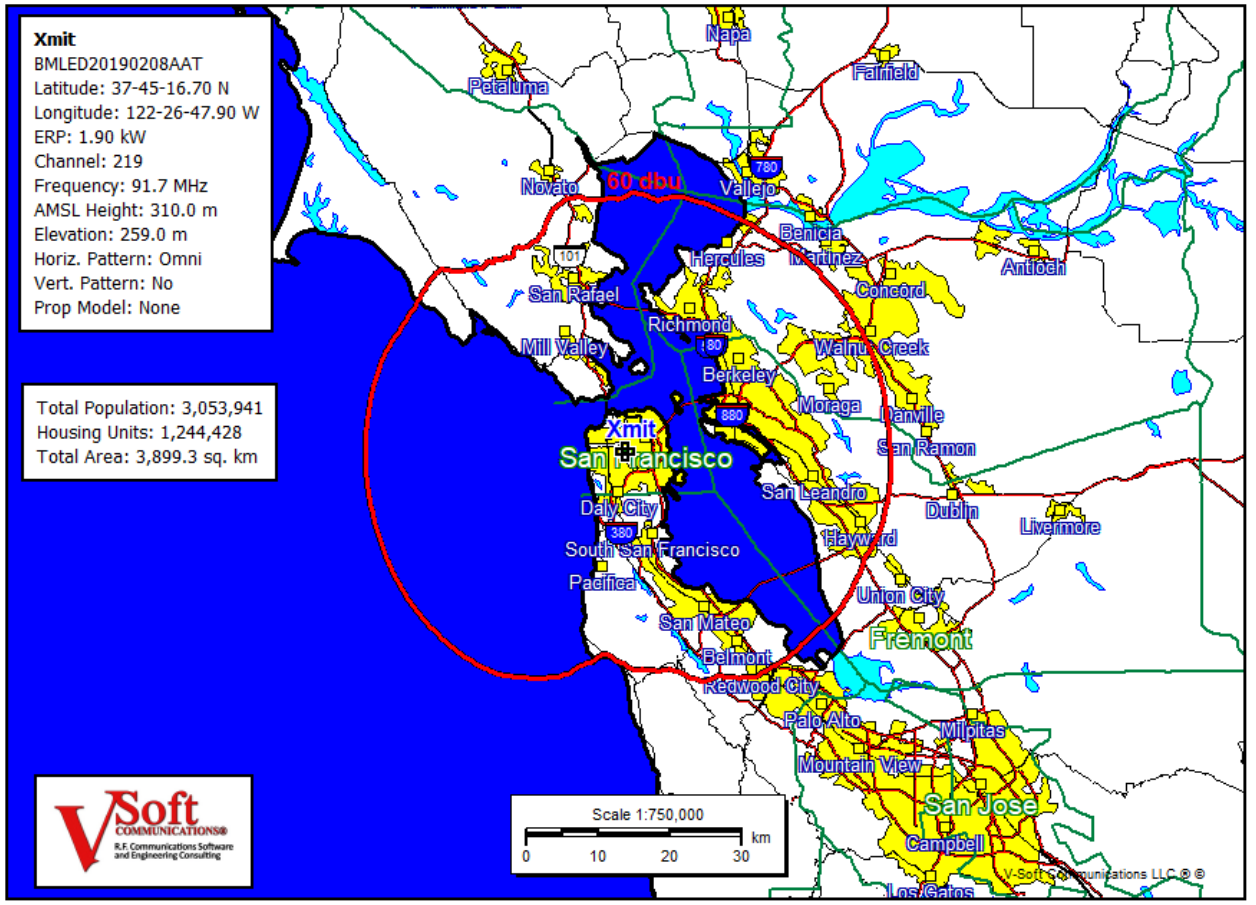
Visualizing Radio Propagation through Prediction

Doug Vernier

Broadcaster's Clinic

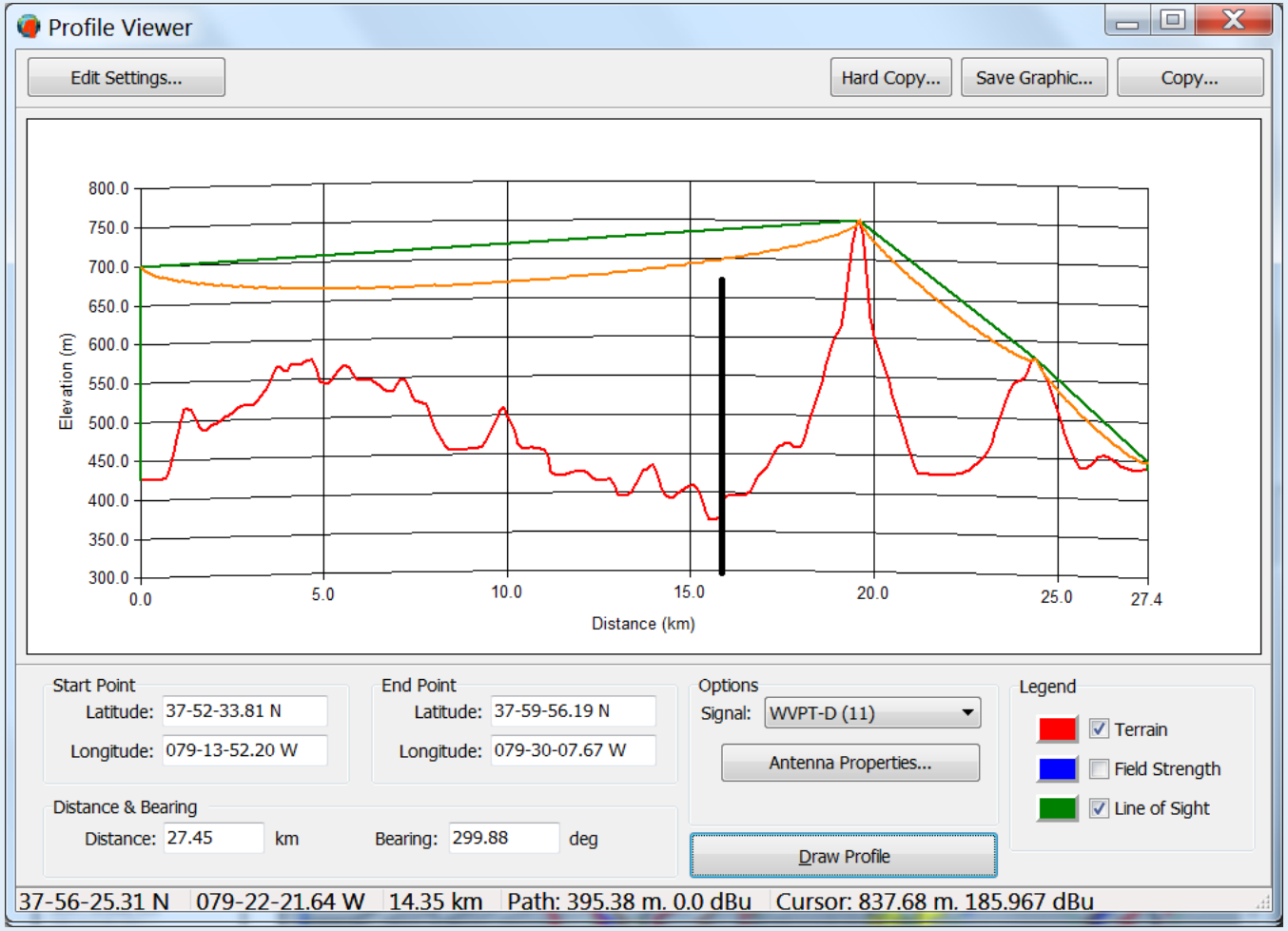
2022

Standard FCC

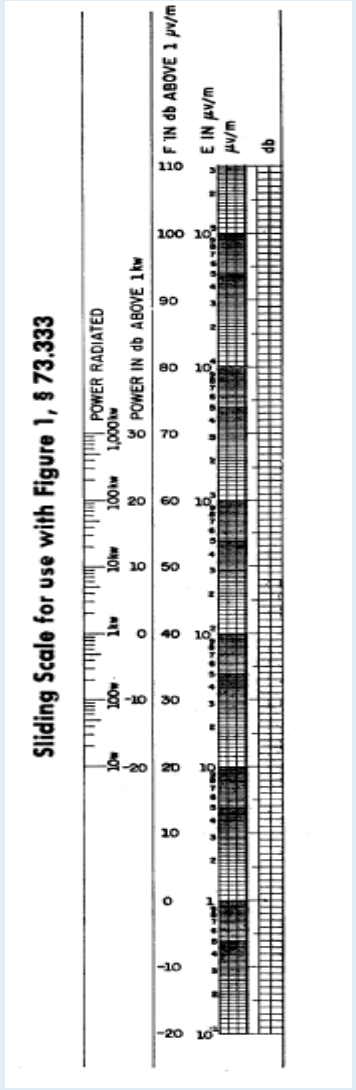


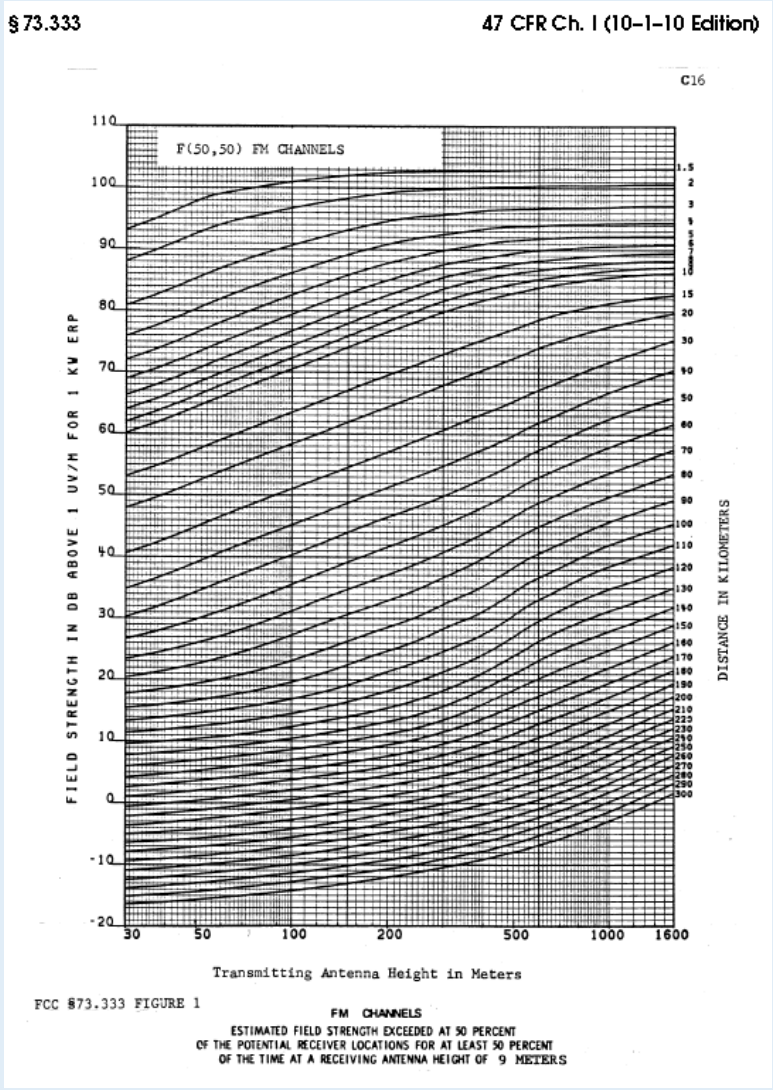
HAAT FM - radial 3 to 16 km

Minimum of 51 elevation points along a radial

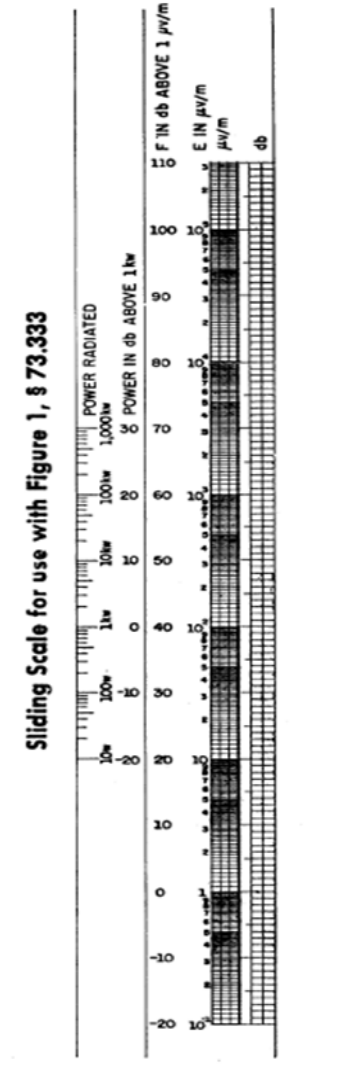


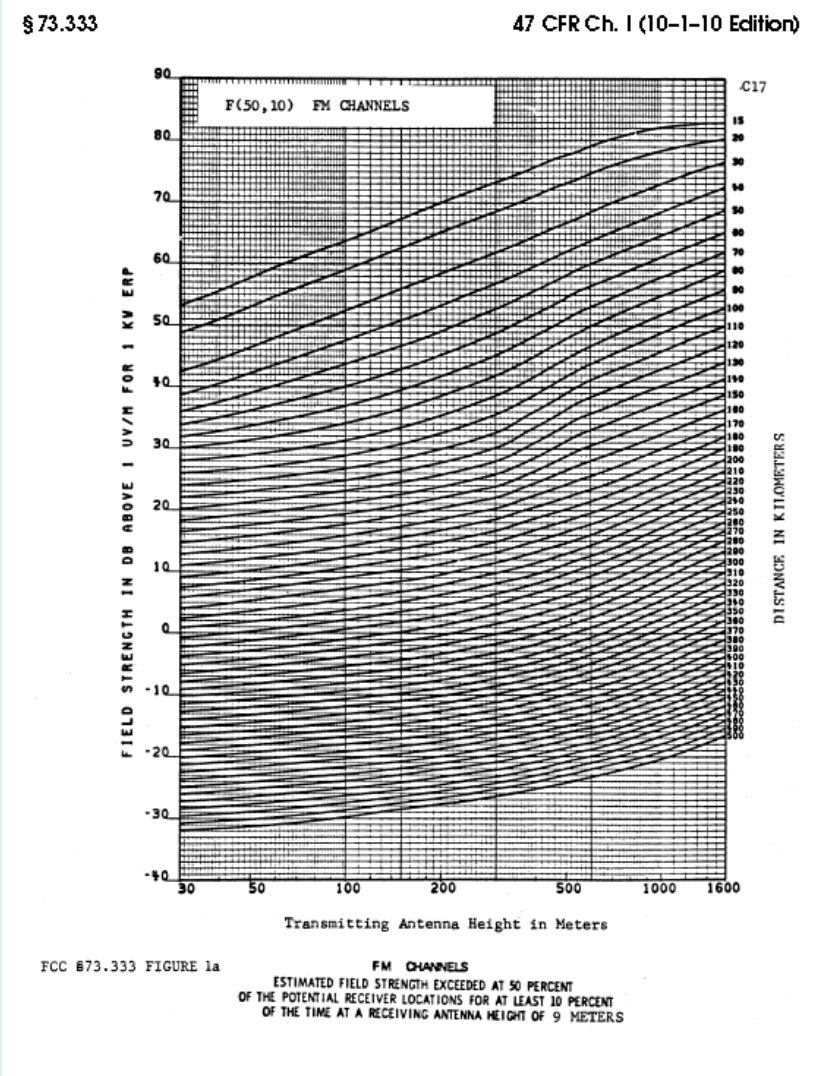
FCC Coverage CURVES F(50-50)





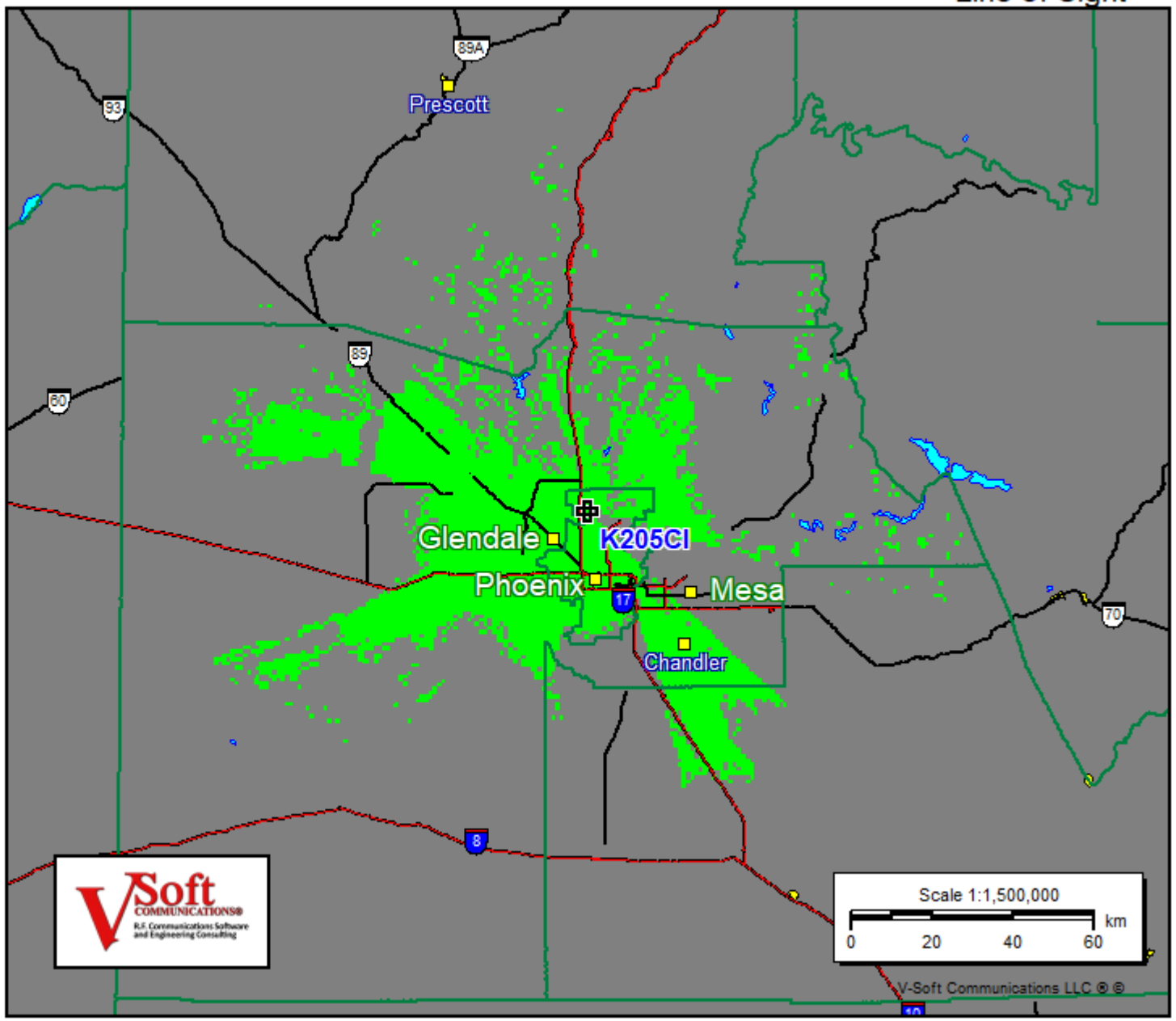
Interference Curves F(50-10)





