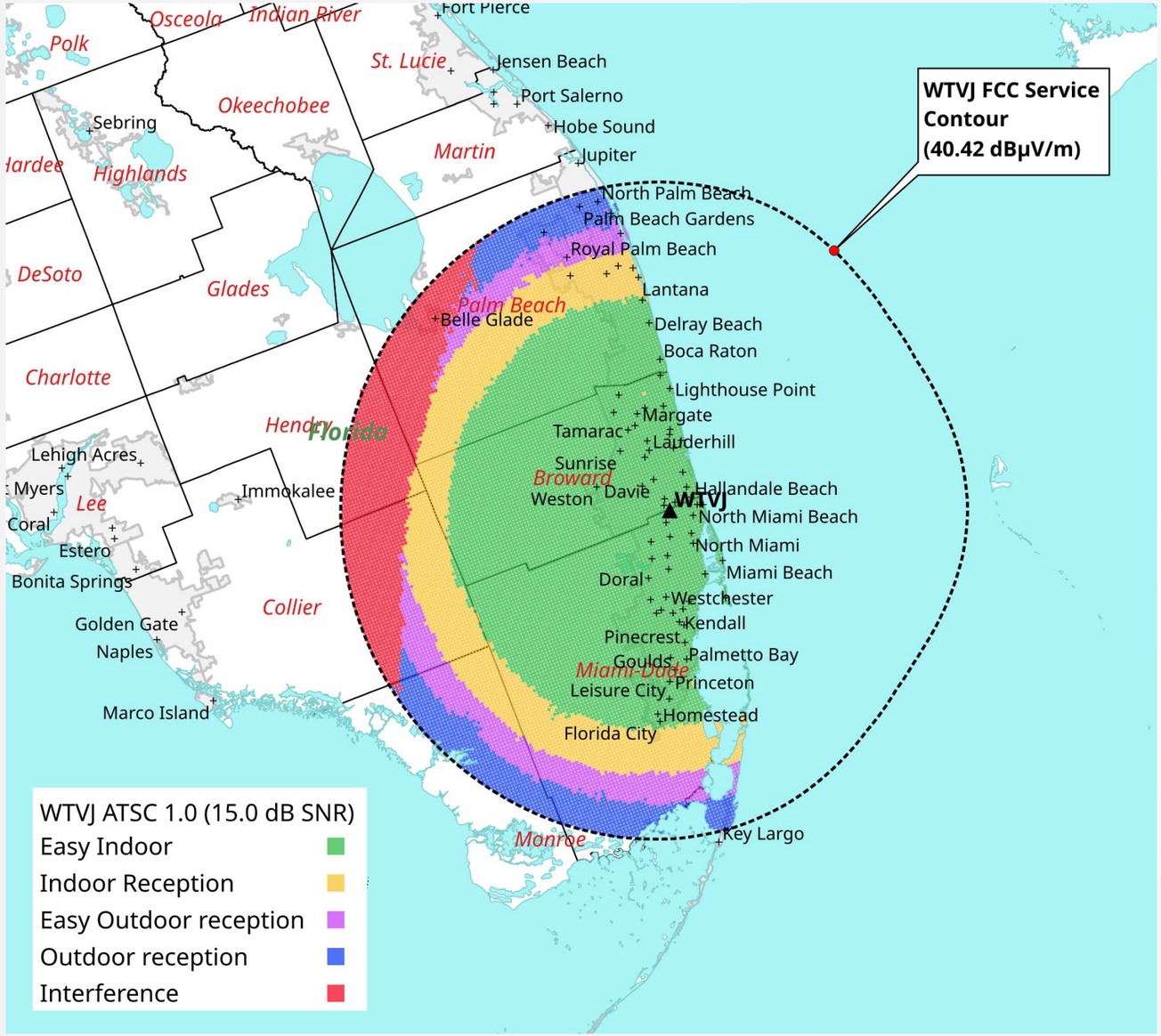
Modified Longley-Rice Coverage Study



- **Modifications**
  - Cell size reduced to 1 km spacing
  - Azimuth & elevation antenna patterns used instead of horizontal-plane azimuth pattern and default OET-69 elevation pattern
  - Longley-Rice errors ignored
- **Coverage difference**
  - Most viewers have indoor (88 dBµV/m) signal
  - The signal is available beyond default FCC service contour
  - Plotted service is truncated at the FCC radio-horizon derived azimuth pattern contour
- **Studies done with incomplete antenna data will not be accurate!**

How is ATSC 3.0 coverage defined?

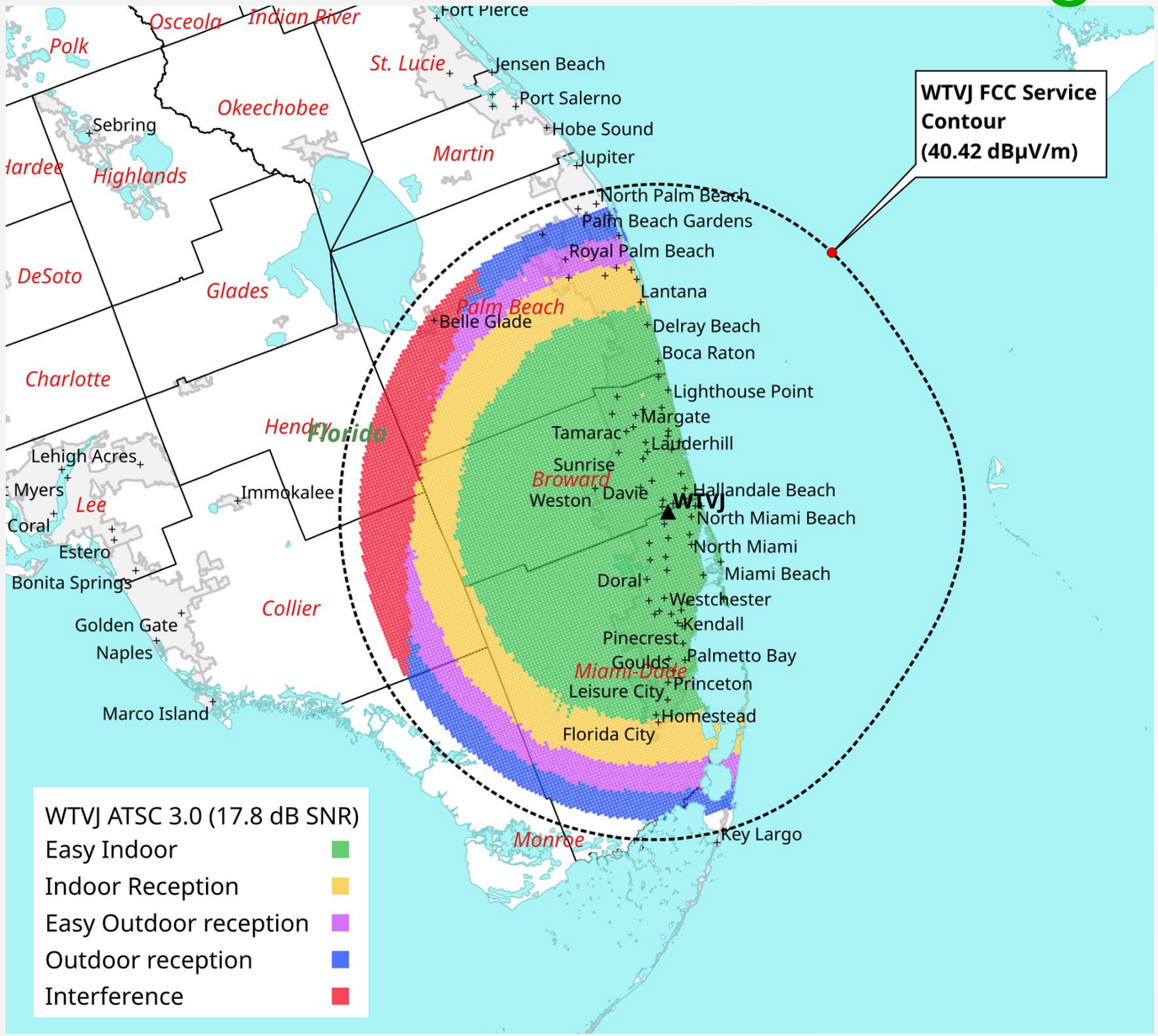
FCC ATSC 3.0 Coverage = ATSC 1.0 Coverage



- **FCC Calculated Coverage**
  - ATSC 3.0 coverage and interference are calculated exactly the same as ATSC 1.0 coverage
  - ATSC 3.0 coverage = ATSC 1.0 coverage
- **ATSC 3.0 coverage will match ATSC 1.0 coverage if ATSC 3.0 required CNR = 15.0 dB**
  - FCC Noise-Limited Service Contour at 40.42 dBµV/m using FCC OET-69 planning factors
- **ATSC 3.0 Coverage Options**
  - Unlike ATSC 1.0, ATSC 3.0 modulation and coding affect field strength & coverage
  - More bits = less coverage
  - Less bits = more coverage

When is Real ATSC 3.0 Coverage Different?

