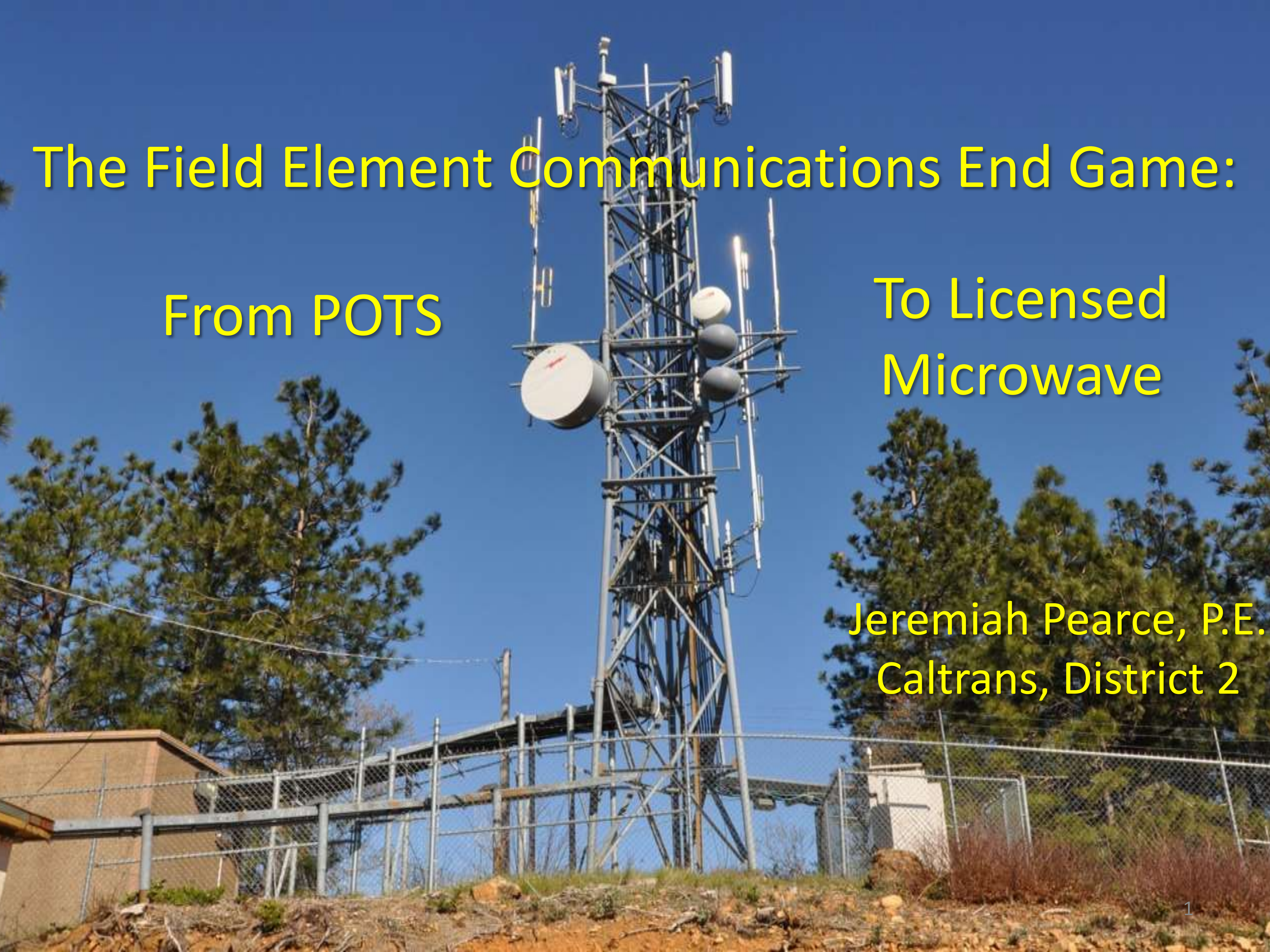


The Field Element Communications End Game:

From POTS

To Licensed Microwave

Jeremiah Pearce, P.E.
Caltrans, District 2

Presentation Summary

- Concept review

Presentation Summary

- Concept review
- Interference

Presentation Summary

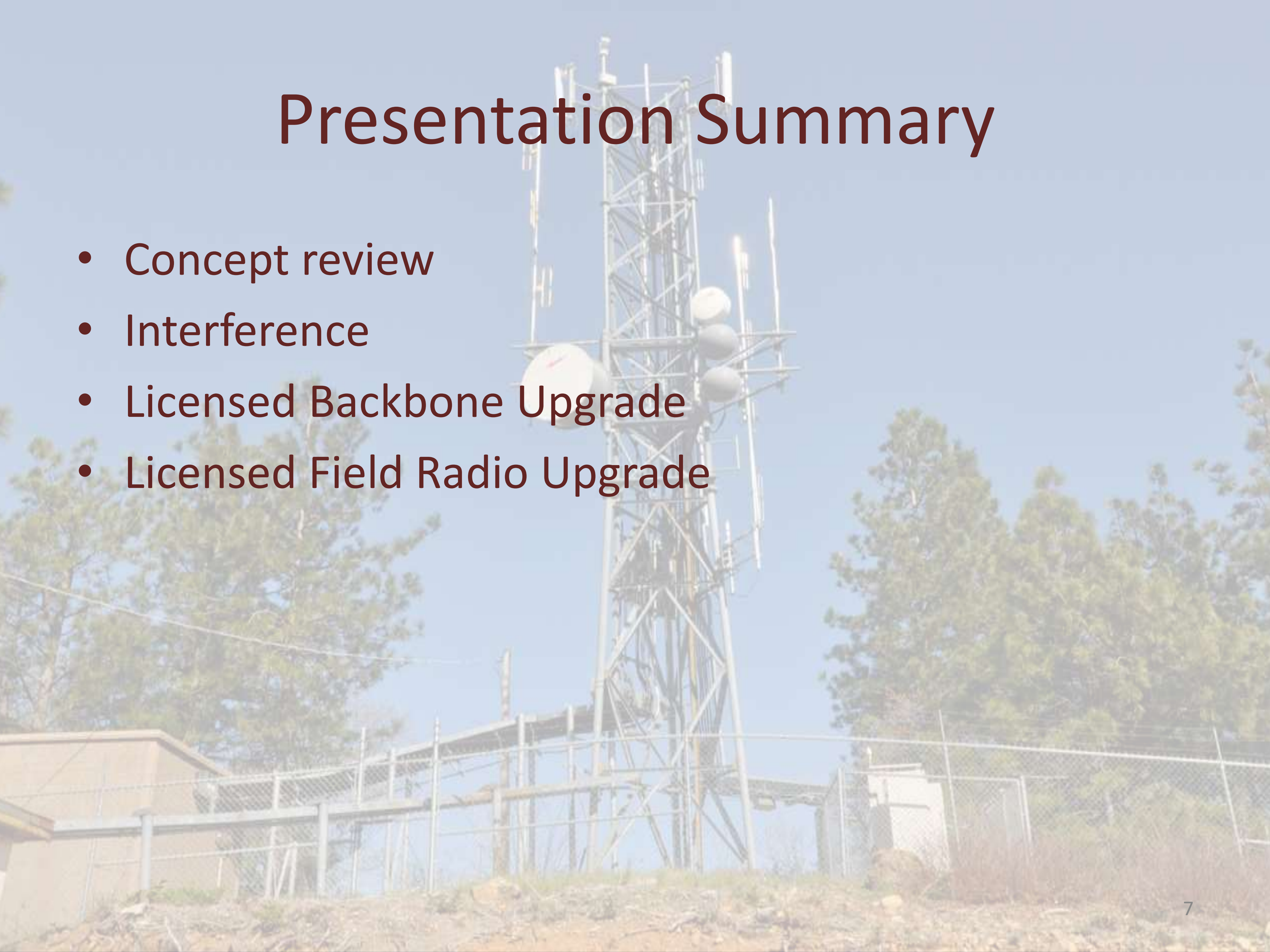
- Concept review
- Interference
- Licensed Backbone Upgrade

Presentation Summary

- Concept review
- Interference
- Licensed Backbone Upgrade
  - Last step in our deployment strategy

Presentation Summary

- Concept review
- Interference
- Licensed Backbone Upgrade
  - Last step in our deployment strategy
  - Desire for higher bandwidth to the roadside and frequency protection.



Presentation Summary

- Concept review
- Interference
- Licensed Backbone Upgrade
- Licensed Field Radio Upgrade

Presentation Summary

- Concept review
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Presentation Summary

- Concept review
- Interference
- Licensed Backbone Upgrade
- Licensed Field Radio Upgrade
- Towers Project

Presentation Summary

- Concept review
- Interference
- Licensed Backbone Upgrade
- Licensed Field Radio Upgrade
- Towers Project
  - Driven by field radio upgrade antenna requirements

Presentation Summary

- Concept review
- Interference
- Licensed Backbone Upgrade
- Licensed Field Radio Upgrade
- Towers Project
- Bradley north backbone extension

Presentation Summary

- Concept review
- Interference
- Licensed Backbone Upgrade
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- Bradley north backbone extension
  - Next hop north of Sugarloaf

Presentation Summary

- Concept review
- Interference
- Licensed Backbone Upgrade
- Licensed Field Radio Upgrade
- Towers Project
- Bradley north backbone extension
  – Next hop north of Sugarloaf
  – Expand microwave system up the I-5 corridor.

Presentation Summary

- Concept review
- Interference
- Licensed Backbone Upgrade
- Licensed Field Radio Upgrade
- Towers Project
- Bradley north backbone extension
  - Next hop north of Sugarloaf
  - Expand microwave system up the I-5 corridor.
  - Move ISM band equipment to edge

List of Acronyms

FCC – Federal Communications Commission

FDD – Frequency-Division Duplexing

TDD – Time-Division Duplexing

IDU – Indoor Unit

ODU – Outdoor Unit

POTS – Plain Old Telephone Service

ISDN – Integrated Services Digital Network

ISM – Industrial, Scientific, and Medical (License free spectrum)

TMC – Transportation Management Center

List of Acronyms

IP – Internet Protocol

ITS – Intelligent Transportation System

DDR – Dial-on-Demand

PSTN – Public Switched Telephone Network

RSL – Received Signal Level

ARP – Address Resolution Protocol

NMS – Network Management System

SSH – Secure Shell

SSL – Secure Sockets Layer

LTE – Long Term Evolution

Concept Review

- Relevant Past Presentations
  - "Microwave Communications for Rural ITS Applications", Ian Turnbull, June 2006 http://www.westernstatesforum.org/Documents/2006/2006%20WSRTTIF%20Turnbull.pdf
    - Relevant topics
      - Deployment strategy
      - Frequency planning
      - Path clearances and calculations
      - Reliability requirements
      - Link Budget

Concept Review

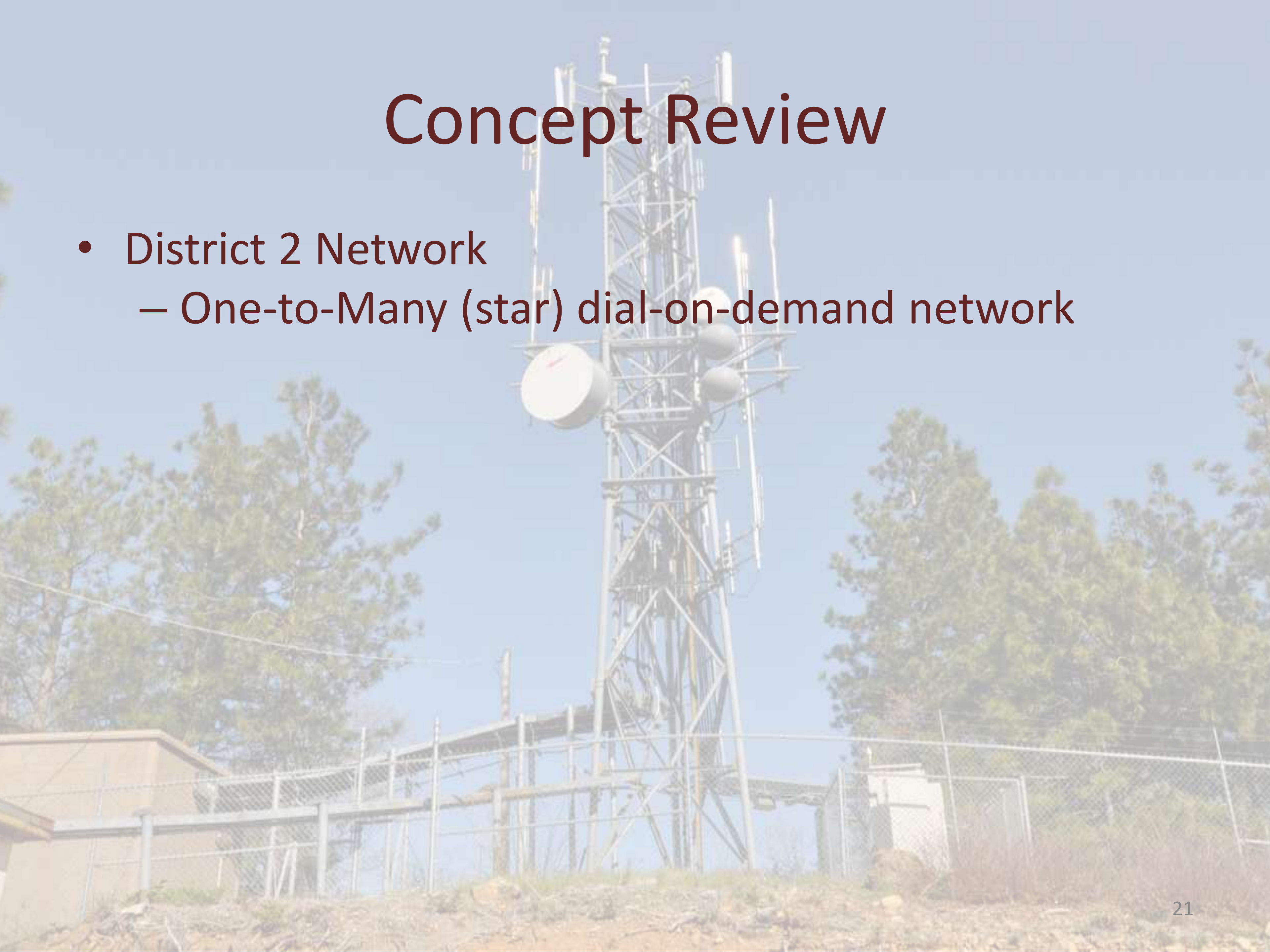
- Relevant Past Presentations
  - “Field Element Network Design for a Rural Transportation Management Center, Parts One and Two” Ian Turnbull and Jeremiah Pearce, June 2012
- Relevant topics
  - Small, winter operations, wildfires, floods, major freight corridor incidents, etc.
  - Harsh field conditions, telecommunications issues
  - TMC architecture (Dial-on-Demand, ITS Node, etc)

Concept Review

- Relevant Past Presentations
  - “Field Element Network Design for a Rural Transportation Management Center, Parts One and Two” Ian Turnbull and Jeremiah Pearce, June 2012

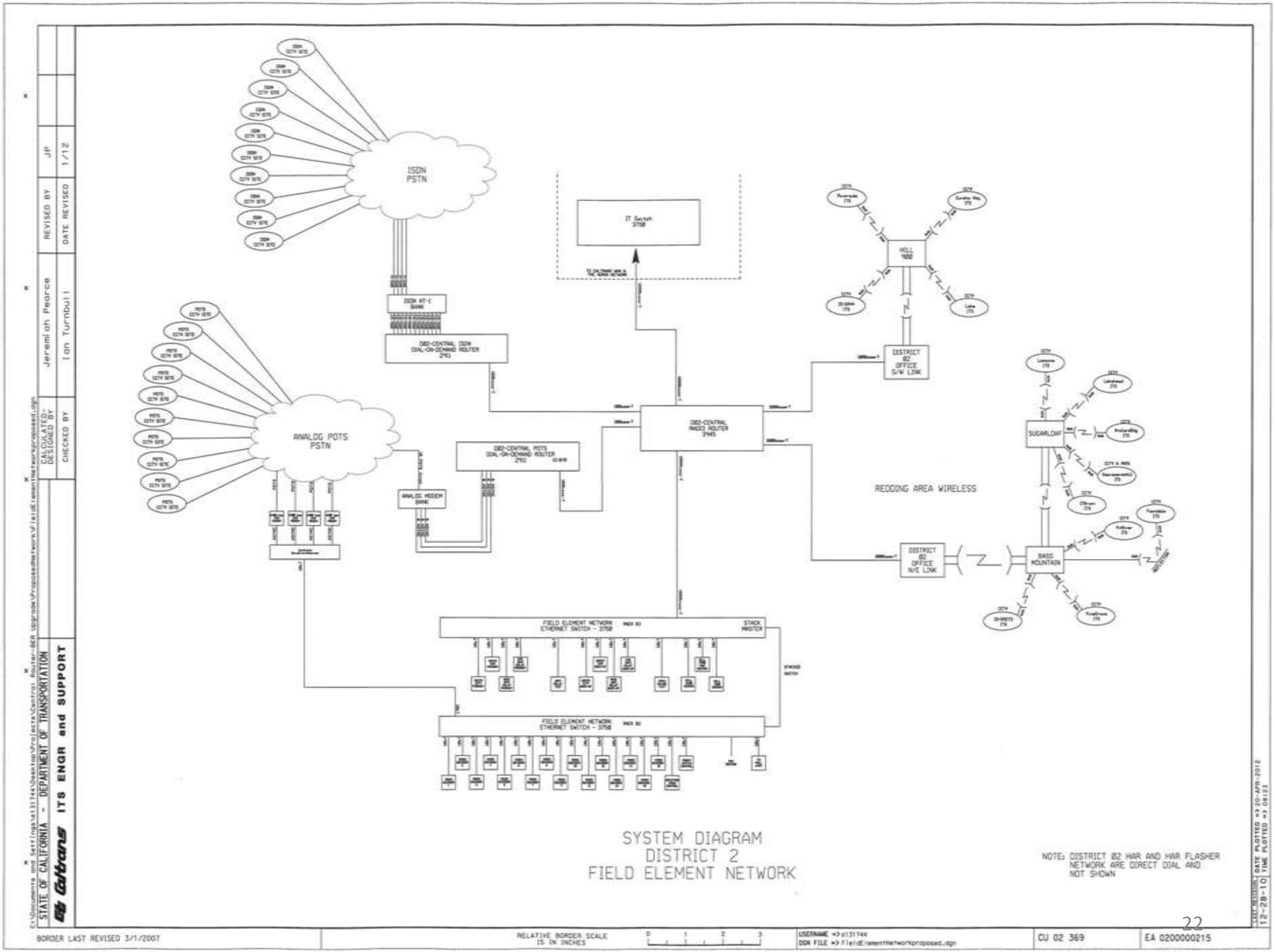
http://www.westernstatesforum.org/Documents/2012/presentations/CaltransD2_Turnbull_FINAL_FEN-TMCPrequel.pdf

http://www.westernstatesforum.org/Documents/2012/presentations/CaltransD2_Pearce_Final2_FEN_TMC_Part2.pdf