Line of Sight

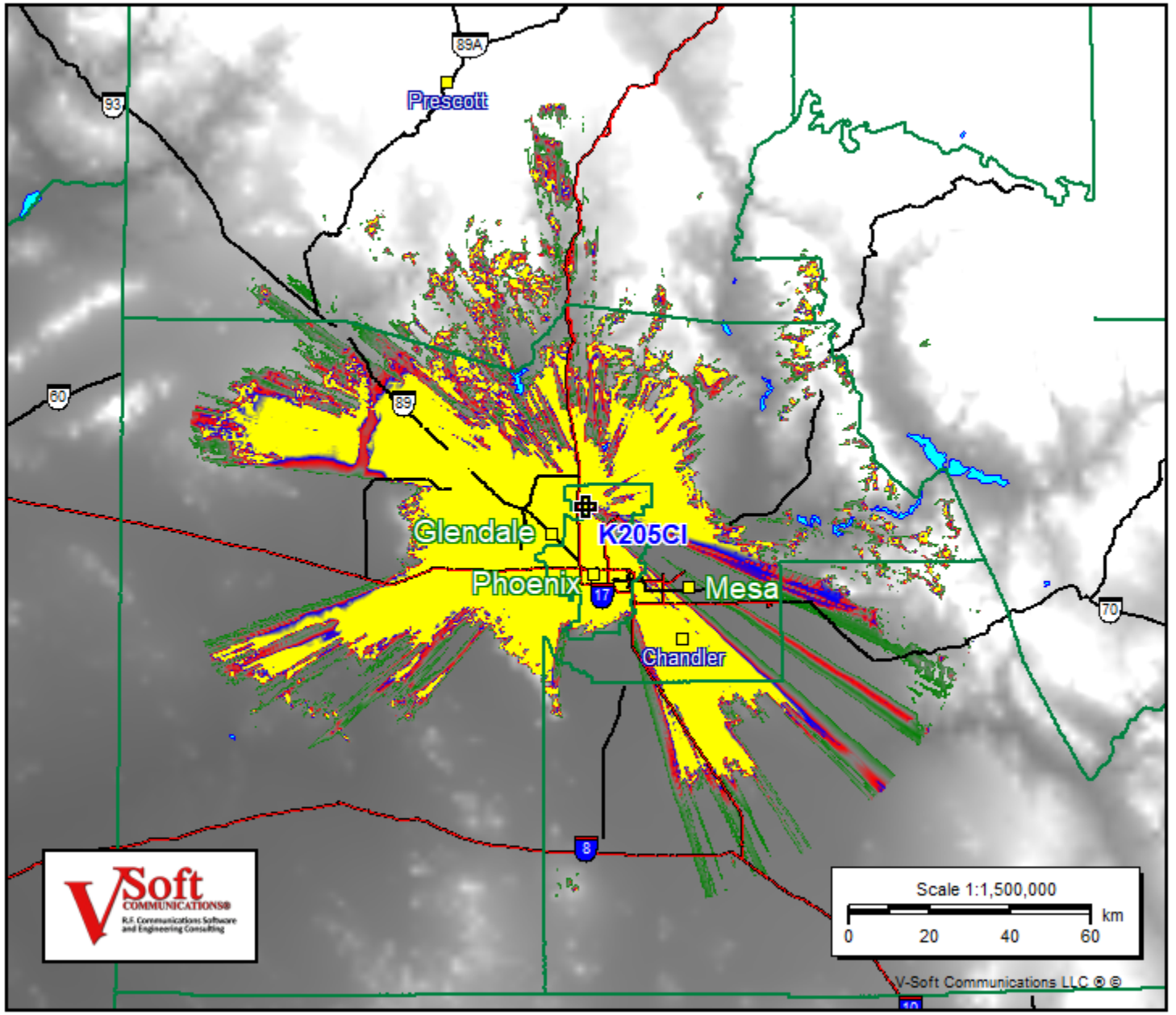
K205CI
BLFT19941109TJ
Latitude: 33-35-47.10 N
Longitude: 112-05-31.50 W
ERP: 0.01 kW
Channel: 205
Frequency: 88.9 MHz
AMSL Height: 630.0 m
Elevation: 594.86 m
Horiz. Pattern: Directional
Vert. Pattern: No
Prop Model: Line of Sight
Receiver Ht AG: 9.1 m
Earths curvature: 1.3



Line of Sight
Clear
Blocked

Shadow Depth with Terrain

K205CI
BLFT19941109TJ
Latitude: 33-35-47.10 N
Longitude: 112-05-31.50 W
ERP: 0.01 kW
Channel: 205
Frequency: 88.9 MHz
AMSL Height: 630.0 m
Elevation: 594.86 m
Horiz. Pattern: Directional
Vert. Pattern: No Shadow Depth



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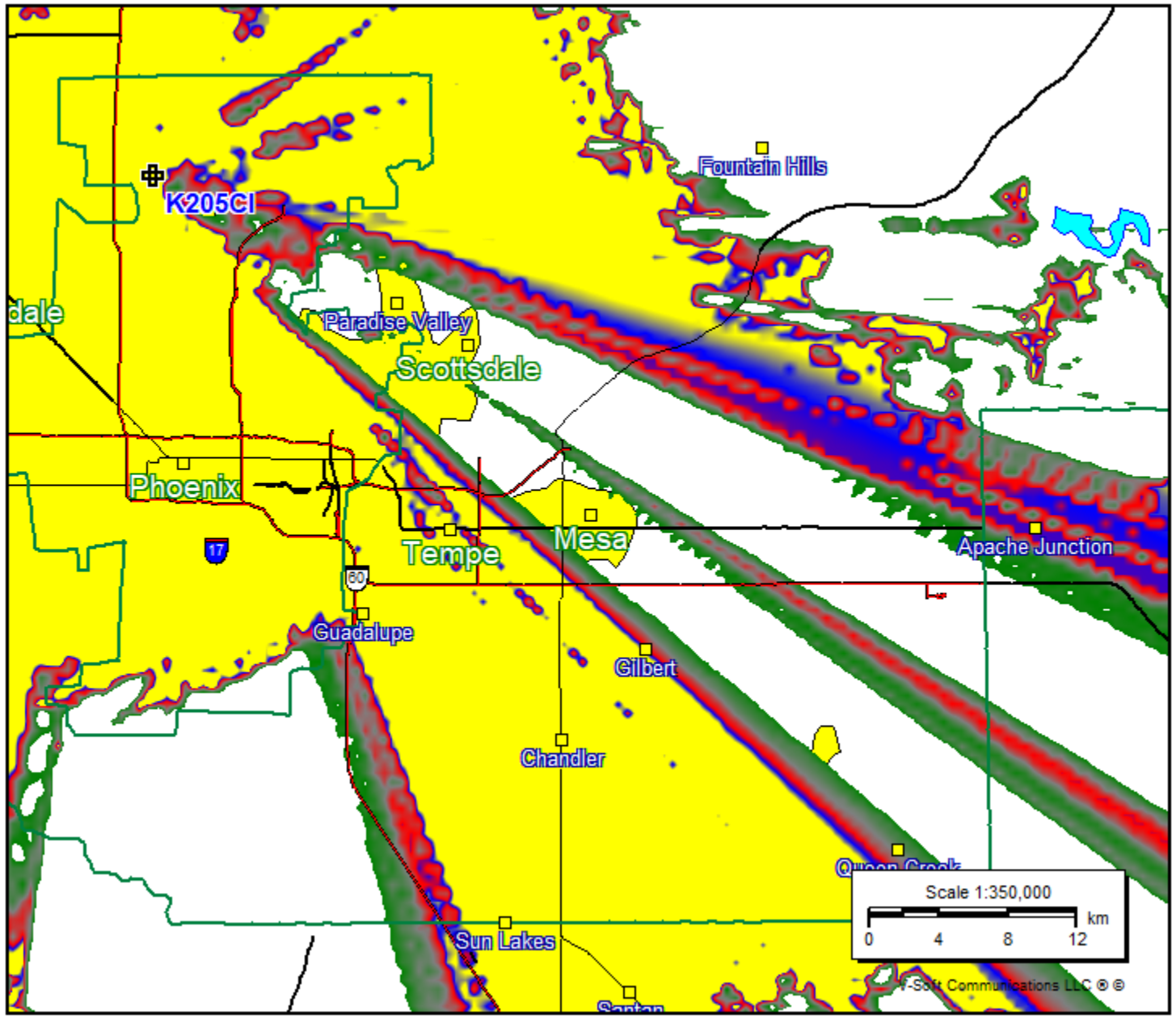
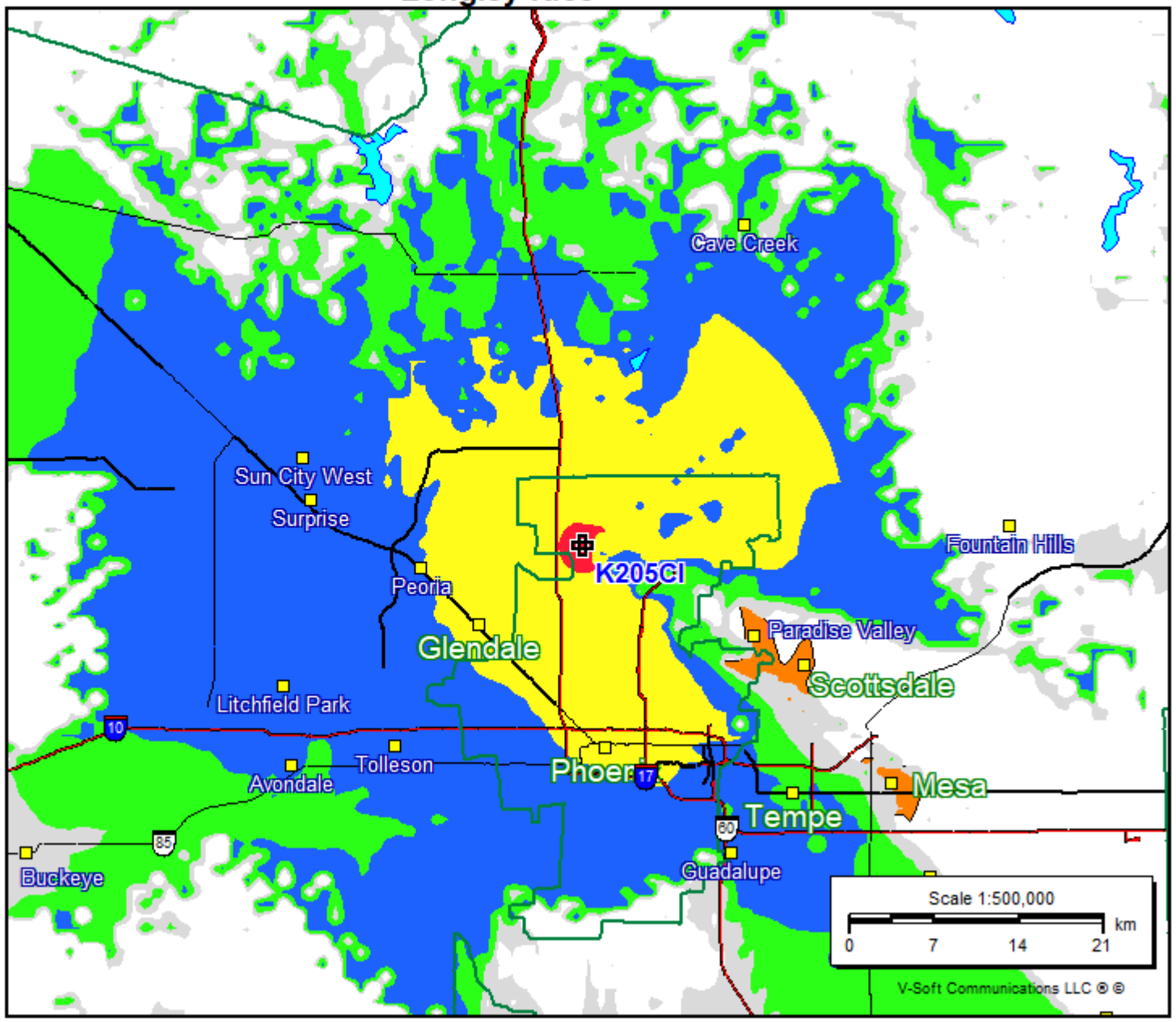
ERP: 0.01 kW
Channel: 205
Frequency: 88.9 MHz
AMSL Height: 630.0 m
Elevation: 594.86 m
Horiz. Pattern: Directional
Vert. Pattern: No
Shadow Depth



	> 0.0 m
	-10.0 - 0.0
	-20.0 - -10.0
	-50.0 - -20.0
	-100.0 - -50.0

Longley-Rice

K205CI
BLFT19941109TJ
Latitude: 33-35-47.10 N
Longitude: 112-05-31.50 W
ERP: 0.01 kW
Channel: 205
Frequency: 88.9 MHz
AMSL Height: 630.0 m
Elevation: 594.86 m
Horiz. Pattern: Directional
Vert. Pattern: No
Prop Model: Longley-Rice
Climate: Cont temperate
Conductivity: 0.0050
Dielec Const: 15.0
Refractivity: 311.0
Receiver Ht AG: 9.1 m
Receiver Gain: 0 dB
Time Variability: 50.0%
Sit. Variability: 50.0%
ITM Mode: Broadcast



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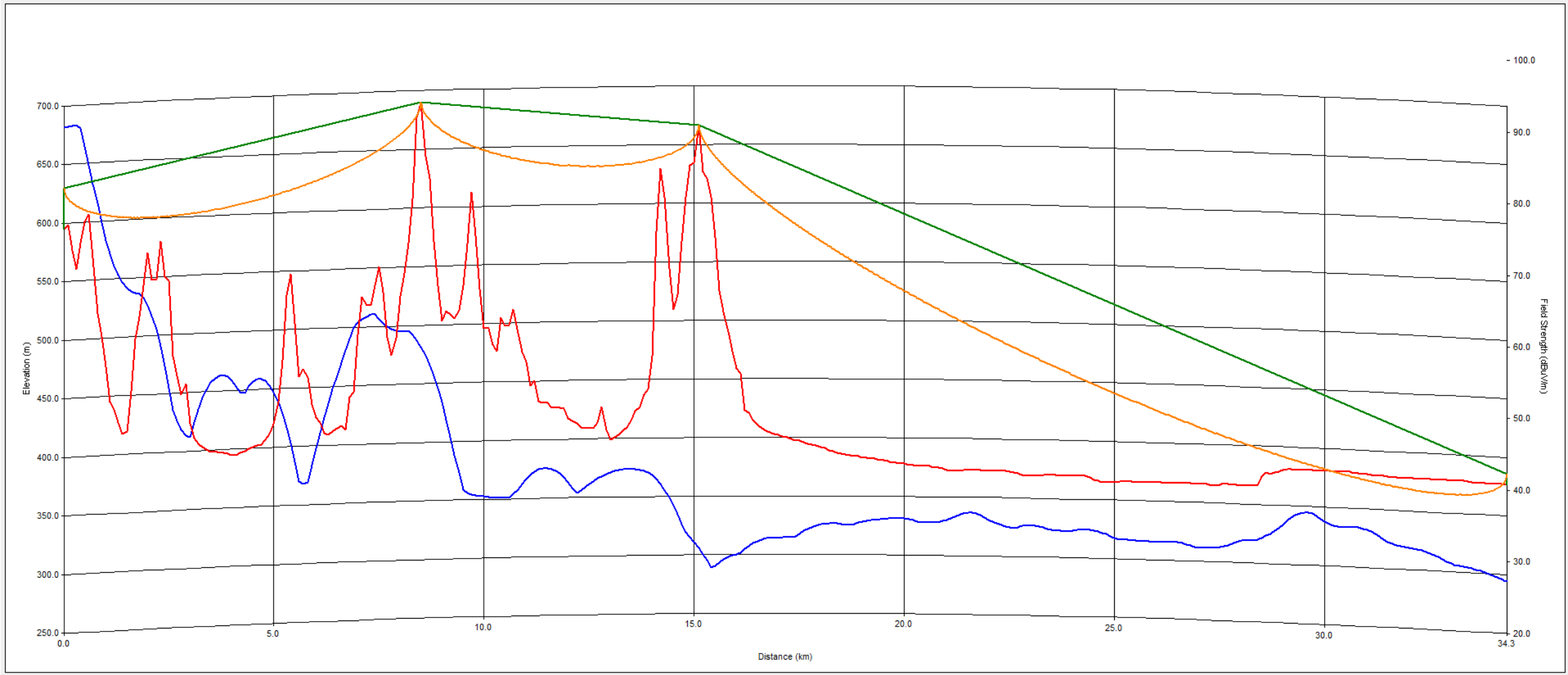


Start Point
Latitude: 33-35-47.10 N
Longitude: 112-05-31.50 W

End Point
Latitude: 33-24-23.16 N
Longitude: 111-48-01.87 W

Distance & Bearing
Distance: 34.32 km
Bearing: 127.79 deg

Options
Signal: K205CI (205)
Antenna Properties...
Draw Profile

Legend
Terrain
Field Strength
Line of Sight

What is the Longley-Rice Model?

"Longley-Rice", named for Anita Longley & Phil Rice in 1968, models radio propagation between 20 MHz and 20 GHz.