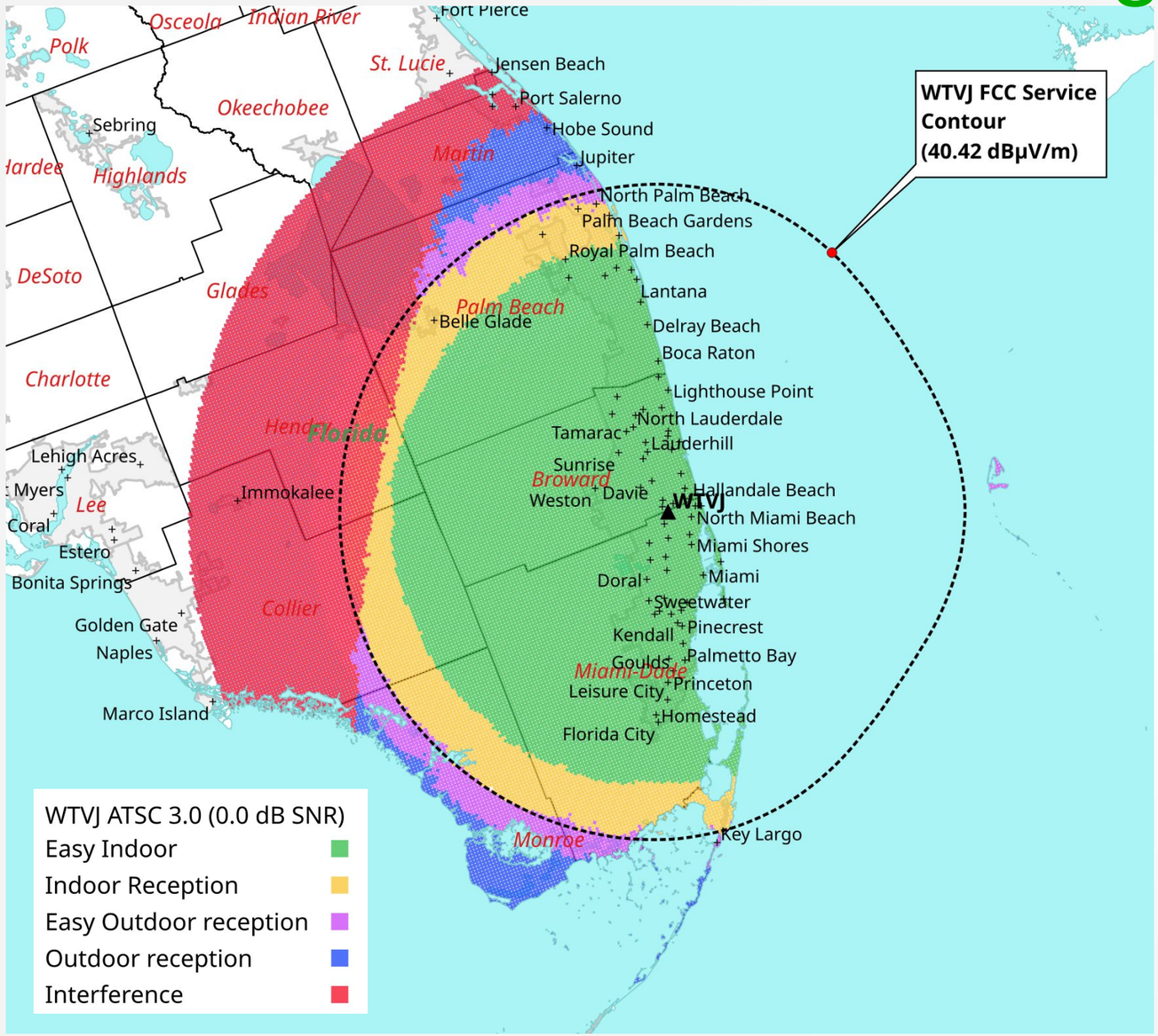
ATSC 3.0 Coverage @ 17.8 dB CNR



- **Different modulation and coding will change the required CNR**
  - WTVJ coverage from LDM enhanced layer
  - LDM Injection level = 4 dB
  - QAM256 modulation with 7/15 code rate
  - Required AWGN CNR = 17.8 dB
  - 20.04 Mbps data rate
- **Higher CNR requirement reduces coverage compared with ATSC 1.0**
  - Very little difference in “Easy Indoor” coverage
  - LDM robust layer will aid signal acquisition and receiver signal lock (not considered in CNR calculation)
  - Signaling and data are transmitted in the robust LDM layer which has better coverage

Can ATSC 3.0 increase coverage?

ATSC 3.0 Coverage @ 0 dB CNR



- **ATSC 3.0 can transmit a more robust signal in the same channel as the less robust signal**
  - WTVJ coverage from LDM robust layer
  - LDM Injection level = 4 dB
  - QPSK modulation with 6/15 code rate
  - Required AWGN CNR = -0.2 dB
  - 4.29 Mbps data rate

- **Lower CNR requirement increases coverage**
  - Significant improvement and new coverage in areas which had interference
  - Interference limits more distant coverage
  - TV set data indicates reception as far away as Key West and Melbourne FL

Defining Coverage: Summary

- **Coverage is defined by a minimum field strength over an area or at a point**
  - FCC defined 3 field strengths for analog TV – Grade B, Grade A, City Grade
  - FCC defines 2 field strengths for ATSC TV – Noise Limited & Community Grade
  - For ATSC 3.0 and 5G Broadcast, modulation and coding determine required field strength for different reception conditions (can be more or less than FCC levels)
- **FCC contours show the distance to a specific predicted field strength**
  - Distance is calculated over 8 or more radials from the transmit antenna
  - Distance based on height above average terrain and power level
  - FCC contours do not provide field strength data at points inside the contour
- **Terrain sensitive models show field strength at one or more points**
  - Field strength is calculated to points inside an area considering all terrain along the path
- **Accurate coverage predictions require accurate data**
- ***Field strength calculations are the same for ATSC 1.0, ATSC 3.0, and 5G Broadcast but required field strengths may be different!***

How do we calculate coverage?

Field-Strength Requirements

- **Planning factors are used to determine required field strength for specific conditions**
  - FCC OET-69 is the basis for FCC TV broadcast coverage
  - Planning factors also defined by EBU, ITU, and others
- **Adjust field strengths from existing planning factors to allow for different reception conditions**
  - Lower antenna gain and height
  - Local obstructions including trees, buildings
  - Required reliability
- **Adapt existing planning factor field strengths for use with ATSC 3.0 and 5G Broadcast**
  - Adjust required field strength to reflect required carrier-to-noise ratio (CNR)
  - Adjust required desired to undesired interference ratio to reflect required CNR

What are the planning factors?

FCC OET-69 Planning Factors

Table 3

Planning Factors for DTV Reception

Planning Factor	Symbol	Low VHF	High VHF	UHF
Geometric mean frequency (MHz)	F	69	194	615
Dipole factor (dBm-dBu)	K_d	-111.8	-120.8	-130.8
Dipole factor adjustment	K_a	none	none	see text
Thermal noise (dBm)	N_t	-106.2	-106.2	-106.2
Antenna Gain (dBd)	G	4	6	10
Downlead line loss (dB)	L	1	2	4
System noise figure (dB)	N_s	10	10	7
Required Carrier to Noise ratio (dB)	C/N	15	15	15

- **Longley-Rice Parameters (OET-69 Table 4)**
  - Height of TV antenna above ground: 10 meters
  - Polarization: Horizontal
  - Surface refractivity: 301 N-units (parts per million)
  - Continental temperate climate (5)
- **Variability**
  - For service: 50% of locations, 90% of the time – F(50,90)

Convert planning factors to field strengths

FCC OET-69 Field Strengths

- **FCC Field Strengths Based on OET-69 Planning Factors (ATSC 1.0 or ATSC 3.0)**
  - *Noise-Limited Service area*
    - 28 dBµV/m (channels 2-6)
    - 36 dBµV/m (channels 7-13)
    - 41 dBµV/m (UHF before adjustment: *41 - 20 log[615/(frequency in MHz)]*)
  - *Community Grade*
    - 35 dBµV/m (channels 2-6)
    - 43 dBµV/m (channels 7-13)
    - 48 dBµV/m (channels 14-36)

These signal levels are based on an outdoor gain antenna 10 meters (32.8 ft) above ground!

- **Factors limiting available indoor field strength**
  - Loss due to building material
    - iBlast study found average loss 18.5 dB in Portland and 21.5 dB in San Jose
    - 1963 FCC study showed NYC loss 21 to 26 dB at UHF
    - MSW measured UHF loss median 11.65 dB
    - Mobile home loss 28 dB
  - Loss due to lower antenna height (6 feet)
    - MSW measurements: 5.01 dB average
    - MSW standard deviation: 8.33 dB
    - MSW average + standard deviation: 13.54 dB
  - Indoor antenna gain ~ 0 dB @ UHF, loss @ VHF
  - Surrounding buildings and trees add multipath and additional loss increasing required field strength
- **More information & references available on-line**
  https://www.tvtechnology.com/opinions/dtv-in-the-house-part-1

"Worst Case" Field Strength for Indoor Reception: 88 dBµV/m

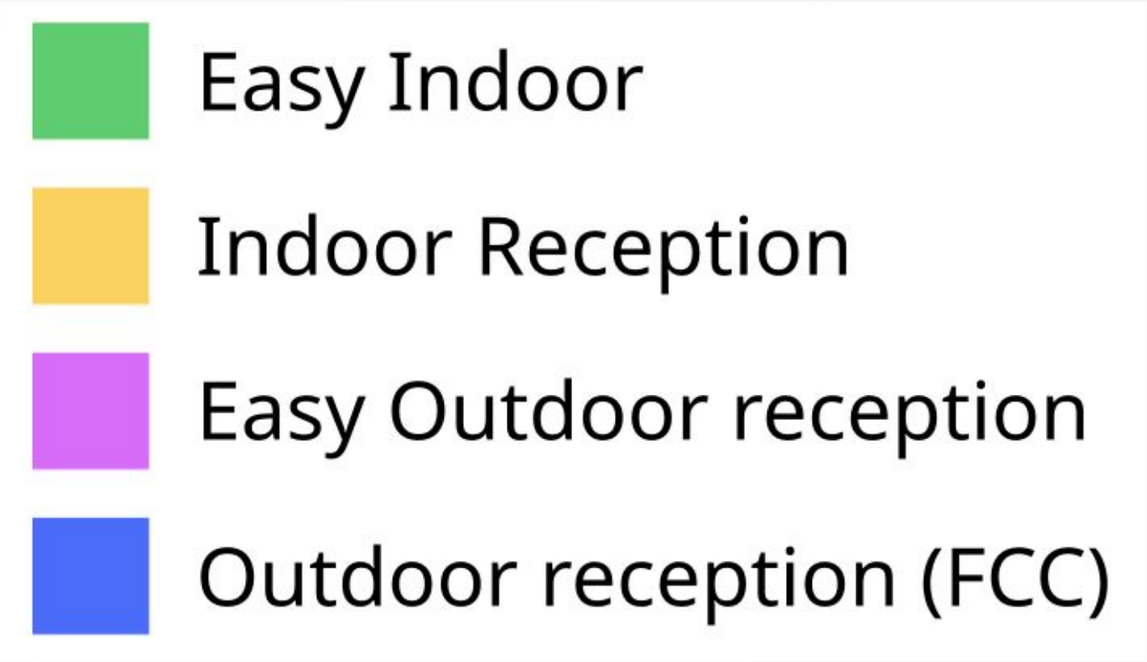
Field Strengths for Coverage

Worst case (previous slide): 88 dBµV/m

Median case (MSW paper): 75.5 dBµV/m

FCC Community Grade + 20 dB: 68 dBµV/m

FCC OET-69 Noise Limited (28 to 41 dBµV/m



Calculating Required Field Strength:

- **Planning factors provide the minimum required power**
- **Antenna gain (or loss) determines field strength required at the antenna**
- **Environmental losses (height, building, multipath) increase required field strength**
- **Increase field strength to improve reliability**

How do we determine required field strength for ATSC 3.0 and 5G Broadcast?