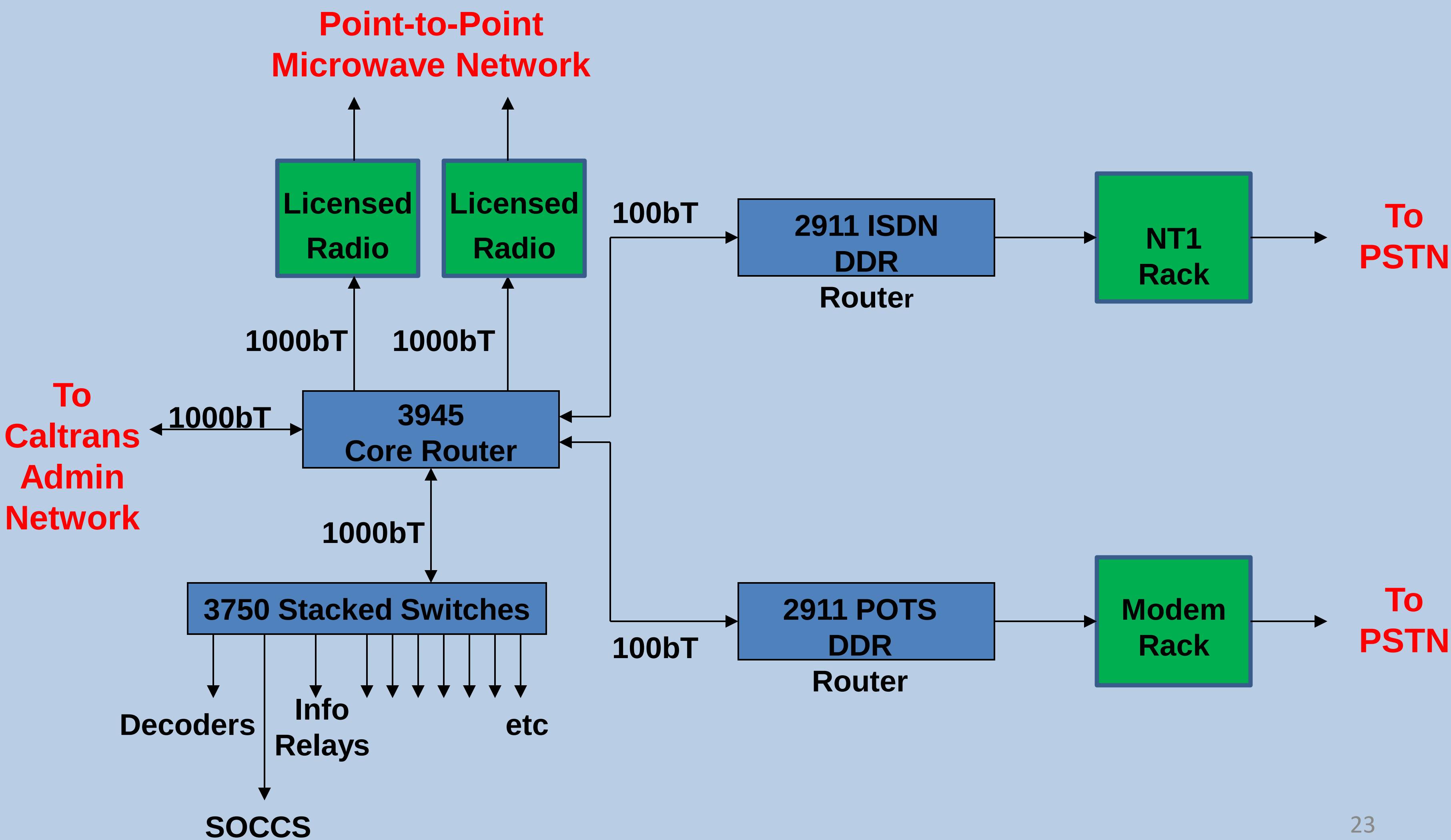
Concept Review

- District 2 Network
  - One-to-Many (star) dial-on-demand network



ISDN PSTN
ISDN NT-1 BANK
D02-CENTRAL ISDN DIAL-ON-DEMAND ROUTER 2901
IT Switch 3750
ANALOG POTS PSTN
ANALOG MODEM BANK
D02-CENTRAL POTS DIAL-ON-DEMAND ROUTER 2901
D02-CENTRAL RADIO ROUTER 3945
HILL 900
DISTRICT 02 OFFICE S/W LINK
SUGARLOAF
BASS MOUNTAIN
DISTRICT 02 OFFICE N/E LINK
REDDING AREA WIRELESS
FIELD ELEMENT NETWORK ETHERNET SWITCH - 3750
STACK MASTER
SYSTEM DIAGRAM
DISTRICT 2
FIELD ELEMENT NETWORK
NOTE: DISTRICT 02 HAR AND HAR FLASHER NETWORK ARE DIRECT DIAL AND NOT SHOWN
STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION
Caltrans ITS ENGR and SUPPORT
CALCULATED-DESIGNED BY Jeremiah Pearce
CHECKED BY Ian Turnbull
REVISED BY JP
DATE REVISED 1/12
BORDER LAST REVISED 3/1/2007
RELATIVE BORDER SCALE IS IN INCHES
CU 02 369
EA 0200000215
LAST REVISION 12-28-10

FEN Core

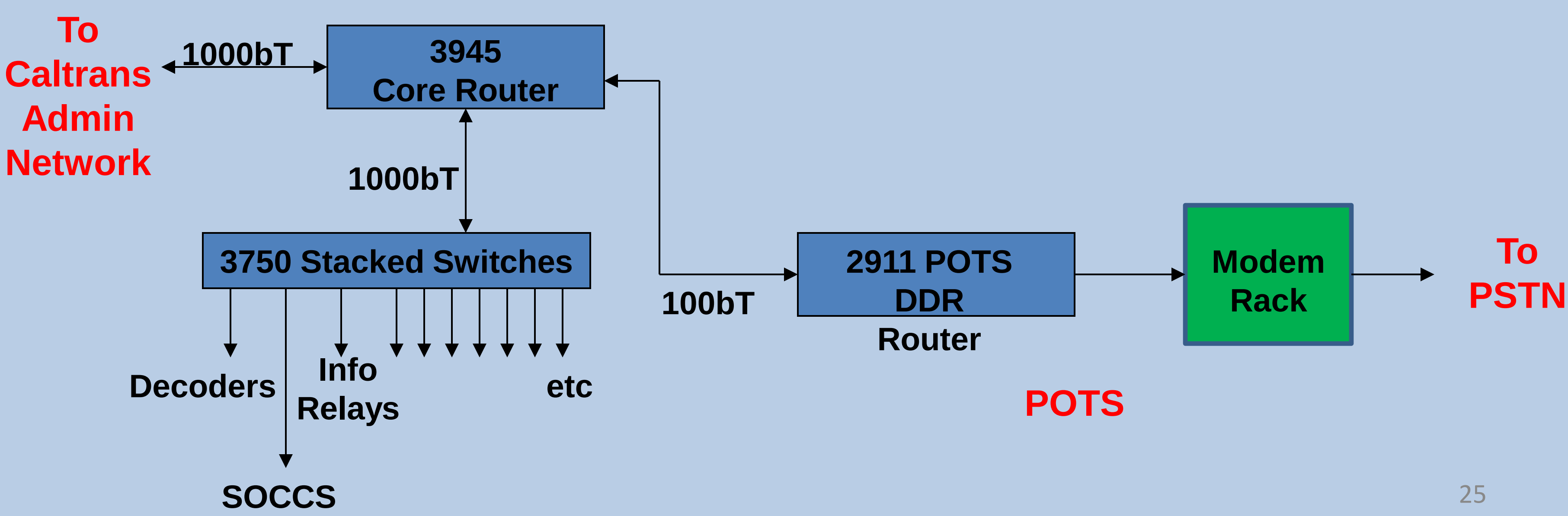


Point-to-Point
Microwave Network
Licensed Radio
Licensed Radio
1000bT
1000bT
100bT
2911 ISDN DDR Router
NT1 Rack
To PSTN
To Caltrans Admin Network
1000bT
3945 Core Router
1000bT
3750 Stacked Switches
Decoders
Info Relays
etc
SOCCS
100bT
2911 POTS DDR Router
Modem Rack
To PSTN

Concept Review

- District 2 Network
  - One-to-Many (star) dial-on-demand network
    - POTS

FEN Core



To
Caltrans
Admin
Network
1000bT
3945
Core Router
1000bT
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Decoders
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Relays
etc
SOCCS
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2911 POTS
DDR
Router
POTS
Modem
Rack
To
PSTN

Concept Review

- District 2 Network
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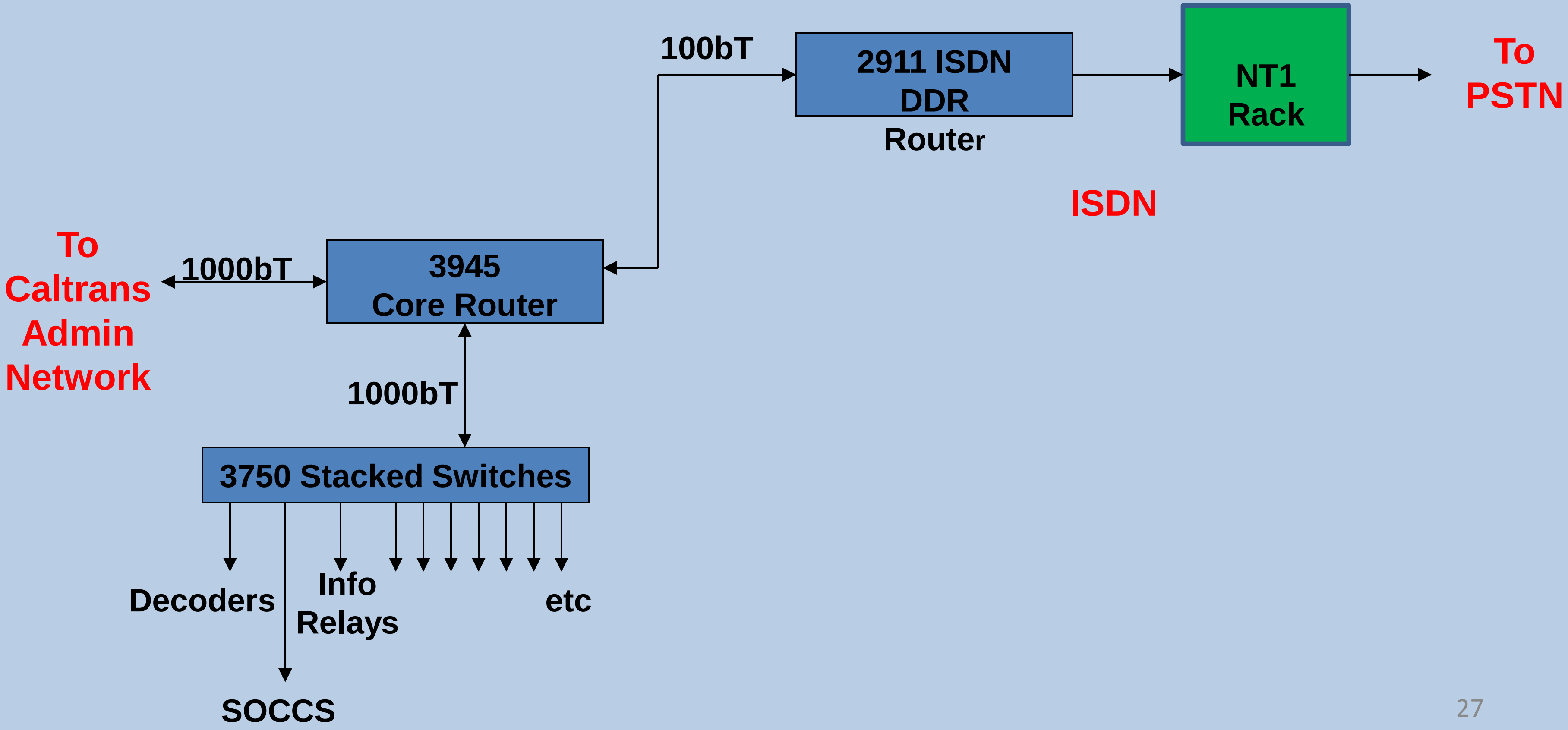
    - ISDN

FEN Core


100bT
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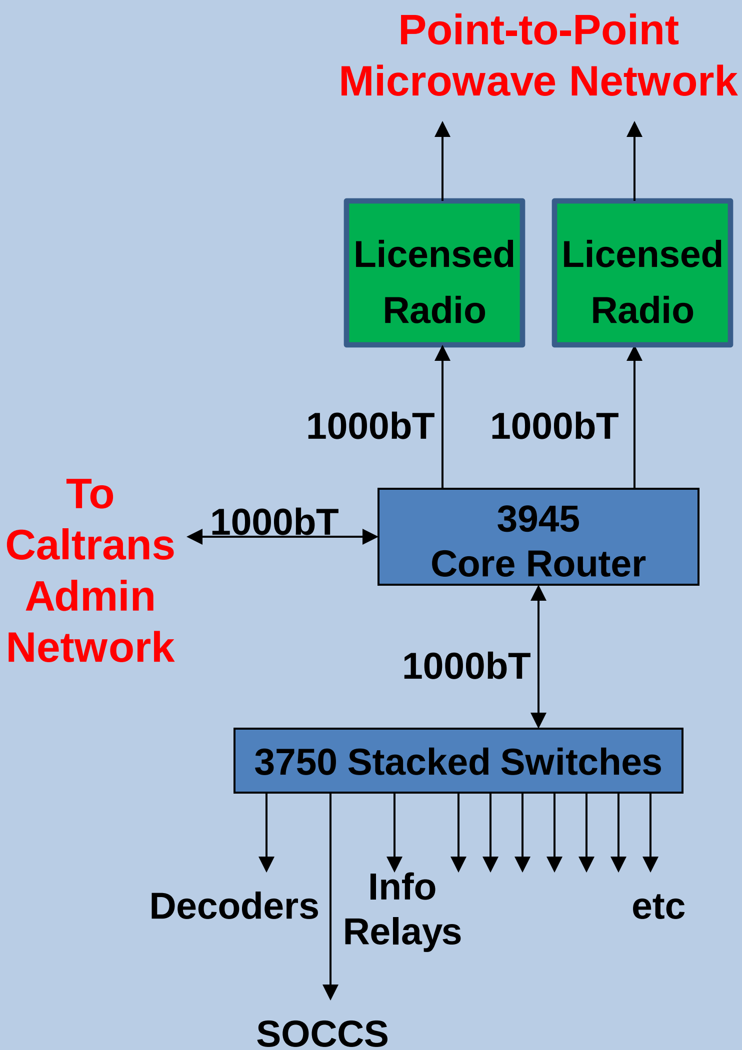
  - Point-to-Point Microwave network (extended star)

FEN Core



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  - All IP network

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Concept Review

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    - ISDN
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  - Why IP is important
    - Layered approach

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    - Troubleshooting tools

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    - Layered approach
    - Portability
    - Scalability
    - Troubleshooting tools
    - Off the shelf equipment is deployable quickly

Concept Review

- District 2 Network Deployment Strategy
  - Phased deployment approach

Concept Review

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  - Phased deployment approach
    - Site turn-up: Best available “inexpensive” and reliable Telco services

Concept Review

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    - Upgrade to ISM band microwave overtime if Line-of-Site is available

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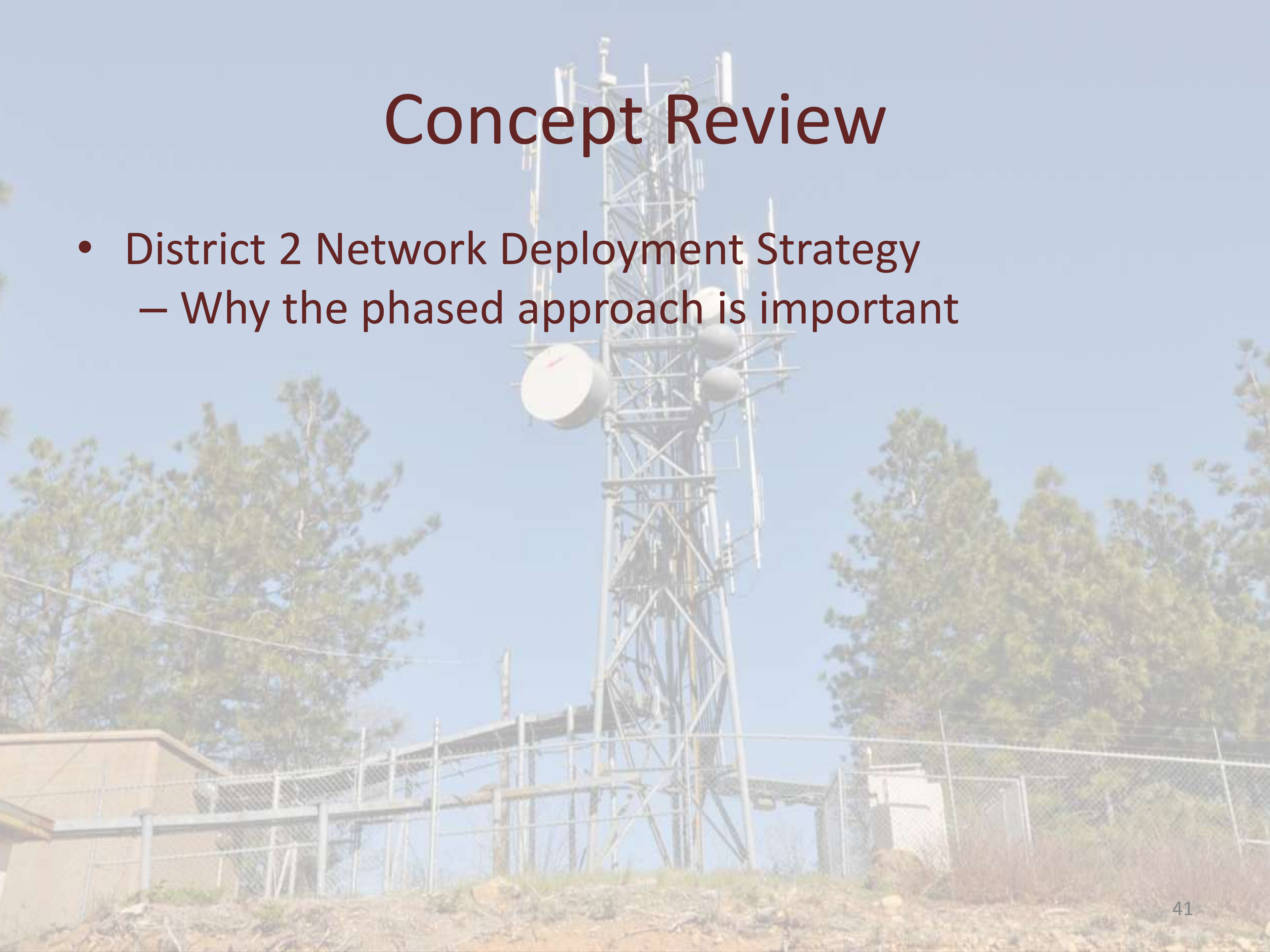
- District 2 Network Deployment Strategy
  - Phased deployment approach
    - Site turn-up: Best available “inexpensive” and reliable Telco services
    - Upgrade to ISM band microwave overtime if Line-of-Site is available
    - Upgrade from ISM band to licensed microwave for frequency protection



Concept Review

- District 2 Network Deployment Strategy
  - Why the phased approach is important

Concept Review

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  - Why the phased approach is important
    - Turning up with Telco services is quick, establishing a presence in a communication facility can take time, even if your already in (i.e. need more rack space)

Concept Review

- District 2 Network Deployment Strategy
  - Why the phased approach is important
    - Turning up with Telco services is quick, establishing a presence in a communication facility can take time, even if your already in (i.e. need more rack space)
    - Having Telco connectivity buys us time to establish an ISM band link. ISM band link connectivity then buys additional time to license the link. We sacrifice frequency protection going to ISM, but the bandwidth is improved from the Telco services

It can take time to get your equipment into an existing facility

Concept Review

- District 2 Network Deployment Strategy
  - Why the phased approach is important