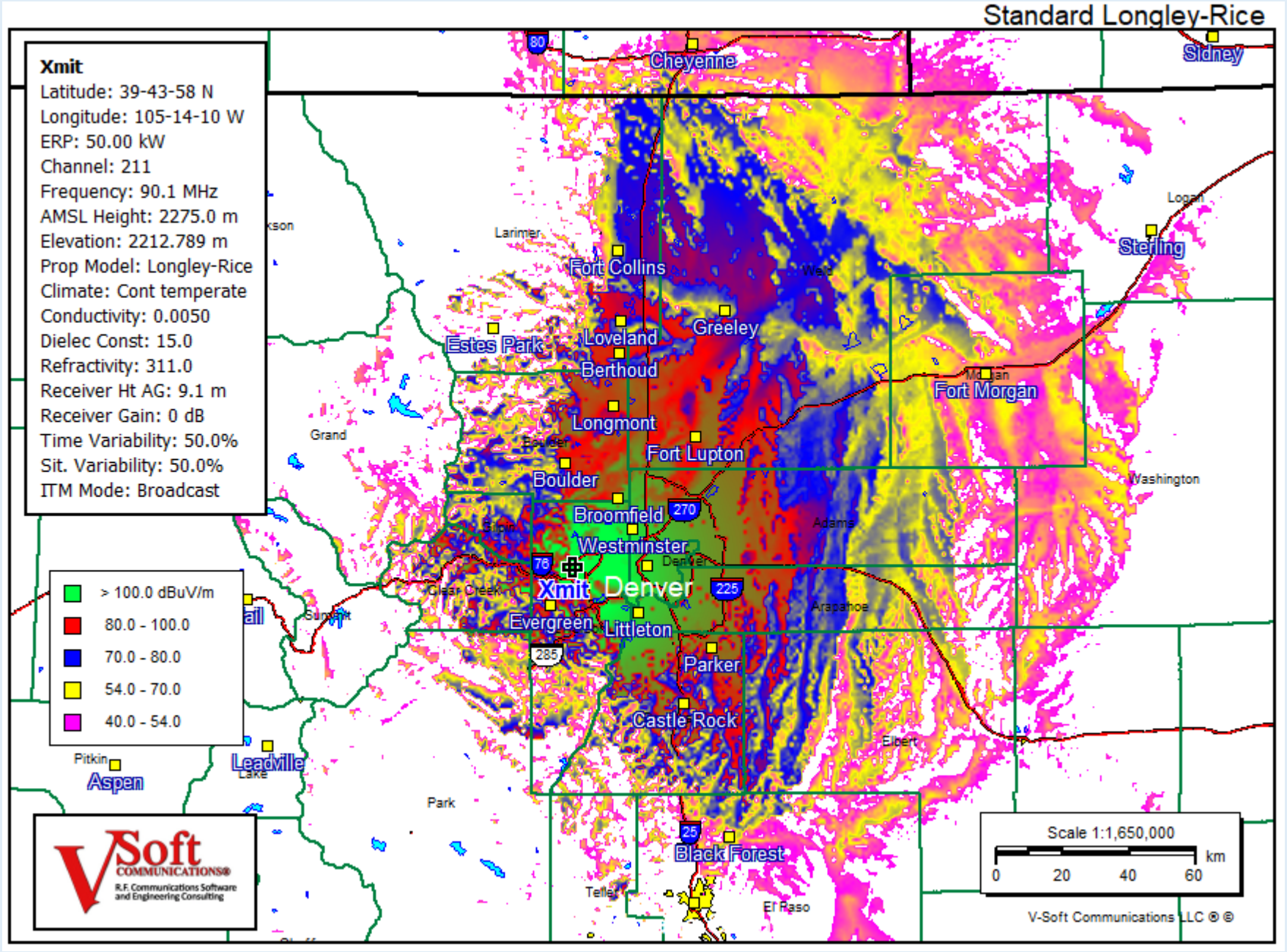
The model, based on electromagnetic theory and statistical analyses of terrain features and a cache of radio measurements, predicts the median attenuation of a radio signal as a function of distance and the variability of the signal in time and in space.

Mathematical Statistics

Inputs:

- Frequency (20 – 20,000 MHz)
- Transmitter antenna parameters:
- Transmitter antenna height (above mean sea level – meters.)
- Transmitter antenna height (above ground – meters.)
- Transmitter power. Transmitter antenna pattern.
- Receiver antenna height above ground – meters, and gain
- System antenna polarization (vertical or horizontal)
- System Ground Conductivity (mhoS/m)
- System dielectric constant (Permittivity)
- System surface refractivity (Adjusted to sea level.)
- Climate Zone
- Time, Location and Situation Variability

Longley-Rice, as is the case of all propagation algorithms, delivers a value of attenuation at a point. Interpreting this on a larger scale is up to you. This is where visualization comes in.


Standard Longley-Rice
Xmit
Latitude: 39-43-58 N
Longitude: 105-14-10 W
ERP: 50.00 kW
Channel: 211
Frequency: 90.1 MHz
AMSL Height: 2275.0 m
Elevation: 2212.789 m
Prop Model: Longley-Rice
Climate: Cont temperate
Conductivity: 0.0050
Dielec Const: 15.0
Refractivity: 311.0
Receiver Ht AG: 9.1 m
Receiver Gain: 0 dB
Time Variability: 50.0%
Sit. Variability: 50.0%
ITM Mode: Broadcast
> 100.0 dBuV/m
80.0 - 100.0
70.0 - 80.0
54.0 - 70.0
40.0 - 54.0
Cheyenne
Sidney
Fort Collins
Sterling
Greeley
Loveland
Estes Park
Berthoud
Fort Morgan
Longmont
Fort Lupton
Boulder
Broomfield
Westminster
Xmit
Denver
Evergreen
Littleton
Parker
Castle Rock
Aspen
Leadville
Black Forest
Scale 1:1,650,000
km
0
20
40
60
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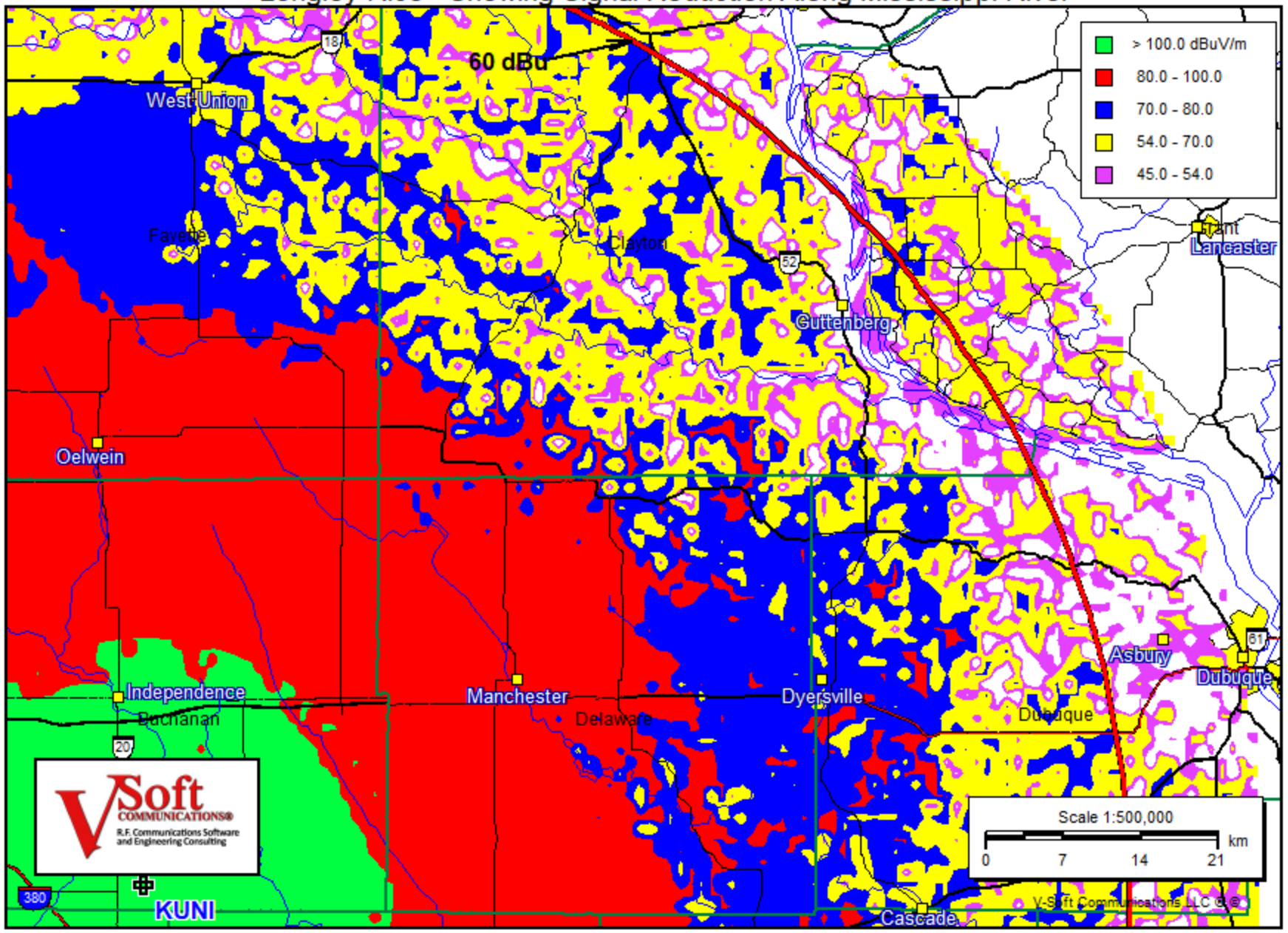
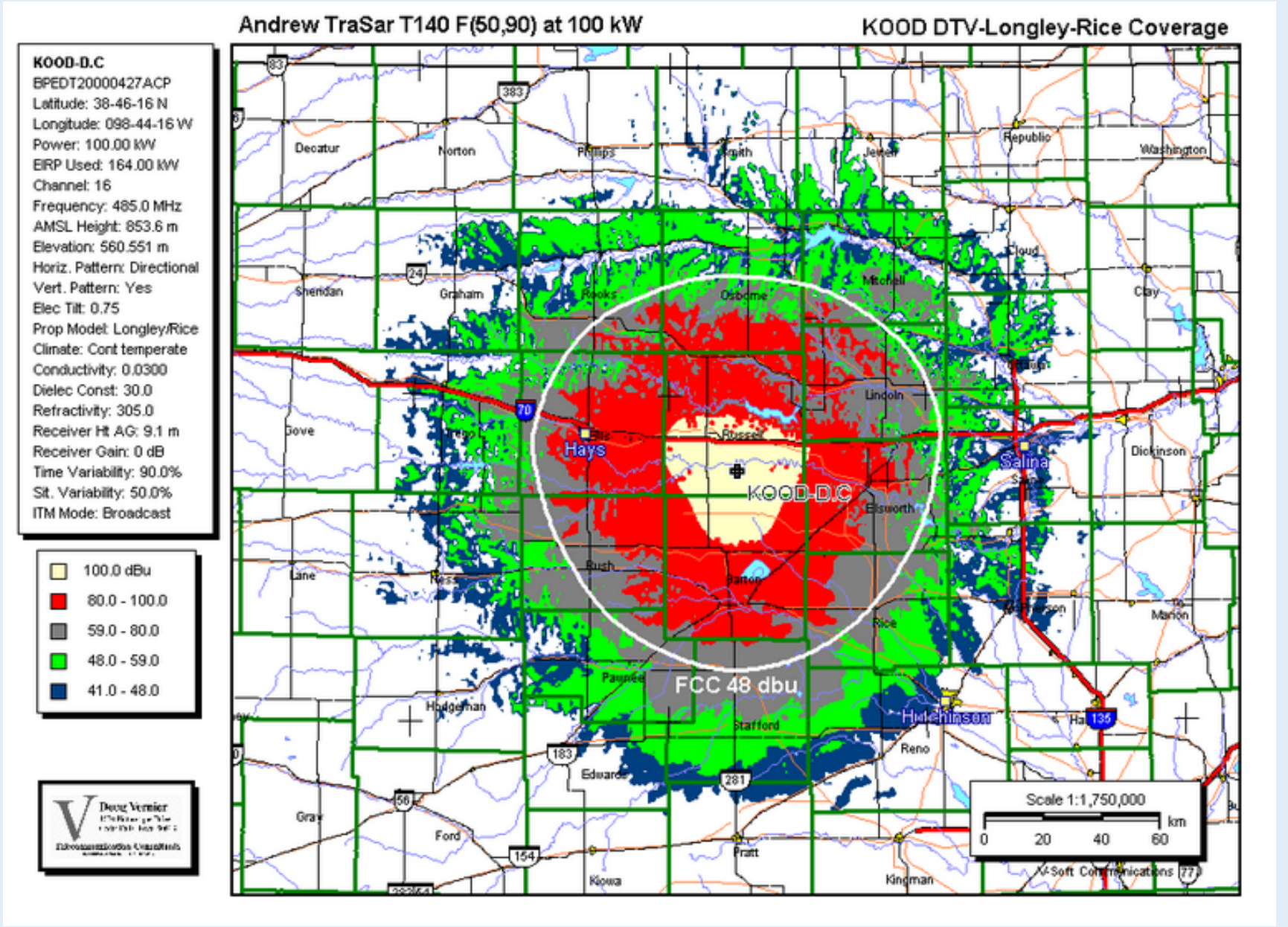
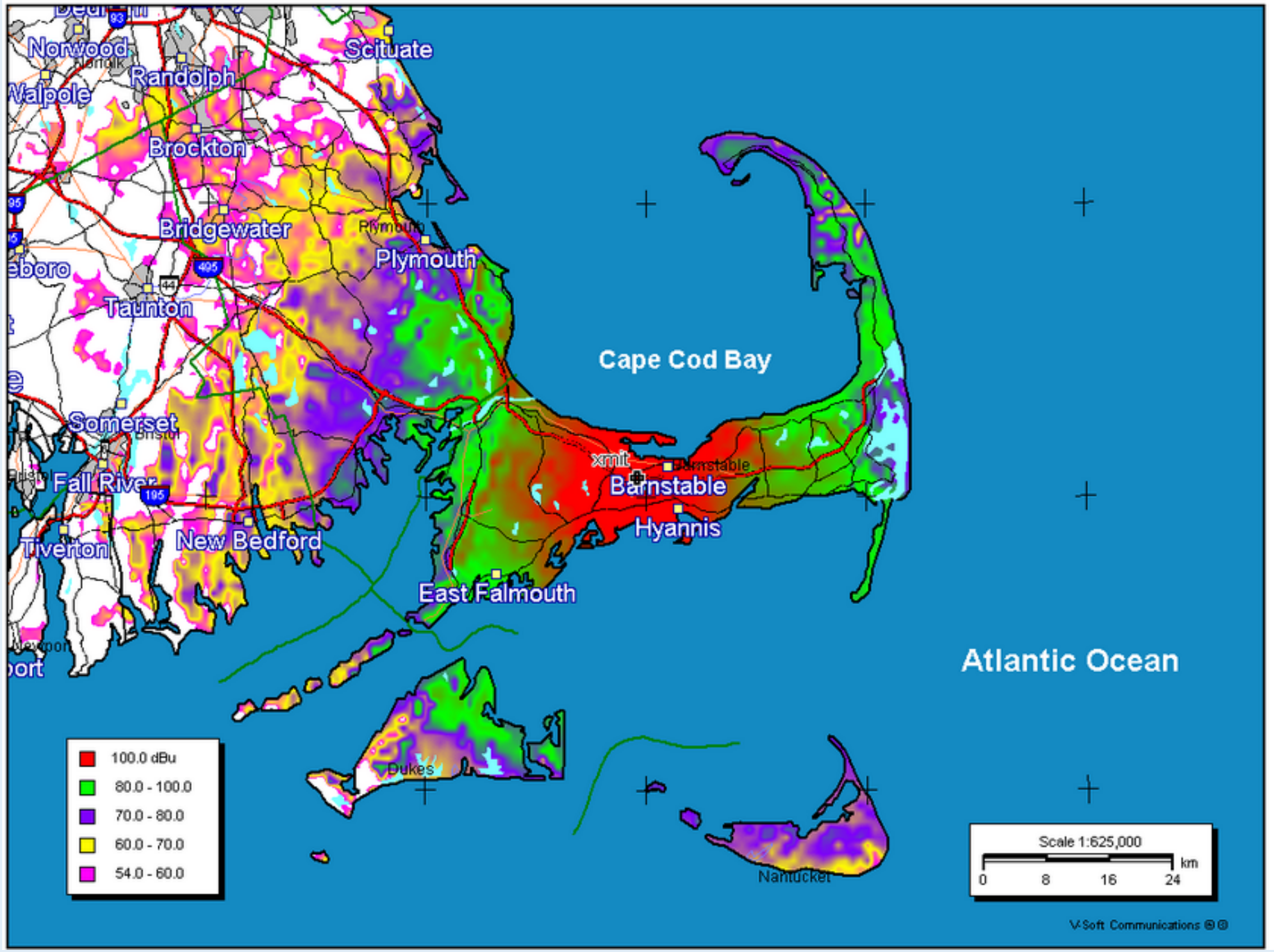
R.F. Communications Software and Engineering Consulting

Longley-Rice - Showing Signal Reduction Along Mississippi River




Andrew TraSar T140 F(50,90) at 100 kW
KOOD DTV-Longley-Rice Coverage
KOOD-D.C
BPEDT20000427ACP
Latitude: 38-46-16 N
Longitude: 098-44-16 W
Power: 100.00 kW
EIRP Used: 164.00 kW
Channel: 16
Frequency: 485.0 MHz
AMSL Height: 853.6 m
Elevation: 560.551 m
Horiz. Pattern: Directional
Vert. Pattern: Yes
Elec Tilt: 0.75
Prop Model: Longley/Rice
Climate: Cont temperate
Conductivity: 0.0300
Dielec Const: 30.0
Refractivity: 305.0
Receiver Ht AG: 9.1 m
Receiver Gain: 0 dB
Time Variability: 90.0%
Sit. Variability: 50.0%
ITM Mode: Broadcast
100.0 dBu
80.0 - 100.0
59.0 - 80.0
48.0 - 59.0
41.0 - 48.0
KOOD-D.C
FCC 48 dbu
Hays
Salina
Hutchinson
Scale 1:1,750,000
km
0 20 40 60
Decatur
Norton
Phillips
Smith
Jewell
Republic
Washington
Sheridan
Graham
Rooks
Osborne
Mitchell
Cloud
Clay
Lincoln
Ellsworth
Dickinson
Russell
Barton
Rush
Ness
Lane
Rice
Marion
Pawnee
Stafford
Reno
Hodgeman
Edwards
Gray
Ford
Kiowa
Pratt
Kingman
Gove
70
24
383
183
281
56
154
135