Calculating Required Field Strength for ATSC 3.0

Calculation based on OET-69 Planning Factors:

1) Determine required OET-69 field strength for the channel at ATSC 1.0 15 dB CNR

2) Calculate required ATSC 3.0 CNR requirement based on modulation and coding ("ATSC 3.0 CNR")

3) Calculate difference in required CNR:
Adjustment (dB) = ATSC 3.0 CNR – 15.0

4) Req Field Strength = ATSC 1.0 Field Strength + Adjustment
Note: Adjustment may increase (positive) or decrease (negative) the required ATSC 3.0 field strength

Example (channel 31):

LDM Injection level = 4 dB
QPSK modulation
6/15 code rate
Required AWGN CNR = **-0.2 dB**
(4.29 Mbps data rate)

Minimum Field Strength:

FCC ATSC 1.0 Noise-limited:
40.42 dBµV/m
Threshold adjustment:
-0.2 – 15.0 = **-15.2**
ATSC 3.0 threshold field strength:
40.42 + -15.2 = **25.22 dBµV/m**
(with OET-69 antenna and height)

How does this impact different ATSC 3.0 receive environments?

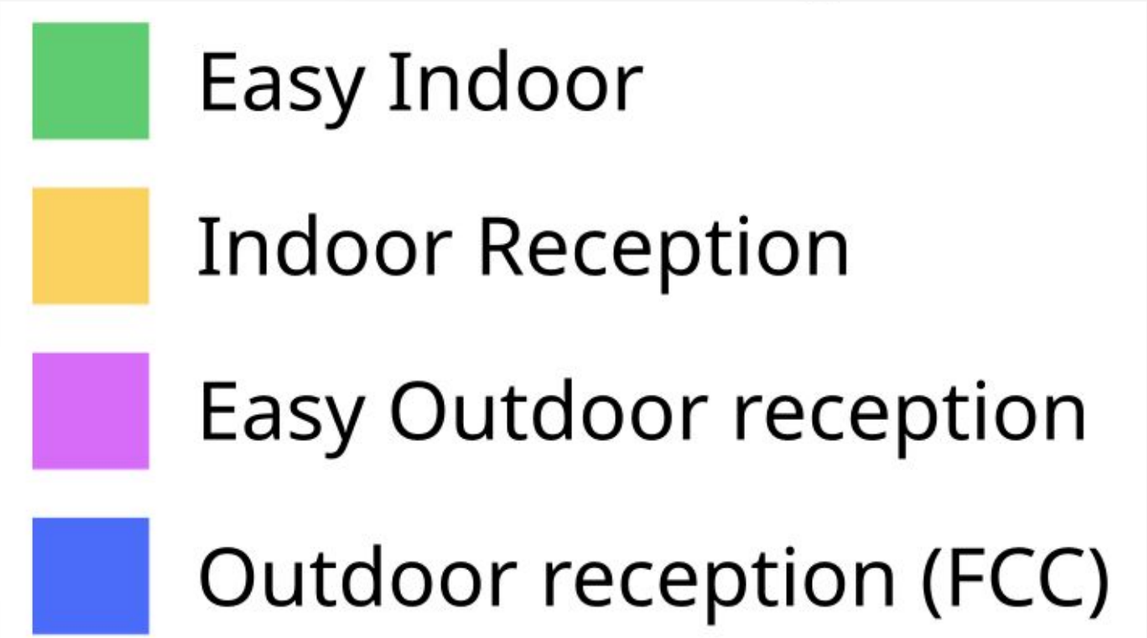
ATSC 3.0 LDM Example Field Strengths

88 dBµV/m – 15.2 = 62.8 dBµV/m

75.5 dBµV/m – 15.2 = 60.3 dBµV/m

68 dBµV/m – 15.2 = 52.8 dBµV/m

Noise Limited (25.22 dBµV/m)

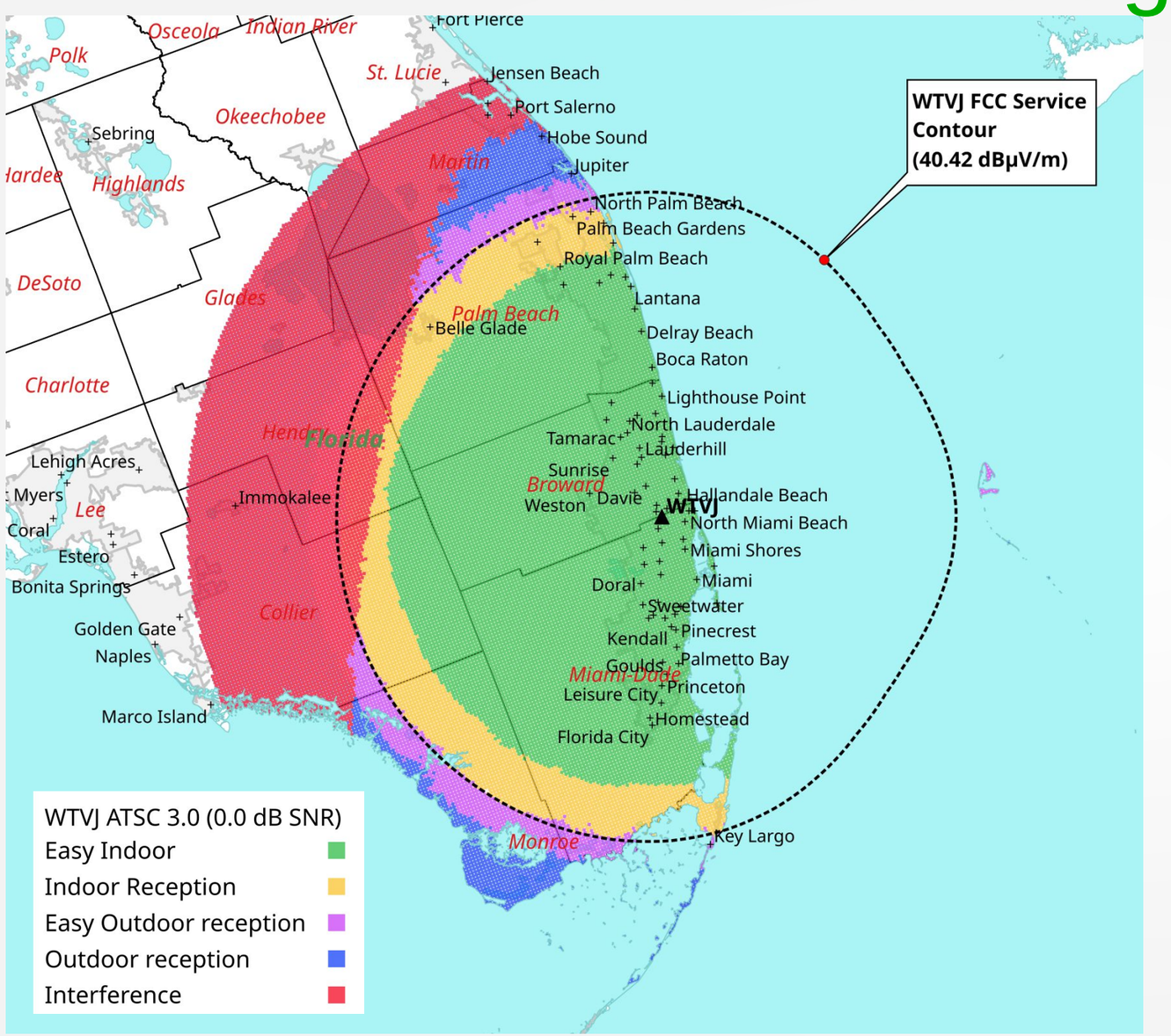


Coverage environments previously defined based on FCC OET-69 planning factors are adjusted for significantly lower threshold with ATSC 3.0 LDM robust layer

Interference ratios also change and are reflected in the predicted coverage

What does this look like on a map?

ATSC 3.0 Coverage – 0 dB CNR



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- **Lower CNR requirement increases coverage**
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How does 5G Broadcast Compare?

Calculating 5G Broadcast Coverage

- Substitute required CNR for 5G Broadcast Physical layer for the ATSC 3.0 required CNR
- Example from IEEE Transactions on Broadcasting paper:
  Evaluation of ATSC 3.0 and 3GPP Rel-17 5G Broadcasting Systems for Mobile Handheld Applications
  by
  Seok-Ki Ahn, Sungjun Ahn, Jeongchang Kim, Hyeongseok Kim, Sunhyoung Kwon, Sungho Jeon, Mats Ek, Sesh Simha , Anindya Saha, Prashant M. Maru, Parag Naik, Mark Aitken, Pablo Angueira, Yiyan Wu, and Sung-Ik Park

What 5G Field strength is required for mobile?

IEEE TRANSACTIONS ON BROADCASTING, VOL. 69, NO. 2, JUNE 2023

TABLE V
CONFIGURATIONS FOR DATA CHANNELS (8MHZ BW)

		Svc1	*Svc2*	*Svc3*
ATSC 3.0	Code Rate	8/15		
	Constellation	QPSK	16-NUC	64-NUC
	Data Rate	5.36Mbps	10.73Mbps	16.09Mbps
	Required CNR (AWGN)	1.2dB	6.4dB	10.4dB
5G Broadcast	MCS Index	8	14	20
	TBS	5544	10296	15840
	Code Rate	0.58	0.54	0.553
	Constellation	QPSK	16-QAM	64-QAM
	Data Rate	5.41Mbps	10.04Mbps	15.44Mbps
	Required CNR (AWGN)	2.3dB	7.3dB	12.1dB

Calculating 5G Broadcast Coverage

- Example from *5G Media2Go Audiovisual Services for In-Car Infotainment Systems*
- 5G Media2Go project was created to verify 5G Broadcast was capable of providing linear media services to in-car infotainment systems
- Project used two 5G high power, high tower transmitters and a set of low power transmitters
- Final report: https://www.5g-mag.com/post/5g-media2go-audiovisual-service-for-autonomously-driving-cars
- See EBU TR 063 for other 5G scenarios: https://tech.ebu.ch/docs/techreports/tr063.pdf

Note difference in location variability and height!

Theoretical Minimum Field Strength Requirement Scenario 1 Car Mounted		MCS9	MCS16
Equivalent noise band width	B [Hz]	5000000	5000000
Boltzmann's constant	k [Ws/K]	1.38E-23	1.38E-23
absolute temperature	T [K]	290	290
Receiver noise figure (TR 063)	F [dB]	6.0	6.0
Receiver noise input power	P_n [dBW]	**-131.0**	**-131.0**
RF signal/noise ratio 200 µs CP (TR 063)	C/N [dB]	9.0	15.2
Estimated C/N degradation due to SFN Doppler v = 100 km/h	[dB]	0.6	2.0
Overall RF signal to noise ratio	C/N [dB]	**9.6**	**17.2**
Min. receiver signal input power	P_{smin} [dBW]	**-121.4**	**-113.8**
Frequency	f [MHz]	626	626
Wave length	λ [m]	**0.479**	**0.479**
Receiver antenna gain (TR 063)	g_r [dBd]	0.9	0.9
Feeder loss (TR 063 / BT.2254)	Lf [dB]	0	0
Equivalent minimum FST at receiver	E_{min} [dBµV/m]	**38.7**	**46.3**
Other losses (TR 063)	L_o [dB]	1	1
Receiver Entry Loss (TR 063)	[dB]	0	0
Min. median FST for planning (50%)	E_{med} [dBµV/m]	**39.7**	**47.3**
Height loss (TR 063 / BT.2254 / P.370) Rural h_2 3.5 m->1.5 m	L_h [dB]	4.9	4.9
Locaction correction 50% - 99% (TR063 / BT.2254 / P.1546)	[dB]	13.0	13.0
Min. FST for 99% in 3.5 m height	**E_{equiv} [dBµV/m]**	**57.6**	**65.2**

Table 6: Theoretical minimum field strength requirements for car mounted reception according to [EBU21], [ITU95], [ITU19] and [ITU21].