Concept Review

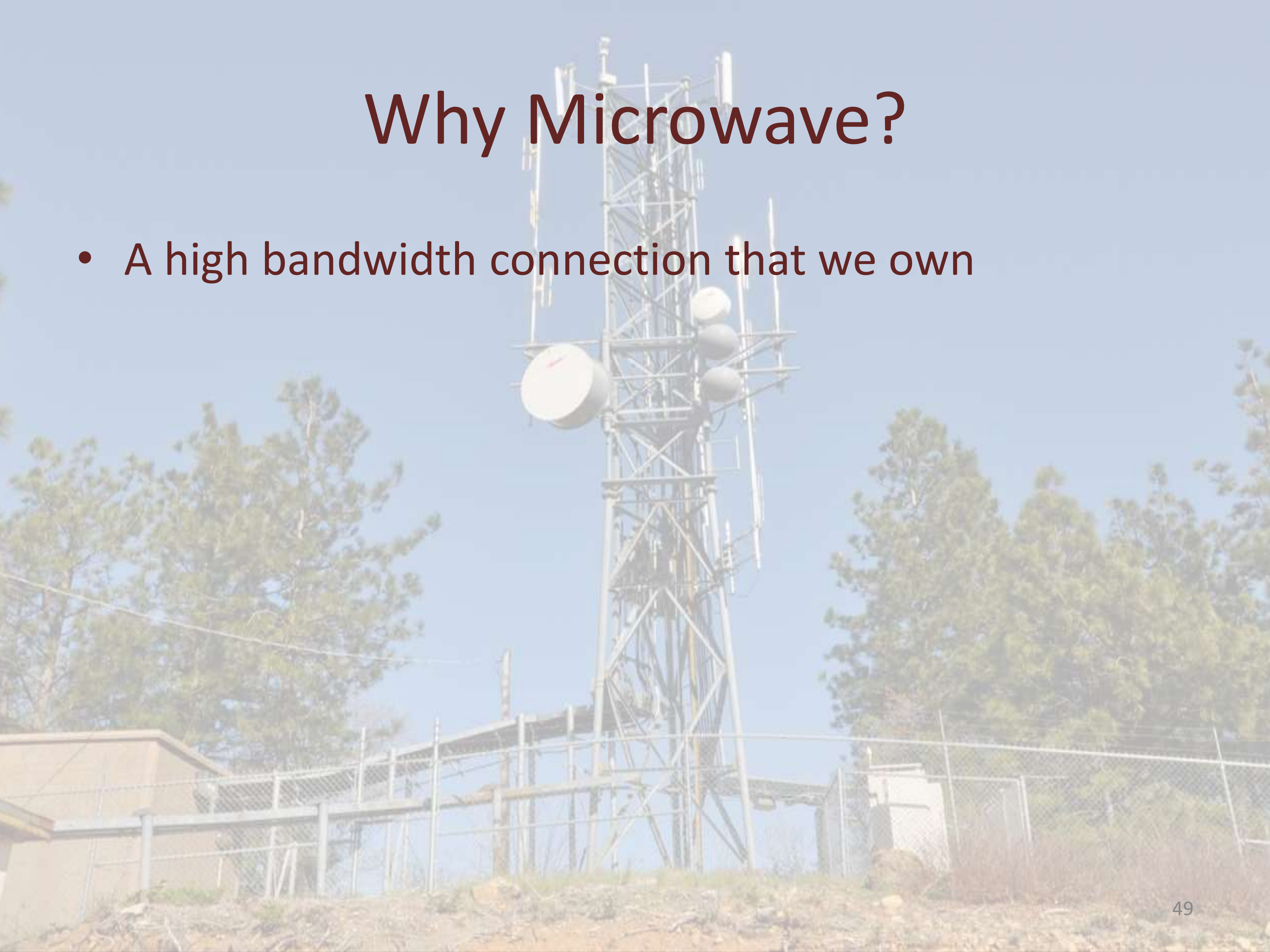
- District 2 Network Deployment Strategy
  - Why the phased approach is important
    - Finally, upgrade to licensed microwave. Allows highest bandwidth connection, frequency protection, the link is always on, and we own it.

Concept Review

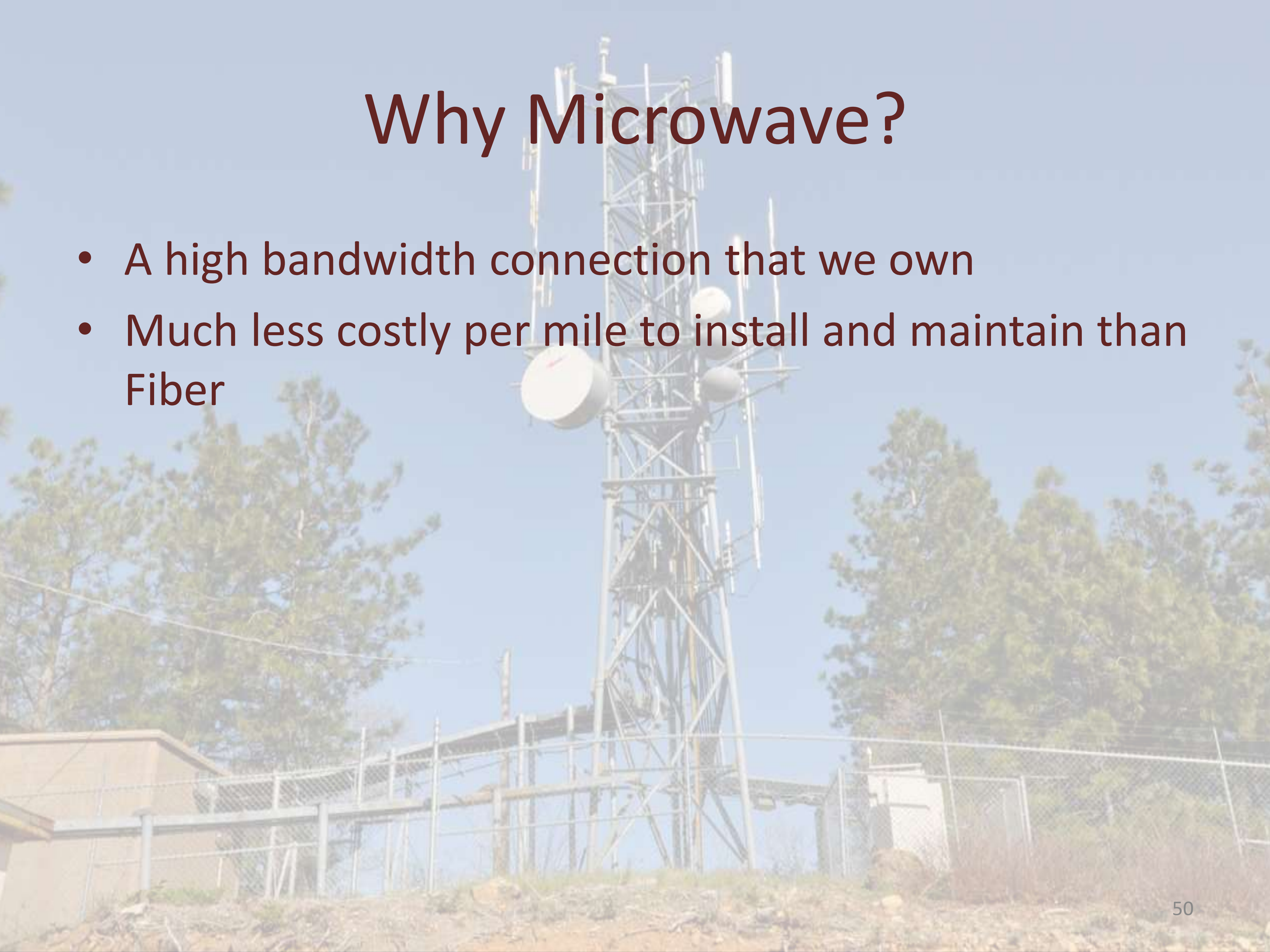
- District 2 Network Deployment Strategy
  – Why the phased approach is important
    - Finally, upgrade to licensed microwave. Allows highest bandwidth connection, frequency protection, the link is always on, and we own it.
    - Deployment strategy has proven effective for the last 10 years, though we have had interference issues on the ISM band, which, we've been able to effectively mitigate.

Why Microwave?

- A high bandwidth connection that we own



Why Microwave?



- A high bandwidth connection that we own
- Much less costly per mile to install and maintain than Fiber

Why Microwave?

- A high bandwidth connection that we own
- Much less costly per mile to install and maintain than Fiber
- Frequency protection from interference sources

Interference Issues

- ISM bands without frequency protected links are susceptible to interference

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- Where and when it usually happens

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  - Mtn Tops (though not always!) because they are aggregation points

High potential for interference

Interference Issues

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  - Often coincides with recent activity at the sites (construction, user upgrades, maintenance, etc.)

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- Where and when it usually happens
  - Mtn Tops (though not always!) because they are aggregation points
  - Often coincides with recent activity at the sites (construction, user upgrades, maintenance, etc.)
- What it does
  - Raises the receiver threshold, which reduces fade margin and link reliability

Interference Issues

- How it manifests itself

Interference Issues

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  - Fading, link seems intermittent

Interference Issues

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  - Fading, link seems intermittent
  - If it’s a strong signal overpowering the link, the interference will bring down the link, but if the violating signal isn’t always on the interference will manifest itself as intermittent

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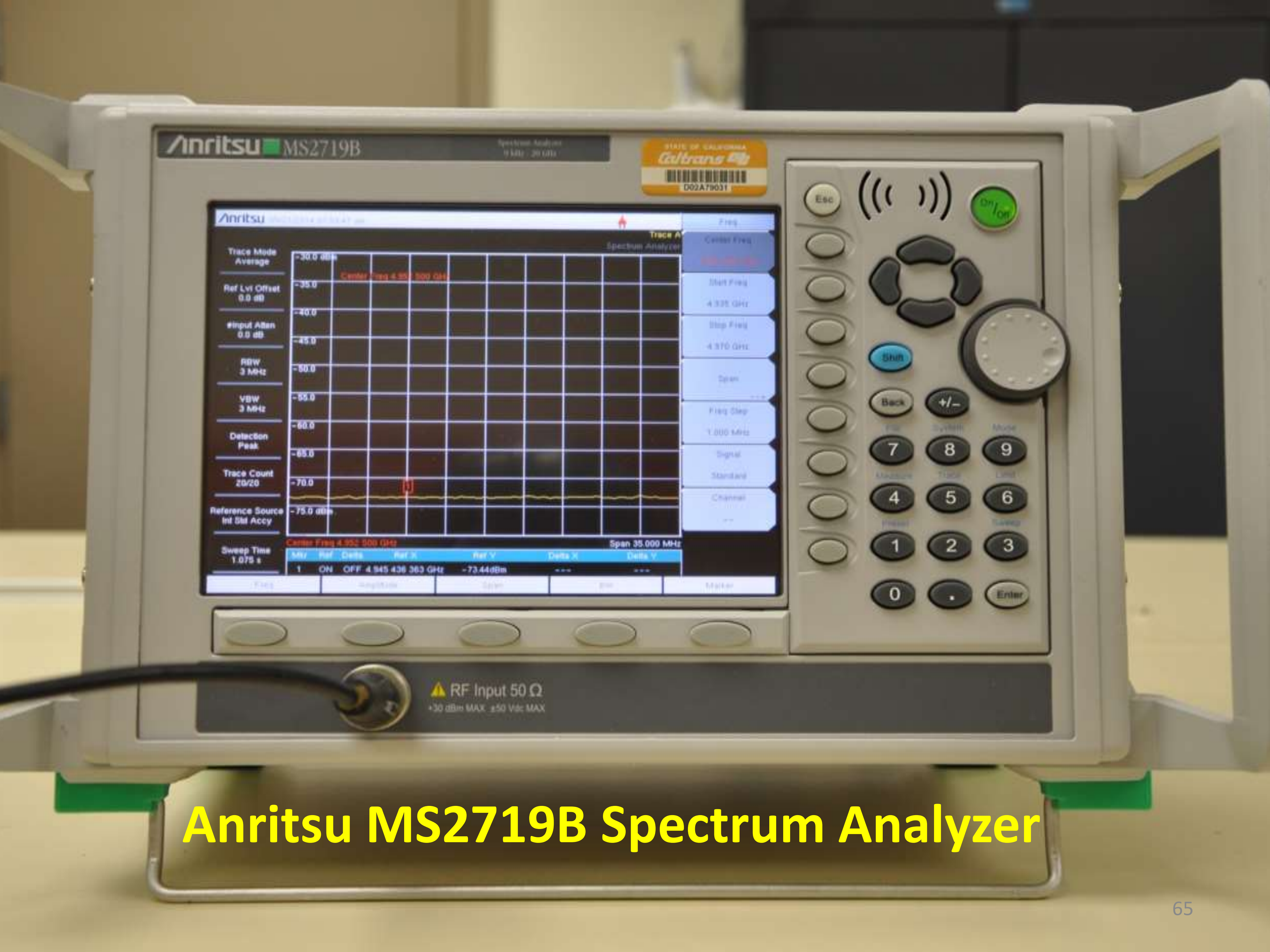
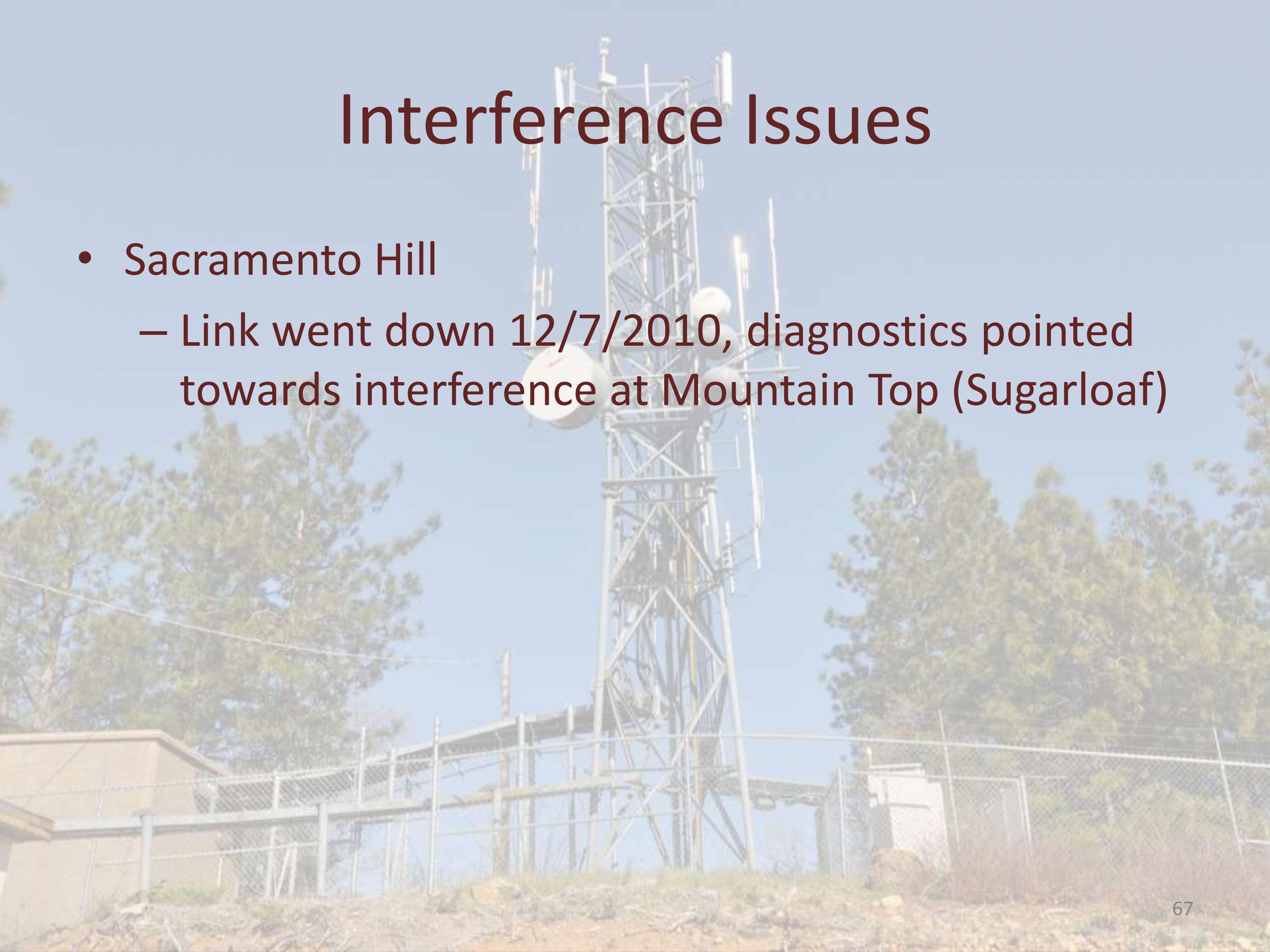
  - Spectrum Analyzer with a noise floor low enough to see your receiver threshold, as low as -95 dBm



Anritsu MS2719B Spectrum Analyzer

Interference Issues

- How it manifests itself
  - Fading, link seems intermittent
  - If it's a strong signal overpowering the link, the interference will bring down the link, but if the violating signal isn't always on the interference will manifest itself as intermittent
  - Not Symmetric (to both ends of the link)
- Troubleshooting tools
  - Spectrum Analyzer with a noise floor low enough to see your receiver threshold, as low as -95 dBm
  - Careful site inspection, what's changed



Interference Issues

- Sacramento Hill
  - Link went down 12/7/2010, diagnostics pointed towards interference at Mountain Top (Sugarloaf)

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  - RSL levels dropped (likely due to an icing event) and link went down intermittently

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  - Violating signal still present, difficult to peak dish
  - Fading event 3/27/2012
  - RSL levels dropped (likely due to an icing event) and link went down intermittently
  - Fact that the violating signal was still there, raised the noise floor, reducing margin and link reliability


Upper Sugarloaf Site


Upper Sugarloaf Site

Upper Sugarloaf Site

Interference Issues

- Sacramento Hill
- Obrien
  - Link went down 5/25/2011

Interference Issues

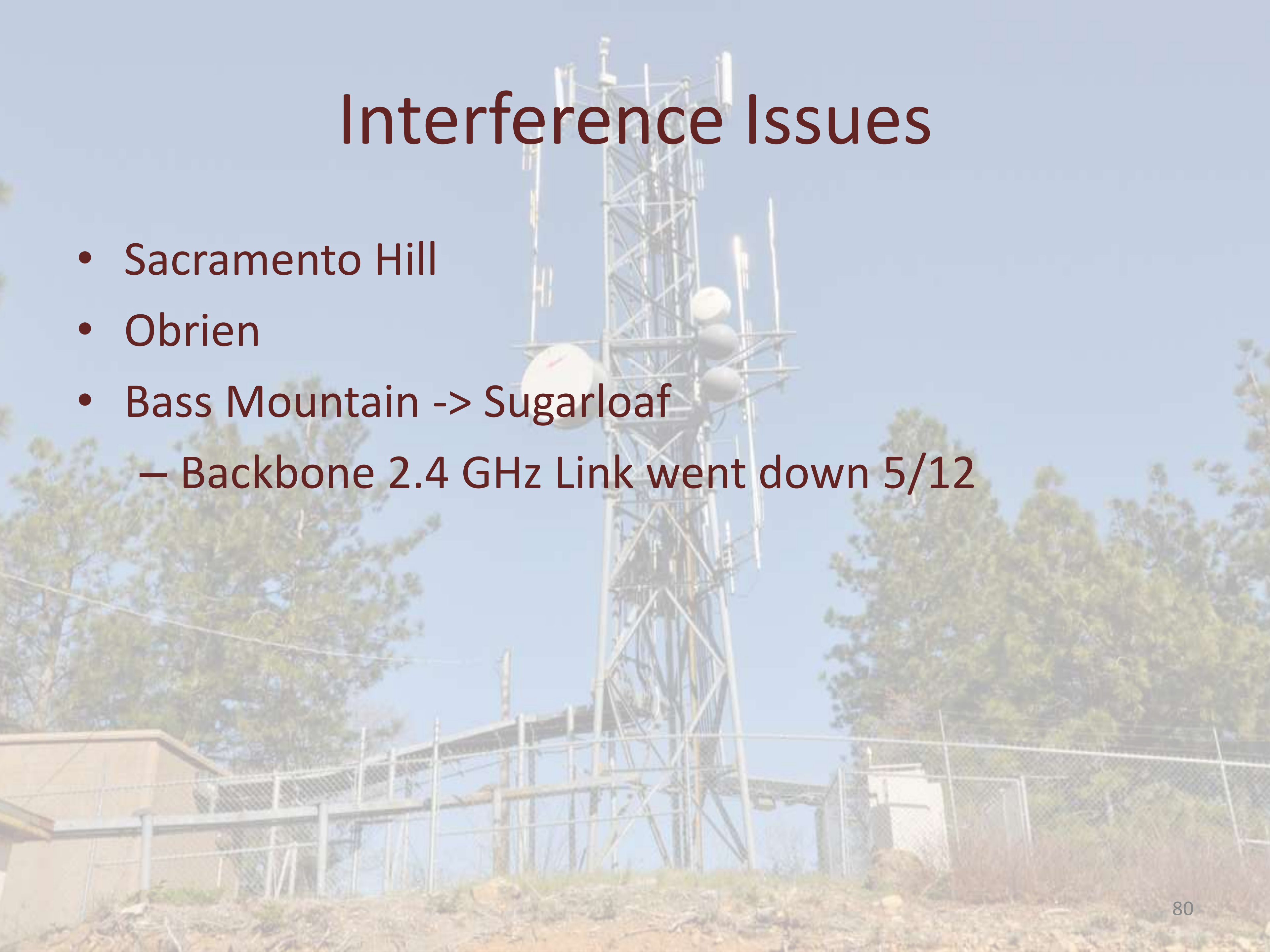
- Sacramento Hill
- Obrien
  - Link went down 5/25/2011
  - Diagnostics pointed towards interference