Norwood
Scituate
Randolph
Walpole
Brockton
Bridgewater
Plymouth
Taunton
Cape Cod Bay
Somerset
Fall River
Barnstable
Hyannis
New Bedford
Tiverton
East Falmouth
Atlantic Ocean
Dukes
Nantucket
100.0 dBu
80.0 - 100.0
70.0 - 80.0
60.0 - 70.0
54.0 - 60.0
Scale 1:625,000
km
0
8
16
24
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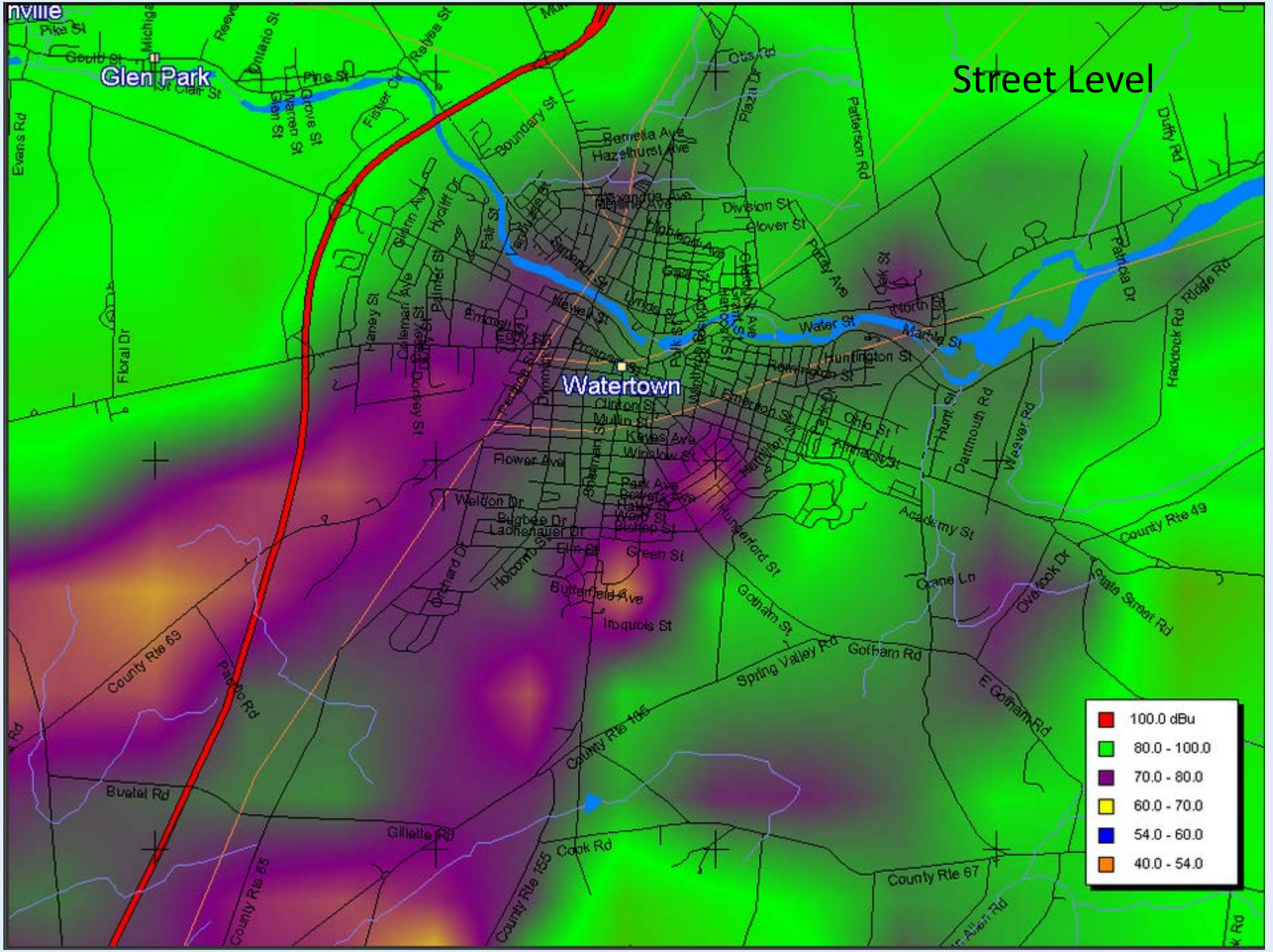
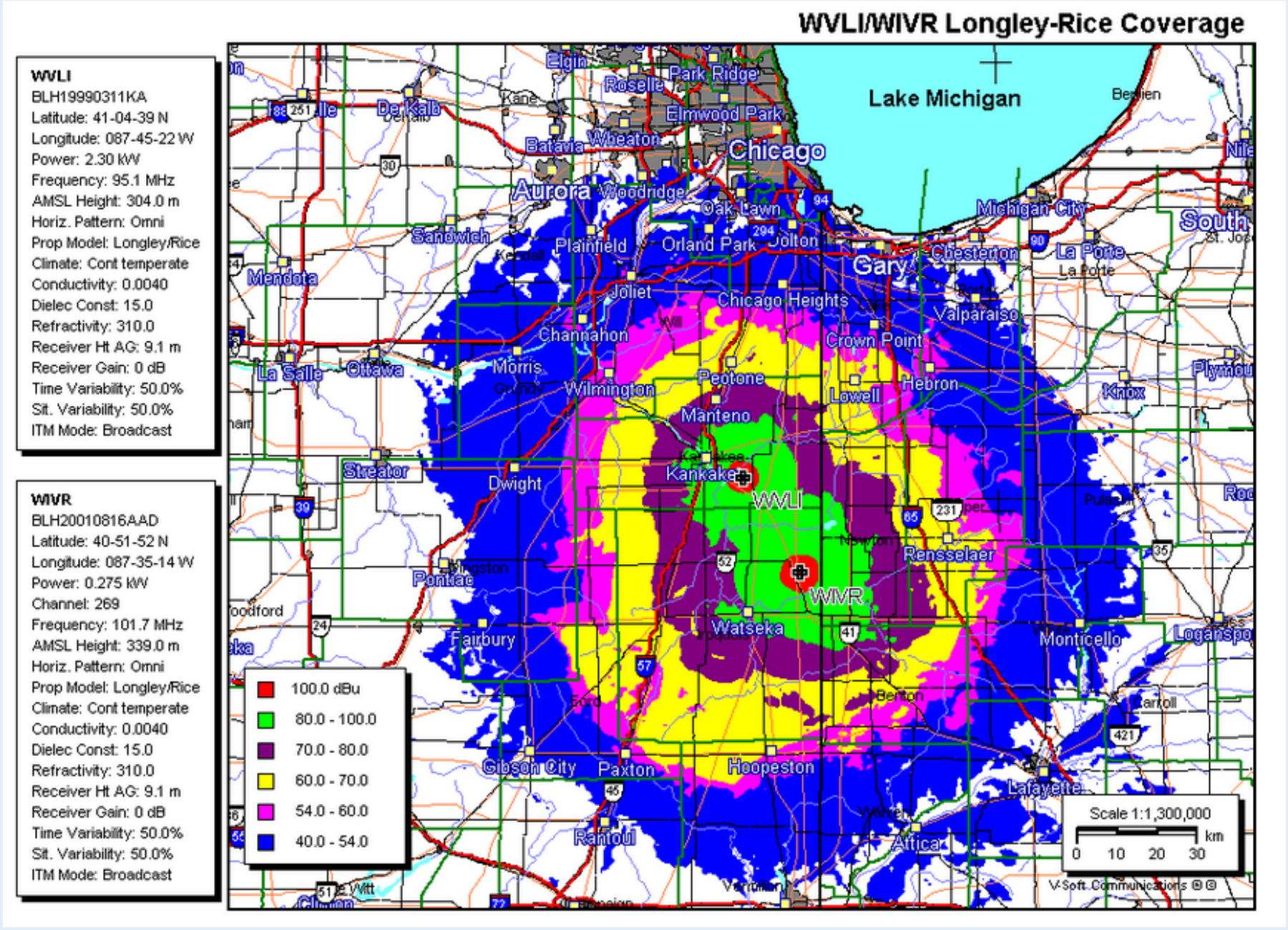
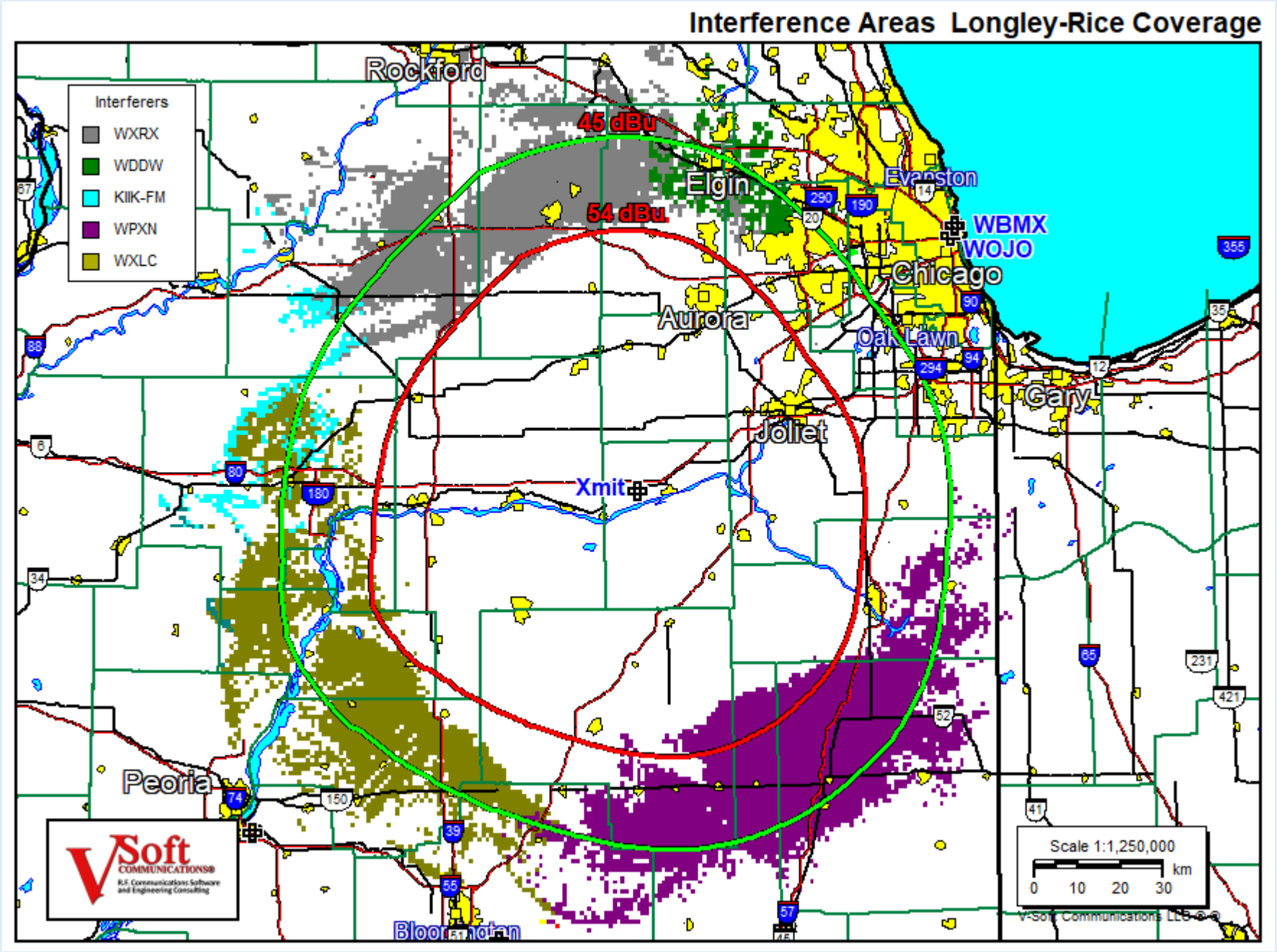
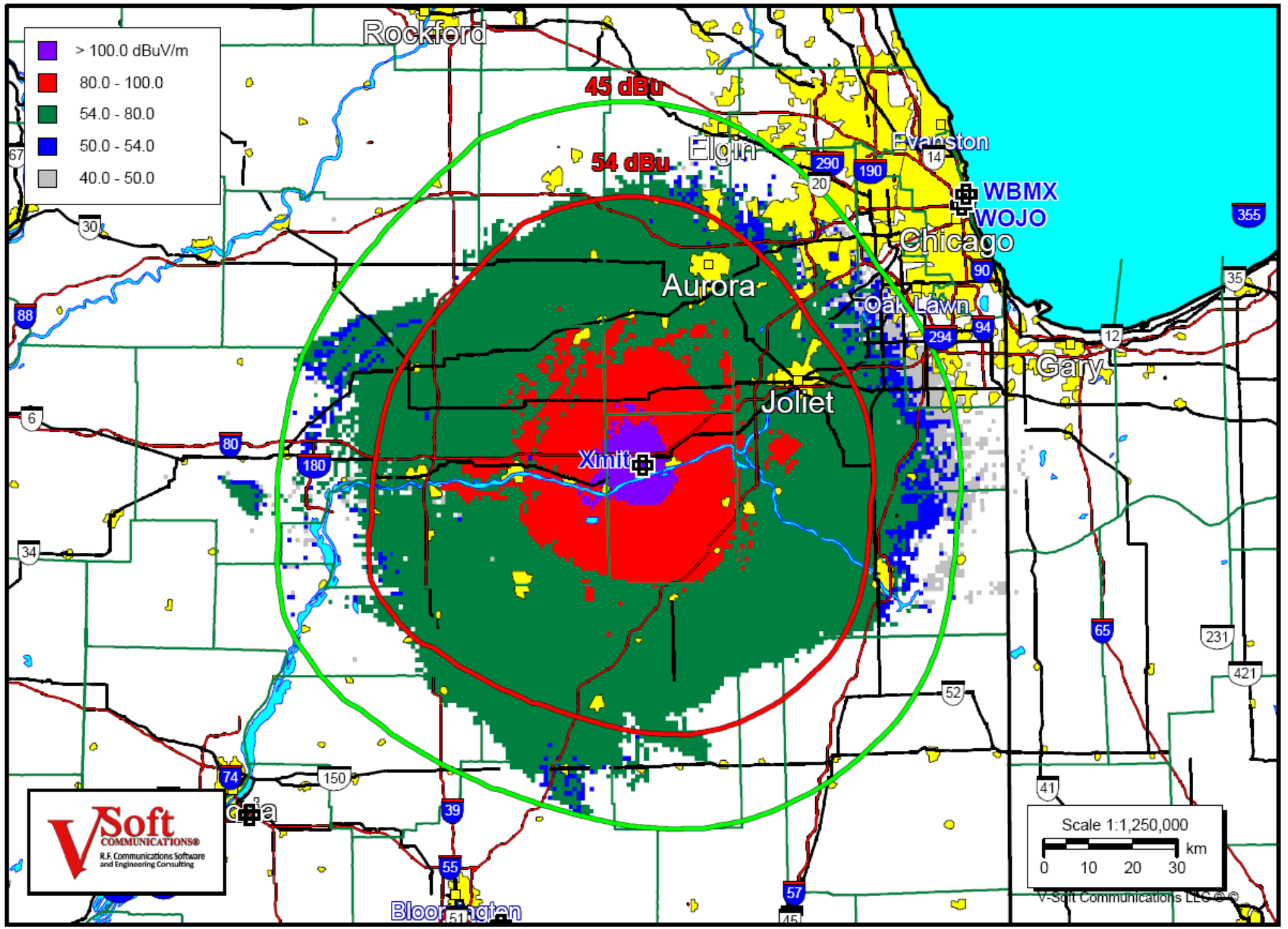

Street Level
Glen Park
Watertown
100.0 dBu
80.0 - 100.0
70.0 - 80.0
60.0 - 70.0
54.0 - 60.0
40.0 - 54.0

WVLI/WIVR Longley-Rice Coverage




Interference Areas Longley-Rice Coverage
Interferers
WXRX
WDDW
KIIK-FM
WPXN
WXLC
45 dBu
54 dBu
Rockford
Elgin
Evanston
WBMX
WOJO
Chicago
Aurora
Oak Lawn
Gary
Joliet
Xmit
Peoria
Bloomington
Scale 1:1,250,000
km
0 10 20 30
V-Soft Communications LLC


> 100.0 dBuV/m
80.0 - 100.0
54.0 - 80.0
50.0 - 54.0
40.0 - 50.0
45 dBu
54 dBu
Rockford
Elgin
Evanston
Chicago
WBMX
WOJO
Aurora
Oak Lawn
Gary
Joliet
Xmit
Bloomington
V-Soft COMMUNICATIONS®
R.F. Communications Software and Engineering Consulting
Scale 1:1,250,000
km
0 10 20 30
V-Soft Communications LLC © ©

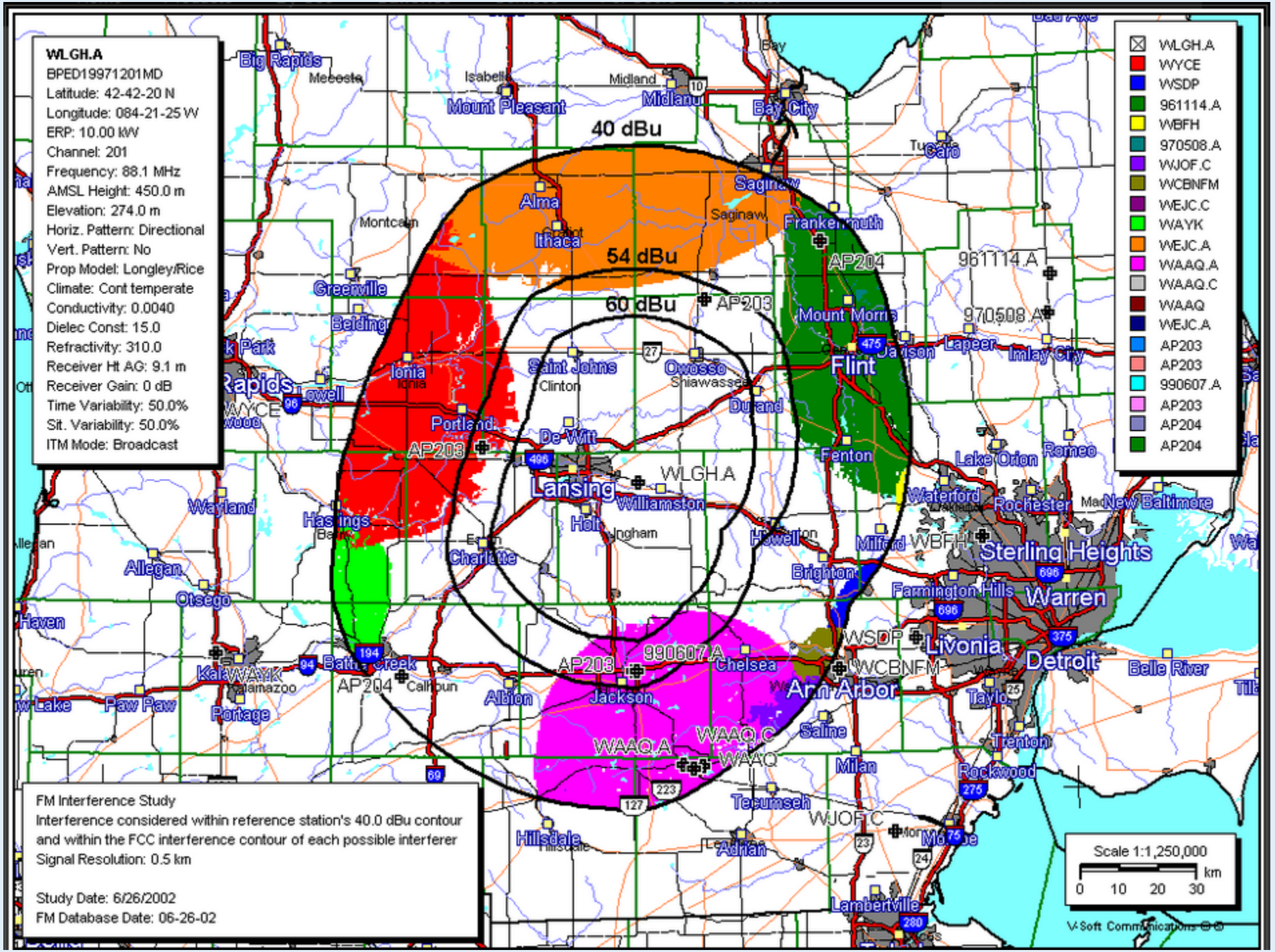
Calculation of Population with No Interference