Comparing 5G Broadcast Coverage

- SET article by Ricardo Seriacopi Rabaçaon on SBTVD physical layer laboratory tests in Phase 3 of the TV 3.0 Project in Brazil compares results for three physical layer standards: Advanced ISDB-T, ATSC 3.0, and 5G Broadcast
- Table shown was translated to English by Google Translate and font size increased to improve readability
- Results shown for the same CNR (same coverage) but capacity varies greatly
- Full article: https://set.org.br/wp-content/uploads/2024/02/REVISTASET_213_ARTIGO-TV-3.0.pdf

Table 1 - Summary of Phase 3 results

Requirement	Minimum specification			*Advanced* ISDB-T	ATSC 3.0	5G *Broadcast/ EnTV*
Will allow deployment of networks with adjustable coverage and capacity, reuse-1 and more efficient use of spectrum (fixedinternal reception and external mobile).	DESPITE	2x2		OK	OK	OK
	Transmission with multiple RF channels	CB		OK	OK	ENOUGH
	High-speed mobile reception	120 km/h		Partially OK	Partially OK	Not verified
	Efficiency spectral (6 MHz - DESPITE)	A layer	@ C/N ȳ 0 dB in channels *Rayleigh*	0,81 bit/s/Hz @ 4,9 Mbps	0,88 bit/s/Hz @ 5,3 Mbps	0,44 bit/s/Hz @ 2,6 Mbps
		Two layers	CP @ C/N ȳ 0 dB in channels *Rayleigh*	2,45 bit/s/Hz @ 3,5(CP) + 11,2 (CS) Mbps	4,0 bit/s/Hz @ 5,3 (CP) + 18,8 (CS) Mbps	1,30 bit/s/Hz @ 1,4 (CP) + 6,5 (CS) Mbps
			CS @ C/N ȳ 16 dB in channels *Rayleigh*			

What tools are available for calculating field strength?

Tools for Calculating Field Strength/Coverage

- **Coverage contour tools**
  - FCC curves
    - Included in most propagation software used by broadcasters
  - ITU-R P.1546
- **Terrain sensitive point to point models**
  - Longley-Rice (ITM)
  - ITU-R P.1812
  - TIREM
  - ITWOM
  - ITU-R P.526
- **Other models**
  - Okumura-Hata
  - CRC-Predict

- **On-Line Tools**
  - Rabbitears.info
  - FCC
- **Software Examples**
  - FCC TVStudy
  - SPLAT!
  - Radio Mobile
  - RadioPlanner
  - V-Soft Probe 5
  - Progira
  - EDX Signal Pro
- **Mapping Tools**
  - Google Earth
  - QGIS

Which model is best?

Evaluating Propagation Models

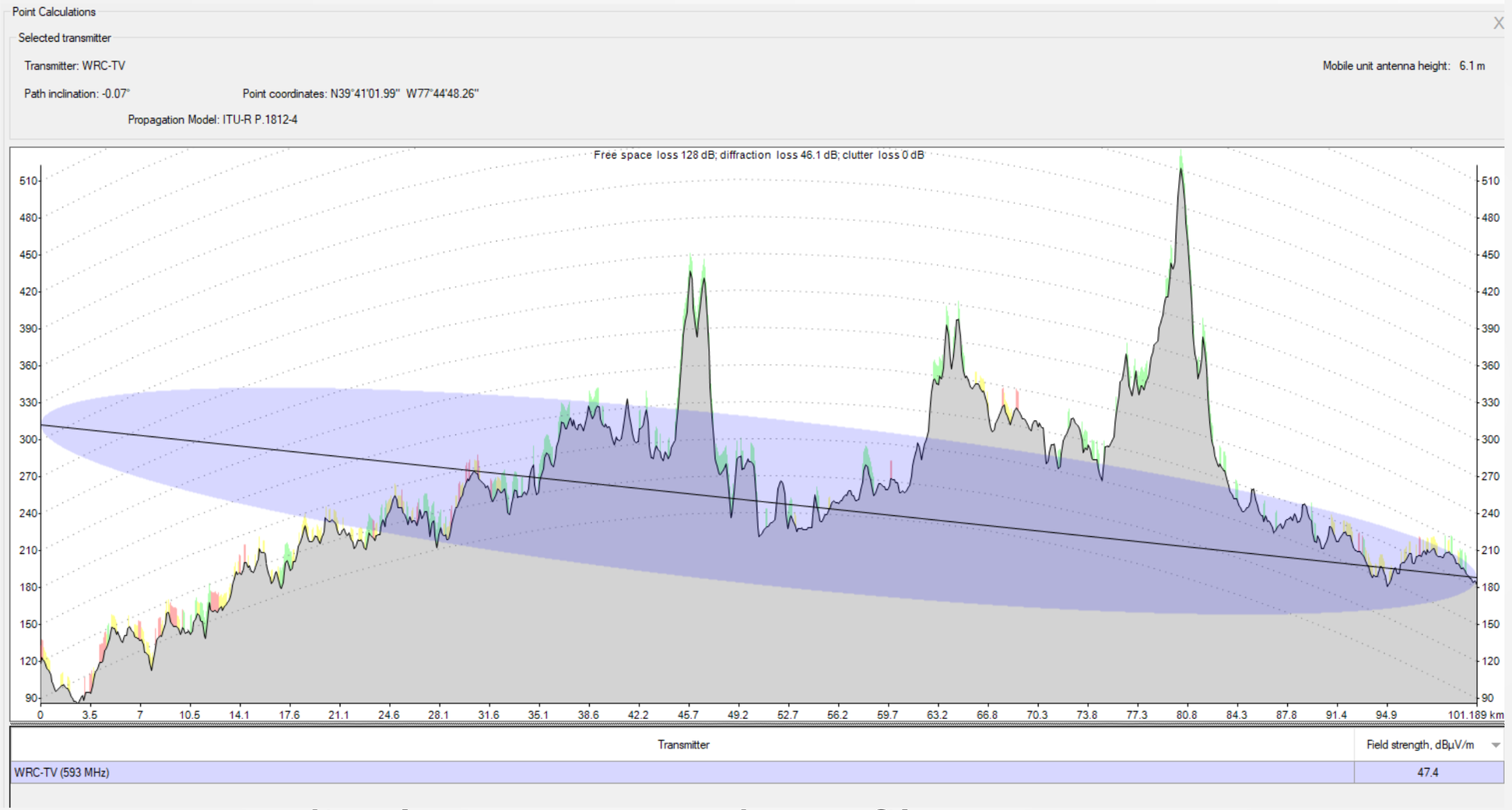
- **Prediction precision depends on precise data**
  - Models that require and use the most accurate terrain and land cover data will provide more precise answers
  - Precision doesn't always equal accuracy
  - Selection of propagation mode for different types of paths & obstructions affects accuracy
- **Table I from:** ***Propagation Models Comparison by Propagation Features*** **compares predictions with real world measurements** (Alberto Leonardo Penteado Botelho in SET International Journal of Broadcast Engineering, August 2019)
- **Longley-Rice and ITU P.1546 ranked below the models shown**

Models vs real world?

Table I - Average error of all paths compared to field measurement.

Average (dB)				
Propagation Model	Selectable Option	DMA	σ	RMS
ITUR 1812-3	Dense Urban	6,9	1,4	7,2
ITUR 526-13	General Method	7,6	1,5	7,9
ITUR 1812-3	Forest / Urban	8,1	1,6	8,5
CRC-Predict	Continntal / Great Lakes / Maritime Overland / Maritime Oversea	8,9	2,4	9,4
ITUR 1812-3	Suburban	9,1	1,7	9,5
ITUR1 812-3	Database	9,1	1,7	9,5
Deygout-Assis	Knife Edge	9,6	2,2	10,1
ITUR G06	Rural / Open / Suburban	9,6	2,2	10,1
Okumura - Hata	Quasi Open	10,3	2,1	10,8

WRC-TV to Hagerstown MD



RadioPlanner 2.1 Path Profile (USGS DEM)

WRC-TV to Hagerstown: Will it work?

Obstructed Path Field Strength Predictions – WRC-TV to HGR

Model	ITM 7.0 / Longley-Rice 1.22				ITWOM 3.0	P1812-4
Software	*SPLAT!*	*SPLAT!*	*TVStudy*	*TVStudy*	*SPLAT!*	*RadioPlanner 2.1*
Elevation data	ASTER	USGS	USGS	USGS	ASTER	USGS
Clutter data	None	None	None	NLCD 2006	None	OpenStreetMap
Path Loss (dB):						
Free Space	128.15	128.15			128.15	128
Terrain	80.59	71.07			25.08	46.1
Total	208.74	199.23			153.24	174.1
Field (dBµV/m):	**13.7**	**23.67**	**26.8**	**21.8**	**69.2**	**47.4**
Path notes:	Double Horizon	Double Horizon			Double Horizon	
Dominant mode:	Troposcatter	Diffraction			Diffraction	
Model errors:	#3 (Out of range)	None			None	

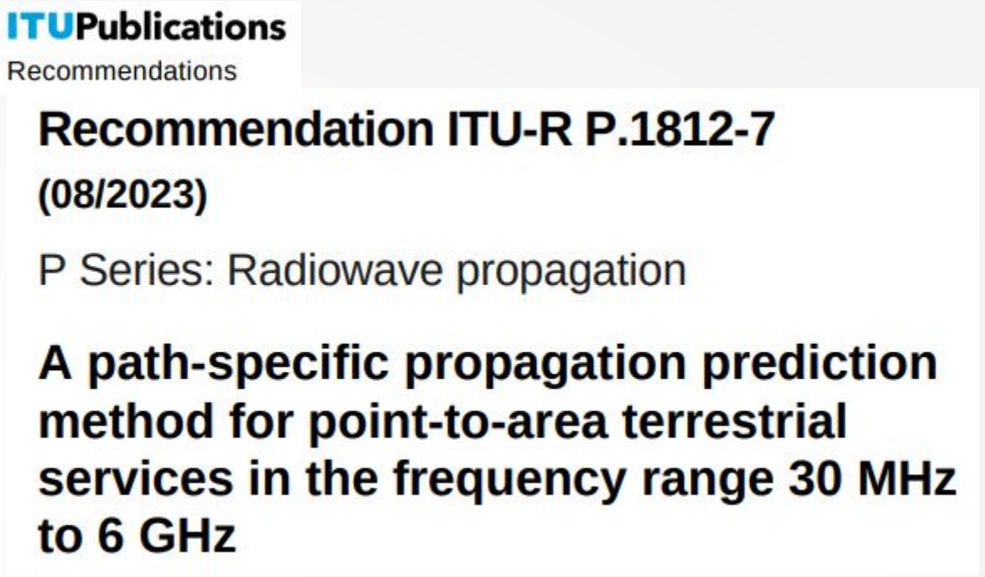
- **Yes! Excellent error free reception with Televes Ellipse Mix antenna ~ 6.1 m (20') AGL**
  - Models predicted significantly different signal levels
  - Field strength not measured, but P.1812-4 appears closest based on CNR (24 to 26 dB) considering antenna gain and LNA
  - More details in 1Q2024 IEEE Broadcast Technology: https://bts.ieee.org/publications/ieee-broadcast-technology.html