Interference Issues

- Sacramento Hill
- Obrien
  - Link went down 5/25/2011
  - Diagnostics pointed towards interference
  - Swapped filters to put the link on a different channel and restored link

Interference Issues

- Sacramento Hill
- Obrien
  - Link went down 5/25/2011
  - Diagnostics pointed towards interference
  - Swapped filters to put the link on a different channel and restored link
  - Noticed some variation in RSL at hilltop, but link has been solid since



Interference Issues

- Sacramento Hill
- Obrien
- Bass Mountain -> Sugarloaf
  - Backbone 2.4 GHz Link went down 5/12

Interference Issues

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- Obrien
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  - Time it was down correlated w/ a tech for another agency at the site

Interference Issues

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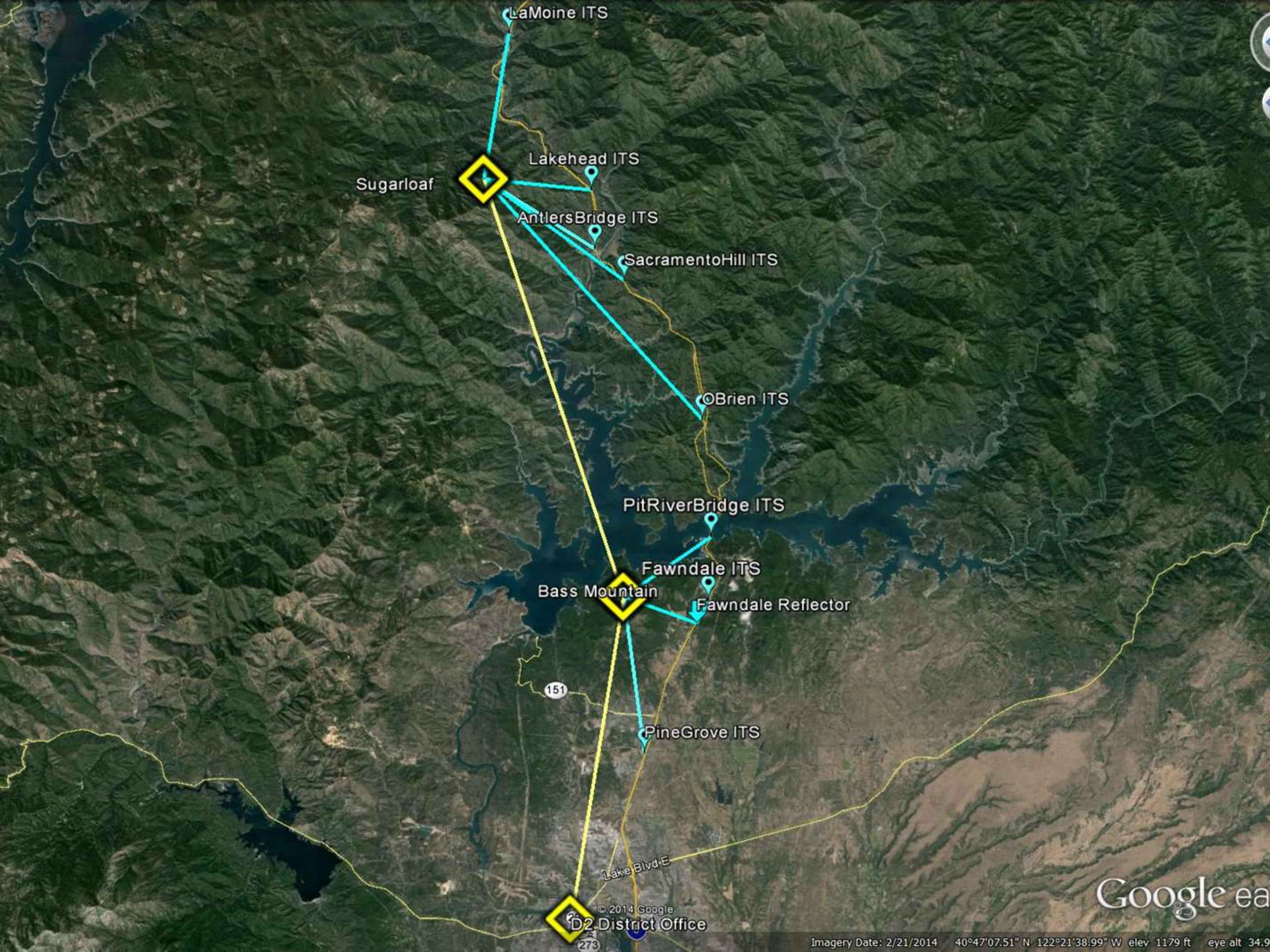
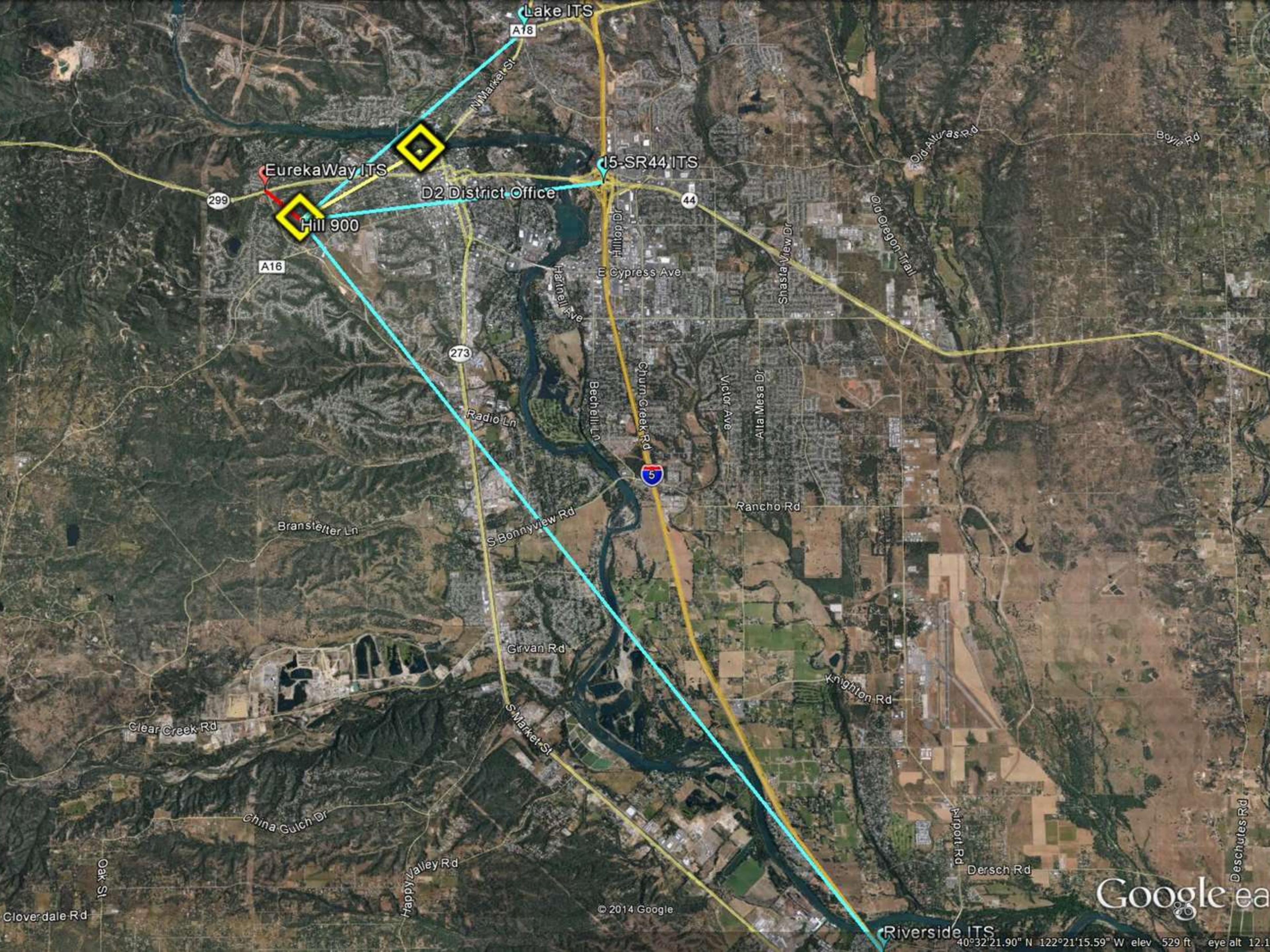
- Obrien
- Bass Mountain -> Sugarloaf
  - Backbone 2.4 GHz Link went down 5/12
  - Diagnostics pointed towards interference
  - Came back up after a few hours
  - Time it was down correlated w/ a tech for another agency at the site
  - Suspect Wi-Fi or mobile hotspot device active



LaMoine ITS
Lakehead ITS
Sugarloaf
AntlersBridge ITS
SacramentoHill ITS
OBrien ITS
PitRiverBridge ITS
Fawndale ITS
Bass Mountain
Fawndale Reflector
151
PineGrove ITS
Lake Blvd E
© 2014 Google
D2 District Office
273
Imagery Date: 2/21/2014
40°47'07.51" N 122°21'38.99" W elev 1179 ft



Lake ITS
A18
N Market St
EurekaWay ITS
I5-SR44 ITS
D2 District Office
Hill 900
299
44
A16
Old Alturas Rd
Boyle Rd
Old Oregon Trail
Shasta View Dr
Hilltop Dr
E Cypress Ave
Hartnell Ave
273
Churn Creek Rd
Victor Ave
Alta Mesa Dr
Bechelli Ln
Radio Ln
5
Rancho Rd
Branstetter Ln
S Bonnyview Rd
Girvan Rd
Knighton Rd
Clear Creek Rd
S Market St
China Gulch Dr
Happy Valley Rd
Airport Rd
Dersch Rd
Deschutes Rd
Oak St
Cloverdale Rd
© 2014 Google
Riverside ITS
40°32'21.90" N 122°21'15.59" W elev 529 ft eye alt 12.1

MICROWAVE BACKBONE

Backbone Network Deployment Strategy

- Deployment strategy
  - Initiate presence with ISM equipment

Backbone Network Deployment Strategy

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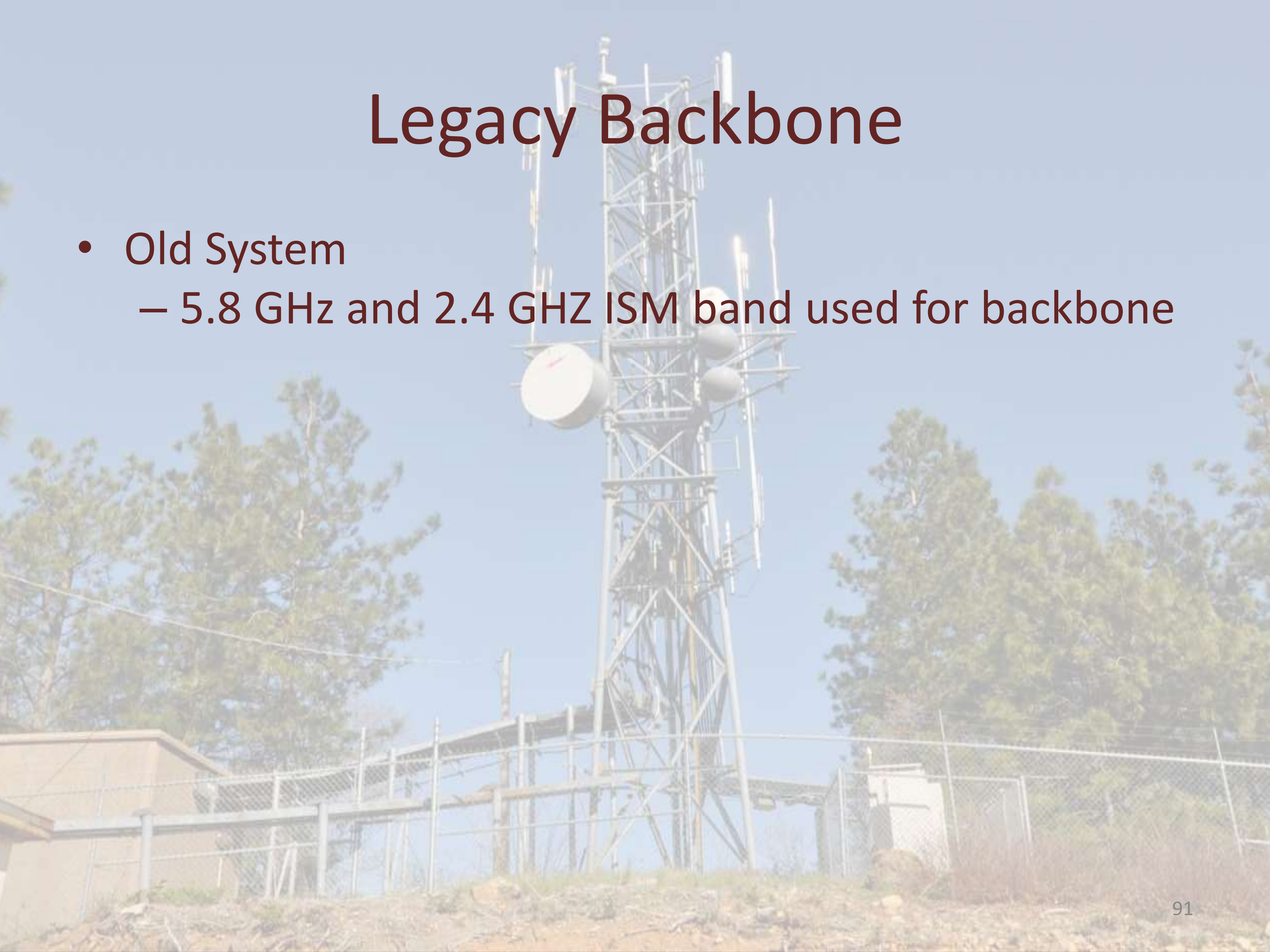
  - Initiate presence with ISM equipment
  - ISM equipment buys time to license.

Backbone Network Deployment Strategy

- Deployment strategy
  - Initiate presence with ISM equipment
  - ISM equipment buys time to license.
  - After license upgrade, remove ISM equipment and install at network edge to continue expanding coverage, continue this process until full build out complete.

Legacy Backbone

- Old System
  – 5.8 GHz and 2.4 GHZ ISM band used for backbone



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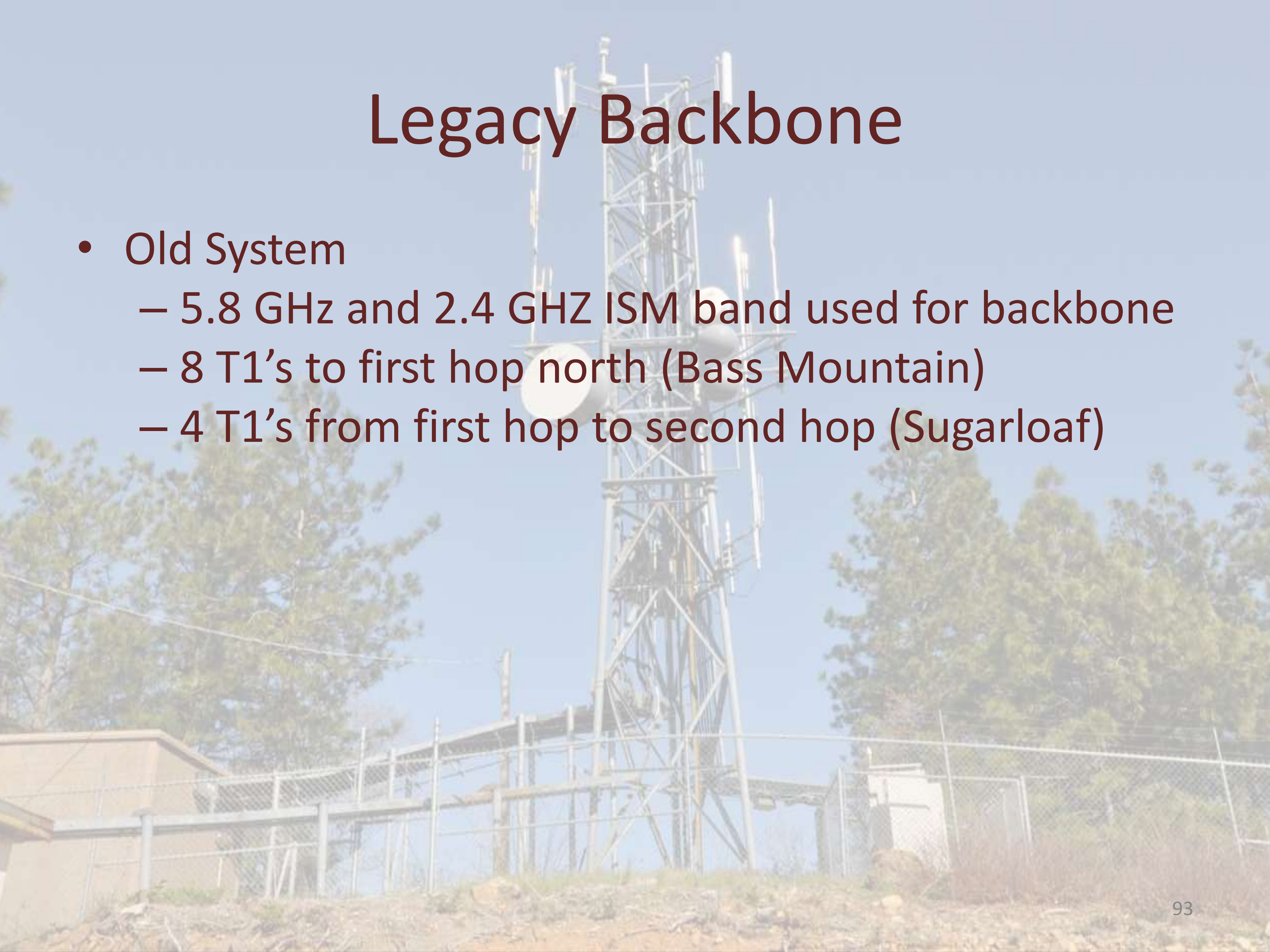

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- Old System
  - 5.8 GHz and 2.4 GHZ ISM band used for backbone
  - 8 T1’s to first hop north (Bass Mountain)
  - 4 T1’s from first hop to second hop (Sugarloaf)
  - Roadside radio’s serial (approx ¼ T1)
  - Western Multiplex radio’s, proven reliable carrier grade radios
  - Excellent sensitivity, approx -90 dBm
  - Direct Sequence Spread Spectrum
  - Full Duplex

Western Multiplex radio front view

Western Multiplex radio rear view

Legacy Backbone

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  - 28+ potential sites North, 12+ potential sites East
  - Not enough capacity for all potential sites, and no room for video upgrade (Frame Rate, resolution, etc)
  - Channelization issues at Mt Tops. Some Mtn Tops can support 7 or 8 roadside sites. Not enough spectrum for roadside links.