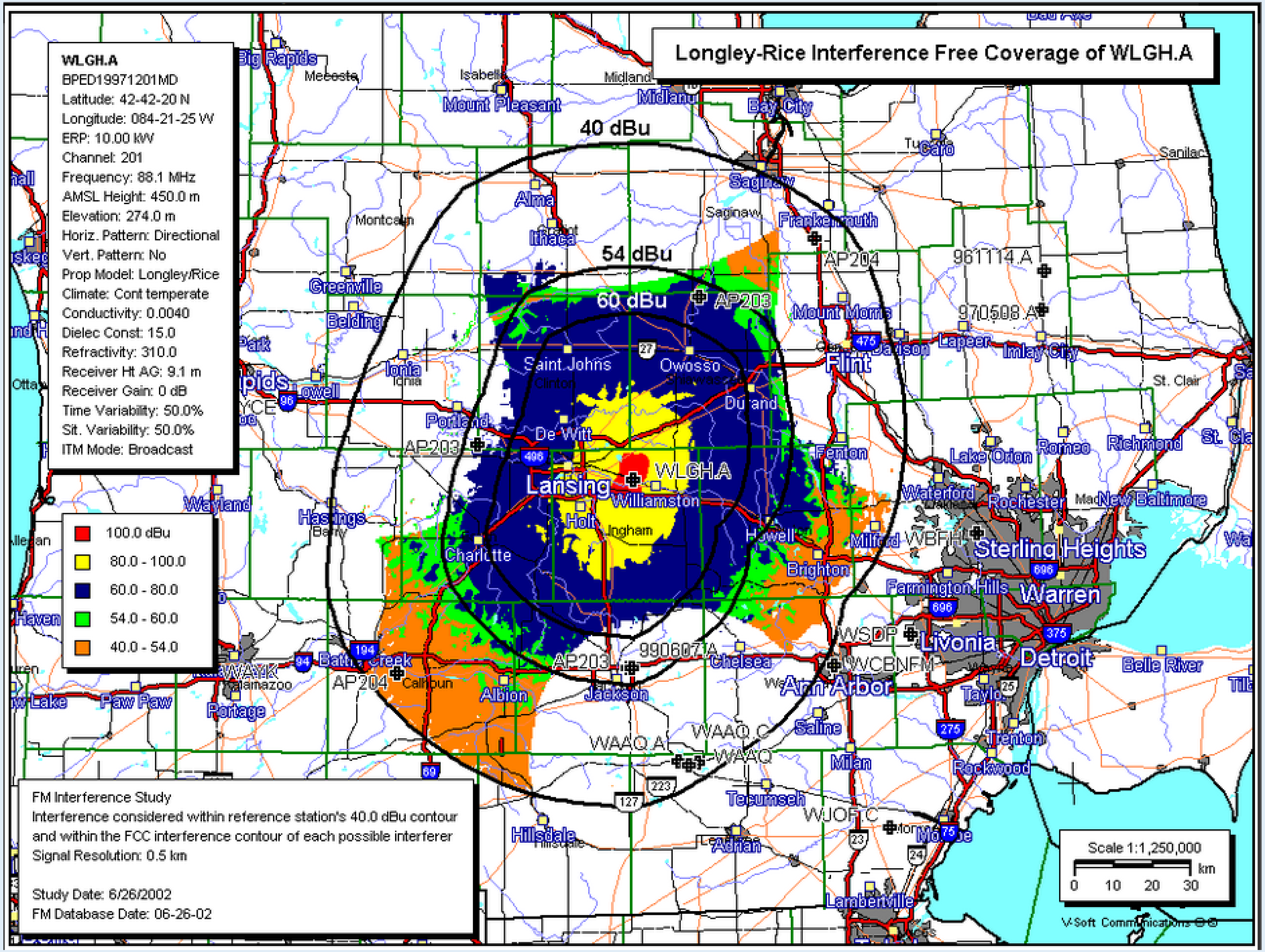
Totals for Xmit (284) to the 45 dBu, (using 30 meter terrain)

	Population	Area
Calculation Area Population:	9,471,751	[38017.9 sq. km]
Not Affected by Terrain Loss:	2,942,759	[22484.3 sq. km]
Interfered Population:	773,030	[8623.1 sq. km]
Interference Free:	2,169,729	[13861.2 sq. km]
Percent Interference:	26.27 %	
Terrain Blocked Population:	6,528,992	[15533.6 sq. km]

Interference Free Breakdown:

White:	1,380,981	[63.6%]
Black:	214,332	[9.9%]
Hispanic:	361,535	[16.7%]
Native American:	2,131	[0.1%]
Asian:	133,528	[6.2%]
Pacific Islander:	385	[0.0%]
Mixed Race:	69,961	[3.2%]
Other:	6,876	[0.3%]
Total:	2,169,729	


WLGH.A
BPED19971201MD
Latitude: 42-42-20 N
Longitude: 084-21-25 W
ERP: 10.00 kW
Channel: 201
Frequency: 88.1 MHz
AMSL Height: 450.0 m
Elevation: 274.0 m
Horiz. Pattern: Directional
Vert. Pattern: No
Prop Model: Longley/Rice
Climate: Cont temperate
Conductivity: 0.0040
Dielec Const: 15.0
Refractivity: 310.0
Receiver Ht AG: 9.1 m
Receiver Gain: 0 dB
Time Variability: 50.0%
Sit. Variability: 50.0%
ITM Mode: Broadcast
40 dBu
54 dBu
60 dBu
WLGH.A
WYCE
WSDP
961114.A
WBFH
970508.A
WJOF.C
WCBNFM
WEJC.C
WAYK
WEJC.A
WAAQ.A
WAAQ.C
WAAQ
WEJC.A
AP203
AP203
990607.A
AP203
AP204
AP204
FM Interference Study
Interference considered within reference station's 40.0 dBu contour
and within the FCC interference contour of each possible interferer
Signal Resolution: 0.5 km
Study Date: 6/26/2002
FM Database Date: 06-26-02
Scale 1:1,250,000
km
0 10 20 30
V-Soft Communications
Big Rapids
Mecosta
Isabella
Midland
Mount Pleasant
Bay City
Saginaw
Alma
Ithaca
Montcalm
Greenville
Belding
Ionia
Grand Rapids
Saint Johns
Clinton
Owosso
Shiawassee
Durand
Flint
Portland
De Witt
Lansing
Williamston
Fenton
Lake Orion
Romeo
Waterford
Rochester
New Baltimore
Wayland
Hastings
Charlotte
Howell
Milford
Sterling Heights
Allegan
Otsego
Brighton
Farmington Hills
Warren
Kalamazoo
Battle Creek
Chelsea
Livonia
Detroit
Belle River
Paw Paw
Portage
Albion
Jackson
Ann Arbor
Saline
Taylor
Trenton
Milan
Rockwood
Tecumseh
Hillsdale
Adrian
Lambertville
Monroe



Longley-Rice Interference Free Coverage of WLGH.A
WLGH.A
BPED19971201MD
Latitude: 42-42-20 N
Longitude: 084-21-25 W
ERP: 10.00 kW
Channel: 201
Frequency: 88.1 MHz
AMSL Height: 450.0 m
Elevation: 274.0 m
Horiz. Pattern: Directional
Vert. Pattern: No
Prop Model: Longley/Rice
Climate: Cont temperate
Conductivity: 0.0040
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Refractivity: 310.0
Receiver Ht AG: 9.1 m
Receiver Gain: 0 dB
Time Variability: 50.0%
Sit. Variability: 50.0%
ITM Mode: Broadcast
100.0 dBu
80.0 - 100.0
60.0 - 80.0
54.0 - 60.0
40.0 - 54.0
40 dBu
54 dBu
60 dBu
WLGH.A
Lansing
Saint Johns
Owosso
Durand
De Witt
Williamston
Holt
Ingham
Charlotte
Howell
Brighton
Fenton
Flint
Saginaw
Bay City
Frankenmuth
Mount Morris
Lapeer
Imlay City
Alma
Ithaca
Greenville
Belding
Ionia
Portland
Hastings
Wayland
Battle Creek
Albion
Jackson
Chelsea
Ann Arbor
Saline
Tecumseh
Adrian
Hillsdale
Milan
Livonia
Detroit
Warren
Sterling Heights
Farmington Hills
Rochester
Waterford
Lake Orion
Romeo
Richmond
New Baltimore
Milford
Taylor
Trenton
Rockwood
Monroe
Lambertville
Belle River
Mount Pleasant
Midland
Big Rapids
Mecosta
Isabella
Montcalm
Caro
Sanilac
St. Clair
Kalamazoo
Portage
Paw Paw
Calhoun
AP203
AP204
990607.A
961114.A
970508.A
WBFH
WSDP
WCBNFM
WAAQ.A
WAAQ.C
WAAQ
WJOF.C
FM Interference Study
Interference considered within reference station's 40.0 dBu contour
and within the FCC interference contour of each possible interferer
Signal Resolution: 0.5 km
Study Date: 6/26/2002
FM Database Date: 06-26-02
Scale 1:1,250,000
km
0 10 20 30
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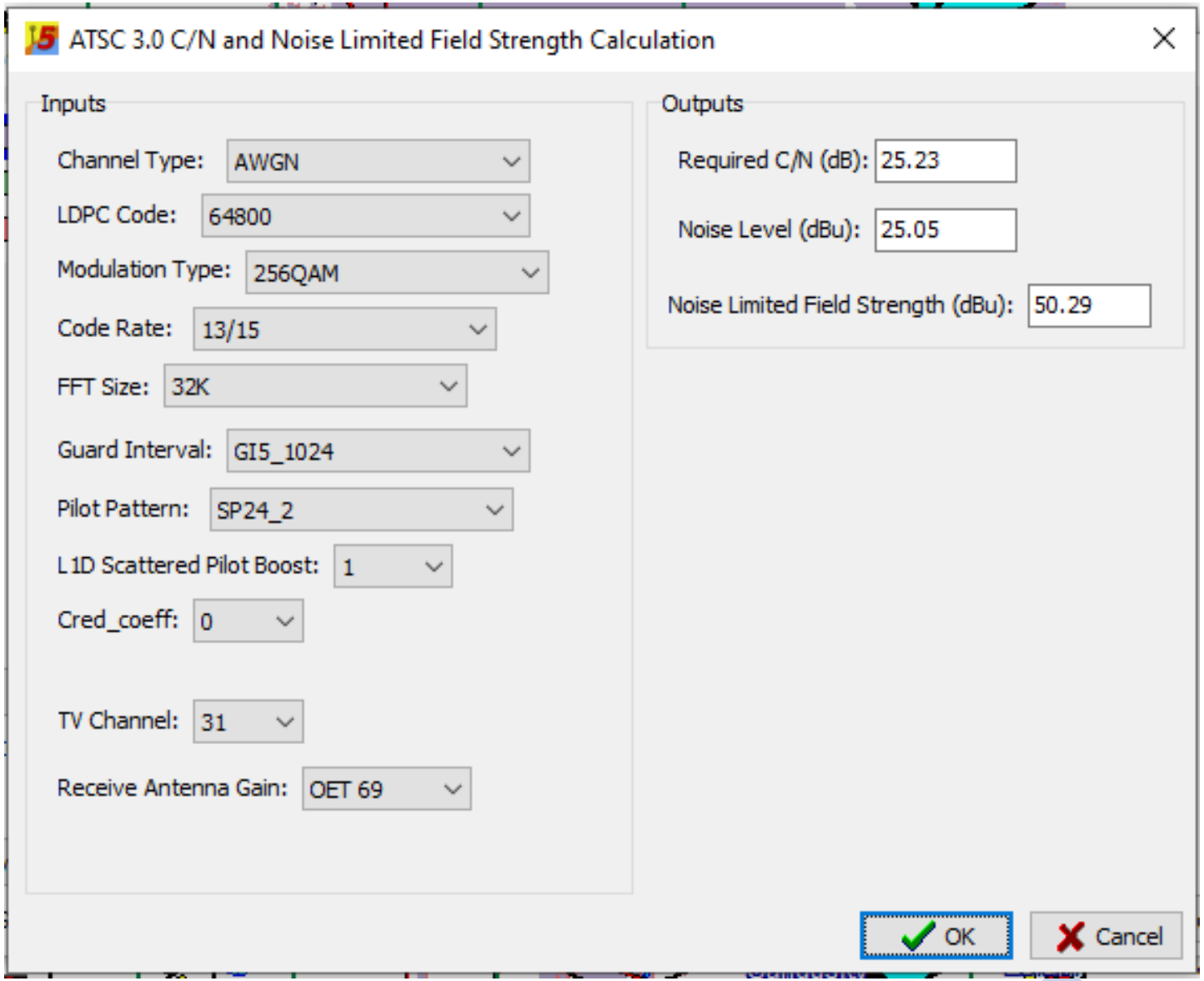
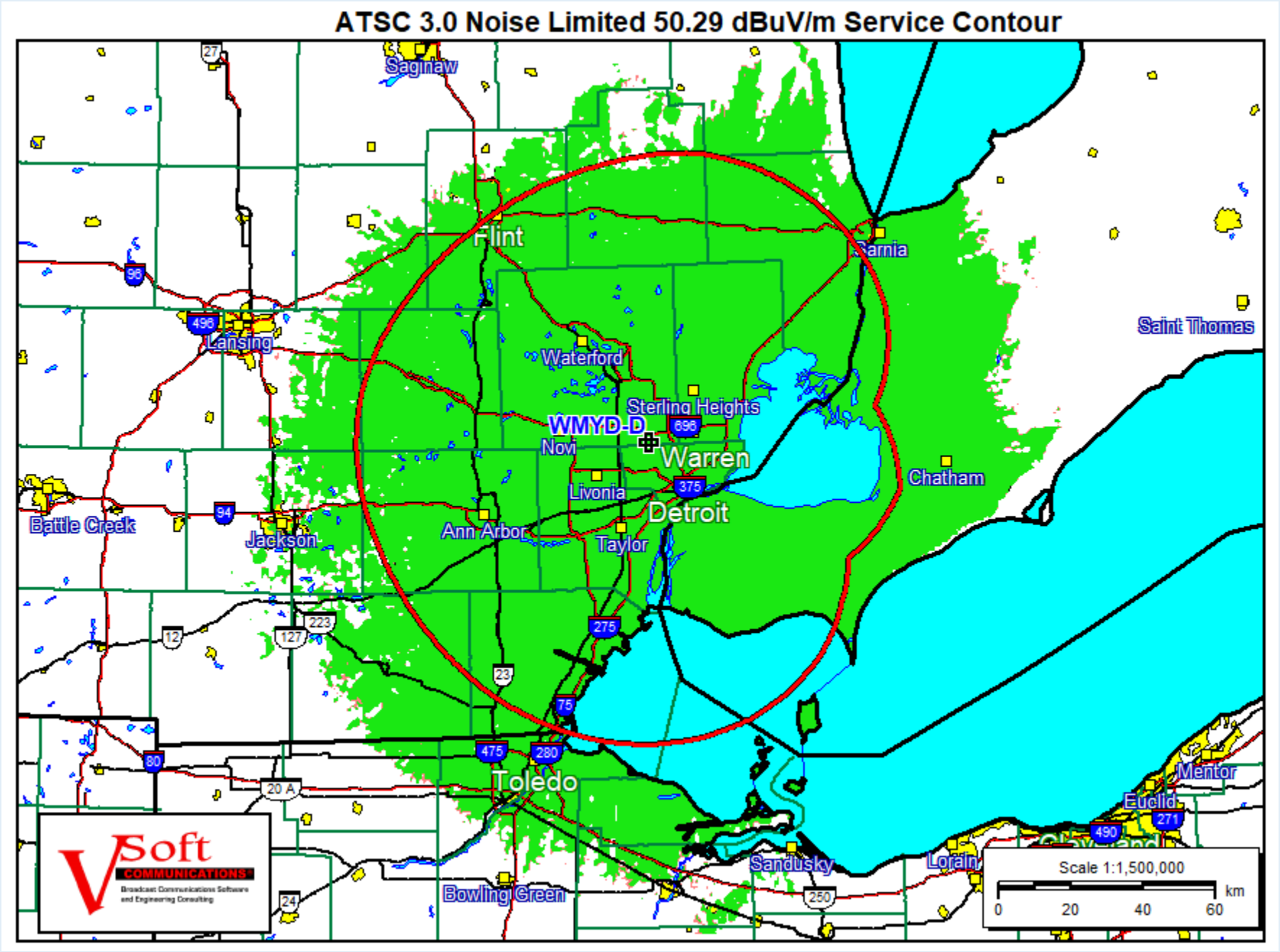
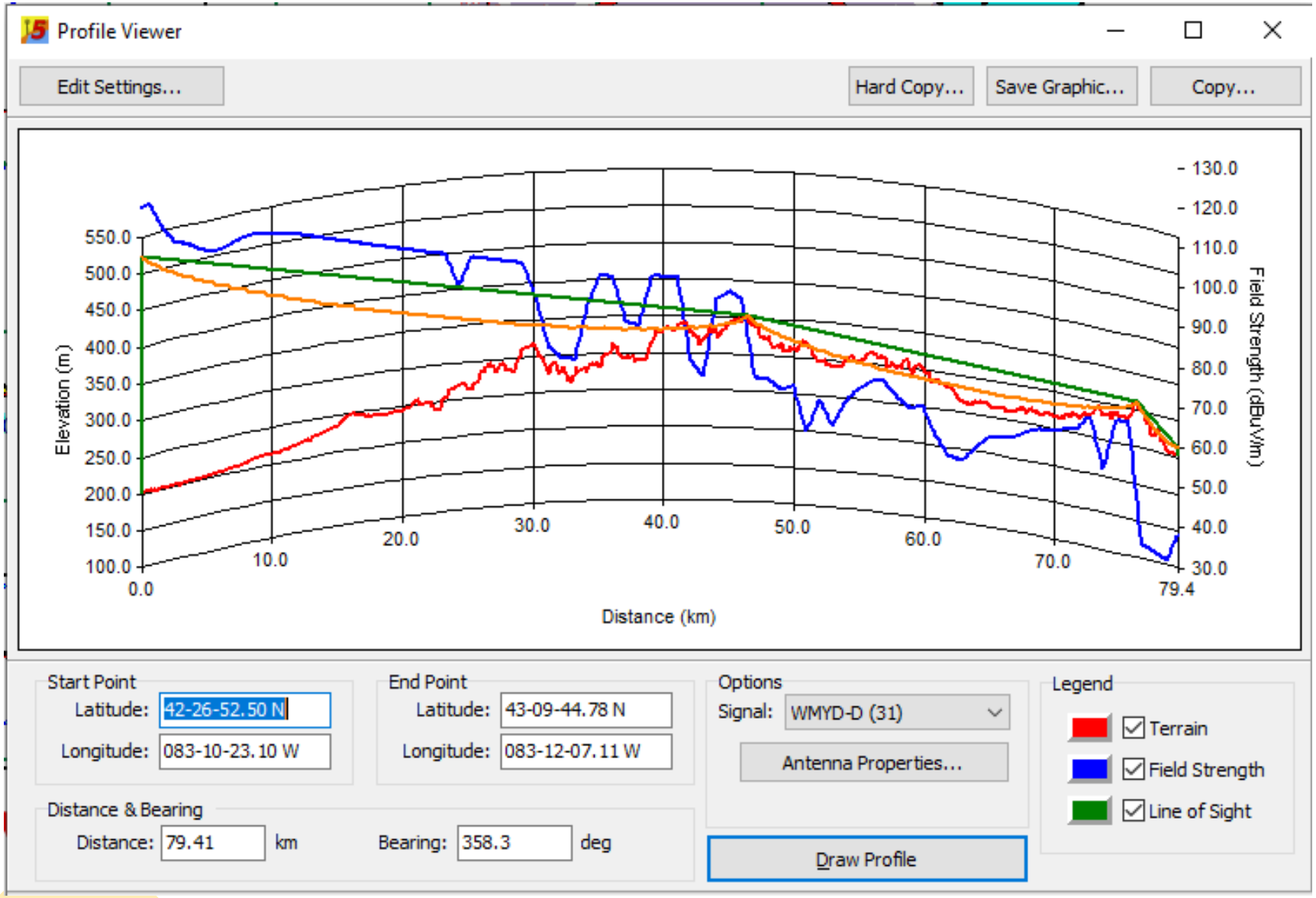
ATSC 3.0 Inputs:

- **Channel type** - AWGN - Additive White Gaussian Noise or Rayleigh – Model of multipath and fading effects
- **LPDC** - Low-Density Parity Check, 64,800 bits, 64k, or 16,200 bits, 16k
- **Modulation** constellation used - QPSK, 16QAM, 64QAM, 256QAM, 1024QAM, 2048QAM
- **Code Rate** - Forward error correction code
- **FFT Size**, (Fast Fourier Transform) for Doppler Protection
- **Guard Intervals** - Protection from time-delay interference caused by multi-path SFN's
- **Pilot Pattern** - Indicates the frequency separation of pilots and the length of the scattered pilot pattern
- **L1D Scattered Pilot Boost** - Higher pilot boosting improves channel estimation accuracy
- **Cred_coeff** -corresponds to increased data capacity and degree of adjacent channel interference
- **Other inputs** - the use of OET 69 & received antenna gain


ATSC 3.0 C/N and Noise Limited Field Strength Calculation
Inputs
Channel Type: AWGN
LDPC Code: 64800
Modulation Type: 256QAM
Code Rate: 13/15
FFT Size: 32K
Guard Interval: GI5_1024
Pilot Pattern: SP24_2
L1D Scattered Pilot Boost: 1
Cred_coeff: 0
TV Channel: 31
Receive Antenna Gain: OET 69
Outputs
Required C/N (dB): 25.23
Noise Level (dBu): 25.05
Noise Limited Field Strength (dBu): 50.29
OK
Cancel


ATSC 3.0 Noise Limited 50.29 dBuV/m Service Contour
Saginaw
Flint
Lansing
Waterford
Sterling Heights
WMYD-D
Novi
Warren
Livonia
Detroit
Ann Arbor
Taylor
Jackson
Battle Creek
Toledo
Bowling Green
Sandusky
Lorain
Mentor
Euclid
Chatham
Saint Thomas
VSoft
COMMUNICATIONS
Broadcast Communications Software and Engineering Consulting
Scale 1:1,500,000
km
0
20
40
60


Profile Viewer
Edit Settings...
Hard Copy...
Save Graphic...
Copy...
Elevation (m)
550.0
500.0
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
79.4
Distance (km)
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
Field Strength (dBuV/m)
Start Point
Latitude: 42-26-52.50 N
Longitude: 083-10-23.10 W
End Point
Latitude: 43-09-44.78 N
Longitude: 083-12-07.11 W
Options
Signal: WMYD-D (31)
Antenna Properties...
Legend
Terrain
Field Strength
Line of Sight
Distance & Bearing
Distance: 79.41 km
Bearing: 358.3 deg
Draw Profile

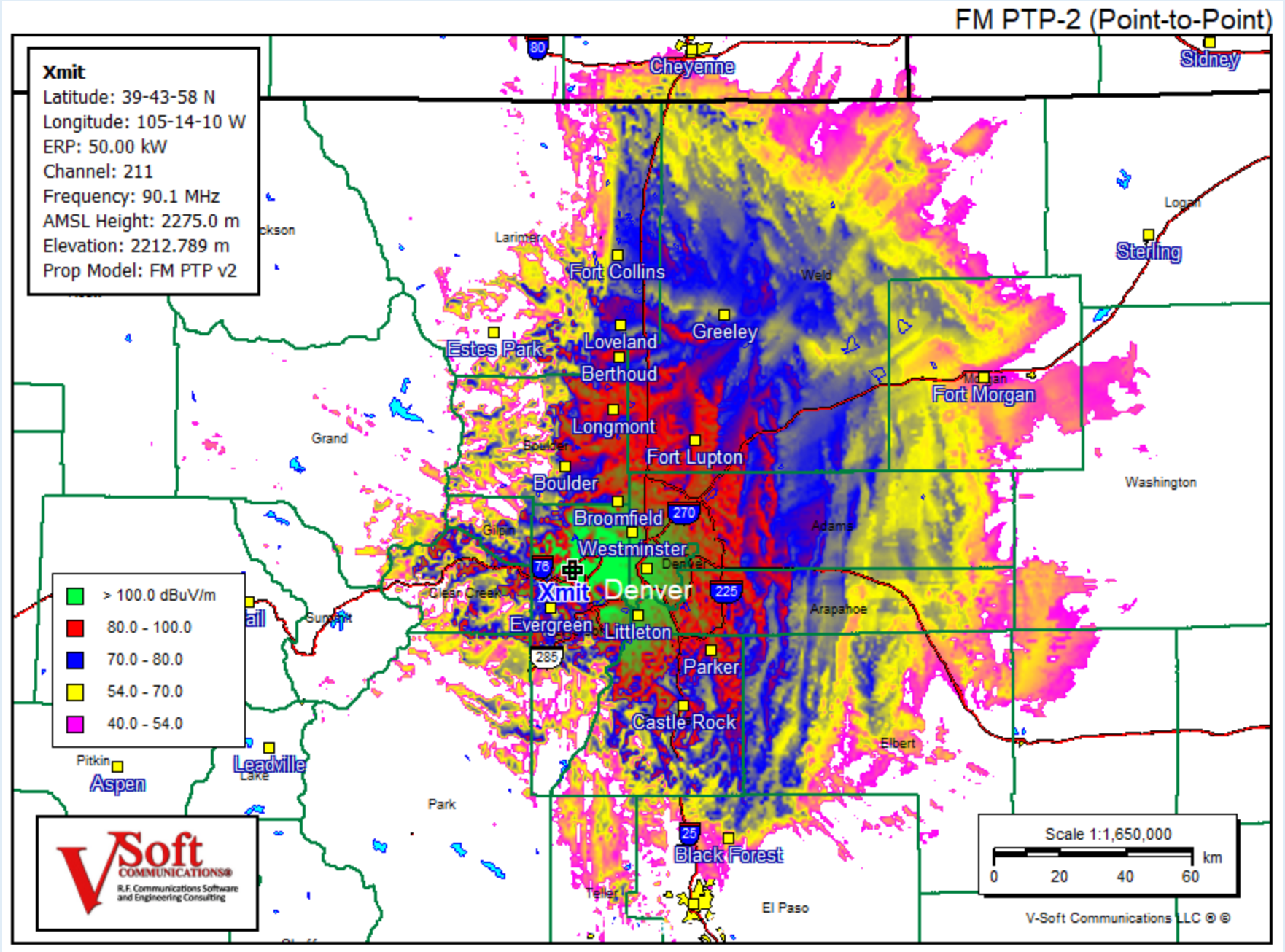
A few Other Propagation Models

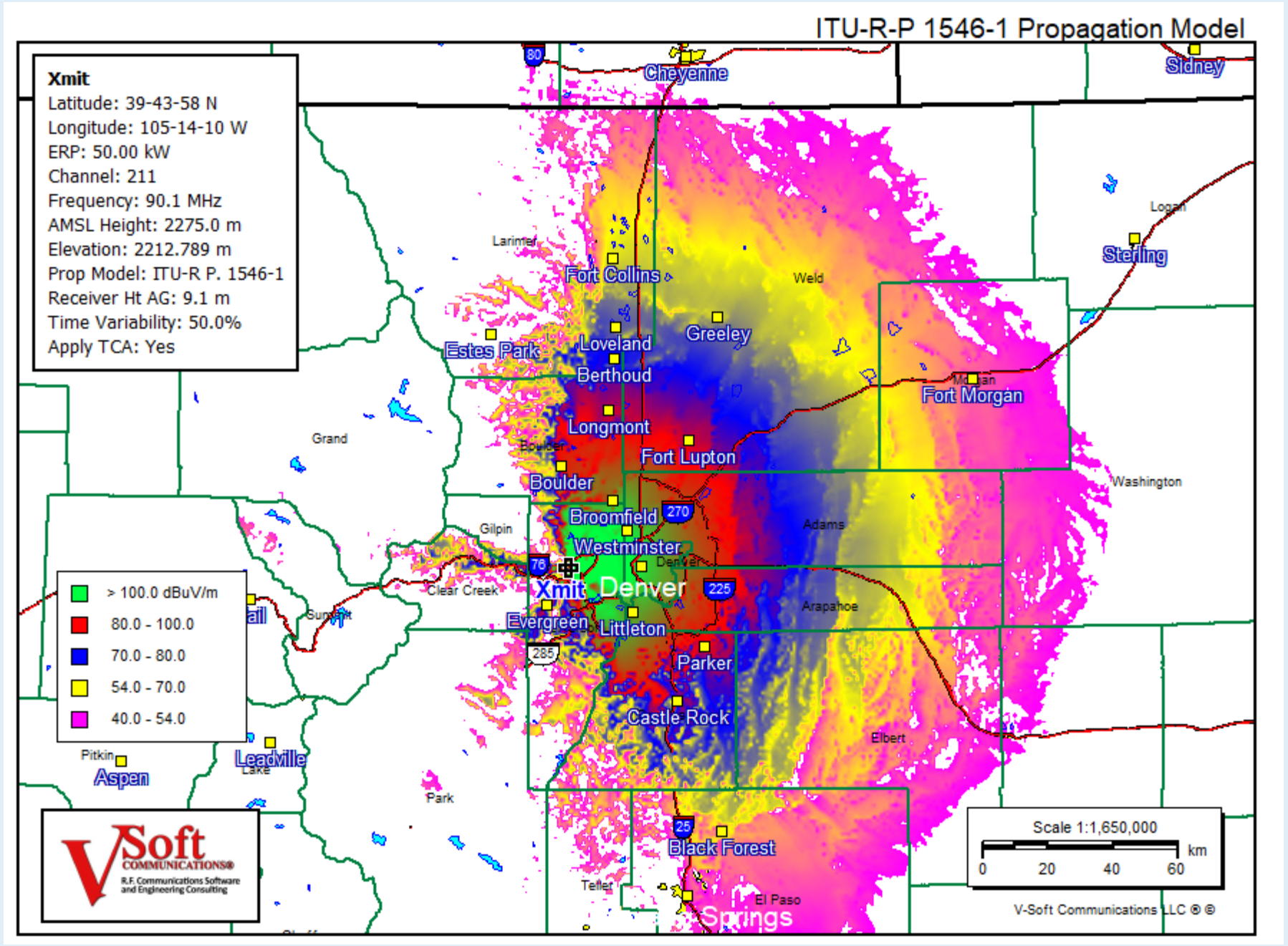
- **PTP-2**, created by Harry Wong at the FCC, uses the terrain value for each point in the specified area of calculation

- **ITU R-P model:** Developed by the International Telecommunications Union, is used widely through out the world, except for in the U.S.

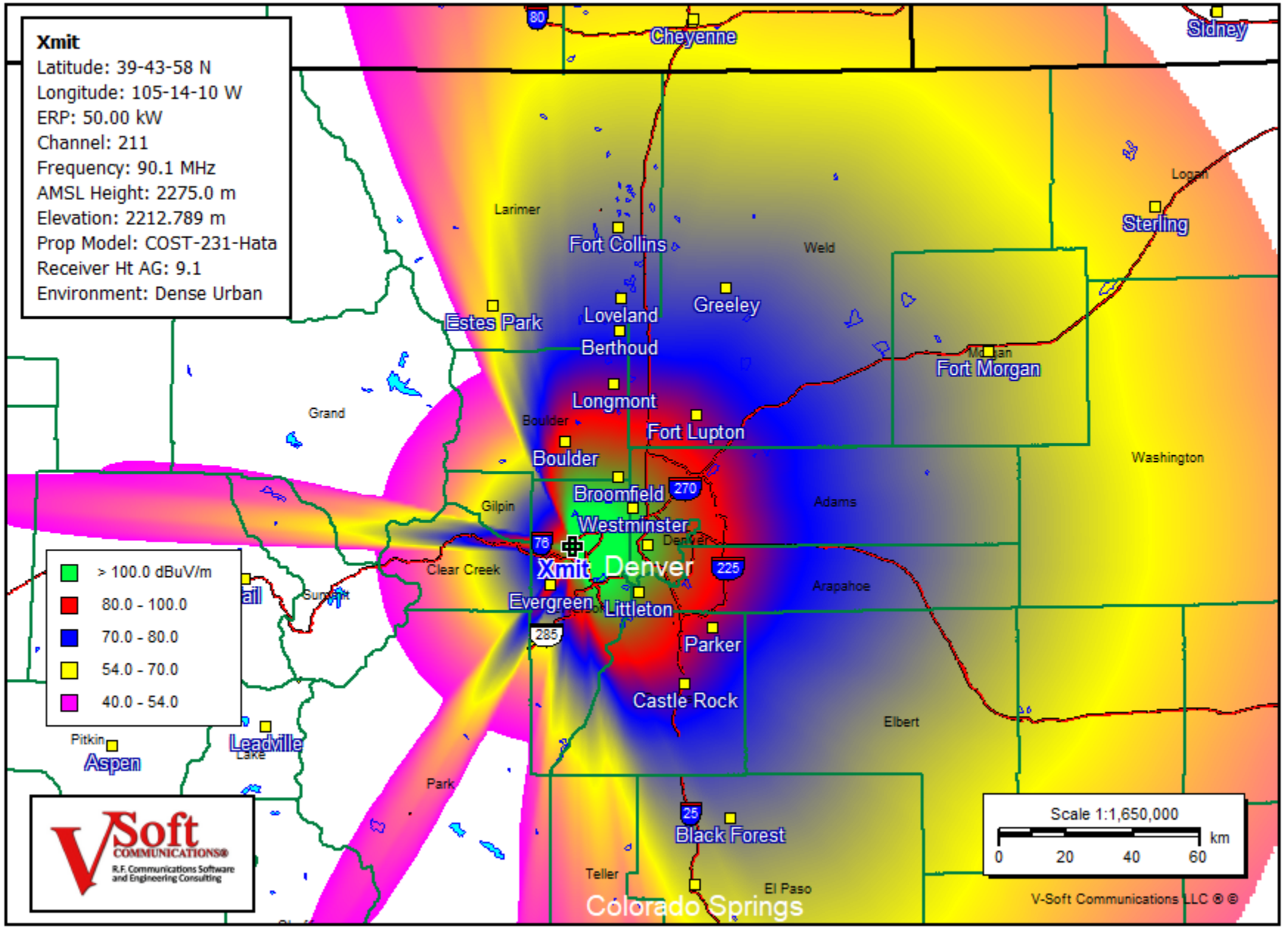
- **Cost-231/Hata** version of the COST-231 propagation model (For use in Urban Areas)
- This model uses HAAT along each radial to determine the attenuation based the equation:
- Path Loss (dB) = 46.3 + 33.9*log(F) - 13.82*log(H) + [44.9 - 6.55*log(H)]*log(D) + C

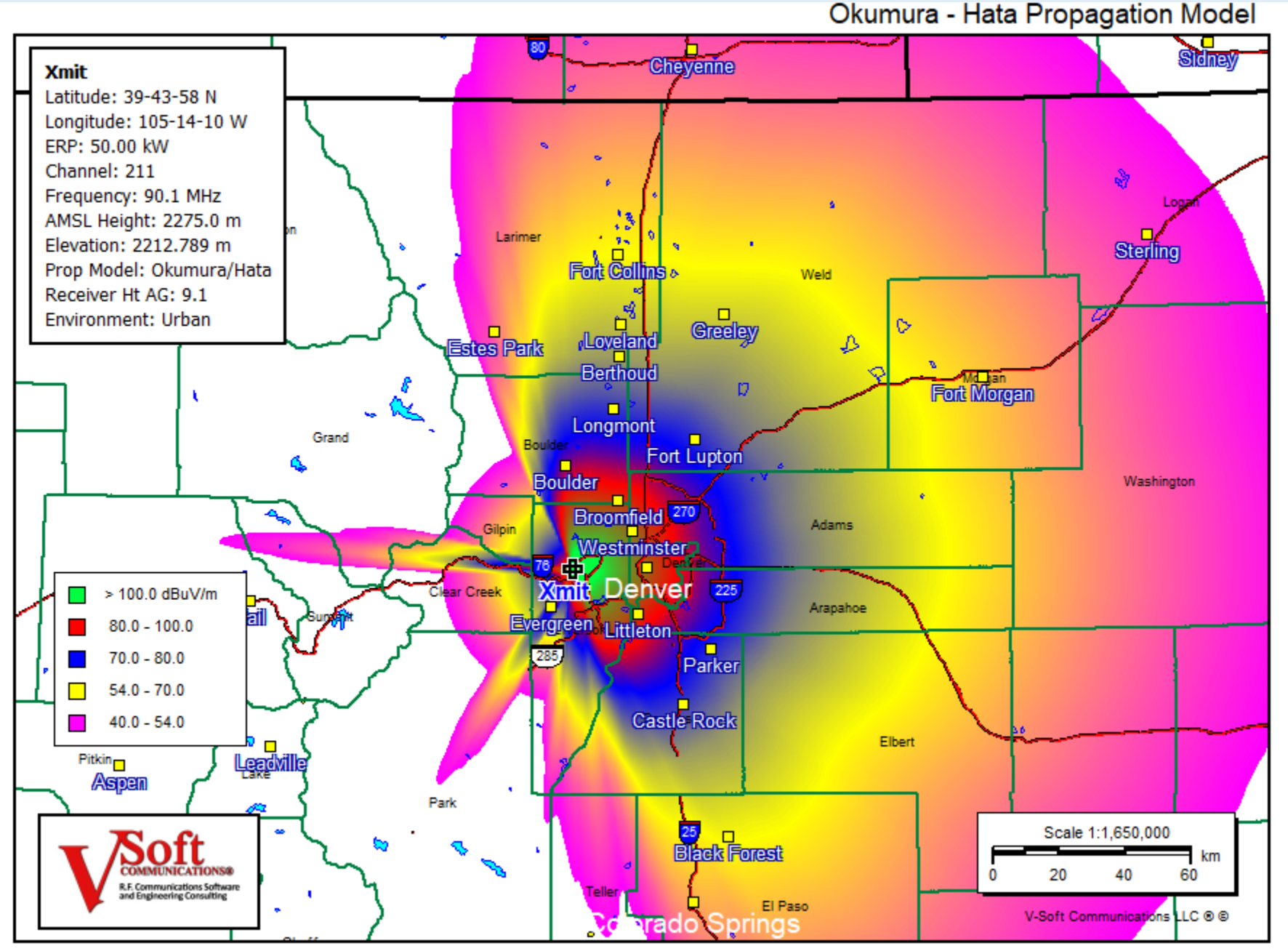
- **Okamura-Hata:**
- Also, a widely used urban model, applicable for frequencies in the range 150–1920 MHz