FCC TVStudy For Coverage Studies

- **FCC TVStudy combined with QGIS can tackle most coverage study requirements**
  - TVStudy output includes text-delimited data and shapefiles that can be easily mapped with the open source QGIS software: https://qgis.org/en/site/
  - QGIS processing tool-box allows extracting population coverage data for any area in which a shapefile is available (county, state, zip code and more available from https://www.census.gov/cgi-bin/geo/shapefiles/index.php)
  - All maps previously shown here were created with TVStudy and QGIS
  - QGIS was used to calculate areas of ATSC 3.0 interference with adjusted D/U ratios for different ATSC 3.0 CNR thresholds
- **Tips on installing TVStudy**
  - https://www.fcc.gov/oet/tvstudy
  - FCC TVStudy can be installed on Linux and MacOS with little difficulty
  - MySQL 5.7 is required – if not available from Linux distribution use the Oracle Generic Binary
  - Successfully installed on Ubuntu variants, Arch Linux, and Fedora
  - A Windows version is available from V-Soft: https://www.v-soft.com/fcc-tvstudy

A More Accurate Terrain Sensitive Model

- **ITU-R P.1812(-7)**
  - P.1812 predicts signal levels exceeded for a given percentage (≥ 1% and ≤50%) of an average year at given percentage (≥ 50% and ≤99%) of locations for calculating coverage and interference
  - P.1812 inputs include street width and can use clutter height based on clutter height categories
  - Building loss can be included (per ITU-R P.2040)
  - An online tool is available to registered TIES users: https://www.itu.int/ITU-R/eTerrestrial/eBroadcasting
  - No open-source software or open on-line P.1812 tools were found
  - The model is widely available in commercial propagation software
  - The ITU-R P1812-7 recommendation is available at: https://www.itu.int/dms_pubrec/itu-r/rec/p/R-REC-P.1812-7-202308-I!!PDF-E.pdf

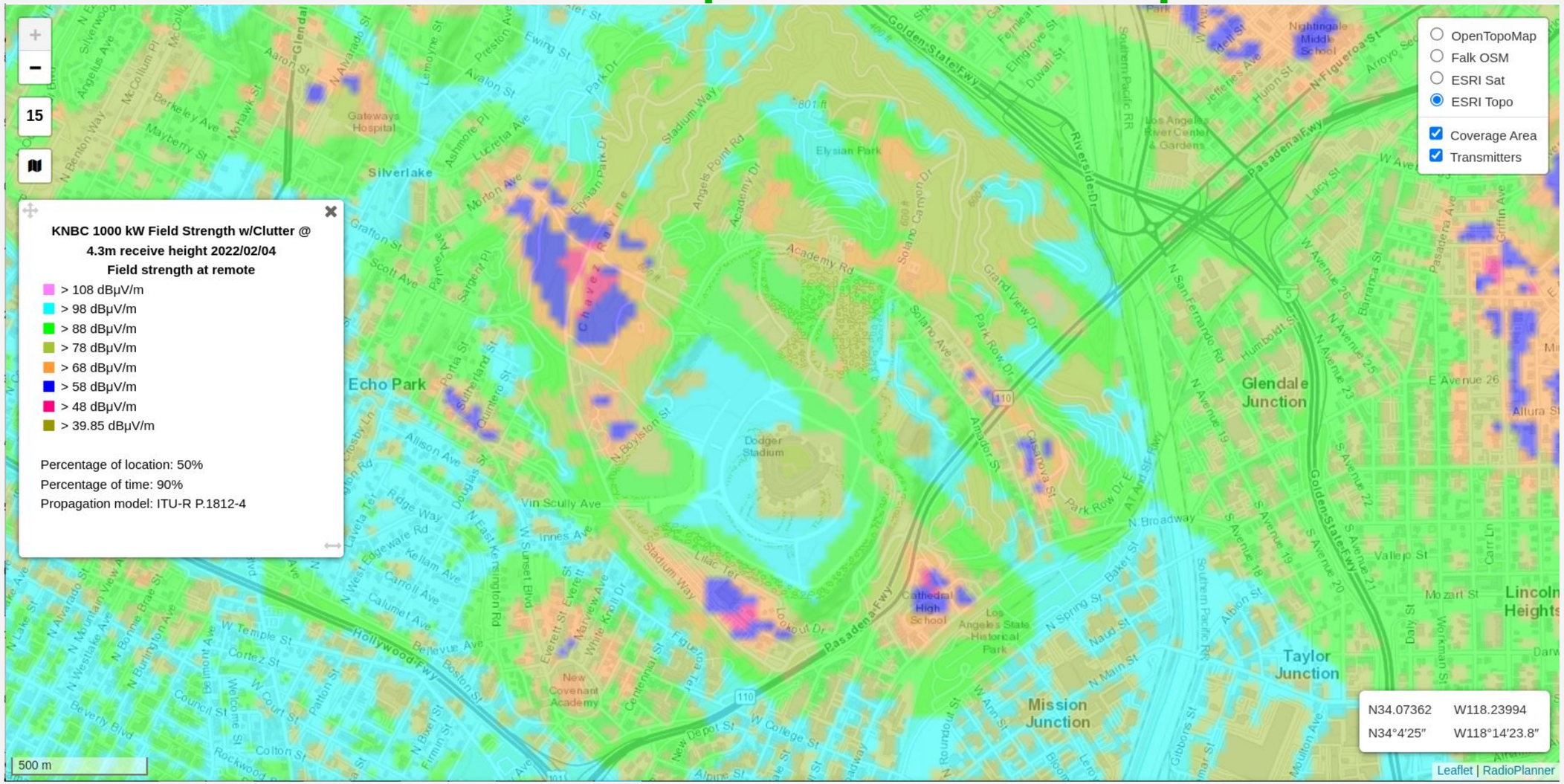


ITU-R P.1812 with RadioPlanner

- **RadioPlanner 3.0 – Commercial RF planning tool from CTT**
  - Longley-Rice, ITU-R P.1546, P.1812, Okumura-Hata, 3GPP-TR 38.901 models included
  - Uses 30m terrain data and land cover data from OpenStreetMap
  - Option to use alternative terrain and clutter data
  - EDX PAT antenna pattern files can be used for studies with transmit antennas employing variable electrical and mechanical tilt
  - Detailed point-to-point plots available
  - Drive test data can be used to tune models for more accurate coverage prediction
  - Output data as tiled interactive html map or as KMZ, PNG, GeoTiff, CSV or MIF files
  - Multiple transmitter studies are supported
  - Does NOT provide interference studies
  - https://www.wireless-planning.com/radioplanner

What does a RadioPlanner 2.1 P.1812 coverage map look like?