Time to upgrade the microwave backbone

Licensed Backbone Upgrade

- Requirements:
  - Frequency protection

Licensed Backbone Upgrade

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  - Higher bandwidth: 100+ Mbps

Licensed Backbone Upgrade

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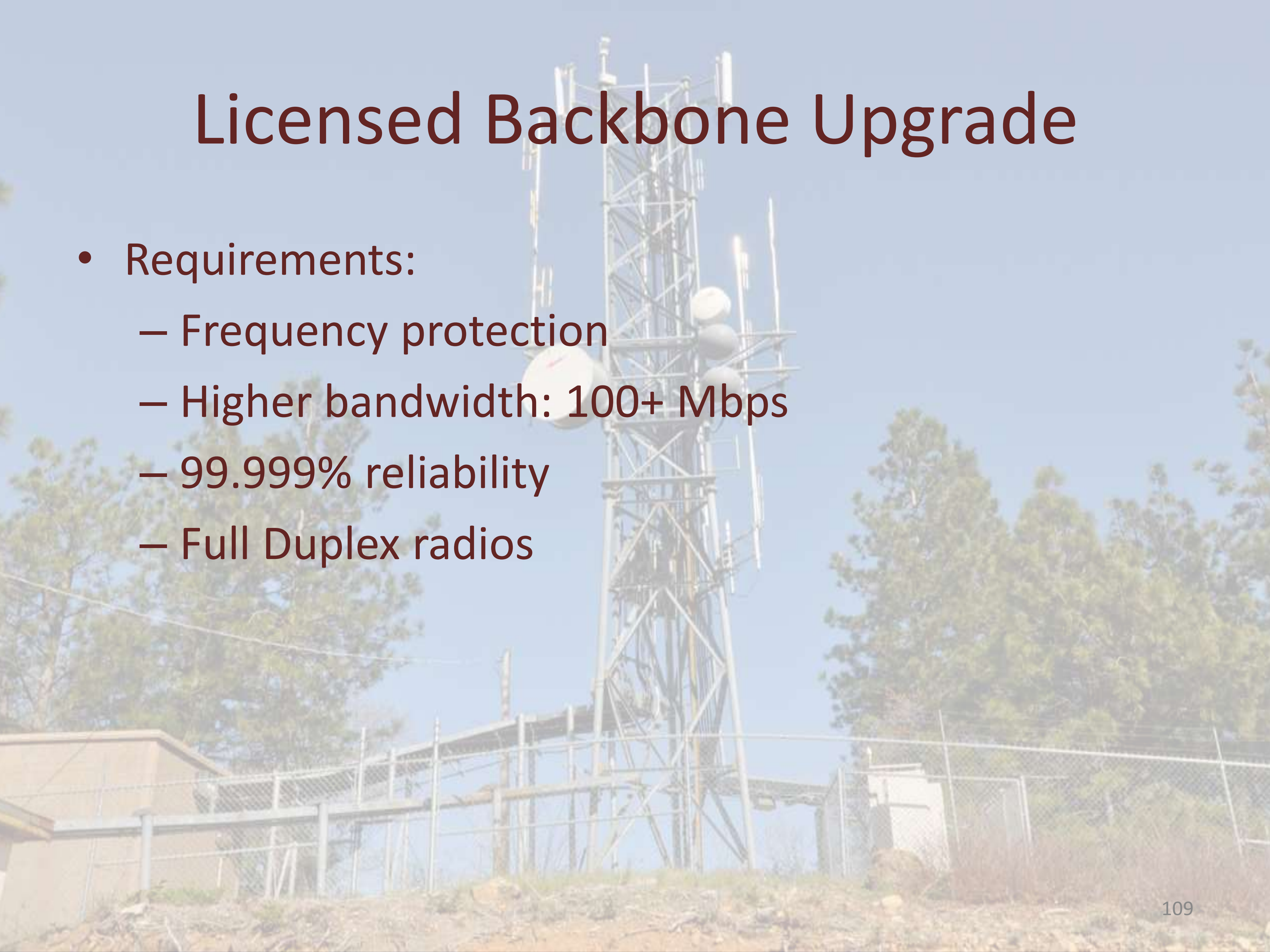

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  - Carrier grade radios
  - All IDU configuration
  - Good spectral efficiency and receiver sensitivity

Licensed Backbone Upgrade

- Steps for selecting frequency, equipment, coordination, etc
  - Frequency coordination w/ Commsearch
  - Market Research
  - Coordination w/ HQ Div of Telecommunications Office and California Public Safety Communications Office

Licensed Backbone Upgrade

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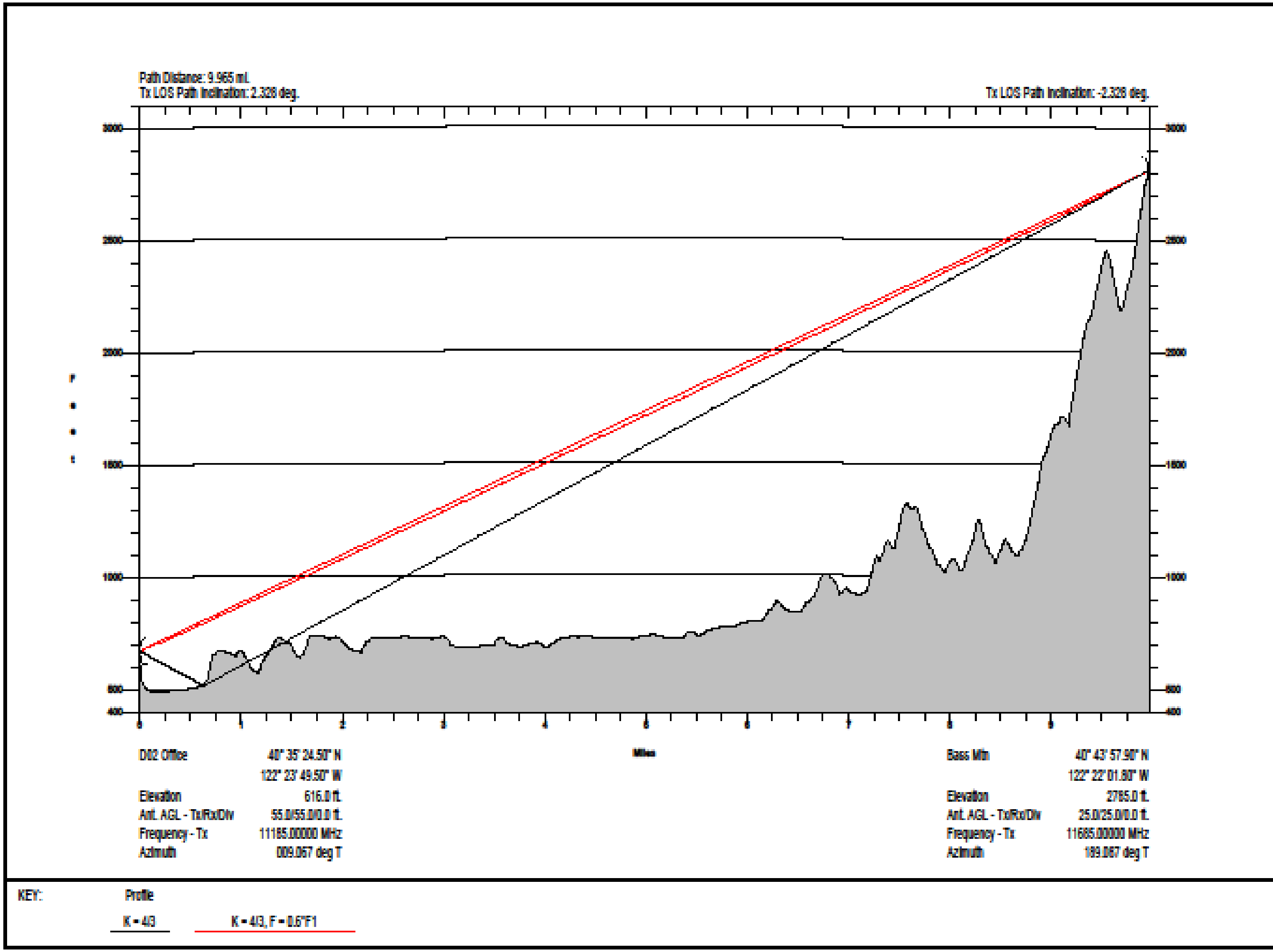
  - 150 Mbps throughput (configurable)
  - True full duplex radios
  - Variety of interfaces available, including order wire
  - Telco and other uses happy with this platform

Classification (All-Indoor)

Frequency Band (GHz):		5.925-6.425	6.525-6.875	10.7-11.7
Interface	DS3 or 2FE	✓	✓	✓
	16DS1 +2FE	✓	✓	✓
	16DS1 +GbE	✓	✓	✓
	2GbE+2FE+16DS1	✓	✓	✓
	OC3	✓	✓	✓
Bandwidth & Capacity (Radio Line Rate)	DS3 or 2FE	10 MHz BW: 45 Mbps, 40 MHz BW: 45 Mbps		
	16DS1 +2FE	10 MHz BW: 45 Mbps; 30 MHz BW: 80/100/175 Mbps, 40 MHz BW: 40/175 Mbps		
	16DS1 +GbE	30 MHz BW: 175 Mbps, 40 MHz BW: 175 Mbps		
	2GbE+2FE+16DS1	30 MHz BW: 200 Mbps		
	OC3	30/40 MHz BW: 155 Mbps		
Modulation/RF Channel (MHz)	32 QAM	-	-	30
	64 QAM	10	10	10/40
	128 QAM	30	30	30
	256 QAM	30	30	30
TX Power (dBm) Minimum Range Std. Pwr (High Pwr)	32 QAM	-	-	30.0
	64 QAM	29.5 (32.5)	29.5 (32.5)	30.0
	128 QAM	29.5 (32.5)	29.5 (32.5)	30.0
	256 QAM	25.5 (28.5)	25.5 (28.5)	25.0
RSL @ 10^{-6} BER Channel	32 QAM	-	-	-70.0
	64 QAM	-77.5	-77.5	-76.5/-71.0
	128 QAM	-70.0	-70.0	-68.0
	256 QAM	-66.0	-66.0	-65.0
System Gain @10^{-6} BER Std. Pwr (High Pwr)	32 QAM	-	-	105.0
	64 QAM	107.0 (110.0)	107.0 (110.0)	106.5/101.0
	128 QAM	99.5 (102.5)	99.5 (102.5)	99.0
	256 QAM	91.5 (94.5)	91.5 (94.5)	90.0
Dispersive Fade Margin @10^{-6} BER	32 QAM	30 MHz = 50dB		
	64 QAM	10 MHz = 60dB, 40 MHz = 50dB		
	128 QAM	30 MHz = 50dB		
	256 QAM	30 MHz = 45dB		
Adaptive Modulation	32 QAM	-	-	30 MHz
	64 QAM	-	-	-
	128 QAM	30MHz	30MHz	30 MHz
	256 QAM	30MHz	30MHz	30 MHz
XPIC Capable		30/40 MHz BW: 175 Mbps		


Bass Mtn from District Office


Bass Mtn from District Office
Close-up



District Office -> Bass Path Profile

Microwave Link Analysis

		Site A	Site B
Site Name	:	D02 Office	Bass Mtn
Location	:	Redding, CA	
Call Sign	:	N/A	N/A
Latitude	:	40° 35' 24.50" N	40° 43' 57.90" N
Longitude	:	122° 23' 49.50" W	122° 22' 01.80" W
Elevation	ft/m:	616.0 / 187.8	2785.0 / 848.9
Azimuth	deg:	9.067	189.0865
Distance	mi/km:	9.965 / 16.0	9.965 / 16.0
Frequency	MHz:	11185.00000	11685.00000
Equipment	:	NEC N-Lite N 100Mbps	NEC N-Lite N 100Mbps
Tx Antenna Height	ft:	55.00	25.00
Tx Antenna Type	:	Andrew HP4-107B	Andrew HP4-107B
Tx Antenna Size / Polarization	ft:	4 / V	4 / V
Tx Transmission Line Length	ft:	120.01	89.99
Tx Transmission Line Type	:	EWP90S	EWP90S
Rx Antenna Height	ft:	55.00	25.00
Rx Antenna Type	:	Andrew HP4-107B	Andrew HP4-107B
Rx Antenna Size / Polarization	ft:	4 / V	4 / V
Rx Transmission Line Length	ft:	120.01	89.99
Rx Transmission Line Type	:	EWP90S	EWP90S
Effective Isotropic Radiated Power	dBm:	65.59	66.96

System Gains		**Site A to B**	**Site B to A**
Tx Antenna Gain	dBi:	40.40	40.80
Rx Antenna Gain	dBi:	40.40	40.80
Transmitter Power	dBm:	31.50	31.50
Total System Gain	dB:	112.30	113.10

System Losses		**Site A to B**	**Site B to A**
Free Space Path Loss	dB:	137.523	137.903
Diffraction Loss	dB:	0.00	0.00
Atmospheric Absorption	dB:	0.26	0.28
Foliage Loss	dB:	0.00	0.00
Tx Jumper Loss	dB:	0.52	0.52
Tx Radome Loss	dB:	0.00	0.00
Tx Connector Loss	dB:	1.12	1.11
Tx Transmission Line Loss	dB:	3.68	2.71
Tx Standby Switch Loss	dB:	0.00	0.00
Tx Power Splitter Loss	dB:	0.00	0.00
Tx RF Branching Loss	dB:	0.00	0.00
Tx Attenuator Pad Loss	dB:	0.00	0.00
Tx Miscellaneous & Safety Loss	dB:	1.00	1.00
Rx Connector Loss	dB:	1.16	1.17
Rx Transmission Line Loss	dB:	2.76	3.61
Rx Jumper Loss	dB:	0.52	0.52
Rx Radome Loss	dB:	0.00	0.00
Rx Hybrid Loss	dB:	0.00	0.00
Rx RF Branching Loss	dB:	0.00	0.00
Rx Attenuator Pad Loss	dB:	0.00	0.00
Rx Miscellaneous & Safety Loss	dB:	1.00	1.00
Total System Loss	dB:	149.53	149.82

Path Calculations		**Site A to B**	**Site B to A**
Unfaded Receive Signal Level	dBm:	-37.23	-36.72
Rx Threshold Level	dBm:	-69.00	-69.00
Fade Margin	dB:	31.77	32.28
Outage	sec/year:	46.60	43.31
Rain Outage	sec/year:	0.00	0.00
Propagation Reliability	%:	99.99985223	99.99986268

Outage Parameters: Vigants - Digital

Climate Factor (c)	0.262	Terrain Factor (w)	140.0	Average Temperature	15.56°C / 60.0°F
CFM	32.28	DFM	0.000	TFM	32.276
BER	1x10E-6	AIFM	0.000	EIFM	0.000

District Office -> Bass Link Analysis

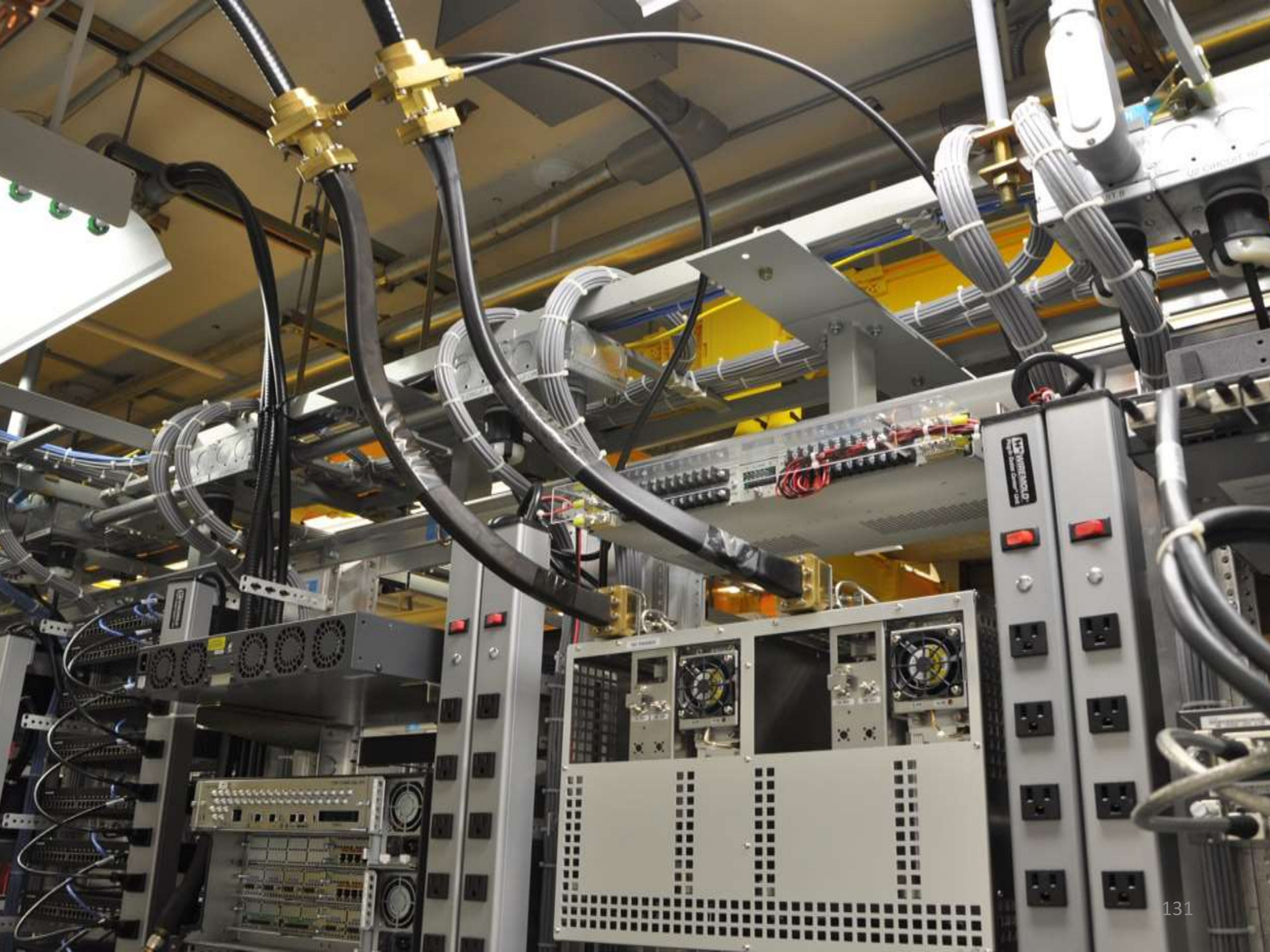
Licensed Backbone Upgrade

- Network design issues
  - Original intent was to interface with the router via an OC-3 card
  - I made a mistake and purchased a “fat-pipe” OC-3 card, I couldn’t channelize the traffic
  - Researched options w/ Cisco, no channelized OC-3 cards available for our platform
  - Two options at this point
    1. Break the signals out with a DSX patch panel
    2. Use the Ethernet interface on the radio

Licensed Backbone Upgrade

- Network design issues
  - We had very limited rack space at one site, the DSX patch panel required a lot of rack space at each mountain top
  - Using the Ethernet interface started making sense
  - Using Ethernet required us to change our network topology
  - Still extended star, as we still route at the mountain tops, but the backbone is one large flat switched network