FM PTP-2 (Point-to-Point)
Xmit
Latitude: 39-43-58 N
Longitude: 105-14-10 W
ERP: 50.00 kW
Channel: 211
Frequency: 90.1 MHz
AMSL Height: 2275.0 m
Elevation: 2212.789 m
Prop Model: FM PTP v2
> 100.0 dBuV/m
80.0 - 100.0
70.0 - 80.0
54.0 - 70.0
40.0 - 54.0
Cheyenne
Sidney
Fort Collins
Loveland
Greeley
Estes Park
Berthoud
Longmont
Fort Lupton
Fort Morgan
Sterling
Boulder
Broomfield
Westminster
Xmit
Denver
Evergreen
Littleton
Parker
Castle Rock
Black Forest
Aspen
Leadville
Larimer
Weld
Grand
Boulder
Gilpin
Clear Creek
Summit
Adams
Arapahoe
Washington
Logan
Pitkin
Lake
Park
Teller
El Paso
Elbert
80
270
76
225
285
25
Scale 1:1,650,000
0 20 40 60 km
V-Soft Communications LLC


ITU-R-P 1546-1 Propagation Model
Xmit
Latitude: 39-43-58 N
Longitude: 105-14-10 W
ERP: 50.00 kW
Channel: 211
Frequency: 90.1 MHz
AMSL Height: 2275.0 m
Elevation: 2212.789 m
Prop Model: ITU-R P. 1546-1
Receiver Ht AG: 9.1 m
Time Variability: 50.0%
Apply TCA: Yes
> 100.0 dBuV/m
80.0 - 100.0
70.0 - 80.0
54.0 - 70.0
40.0 - 54.0
Cheyenne
Sidney
Fort Collins
Loveland
Greeley
Estes Park
Berthoud
Longmont
Fort Lupton
Fort Morgan
Sterling
Boulder
Broomfield
Westminster
Xmit
Denver
Evergreen
Littleton
Parker
Castle Rock
Aspen
Leadville
Black Forest
Springs
Larimer
Weld
Grand
Gilpin
Clear Creek
Adams
Arapahoe
Elbert
Park
Teller
Washington
Logan
Scale 1:1,650,000
km
0 20 40 60
V-Soft Communications LLC

Cost-231/Hata Propagation Model




Okumura - Hata Propagation Model
Xmit
Latitude: 39-43-58 N
Longitude: 105-14-10 W
ERP: 50.00 kW
Channel: 211
Frequency: 90.1 MHz
AMSL Height: 2275.0 m
Elevation: 2212.789 m
Prop Model: Okumura/Hata
Receiver Ht AG: 9.1
Environment: Urban
> 100.0 dBuV/m
80.0 - 100.0
70.0 - 80.0
54.0 - 70.0
40.0 - 54.0
Cheyenne
Sidney
Sterling
Fort Collins
Greeley
Loveland
Estes Park
Berthoud
Longmont
Fort Morgan
Fort Lupton
Boulder
Broomfield
Westminster
Denver
Xmit
Evergreen
Littleton
Parker
Castle Rock
Aspen
Leadville
Black Forest
Colorado Springs
Larimer
Weld
Grand
Boulder
Gilpin
Clear Creek
Adams
Arapahoe
Elbert
Park
Teller
El Paso
Washington
Logan
Pitkin
Lake
Scale 1:1,650,000
km
0 20 40 60
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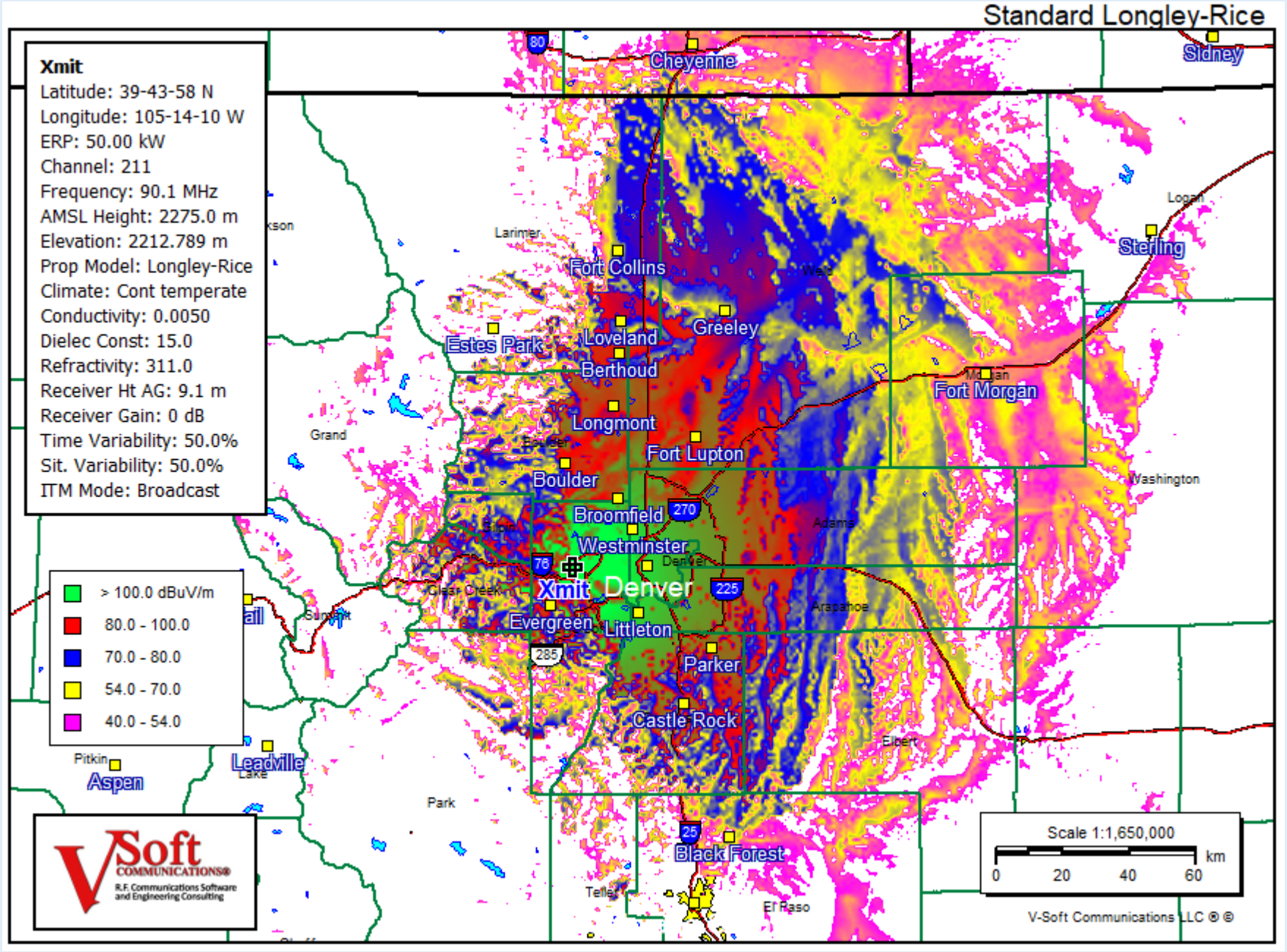
R.F. Communications Software and Engineering Consulting


Standard Longley-Rice
Xmit
Latitude: 39-43-58 N
Longitude: 105-14-10 W
ERP: 50.00 kW
Channel: 211
Frequency: 90.1 MHz
AMSL Height: 2275.0 m
Elevation: 2212.789 m
Prop Model: Longley-Rice
Climate: Cont temperate
Conductivity: 0.0050
Dielec Const: 15.0
Refractivity: 311.0
Receiver Ht AG: 9.1 m
Receiver Gain: 0 dB
Time Variability: 50.0%
Sit. Variability: 50.0%
ITM Mode: Broadcast
> 100.0 dBuV/m
80.0 - 100.0
70.0 - 80.0
54.0 - 70.0
40.0 - 54.0
Cheyenne
Sidney
Fort Collins
Sterling
Greeley
Loveland
Estes Park
Berthoud
Fort Morgan
Longmont
Fort Lupton
Boulder
Broomfield
Westminster
Xmit
Denver
Evergreen
Littleton
Parker
Castle Rock
Aspen
Leadville
Black Forest
Scale 1:1,650,000
km
0
20
40
60
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R.F. Communications Software and Engineering Consulting

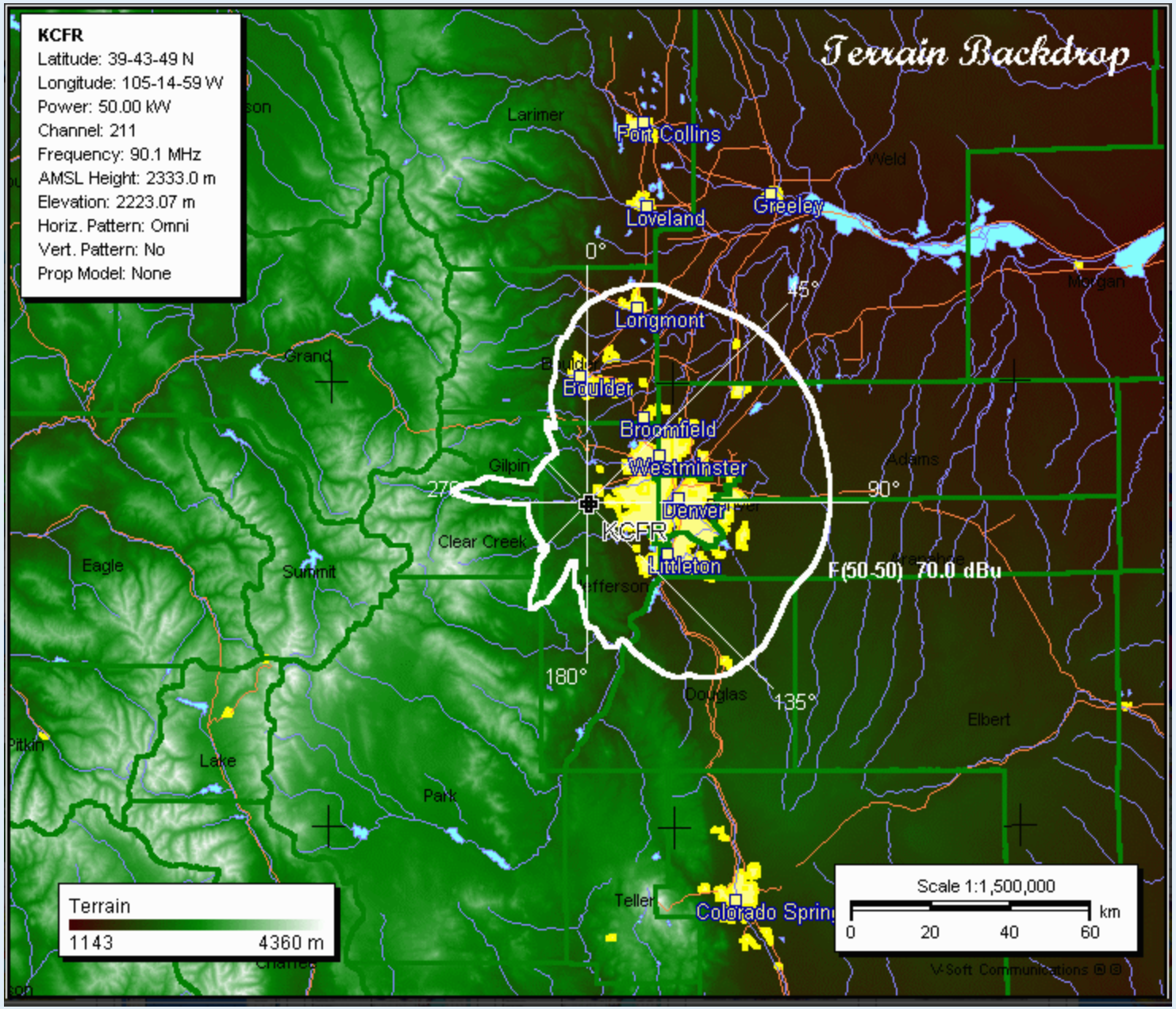
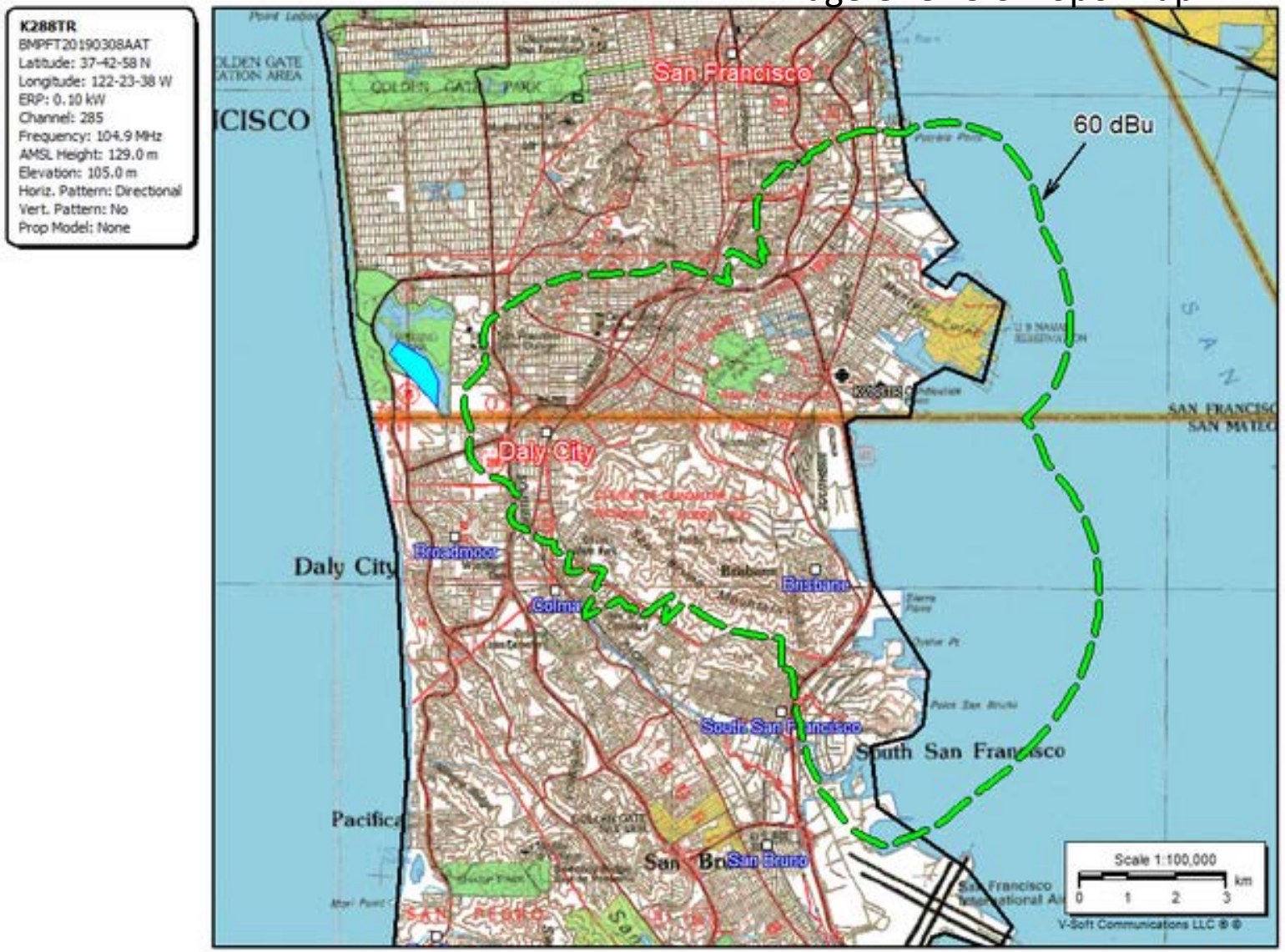

KCFR
Latitude: 39-43-49 N
Longitude: 105-14-59 W
Power: 50.00 kW
Channel: 211
Frequency: 90.1 MHz
AMSL Height: 2333.0 m
Elevation: 2223.07 m
Horiz. Pattern: Omni
Vert. Pattern: No
Prop Model: None
Terrain Backdrop
Larimer
Fort Collins
Weld
Loveland
Greeley
Morgan
0°
45°
Longmont
Grand
Boulder
Broomfield
Gilpin
Westminster
Adams
270°
90°
Denver
KCFR
Clear Creek
Littleton
F(50,50) 70.0 dBu
Eagle
Summit
Jefferson
180°
Douglas
135°
Elbert
Pitkin
Lake
Park
Teller
Colorado Spring
Terrain
1143
4360 m
Scale 1:1,500,000
km
0
20
40
60
V-Soft Communications