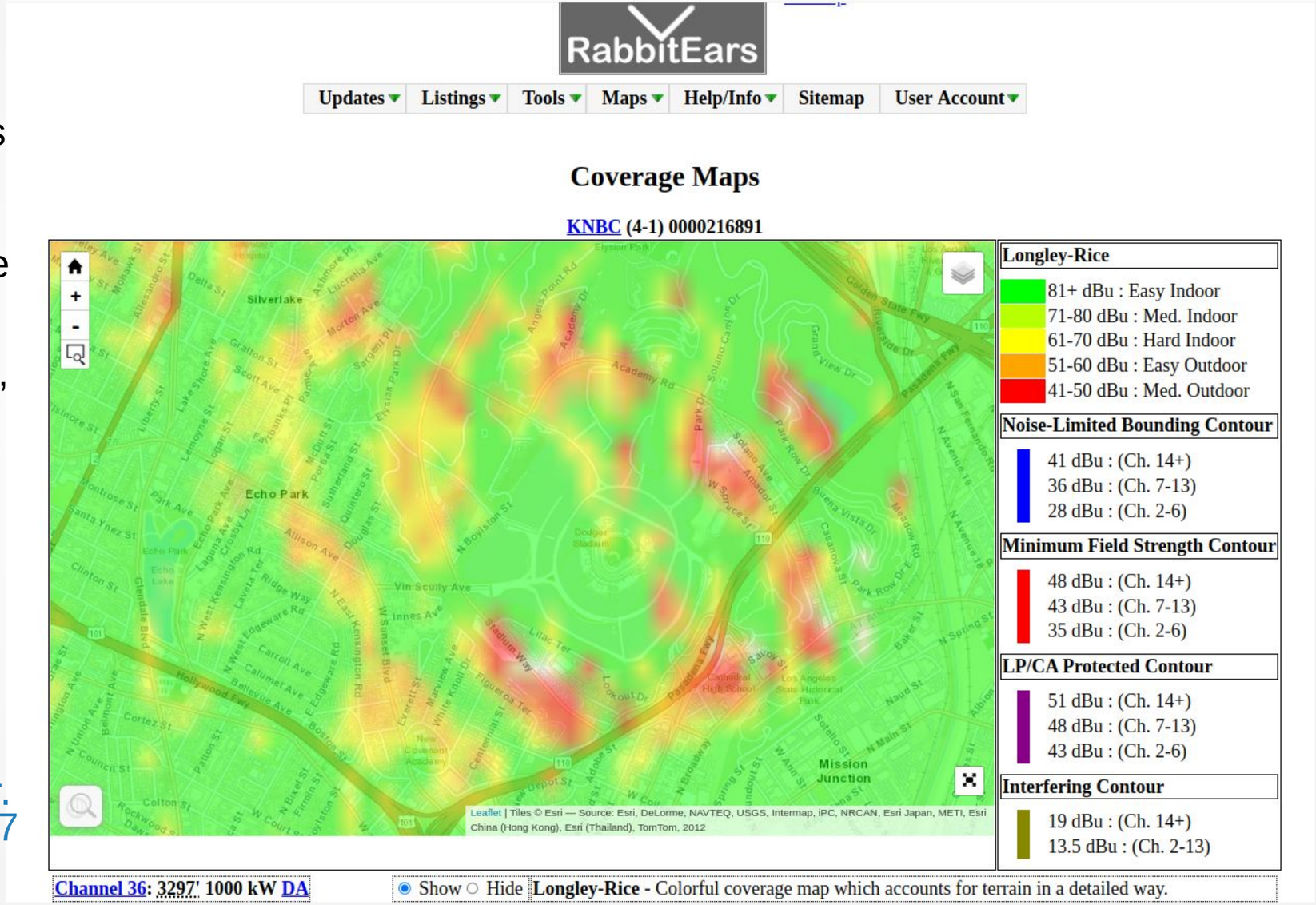
KNBC P.1812-4 map from Radioplanner 2.1



Map shows coverage within a city block! https://coverage.xmtr.com/KNBC/

Longley-Rice Map from Rabbitears.info

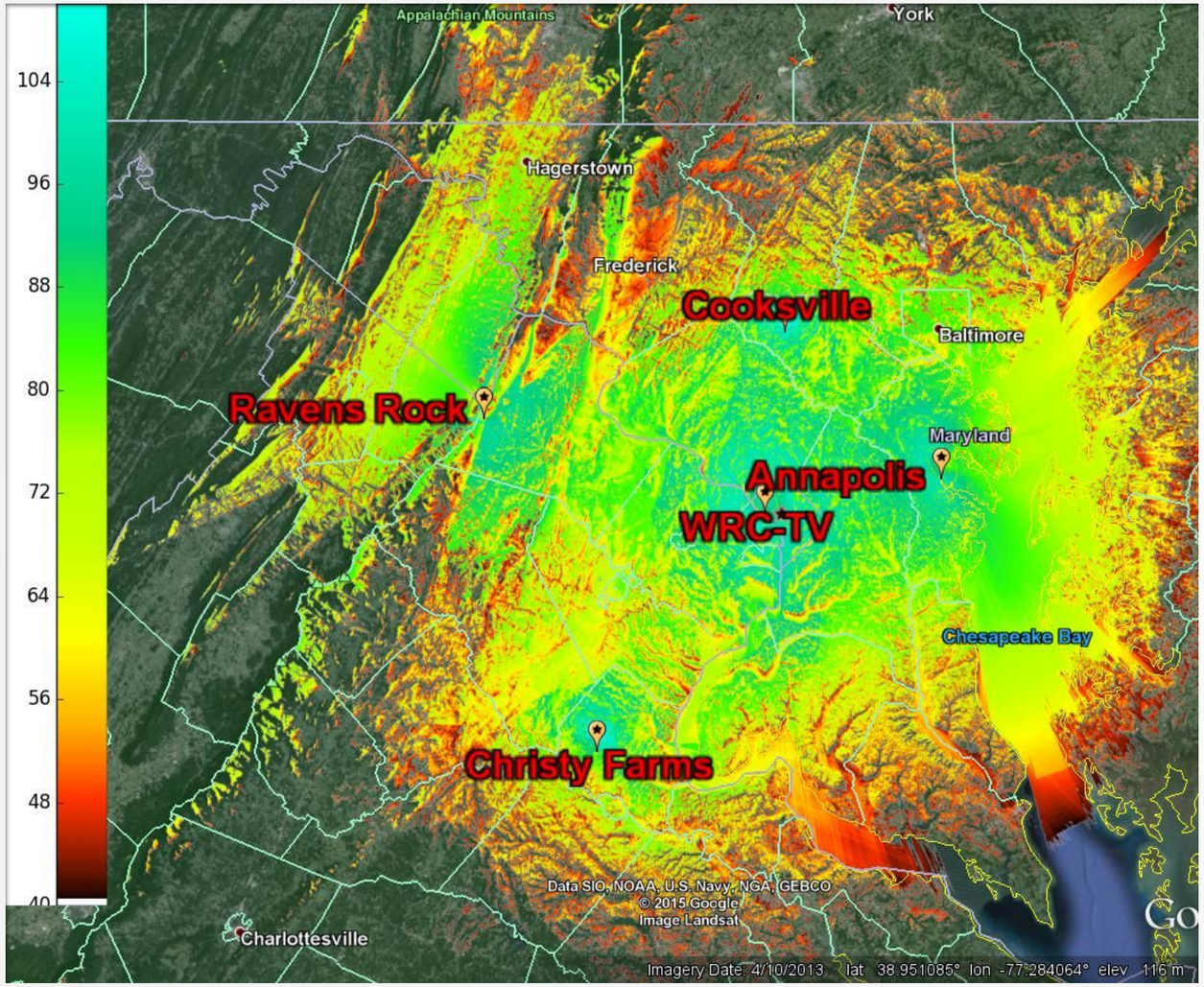
- **https://www.rabbitears.info/**
  - Longley-Rice and FCC contour maps available for all TV stations in FCC LMS
  - Different map overlays available
  - Multiple stations' contours can be shown on one map
- To use:
  - Enter call sign in "Market listings"
  - Click search
  - Click "Technical Data"
  - Click "Rabbitears TV Query"
  - Click "FCC Service Contour" or "Longley-Rice Coverage Map" under technical data for the desired facility
- URL for map shown: https://www.rabbitears.info/contour.php?appid=25076ff3872a41c001874d01d1ea11ea&site=1&map=Y

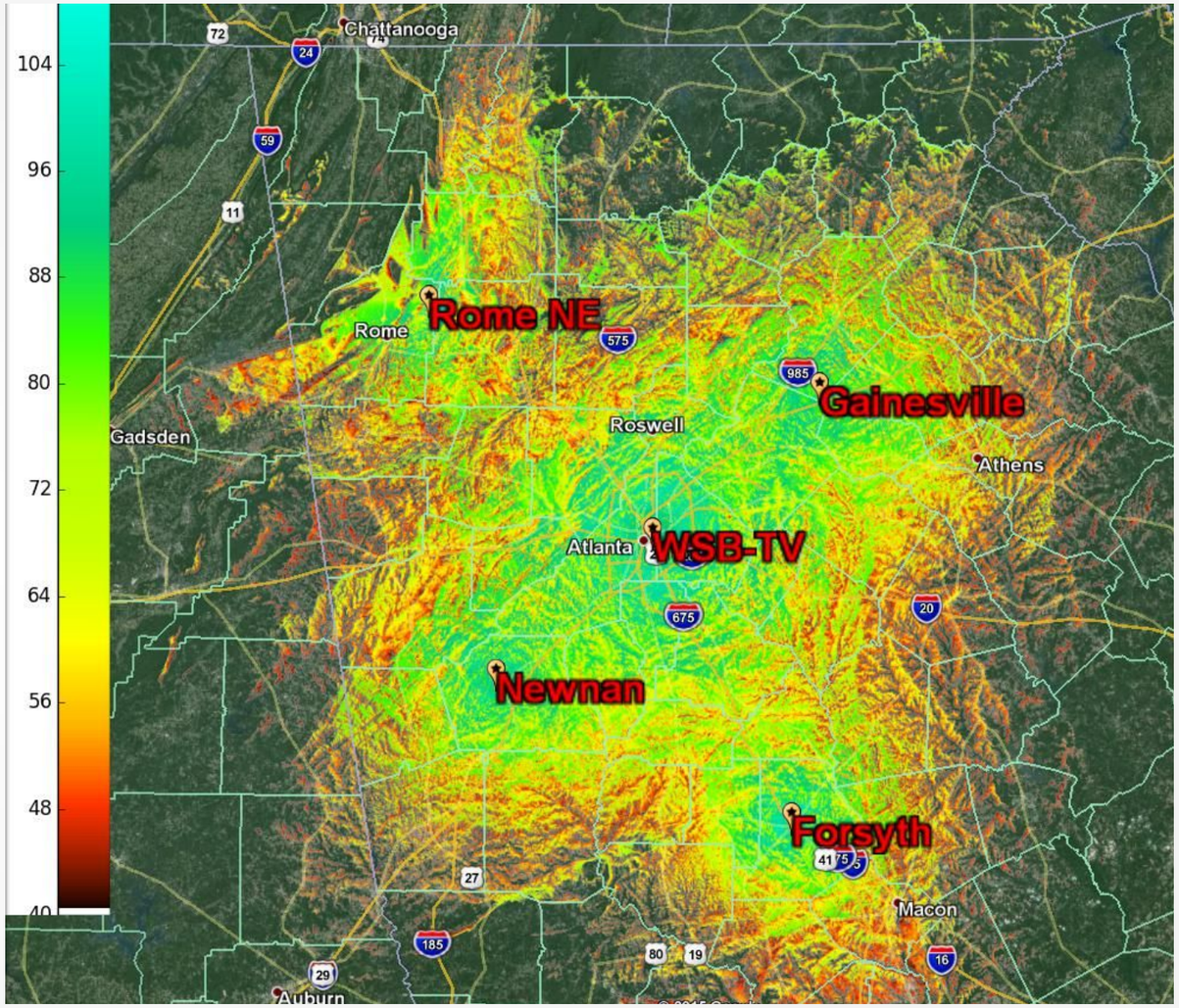


Use SPLAT! For Complex Analysis

- **SPLAT! A free Longley-Rice and ITWOM command line program**
  - SPLAT! Is available at https://www.qsl.net/kd2bd/splat.html and binaries are available in most Linux distributions
  - Compiling from source allows creation of programs with different study sizes and resolutions
  - Output is available as a text file, image file or kml file that can be plotted on Google Earth
  - Different terrain databases can be used for studies after conversion with gdal
    - ASTER terrain data includes large buildings and forest canopy
    - SRTM data is available for most of the world
  - Antenna elevation and azimuth patterns with mechanical beam tilt are supported
- Post processing is required for more detailed studies
  - Python programs are available to convert the text file output to a Numpy array for detailed population, coverage and interference studies
  - Interference studies require post-processing

SPLAT! map for DC & Atlanta SFN studies

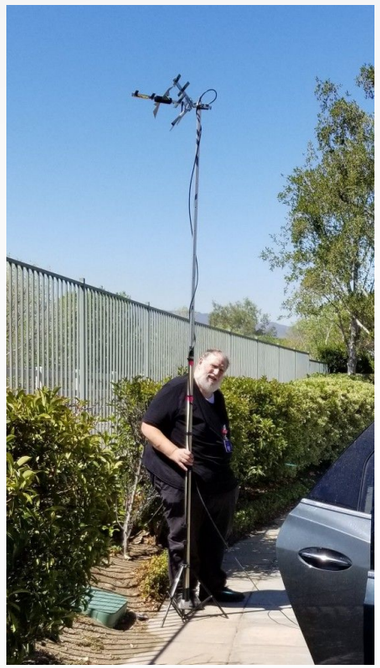




Predicting ATSC 3.0 Broadcast Coverage, IEEE Transactions on Broadcasting, James A Kutzner & Doug Lung
https://ieeexplore.ieee.org/document/7395332

Confirming Coverage with Measurements

- **FCC Measurements**
  - 30 foot mast
  - Horizontal run or grid
  - Precise readings but time consuming



- **Antenna and pole**
  - Closer match to viewer's antennas
  - Quick measurements with software capture

- **Multiple antennas on a vehicle**
  - Very quick measurements with custom software (4x USB tuners and 4x R&S ETL)
  - Used to collect data on 12 stations at 194 locations on four antennas (9,312 meas.)