BassMtnSW
10.20.102.4
cisco



Licensed Backbone Upgrade

- Network design issues
  - Needed a switch to interface with back-to-back radios at mountain tops
  - Specified the Cisco c3750x-24
  - Based on the distances involved and number of hops from the District Office to the network edge, we decided to investigate timing constraints in a switched network (maximum number of hops)

Licensed Backbone Upgrade

- Network design issues
  - 5-4-3 rule, mitigating latency or collision domains?
  - Based on 802.3 spec, generally two points on a network shouldn't be separated by more than,
    - 5 Network segments
    - 4 repeaters
    - 3 of the segments may be populated
  - Determined the rule is intended to mitigate the latency produced by collisions within a network
  - But…

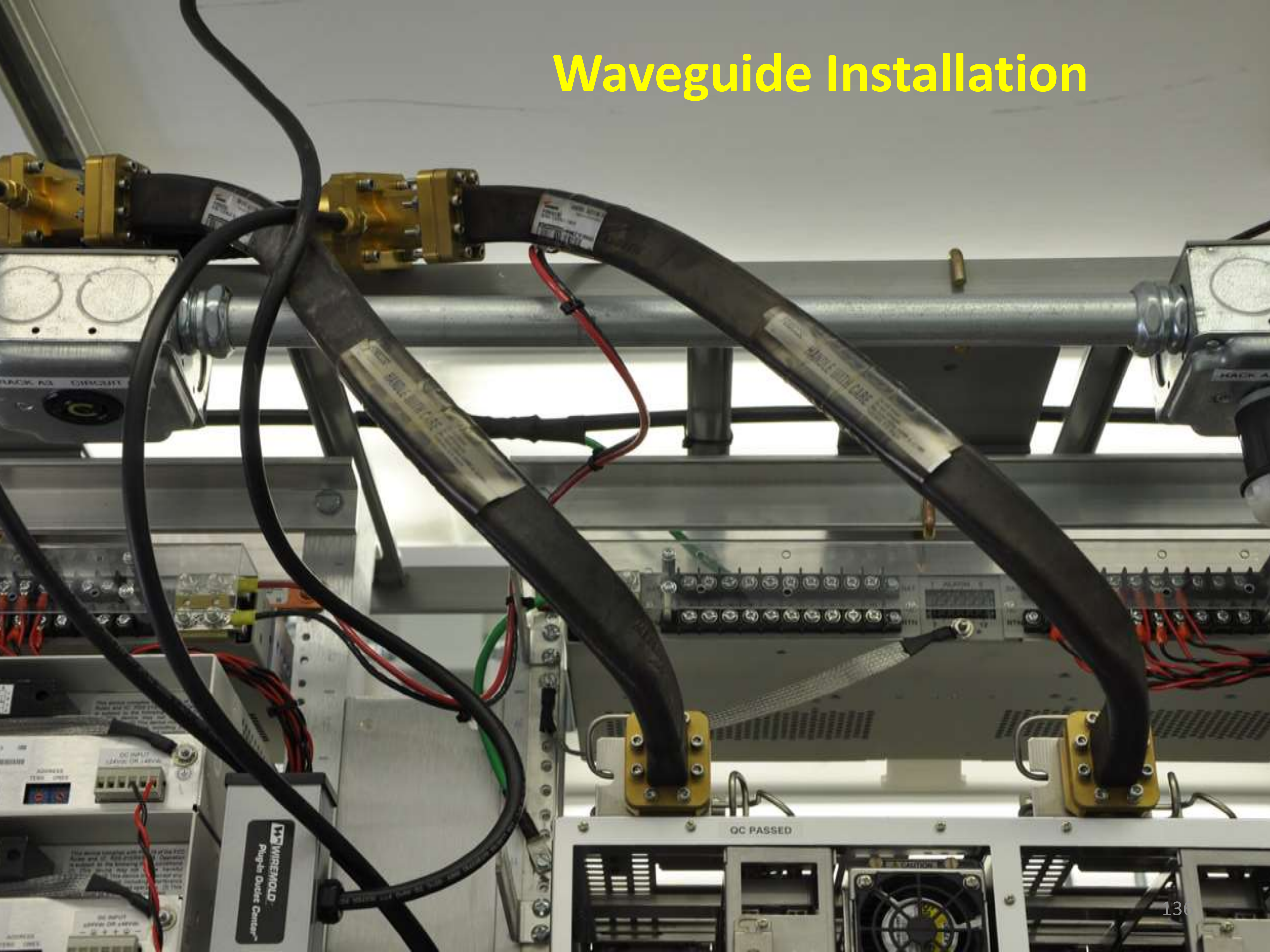
Licensed Backbone Upgrade

- Network design issues
  - We have a switched network, switches break up collision domains
  - Varying sources differ on whether the 5-4-3 rule is applicable to switched networks
  - Concluded the rule not applicable to our network, though we still have a latency issue due to propagation delay

Licensed Backbone Upgrade

- Network design issues
  - Network latency issue due to propagation delay
    - ARP table updates
    - Switch at far end, ARP info will timeout before near end switch receives due to latency
    - Three main components to latency in a switched network, propagation delay, transmission delay, and processing delay
    - Our biggest offender is propagation delay
  - Cisco Solution: Adjust switch timers at full build

Waveguide Installation



Licensed Backbone Upgrade

- Waveguide details
  - EW90 elliptical waveguide

Licensed Backbone Upgrade

- Waveguide details
  - EW90 elliptical waveguide
  - Specs
    - Attenuation @ 11.2 GHz: 3.06 dB/100 ft
    - VSWR: 1.15
    - E-plane minimum bend radius: 7 in
    - H-Plane minimum bend radius: 19 in
    - Maximum twist: 2° / ft

Licensed Backbone Upgrade

- Waveguide details
  - Flex piece, provides vibration isolation to prevent work-hardening of connector


Flex Piece

Licensed Backbone Upgrade

- Waveguide details
  - Flex piece, provides vibration isolation to prevent work-hardening of connector
  - Recommend purchasing connector tools, you can do it by hand, but very difficult


Installation Instructions
Bulletin 37822C
Revision A
Flaring Tools
for use with HELIAX Elliptical Waveguide Connectors and Splices
ANDREW.
Use flaring tools to produce a waveguide flare that has a uniform contact area. You can prepare the connector or splice using Step 1 through Step 4 (below), or you can use the instructions in the connector or splice bulletins.
Tools and Materials Required for Assembly
Flaring Tool(s)
• Single tool (used to flare the major and minor axis)
• Two tool set
Tool No. 1 used to flare the major axis
Tool No. 2 used to flare the minor axis
Note: Always flare the major axis before the minor axis. The flaring procedure is the same whether you use the single tool or the two tool set.
Allen wrench (included)
bottle brush
flat file
hacksaw, fine blade
knife
saw guide (included)
scale, 6 inch (150 mm)
small screwdriver
flare ring assembly
Apply a thin coat of silicone grease
compression ring
dimple
gasket
Figure 2
Step 3: Attach the Flare Ring Assembly
Refer to Figures 2 and 3. Flip the gasket over onto the exposed waveguide to the position shown in Figure 3.
flare ring assembly
approx. 1/8"
compression ring

Licensed Backbone Upgrade

- Waveguide details
  - Flex piece, provides vibration isolation to prevent work-hardening of connector
  - Recommend purchasing connector tools, you can do it by hand, but very difficult
  - Waveguide is required to be pressurized to prevent moisture intrusion which leads to corrosion

Dehydrator front view

Dehydrator rear view

Licensed Backbone Upgrade

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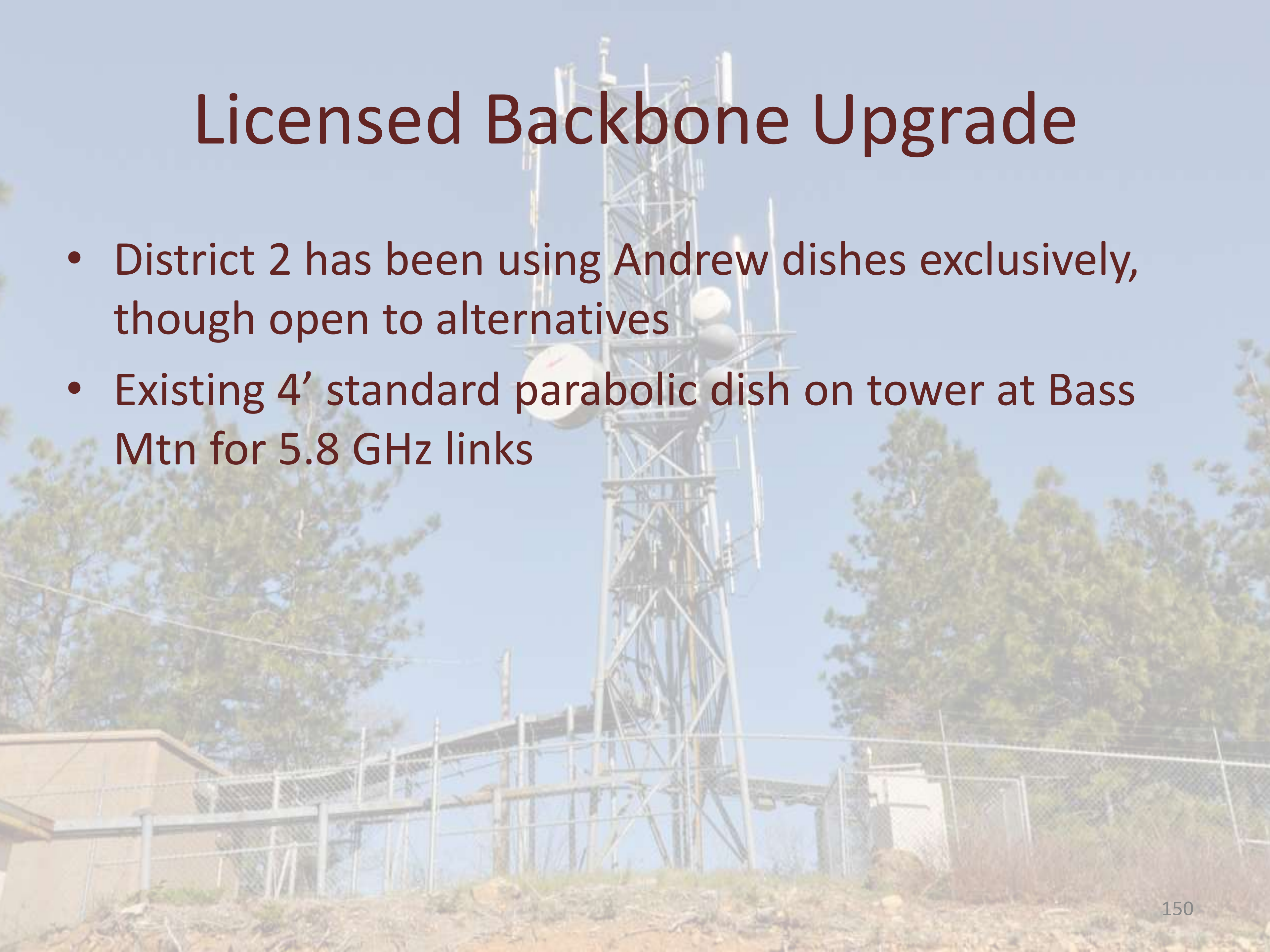
  - Flex piece, provides vibration isolation to prevent work-hardening of connector
  - Recommend purchasing connector tools, you can do it by hand, but very difficult
  - Waveguide is required to be pressurized to prevent moisture intrusion which leads to corrosion
    - We use an Andrew dehydrator to pressurize the waveguide


Microwave Backbone Antenna’s

Licensed Backbone Upgrade

- District 2 has been using Andrew dishes exclusively, though open to alternatives



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- Existing 4' standard parabolic dish on tower at Bass Mtn for 5.8 GHz links

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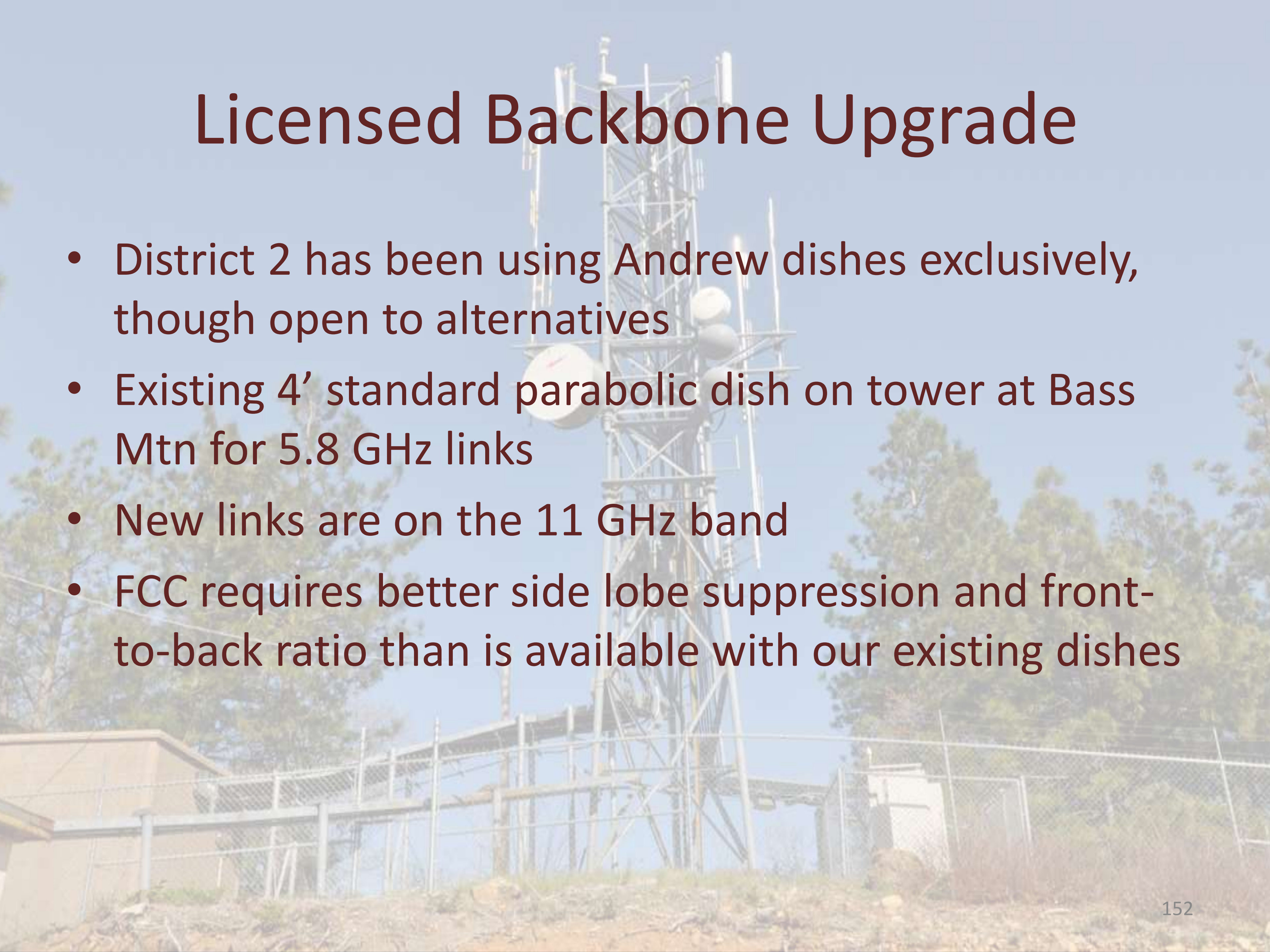
- Existing 4’ standard parabolic dish on tower at Bass Mtn for 5.8 GHz links
- New links are on the 11 GHz band



Licensed Backbone Upgrade

- District 2 has been using Andrew dishes exclusively, though open to alternatives
- Existing 4’ standard parabolic dish on tower at Bass Mtn for 5.8 GHz links
- New links are on the 11 GHz band
- FCC requires better side lobe suppression and front-to-back ratio than is available with our existing dishes

Licensed Backbone Upgrade

Standard Parabolic

Andrew P4F-52-N7A

- Gain: 35.3 dBi
- Beam width: 3° H/V
- Front-to-back ratio: 52 dB
- Cross Poll: 30 dB
- Input: N-Female
- Return Loss: 14 dB
- VSWR: 1.50

High Performance

Andrew HP4-107/B

- Gain: 40.8 dBi
- Beam width: 1.6° H/V
- Front-to-back ratio: 61 dB
- Cross Poll: 30 dB
- Input: Waveguide
- Return Loss: 28.3 dB
- VSWR: 1.08

Licensed Backbone Upgrade

- The “barrel” of the high performance parabolic dish is lined with RF absorbing materials which reduces beam width for side lobe suppression, and increases the front-to-back ratio for interference mitigation

Licensed Backbone Upgrade

- Installation lessons
  - Logistics and keeping the network up while services are transitioned to a new network

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    - Moved exist dish up/down tower while we installed new dish and established link.
  - Andrew dishes – assembly required
  - Peaking the dishes, much more challenging in software, only refreshes every 10 seconds

Licensed Backbone Upgrade

- Issues with Radio Management
  - PNMTj client and remote monitoring

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    - Root NE connects to your Local Network

Licensed Backbone Upgrade

- Issues with Radio Management
  - PNMTj client and remote monitoring
    - Out of band management
    - Each “Head-End” radio assigned an IP and configured as Root NE (Network Element)
    - Root NE connects to your Local Network
    - Route table in local router directs radio management traffic to the Root NE NMS port, while the next hops out are configured as Normal NE’s and PNMTj client “builds the network”

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  - NEC solution is to install a script on a Linux server
  - Script has yet to be installed and tested
  - Currently checking RSL manually (PNMTj client) every morning

Licensed Field Radio Upgrade

Field Radio Deployment Strategy

- Deployment strategy
  - Turn up site with POTS or ISDN Telco services

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  - Upgrade to ISM band microwave overtime if service and line-of-site is available
  - ISM equipment buys time to license
  - After license upgrade, remove ISM equipment and install at network edge to continue expanding coverage, continue this process until full build out complete