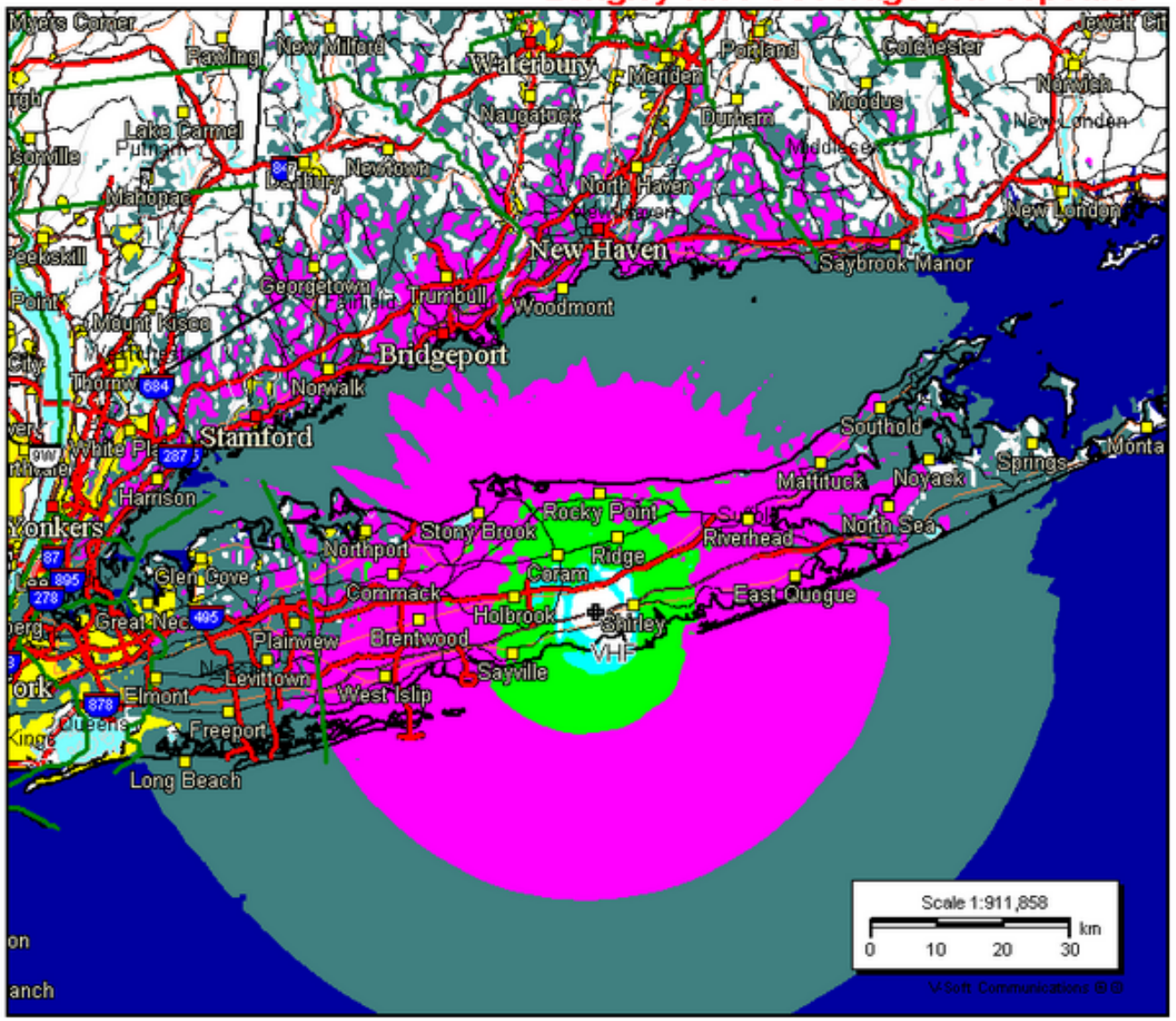
Image Over U.S. Topo Map



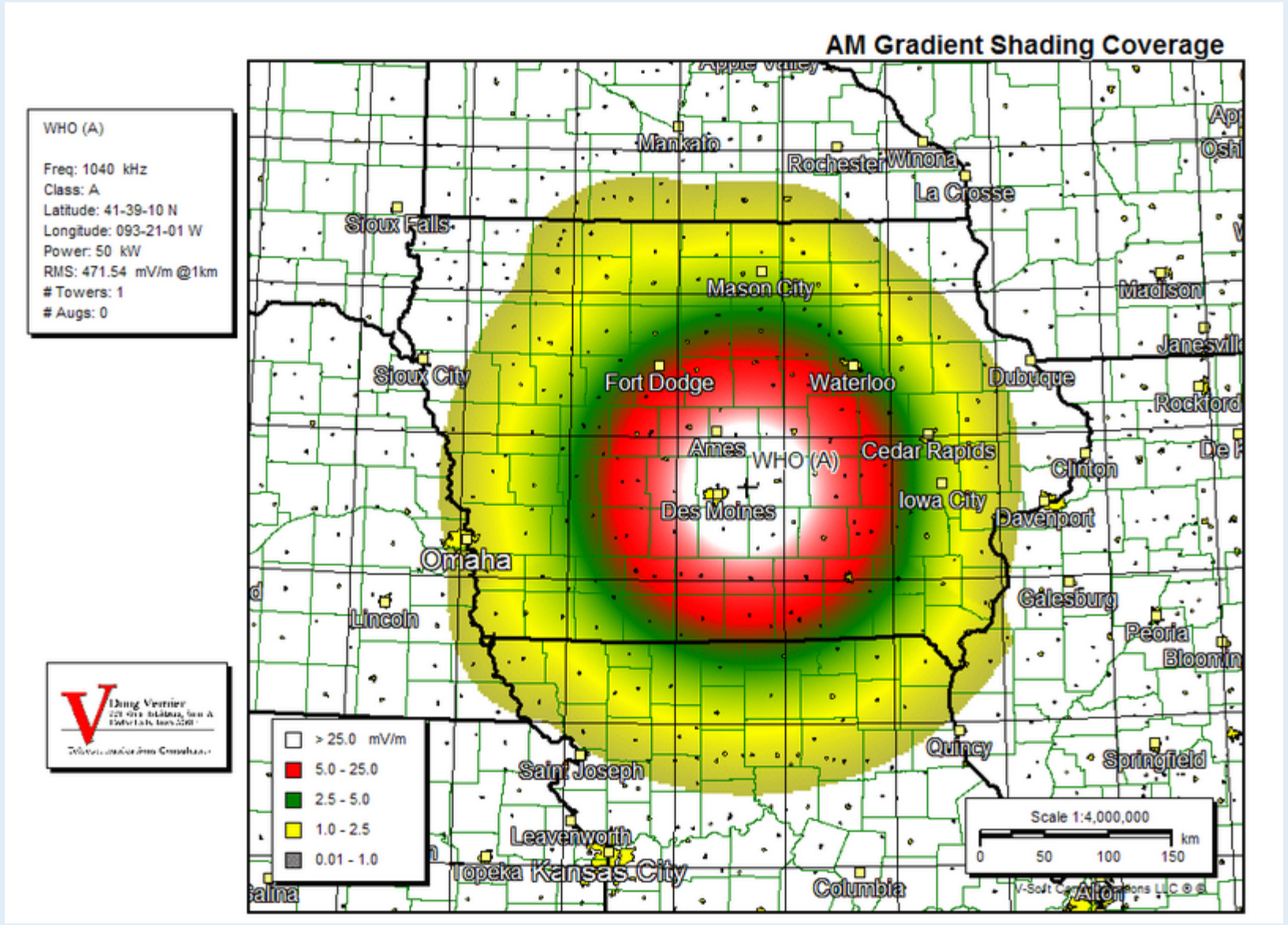
Longley-Rice Coverage VHF repeater

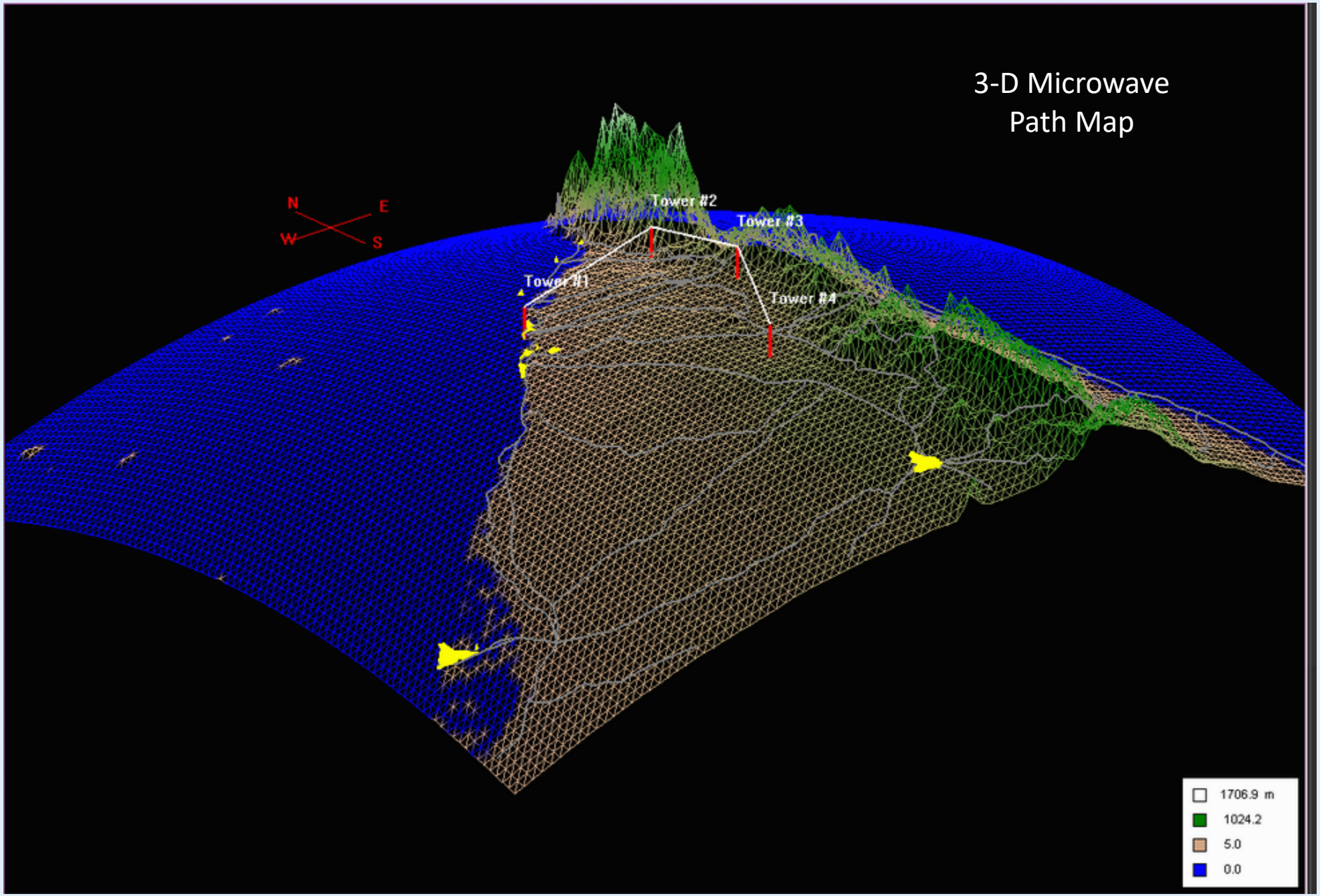
VHF
Latitude: 40-47-31.03 N
Longitude: 072-56-04.34 W
Power: 400.00 W
EIRP Used: 656.00 W
Frequency: 145.21 MHz
AMSL Height: 61.0 m
Elevation: 0.0 m
Horiz. Pattern: Omni
Vert. Pattern: No
Prop Model: Longley/Rice
Climate: Cont temperate
Conductivity: 0.0050
Dielec Const: 15.0
Refractivity: 311.0
Receiver Ht AG: 1.5 m
Receiver Gain: 0 dB
Time Variability: 50.0%
Sit. Variability: 50.0%
ITM Mode: Broadcast
Legend starts at .01 mV/m

Prepared by:
Doug Vernier, K0DV
Web Address:
WWW.V-Soft.COM

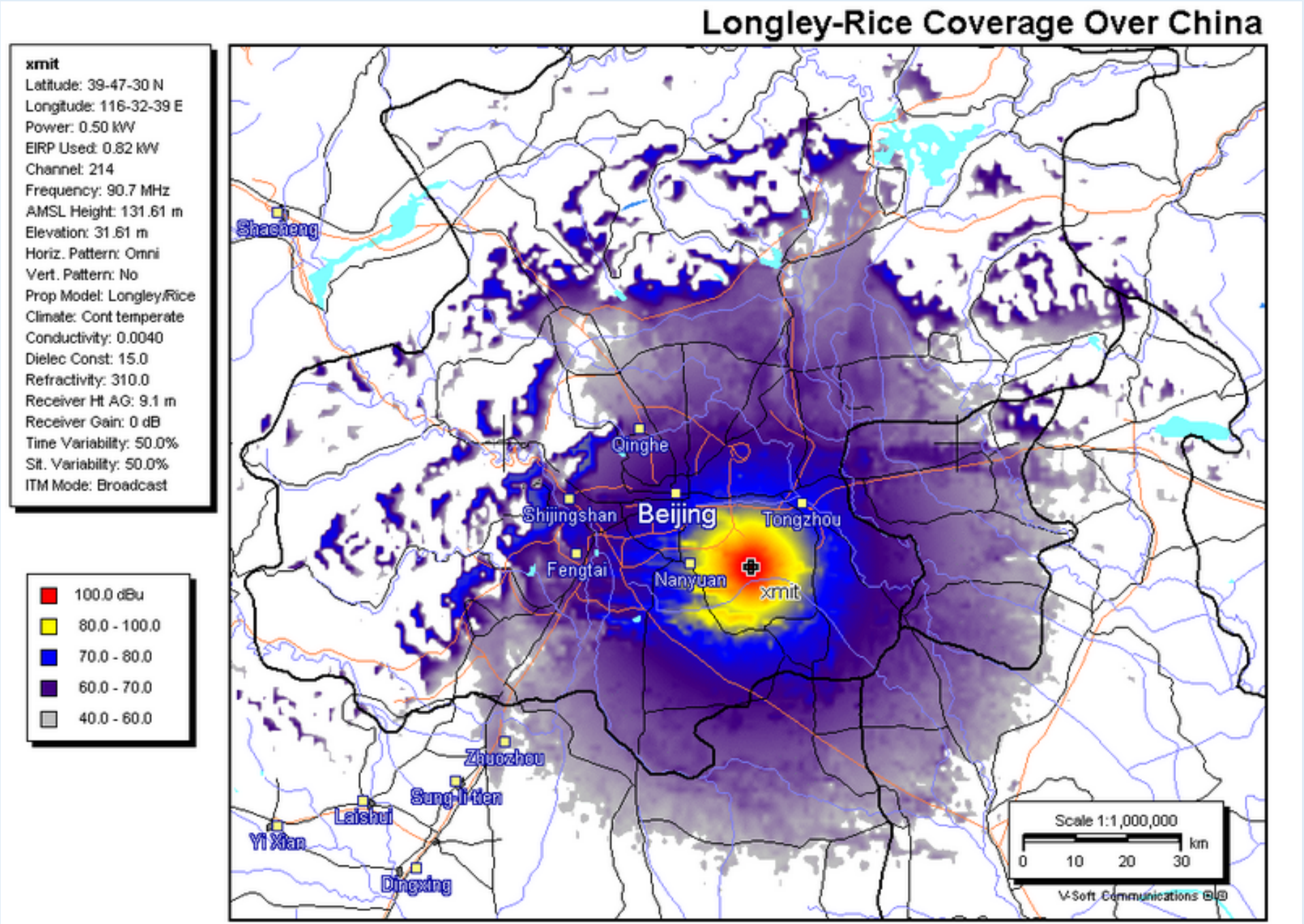


AM Gradient Shading Coverage

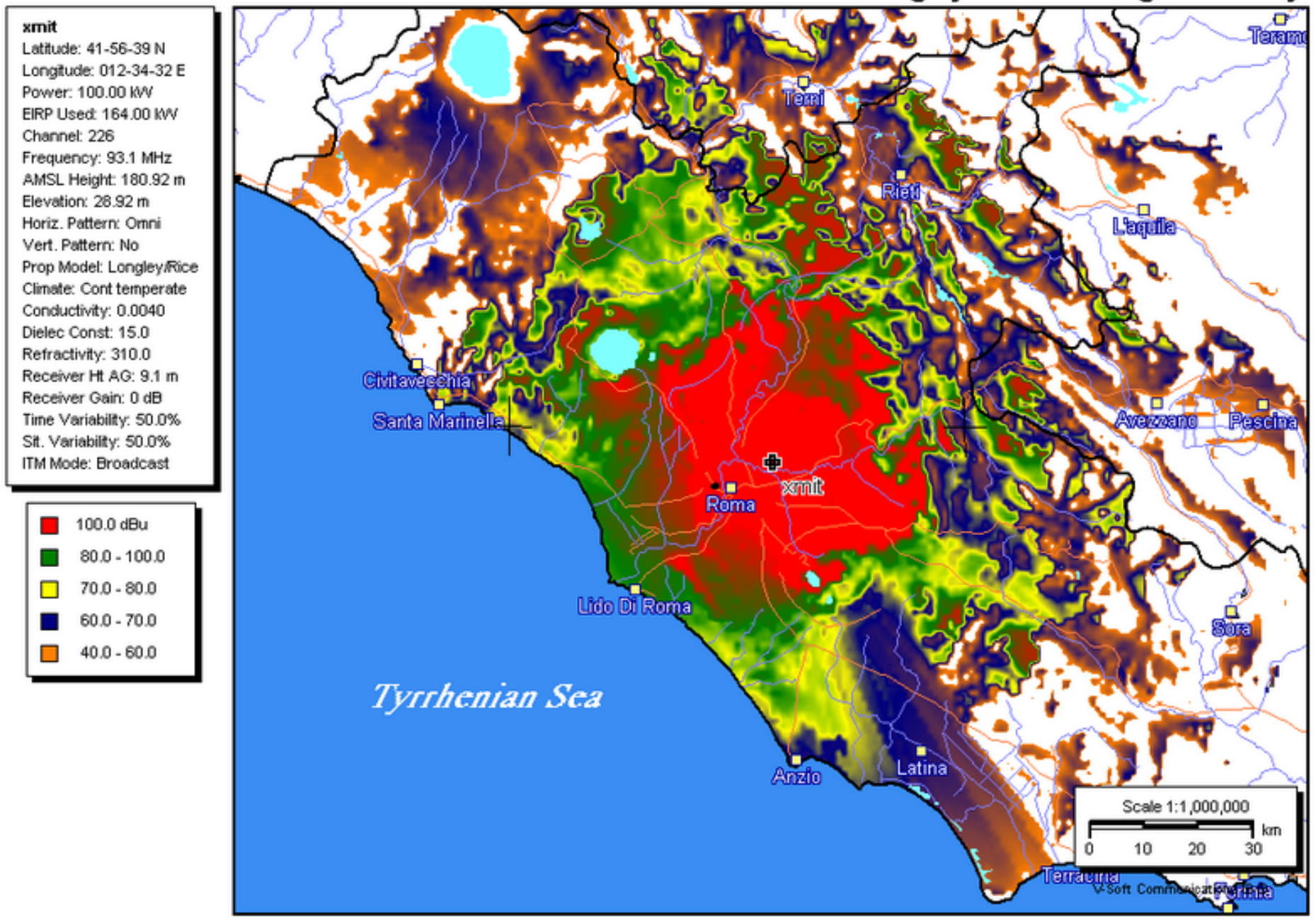



3-D Microwave
Path Map
N
E
W
S
Tower #1
Tower #2
Tower #3
Tower #4
1706.9 m
1024.2
5.0
0.0

Longley-Rice Coverage Over China



Longley-Rice Coverage over Italy



Thank you

Visualizing Radio Propagation

Doug Vernier

Broadcaster's Clinic

2022