References

Planning Factors & Signal Studies

FCC Office of Engineering and Technology Bulletin 69: Longley-Rice Methodology for Evaluating TV Coverage and Interference, February 6, 2004
https://transition.fcc.gov/bureaus/oet/info/documents/bulletins/oet69/oet69.pdf

MTVA DTV Reception Planning Factors Report, William Meintel; Gary Sgrignoli; Dennis Wallace
Meintel, Sgrignoli, & Wallace, LLC, 05/08/07
https://mswdtv.com/wp-content/uploads/2017/07/MTVA_DTV_Planning_Factors_Report_050807_Final.pdf

Evaluation of ATSC 3.0 and 3GPP Rel-17 5G Broadcasting Systems for Mobile Handheld Applications, Seok-Ki Ahn; Sungjun Ahn; Jeongchang Kim; Hyeongseok Kim; Sunhyoung Kwon; Sungho Jeon; Mats Ek; Sesh Simha; Anindya Saha; Prashant M. Maru; Parag Naik; Mark Aitken; Pablo Angueira; Yiyan Wu; Sung-Ik Park
IEEE Transactions on Broadcasting (Volume: 69, Issue: 2, June 2023)
https://ieeexplore.ieee.org/document/9962759

5G Media2Go - Audiovisual Services for In-Car Infotainment Systems, SWR, Stuttgard, 30.03.2023
https://www.5g-mag.com/post/5g-media2go-audiovisual-service-for-autonomously-driving-cars

5G Broadcast Network Planning and Evaluation TR 063, EBU S-SPT, Geneva, August 2021
https://tech.ebu.ch/docs/techreports/tr063.pdf

References (2)

Planning Factors & Signal Studies (continued)

Testes de laboratório da Camada Física da TV 3.0, Ricardo Seriacopi Rabaça, Revista da SET nº 213, Jan/Fev 2024
https://set.org.br/wp-content/uploads/2024/02/REVISTASET_213_ARTIGO-TV-3.0.pdf

DTV in the House, Part 1, Doug Lung, TV Technology, September 4, 2007
https://www.tvtechnology.com/opinions/dtv-in-the-house-part-1

Coverage & Propagation Models

Report No. R-6602, Development of VHF and UHF Propagation Curves for TV and FM Broadcasting, Federal Communications Commission, Office of Chief Engineer, Research Division, September 7, 1966
https://docs.fcc.gov/public/attachments/DOC-310600A1.pdf

Irregular Terrain Model (ITM) (Longley-Rice) (20 MHz – 20 GHz), Institute for Telecommunication Sciences, National Telecommunications and Information Administration
https://its.ntia.gov/research-topics/radio-propagation-software/itm/itm

Recommendation ITU-R P.1812-7: A path-specific propagation prediction method for point-to-area terrestrial services in the frequency range 30 MHz to 6 GHz, International Telecommunications Union, (08/2023)
https://www.itu.int/dms_pubrec/itu-r/rec/p/R-REC-P.1812-7-202308-I!!PDF-E.pdf

References (3)

Coverage & Propagation Models (continued)

Recommendation ITU-R P.1546-6: Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 4 000 MHz, International Telecommunications Union, (08/2019
https://www.itu.int/dms_pubrec/itu-r/rec/p/R-REC-P.1546-6-201908-I!!PDF-E.pdf

Deterministic Equations for Computer Approximation of ITU-R P.1546-2, Sid Shumate, International Symposium on Advanced Radio Technologies, ClimDiff 2008, and The Working Party Meetings for ITU-R WP 3J, 3K, 3L and 3M hosted by National Institute of Standards and Technology, At Hotel Boulderado, Boulder, Colorado, June 2 - 4, 2008 [Detailed explanation of ITWOM]
https://its.ntia.gov/media/33502/shu_s-08.pdf

Recommendation ITU-R P.526-15: Propagation by diffraction, International Telecommunications Union, (10/2019)
https://www.itu.int/dms_pubrec/itu-r/rec/p/R-REC-P.526-15-201910-I!!PDF-E.pdf

Wireless Communication EEE: 464, Taimur Shahzad [Okumura-Hata background including formulas with an example]
https://mycomsats.files.wordpress.com/2011/03/lecture-10-okumura-and-hata-models.pdf

TIREM/SEM Handbook, David Eppink; Wolf Kuebler, Department of Defense Electromagnetic Compatibility Analysis Center, Annapolis, MD, March 1994
https://apps.dtic.mil/sti/pdfs/ADA296913.pdf

References (4)

Comparison of Propagation Models & Software

Report ITU-R BT.2137: Coverage prediction methods and planning software for digital terrestrial television broadcasting (DTTB) networks, International Telecommunications Union, (2008)
https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-BT.2137-2009-PDF-E.pdf

Propagation Models Comparison by Propagation Features, Alberto Leonardo Penteado Botelho, SET International Journal of Broadcast Engineering, V5, 2019
https://www.set.org.br/ijbe/ed5/artigo8.pdf

Analysis of ITU-R VHF/UHF propagation prediction methods performance on irregular terrains covered by forest,
Felipe Macedo da Costa, Luis Alberto Rabanal Ramirez, Maurício Henrique Costa Dias, The Institute of Engineering and Technology, 22 March 2018
https://doi.org/10.1049/iet-map.2017.0992

Free On-line Coverage Prediction Tools

Rabbitears https://www.rabbitears.info/market.php
Enter call sign, in result select “Technical data” then select “Rabbitears TV Query” and then select link for “Longley-Rice Coverage Map” in links below the data for desired FCC authorization

References (5)

Free Online Coverage Prediction Tools (continued)

FCC DTV Reception Maps https://www.fcc.gov/media/engineering/dtvmaps
Enter location – once the map displays the pin can be moved. Click on callsign for signal strength and other details for the station. Note that field strength calculations are based on FCC antenna patterns and may not be accurate for stations with mechanical beam tilt, as shown in the presentation.

FCC FM and TV Propagation Curves https://www.fcc.gov/media/radio/fm-and-tv-propagation-curves
Calculate distance to contour or field strength at a distance given transmitting antenna height above average terrain and effective radiated power (ERP) using FCC propagation curves.

Radio Mobile Online https://www.ve2dbe.com/rmonline_s.asp
Online version of the Radio Mobile Longley-Rice coverage program. Free registration required.

Okumura-Hata curve calculation tool https://www.cdt21.com/technical_tools/okumura-hata-curve/
From Circuit Design, Inc. Inputs limited to transmitter and receive heights, frequency, and distance.

W5GFE Signal Server WebSite https://signalserver.okiefrog.org/
Online version of SPLAT! Fork Signal-Server from https://github.com/lmux/Signal-Server
Longley-Rice and line-of-sight plots for transmitters with non-directional antennas.

References (6)

Free Online Coverage Prediction Tools (continued)

Commscope Egli Path Loss Calculator https://calc.commscope.com/qegli.aspx

Free Propagation and Coverage Software

FCC TVStudy Interference Analysis Software https://www.fcc.gov/oet/tvstudy

Complete open-source software package for calculating coverage using FCC curves and the Longley-Rice model. It downloads current technical data for all U.S. TV stations and many Canadian and Mexican border stations and includes USGS databases for terrain and land use. Available from the FCC for Linux and Mac OS.

SPLAT! RF Signal Propagation, Loss, And Terrain analysis tool https://www.qsl.net/kd2bd/splat.html

John Magliacane's software includes Longley-Rice 1.22 and ITWOM 3.0 models. Digital elevation models must be downloaded separately. SPLAT is available in many Linux distributions or can be built from the source code.

Signal-Server https://github.com/lmux/Signal-Server

Forked from SPLAT! In addition to Longley-Rice and ITWOM this software includes several other models, including Hata, Egli, and COST. It can use 2 meter resolution LIDAR digital elevation data in addition to SRTM data.

Radio Mobile https://www.ve2dbe.com/english1.html

Full featured Windows based Longley-Rice coverage software supporting use of different elevation models, including 1/3 arc-second data. Land-use/cover data can be added to improve predictions.

References (7)

ATSC 3.0 and 5G Broadcast Calculators

Bitstem 5G Broadcast Bandwidth Calculator [Online] https://bitstem.com/mbms-bandwidth
Select channel bandwidth to display approximate net payload bandwidth for different MCS (Modulation Coding Scheme)

ETRI ATSC 3.0 PHY Simulator [Online] https://atsc.agos.co.kr/
A very detailed simulator that requires input of all ATSC 3.0 signal parameter or selection of an ATSC VV parameter set. It will calculate CNR under different conditions (AWGN and Rayleigh RC20/RL20 for simulation, lab and field environments. It supports calculation of multiple PLPs using FDM, TDM or LDM. Data is saved online or can be exported and imported from a csv file.

Enensys ATSC 3.0 Calculator https://www.enensys.com/technologies/atsc3-0-calculator/
Available by email request. The program runs in Excel spreadsheet folders and allows calculation of bandwidth, required CNR and estimated coverage distance by PLP using the HATA model.

NextGen TV Capacity Calculator https://apps.apple.com/us/app/nextgen-tv-capacity-calculator/id1364534247?ls=1
App from One Media for calculating ATSC 3.0 data capacity and CNR after entering some basic parameters for the PLP. Simple to use for quick studies. Currently available as an iPhone app only. (Android version no longer available)

References (8)

Commercial Coverage Prediction Software

FCC TVStudy – Windows version by V-Soft https://www.v-soft.com/fcc-tvstudy
Windows build of the FCC TVStudy source code including MySQL and Java. A companion mapping program is available.

V-Soft Radio Frequency Engineering, Propagation Analysis PC Software https://www.v-soft.com/
V-Soft Probe 5 software use the Longley-Rice model (ITU-R P.1546 optional) for broadcast coverage and OET-69 interference studies. An ATSC 3.0 CNR calculation tool is included.

Progira Plan https://www.progira.com/spectrum-planning-software/
Predicts field strength and required CNR for ATSC 1.0, ATSC 3.0, FeMBMS/5G Broadcast systems. Map plotting uses Esri ARC-GIS. Supported propagation models include: CRC Predict, IRT 2D/3D, ITU-R P.1812, ITU-R P.1546, ITU-R P.526, ITU-R P.368, Deygout-Assis, Longley-Rice, Anatel 1546, Okumara-HATA, COST-231, ITU-R P.526, and Free Space.