LaMoine CCTV
Microwave site


Pollard Flat CCTV
Telco services
Future ISM Upgrade


Vollmers CCTV
No Line-of-Site


Mt Bradley
No presence yet

Legacy Field Radios

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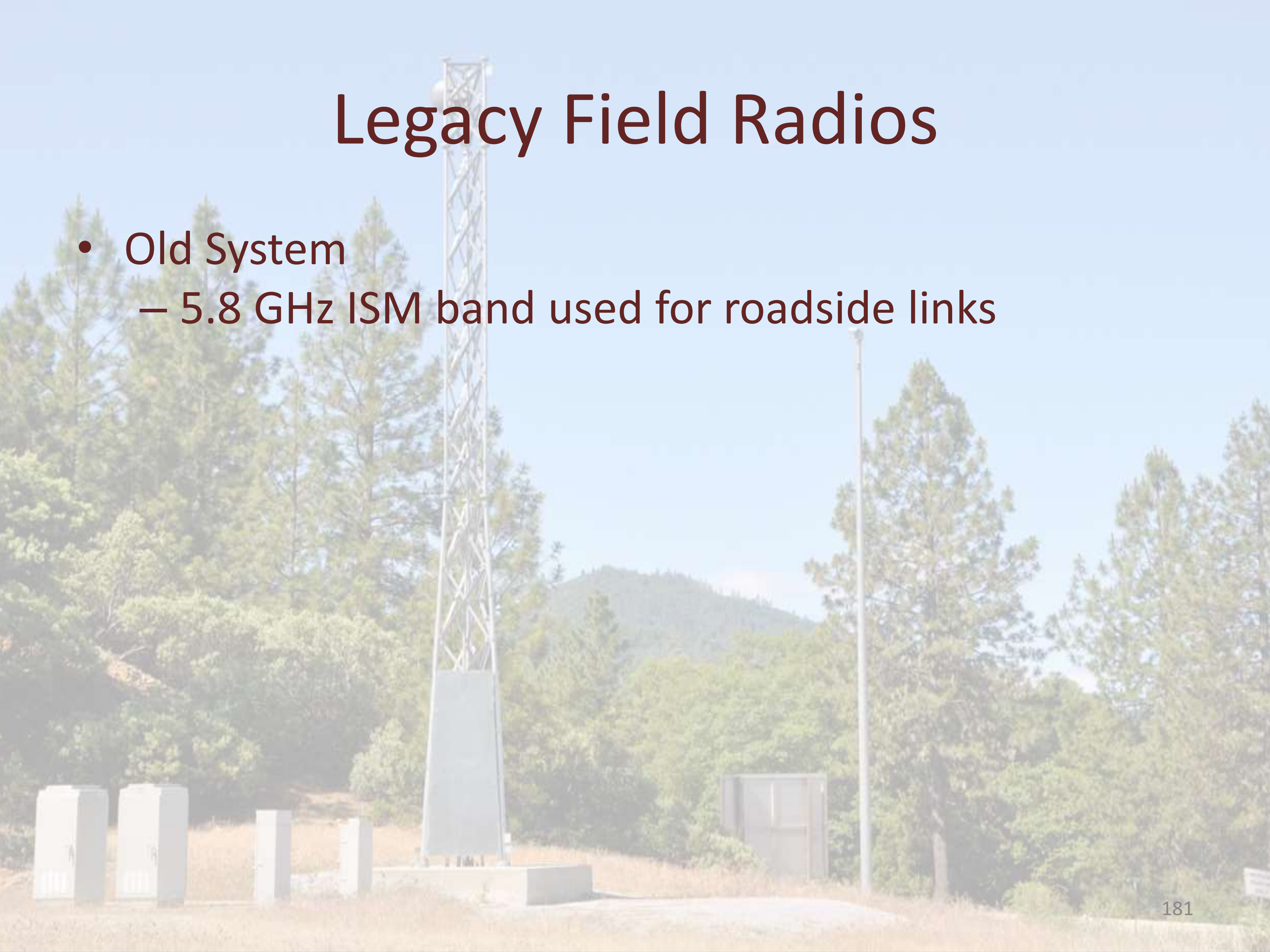

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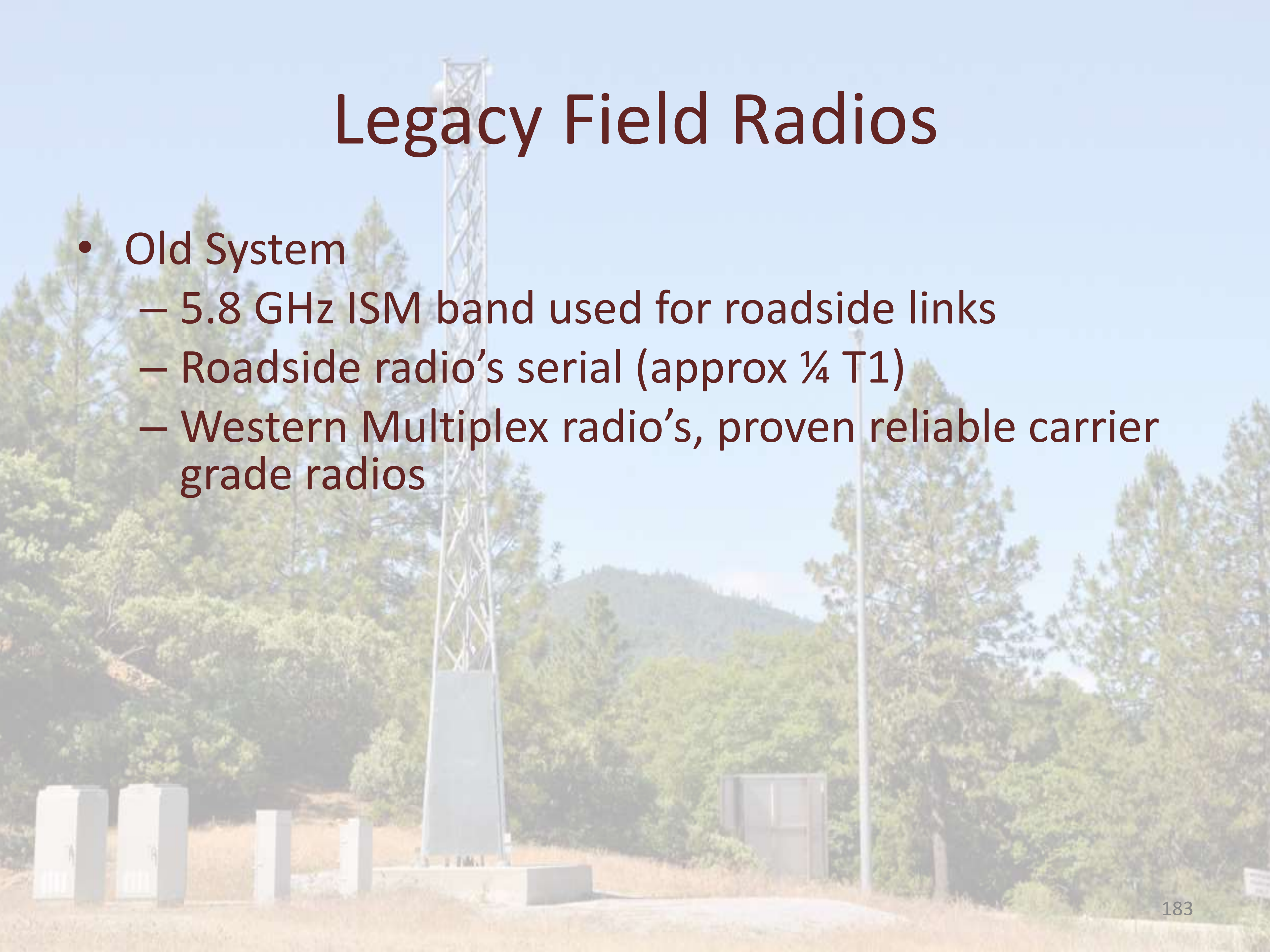

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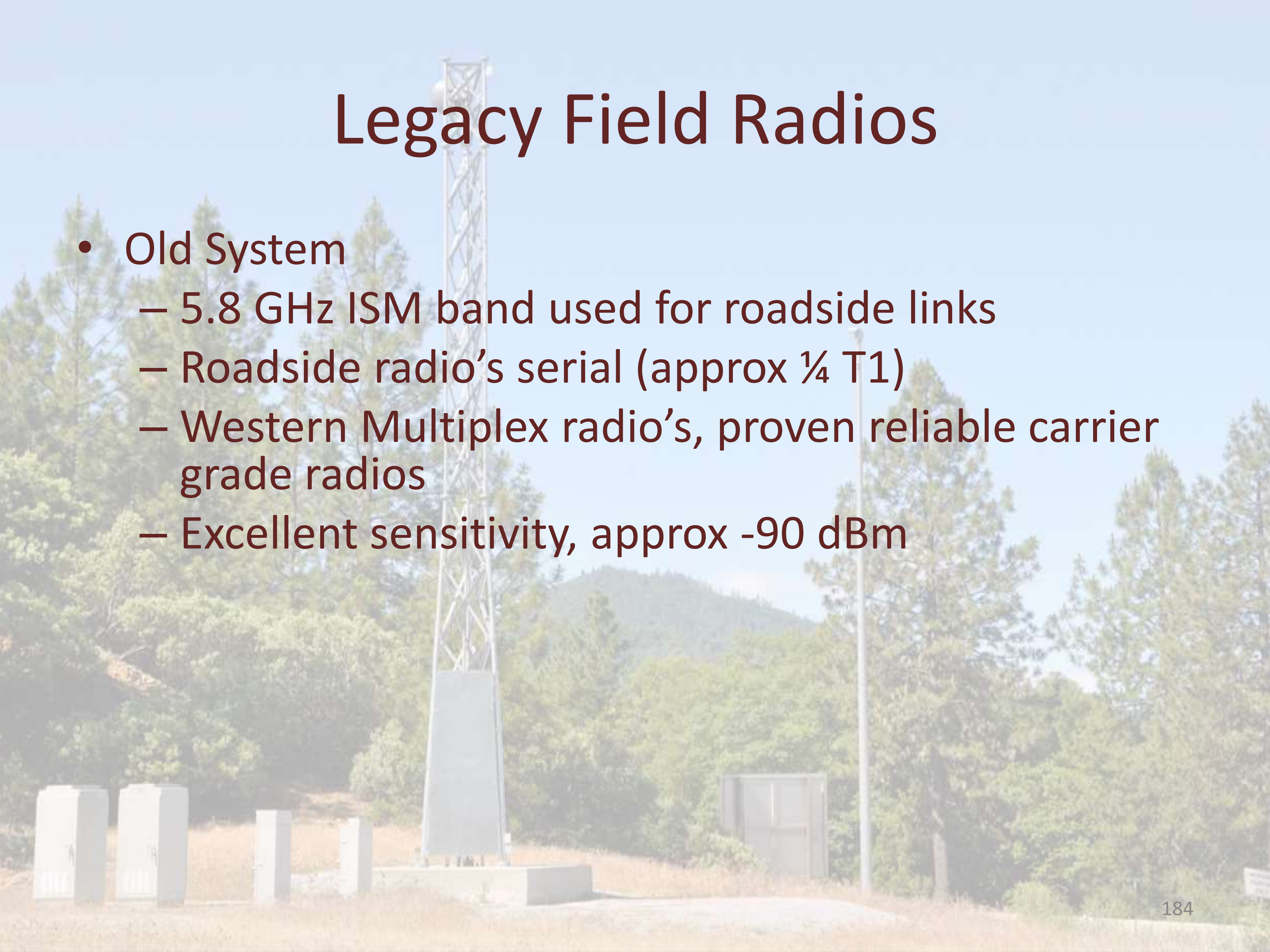

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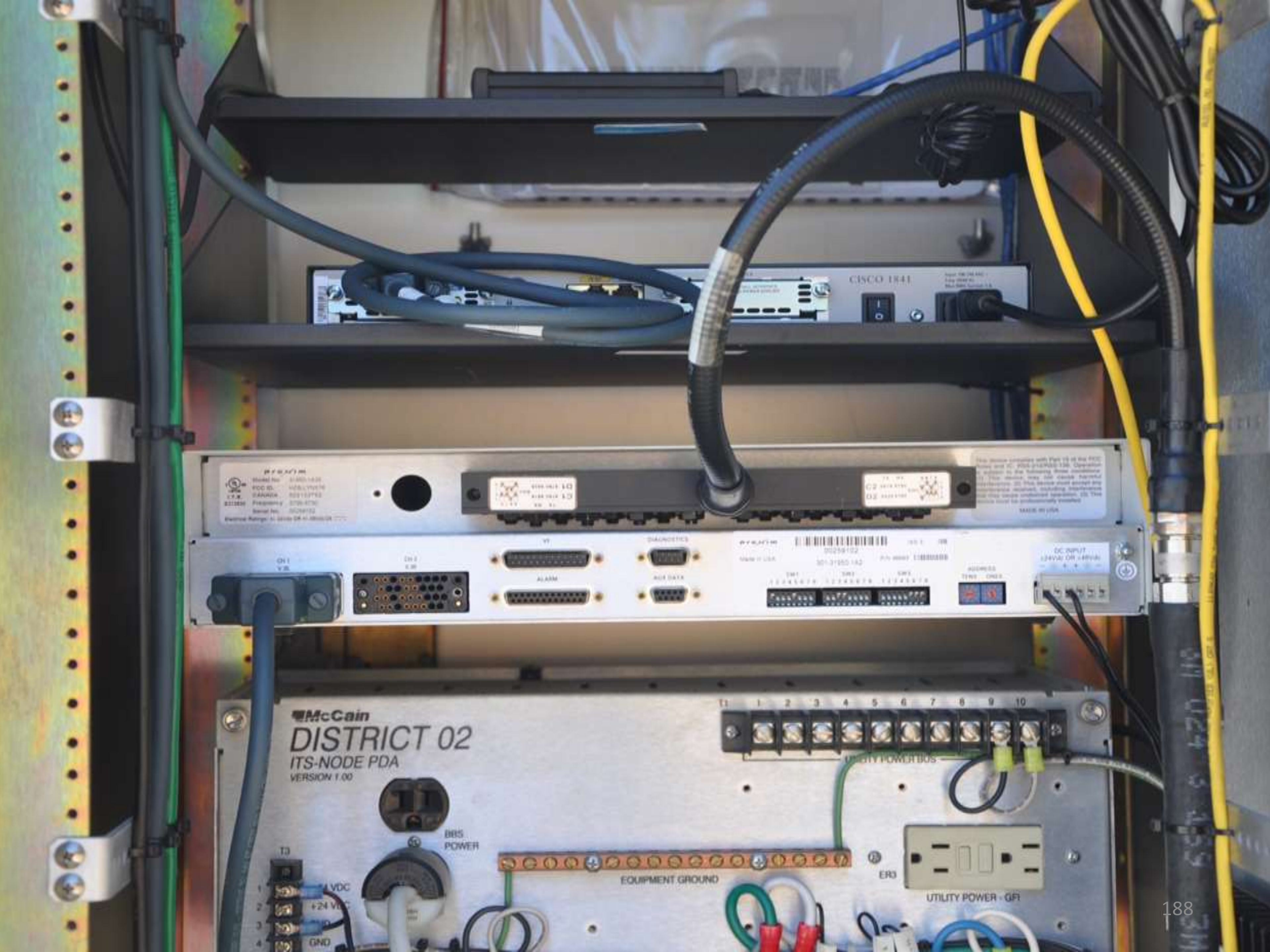
  - Full Duplex

Cisco 1800 Series
Lynx sc6
FRACTIONAL CAPACITY SPREAD SPECTRUM 5.8 GHz RADIO MODEM
Pit_River_Bridge -> Bass
proxim
Tx: 5825
Rx: 5760
SYNC
BER
INPUT 2
INPUT 1
MUTE
FAN
RADIO FAIL
FAR END
ON
GND
RSL
LOCAL TX PWR
ERROR
FAR END LOOPBACK
ENABLE 1
ENABLE 2
DISPLAY FAR END
ORDERWIRE HANDSET
McCain
UTILITY POWER BUS
BYPASS SWITCH
ON BBS
1
2
BYPASS
30A
MAIN
15A
BBS IN
15A
UTIL 1
15A
UTIL 2
15A
UTIL 3
15A
UTIL 4/ HEAT
PS 22416
AC+ PWR
+24 VDC PWR
+24 VDC
DC GND
McCain


CISCO 1841
McCain
DISTRICT 02
ITS-NODE PDA
VERSION 1.00
BBS POWER
EQUIPMENT GROUND
UTILITY POWER - GFI
ER3

Project History

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- Equipment specified
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  - Scala PR-950 half-parabolic antenna

Project History

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- Equipment specified
  - 4RF radio
  - Scala PR-950 half-parabolic antenna
- Early Requirements
  - T1 to the roadside
  - Licensed link (frequency protection)
  - 99.999% reliability
  - Reuse the coax currently used for the 5.8 GHz link
  - All IDU, carrier grade radios

Project History

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- Project revisited December 2013
  - Throughput requirement changed from T1 to the roadside to 10 Mbps to the roadside
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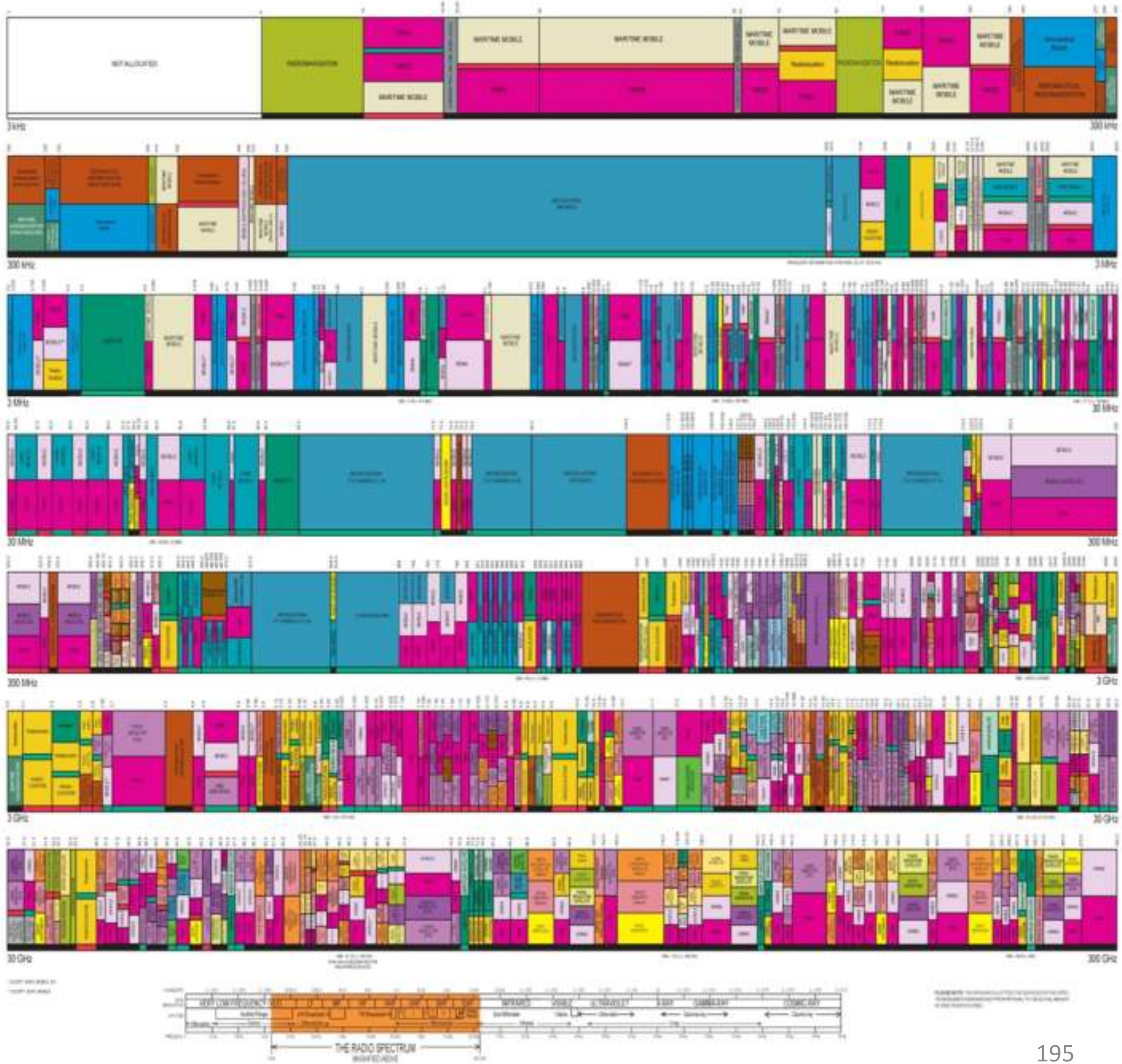
- Project revisited December 2013
  - Throughput requirement changed from T1 to the roadside to 10 Mbps to the roadside
  - Equipment on 900 MHz band (specified by the FCC) didn't offer channels wide enough to support our throughput requirements
- Began to research other bands…

UNITED STATES FREQUENCY ALLOCATIONS

THE RADIO SPECTRUM



Licensed Field Radio Upgrade

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- Currently a good variety of equipment available on the market for the 4.9GHz band, just took a couple of years for technology to catch up with the FCC
- Looked at other bands and markets, couldn’t find anything below 6 GHz we could operate on and met our throughput requirements

Licensed Field Radio Upgrade

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  - 4940 – 4990 MHz, CFR 47 90 subpart y
  - Eligibility defined by CFR Title 47 Part 90.523(a) “State or local government entities. Any territory, possession, state, city, county, town, or similar State or local government entity is eligible…”

Licensed Field Radio Upgrade

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  - Eligibility defined by CFR Title 47 Part 90.523(a) “State or local government entities. Any territory, possession, state, city, county, town, or similar State or local government entity is eligible…”
  - Permissible operations
    - Unattended and continuous operation
    - Voice, data, and video operations are permitted

Licensed Field Radio Upgrade

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  - Permanent fixed point-to-point and point-to-multipoint stations must be licensed individually on a site-by-site basis. Such stations are accorded primary status.