RadioPlanner 3.0 https://www.wireless-planning.com/radioplanner
Planning tool for broadcast TV and FM as well as 5G (NR) that includes the ITU-R P.1812-6 model. See detailed description and example in the presentation slides.

Radiosoft Comstudy https://www.radiosoft.com/products/radio-engineering/comstudy/
Coverage and OET-69 interference calculations for broadcast TV. Options are available for AM and FM studies. Access to updated FCC, ITU and other transmitter databases is available.

References (9)

Commercial Coverage Prediction Software

ATDI HTZ Communications https://atdi.com/products-and-solutions/htz-communications/
Comprehensive coverage analysis for all broadcast standards and 5G-NR. Over 50 empirical, deterministic and hybrid propagation models, including all ITU-R models, Okumura-Hata, Cost-Hata, Irregular Terrain Model-Longley Rice, ITU and 3GPP models are available.

Cloud RF *https://cloudrf.com/*
Cloud based studies with terrain databases down to 2 meter resolution. Supported propagation models include Longley-Rice, Okimura-HATA, COST-231, and Egli. Their “SLEIPNIR” model was designed to work with high resolution LIDAR surface models and 3-D clutter. Cloud RF claims it is 10 times faster than open source engines for some scenarios.

EDX Signal Pro https://edx.com/signal-pro/
Comprehensive coverage software. Signal Pro supports a wide range of propagation models: https://edx.com/fun-with-propagation-models/

References (10)

Additional articles and tools

Evaluation of ATSC 3.0 and 3GPP Rel-17 5G Broadcasting Systems for Mobile Handheld Applications, Seok-Ki Ahn; Sungjun Ahn; Jeongchang Kim; Hyeongseok Kim; Sunhyoung Kwon; Sungho Jeon; Mats Ek; Sesh Simha; Anindya Saha; Prashant M. Maru; Parag Naik; Mark Aitken; Pablo Angueira; Yiyan Wu; Sung-Ik Park, IEEE Transactions on Broadcasting (Volume: 69, Issue: 2, June 2023) https://ieeexplore.ieee.org/document/9962759

Predicting ATSC 3.0 Broadcast Coverage, James A Kutzner, Doug Lung, IEEE Transactions on Broadcasting (Volume: 62, Issue: 1, March 2016) https://ieeexplore.ieee.org/document/7395332

Coverage Analysis with Open Source Tools, Doug Lung, IEEE Broadcast Technology in *RF News and Views* (2015-now)
https://bts.ieee.org/publications/ieee-broadcast-technology.html
Additional links to download examples, and source code for use with TVStudy and QGIS
https://www.transmitter.com/bts/BTS2016-Coverage-Analysis-Part-5.html
https://www.transmitter.com/bts/BTS2016-Coverage-Analysis-Part-6.html
https://www.transmitter.com/bts/BTS2016-Coverage-Analysis-Part-7.html
https://www.transmitter.com/bts/Programs/

QGIS https://qgis.org/en/site/
“A Free and Open Source Geographic Information System” Create, edit, visualise, analyse and publish geospatial information on Windows, macOS, Linux, BSD and mobile devices. Ideally suited for use with TVStudy output data.

Questions?

Contact: Doug Lung
Email: dlung@transmitter.com

Presentation available at:
https://transmitter.com/tc2024/

Bonus Slides

Selecting a Propagation Model

- **Required FCC Filing:**
  - FCC curves (chart or TVStudy)
  - Longley-Rice (TVStudy)
- **Available for free:**
  - FCC curves (chart or TVStudy)
  - Longley-Rice (TVStudy, SPLAT!, Radio Mobile
  - ITWOM (SPLAT!)
  - Okumura-Hata (source code available)
  - ITU P.1546-6 (Matlab code)
- **Available On-Line Maps and Calculators:**
  - FCC curves (FCC.gov, Rabbitears.info)
  - Longley-Rice (Radio Mobile. FCC, Rabbitears.info)
  - Okumura-Hata

- **Calculation of field strength at a specific location or group of locations in an area:**
  - Longley-Rice (free and commercial programs)
  - ITU P.1812 (commercial programs)
  - TIREM (commercial programs)
  - ITWOM (free and commercial programs)
- **Area coverage models based on empirical data**
  - FCC Curves
  - ITU P.1546
- **Diffraction based models (point to point)**
  - ITU P.526

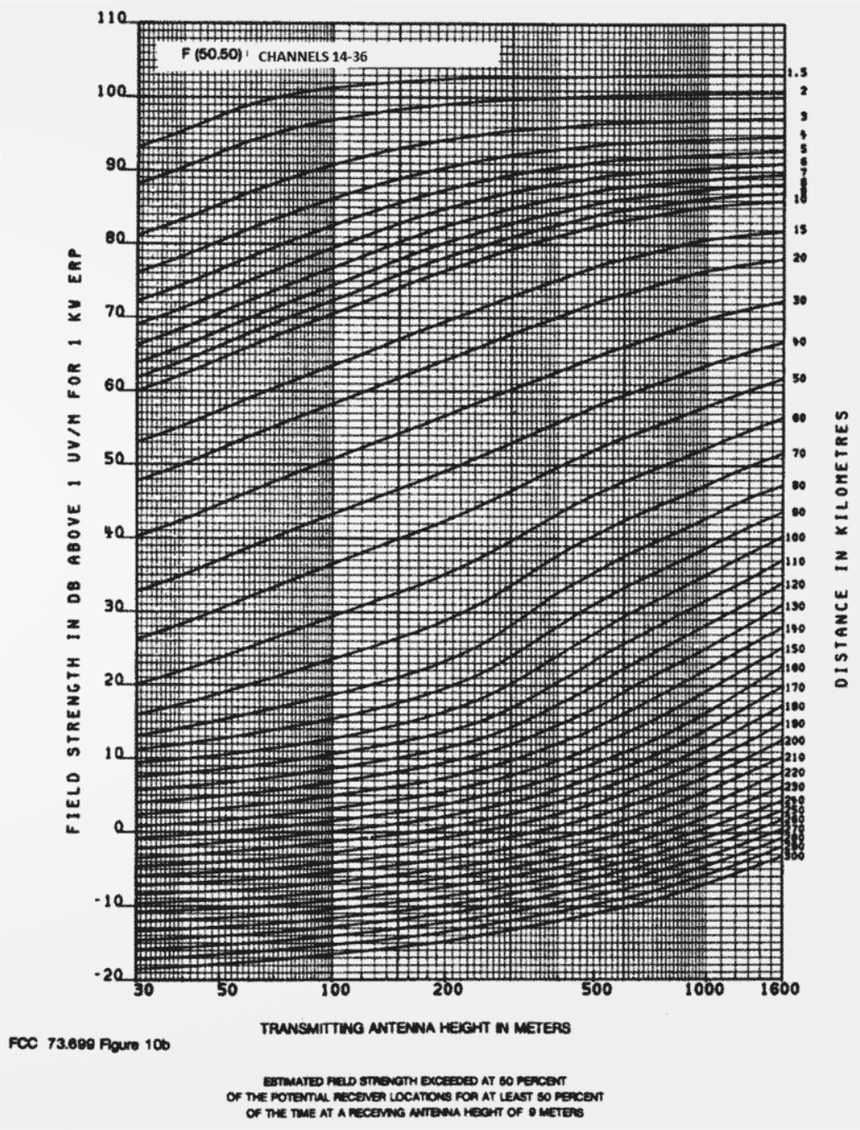
What are the features of these models?

FCC Curves Contour Calculation

- **FCC curves are based on analog TV and FM radio field measurements updated in FCC Report R-6602 dated September 7, 1966**
  - Refer to the report for details on the measurements and how the curves were created:
  - **https://docs.fcc.gov/public/attachments/DOC-310600A1.pdf**

- **Steps for calculating the distance to contour using the curves are defined in FCC Rules Section 73.619(b)**
  - **https://www.ecfr.gov/current/title-47/section-73.619**

- **FCC Distance to Contour Calculator:**
  - **https://www.fcc.gov/media/radio/fm-and-tv-propagation-curves**
  - Transmit ERP and antenna height above average terrain are required inputs along with field strength or distance



Terrain Sensitive Point to Point Models

- **Longley-Rice (ITM)**
  - The only software model accepted by the FCC for broadcast TV coverage and interference studies
  - Freely available source code has made this the most widely available terrain sensitive coverage model
  - Accuracy depends on the resolution and accuracy of data provided
  - Field strength predictions over paths with diffraction over steep obstructions are often inaccurate
  - Combine with land-use data to improve accuracy
  - Detailed description and link to code available at: https://its.ntia.gov/research-topics/radio-propagation-software/itm/itm

Irregular Terrain Model (ITM) (Longley-Rice) (20 MHz – 20 GHz)

Abstract: The ITS model of radio propagation for frequencies between 20 MHz and 20 GHz (the Longley-Rice model) (named for Anita Longley & Phil Rice, 1968) is a general purpose model that can be applied to a large variety of engineering problems. The model, which is based on electromagnetic theory and on statistical analyses of both terrain features and radio measurements, predicts the median attenuation of a radio signal as a function of distance and the variability of the signal in time and in space.

Terrain Sensitive Point to Point Models

- **TIREM**
  - “Terrain Integrated Rough Earth Model” is licensed by Alion Science and Technology Corporation
  - TIREM generally predicts results closer to measured values and is used by the U.S. Department of Defense
  - TIREM is proprietary closed source but available in some commercial software – export and other restrictions may apply to some versions
- **ITWOM**
  - “Irregular Terrain With Obstructions Model” developed by Sid Shumate at Givens & Bell
  - Requires accurate clutter height data for best performance
  - Provides more accurate coverage in the presence of obstructions
  - Available with open source SPLAT! software but without ability to incorporate land cover data
- **ITU-R P.526**
  - Propagation by diffraction for different obstacle types
  - Provides results in dB relative to free space propagation
  - Limited use for wide area broadcast coverage studies

Other Propagation Models

- **ITU-R P.1546**
  - Widely used method for point-to-area predictions for terrestrial services
  - Empirical model with propagation curves based on measurements in mainly temperate climates
  - Maximum time variability percentage is 50%
  - Available in commercial software
  - Matlab code available at: https://github.com/eeveetza/p1546
  - The ITU-R P.1546-6 Recommendation is available at: https://www.itu.int/dms_pubrec/itu-r/rec/p/R-REC-P.1546-6-201908-I!!PDF-E.pdf
- **Okumura-Hata**
  - Provides path loss based on height above average terrain
  - Specific obstacles not considered – used primarily for point to area studies
  - On-line calculator: https://www.cdt21.com/technical_tools/okumura-hata-curve/
  - GNU C program: https://www.nsnam.org/docs/release/3.17/doxygen/okumura-hata-propagation-loss-model_8cc.html