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  - All licensees shall cooperate in the selection and use of channel in order to reduce interference

Licensed Field Radio Upgrade

- A little bit about the 4.9 GHz band
  - 18 channels in the band
    - Channels 1 – 5 are 1 MHz wide
    - Channels 6 – 13 are 5 MHz wide
    - Channels 14 – 18 are 1 MHz wide
  - Channels can be aggregated to 5, 10, 15, or 20 MHz widths

Licensed Field Radio Upgrade

- A little bit about the 4.9 GHz band
  - Power limits associated with channel bandwidth
    - 1 MHz -> 20 dBm Max conducted output
    - 5 MHz -> 27 dBm Max conducted output
    - 10 MHz -> 30 dBm Max conducted output
    - 15 MHz -> 31.8 dBm Max conducted output
    - 20 MHz -> 33 dBm Max conducted output

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- A little bit about the 4.9 GHz band
  - Power limits associated with channel bandwidth
  - No EIRP limits, however…
  - Point-to-point operations may employ antennas with directional gain up to 26 dBi without reduction of output power
  - Corresponding power reduction should be in the amount in dB that the directional gain of the antenna exceeds 26 dBi

Licensed Field Radio Upgrade

- A little bit about the 4.9 GHz band
  - Licensing process
    - Register with the FCC's Universal Licensing System (ULS)
    - As a registered user, login to the FCC account and select, "Apply for a New License"
    - Complete the information in the pop-up java applet and submit
    - The FCC will grant the license within 1 – 3 business days…

Licensed Field Radio Upgrade

- A little bit about the 4.9 GHz band
  - Unless you work for the State of California, then it will take 10 weeks, and counting…
  - We are required to obtain FCC licenses through the State Public Safety Communication Office (PSCO)
  - Submitted request 3/12/14 and have not received license

Licensed Field Radio Upgrade

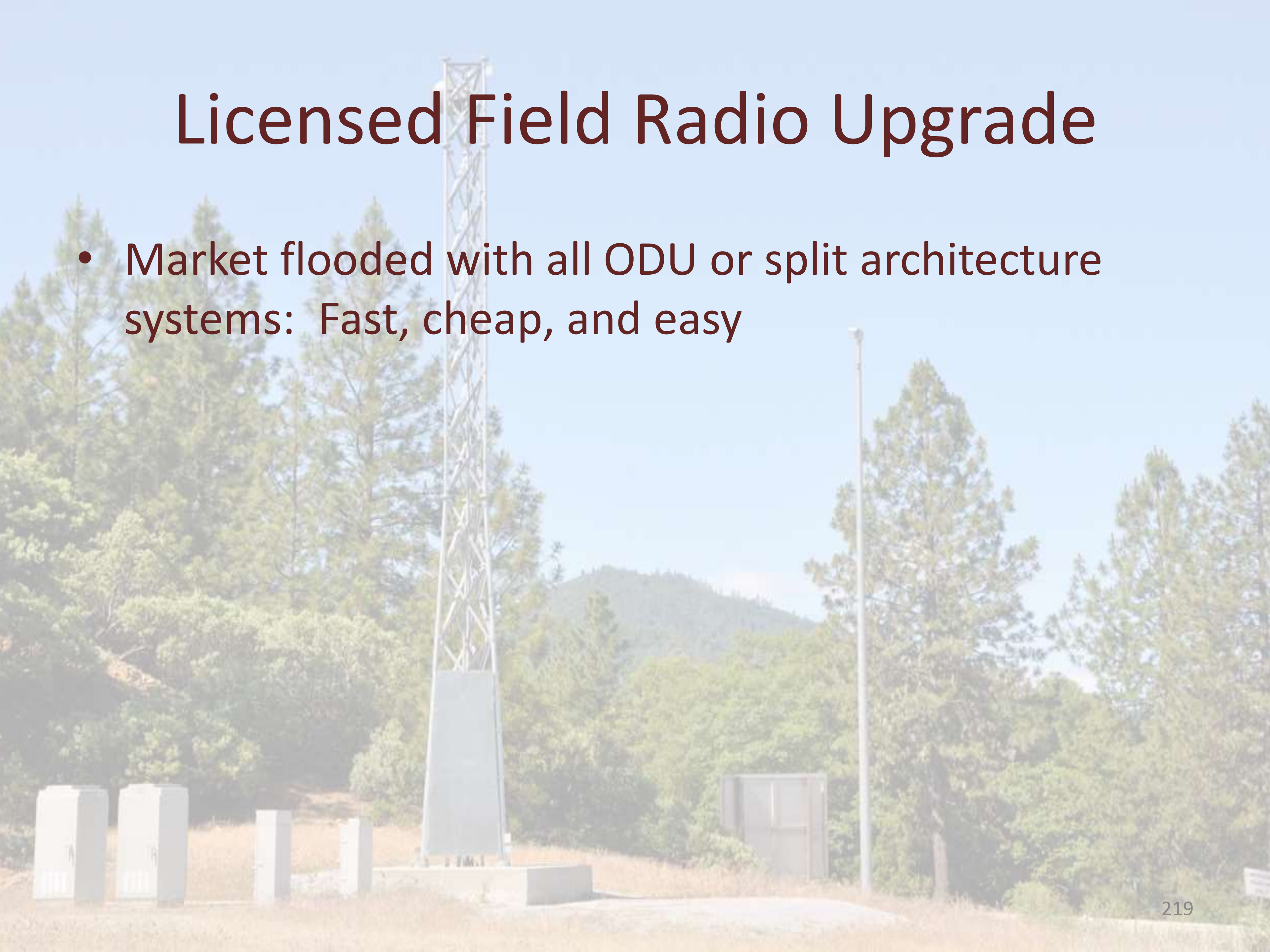
- A little bit about the 4.9 GHz band
  - FCC mandated frequency coordination process established by creating Regional Planning Committees (RPC)
  - The Northern California RPC, Region 6, hasn’t updated their website since 2004
  - Talked to a 4.9 GHz band user, never heard of the RPC and was under the impression that coordination was not required
  - http://www.rgn6rpc.org/4940main.htm

Licensed Field Radio Upgrade

- Used requirements to screen 14 different radio manufacturers
  - Form Factor – IDU (indoor unit)
  - Duplexing - FDD (frequency division duplexing)
  - Throughput – 10 Mbps to the roadside
  - Channelization – Need at least 5 channels
  - Security – Network security (SSL, SSH, etc)
  - Receiver threshold – Hard to quantify, need good enough to make 99.999% reliability
  - Power – (-)48V compatible, 24/48V preferred

Licensed Field Radio Upgrade

- Market flooded with all ODU or split architecture systems: Fast, cheap, and easy



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- This is the way the carrier market seems to be going
- Researched the industrial market and the broadcast market
- Bench tested two sets of radios, Exalt EX-4.9i and Moseley NX-GEN-S

Licensed Field Radio Upgrade

- Exalt was tested before Moseley was known as an option

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- Sacrificed duplexing over the form factor and decided to request a trial unit from Exalt to test a link

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- Sacrificed duplexing over the form factor and decided to request a trial unit from Exalt to test a link
- Exalt Ex-4.9i Spec

EX-4.9i

All-Indoor, Carrier-Class 4.9 GHz TDD Radio
for Emergency Response, Public Safety and Government Agencies

The EX-4.9i all-indoor digital microwave radio is the highest capacity carrier-class, TDD radio operating in the 4.9 GHz public safety band. The EX-4.9i delivers up to 55 Mbps of aggregate user throughput and up to four T1/E1s at 99.999% availability. Featuring native TDM and native Ethernet transport and full software configurability and upgradeability, the EX-4.9i was designed to meet demanding deployment and security requirements of emergency response, public safety and government organizations seeking the accessibility benefits of an all-indoor configuration.

Carrier-class TDD. The EX-4.9i combines native TDM and native Ethernet transport with low, fixed latency to deliver guaranteed throughput and service quality. Capacity can be allocated variably between TDM and Ethernet via software, while the selectable throughput symmetry control feature enables radio capacity to efficiently match asymmetric traffic requirements, such as those associated with video surveillance systems.

Security, Management and Data Networking. The EX-4.9i delivers the highest data and management security available with included 96-bit encryption, optional 128- and 256-bit AES encryption and secure SNMP v3 management, together with enhanced fault management and diagnostic features. The 802.1Q VLAN option provides built-in network administration and security flexibility.

ExaltSync™ Synchronization. The ExaltSync technology embedded in the EX-4.9i radio allows multiple radio systems to be collocated in close proximity without self-interference, minimizing antenna separation and ensuring reuse of scarce spectrum across all collocated systems.

Industry-leading Spectrum Management. The EX-4.9i provides unparalleled transmission resiliency and spectral efficiency. Selectable modulation, selectable channel bandwidth and frequency reuse capabilities facilitate inter-agency frequency coordination and collaboration. A built-in spectrum analyzer is even included, helping to accelerate deployment and simplify troubleshooting.

Primary Specifications		EX-4.9i
Maximum Capacity[1]	TDM	4xT1/E1
	Ethernet (Aggregate)	55 Mbps
Frequency (GHz)		4.940-4.990
Maximum Range[2]		> 10 miles at 99.999% throughput availability

[1] Please refer to the Exalt Throughput and Range Specification document for detailed capacity information.

[2] Distance based upon FCC regulations, average climate and terrain, 6' dish antennas, 3 dB transmission system losses at each end. Larger or shorter distances will apply for alternative antennas, country regulations, transmission system losses, path topologies and radio configurations. See Exalt's path planning tool to model your scenario.

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  - Exalt uses a generic installation and maintenance manual for several products within the Ex-i line

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  - One of the features in question was access security, for example https, SSH, SSL, etc
  - Exalt response was, “no one had asked for that feature”, they didn’t know their market

Licensed Field Radio Upgrade

- Exalt link testing results
  - Measured RSL levels with a power meter and compared measured value with value reported by the radio
  - Measured value was 3-4 dB lower than the configured value
    - Due to the fact that this a TDD link, the link was set up for 50/50 symmetry (50% Tx, 50% Rx) so the meter was measuring half the power

Licensed Field Radio Upgrade

- Exalt link testing results
  - Measured Transmit Power with a power meter and compared measured value with configured value
  - Measured value was 3-4 dB lower than the configured value, as expected due to the nature of the TDD link
  - However the configured value increased at a different rate than the measured value
    - Configured at 4 dBm -> measured 0 dBm
    - Configured at 13 dBm -> measured 6 dBm

Licensed Field Radio Upgrade

- Exalt link testing results
  - A couple more things to remember about TDD link design

Licensed Field Radio Upgrade

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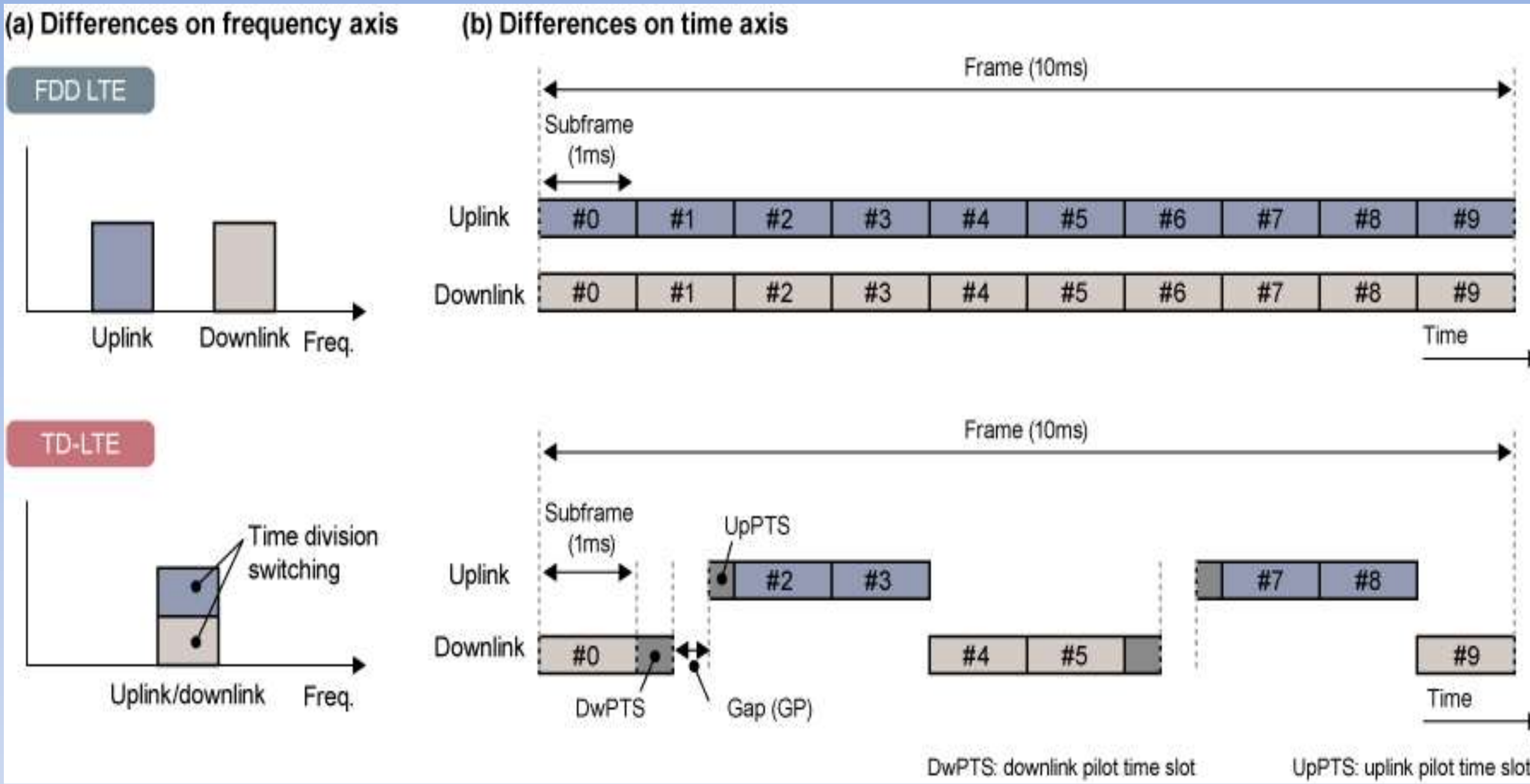
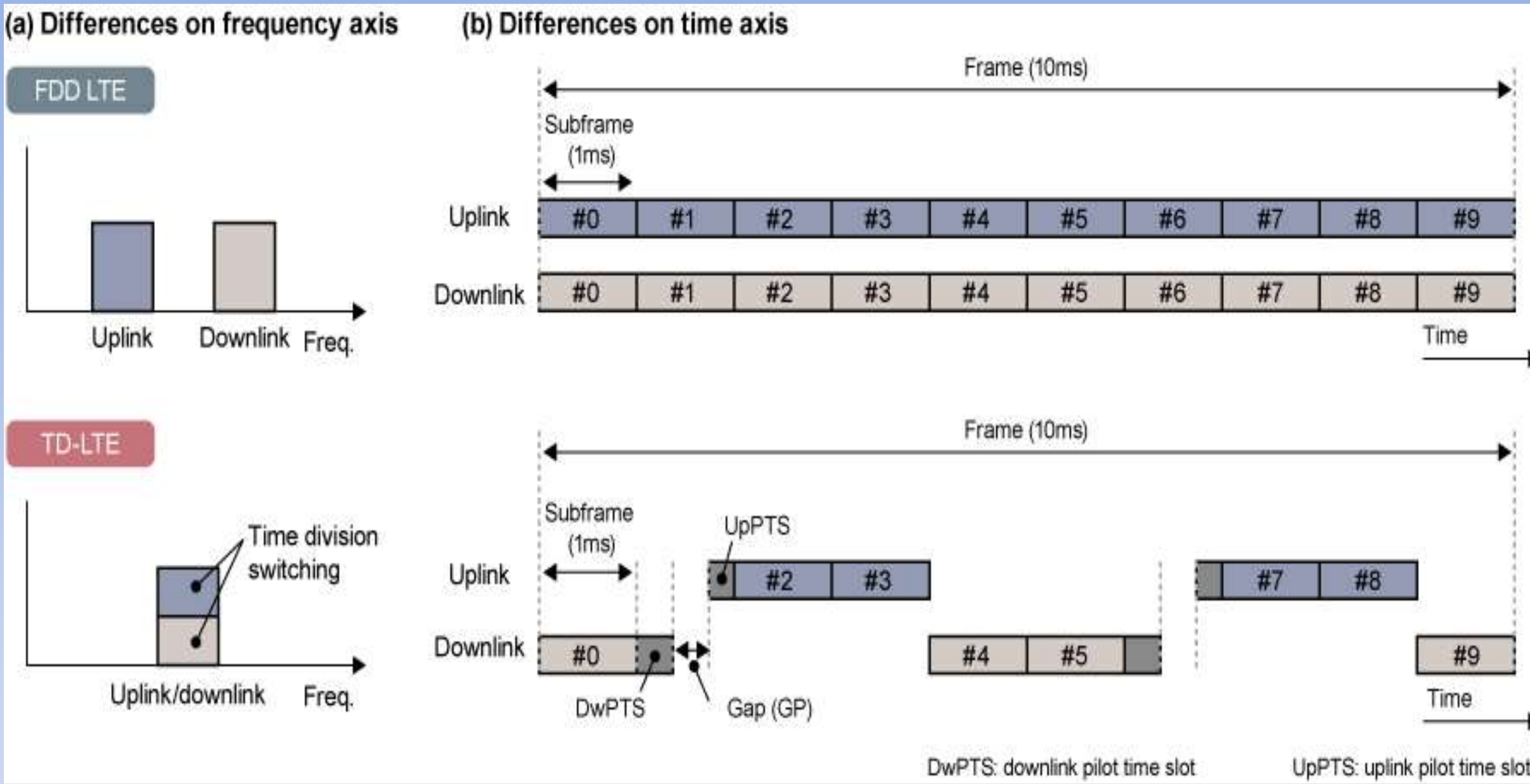
    1. Link distance has a significant impact on throughput



FDD vs. TDD

- Graph shown is from an LTE system
  - GP – Guard Period (variable depending on distance)



FDD vs. TDD

- Range increase -> GP increase -> frame size decrease -> LOWER THROUGHPUT!

Licensed Field Radio Upgrade

- Exalt link testing results
  - A couple more things to remember about TDD link design
    1. Link distance has a significant impact on throughput

    For the Exalt systems, the link can be optimized for latency or throughput by configuring a couple of variables

    a) FRAME SIZE – Increasing frame size increases throughput, but also increases latency, while decreasing frame size has the inverse effect

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    For the Exalt systems, the link can be optimized for latency or throughput by configuring a couple of variables

    b) SYMMETRY – Changing the symmetry can increase the throughput, as you're reducing the number of GP's in the frame

Exalt EX-4.9 Calculator v3.4.1

Project Title	Exalt 4.9GHz Microwave Link		
	Other - enter to right----->	50	Alternative Max EIRP (dBm)
Frequency Band (GHz)	4.9		
Path Length	3	Units: (•) Miles ( ) Kilometers	
Free Space Path Loss (dB)	119.9	(for reference only)	
Climate	0.25 (Average)	0	Alternative Climate Factor
Terrain	1.00 (Average)	0	Alternative Terrain Factor
RF Noise Value	-95dB (Average)	0	Alternative RF Noise Value (-dBm)
Channel Bandwidth Setting	10MHz	1 ms	TDD Frame Size
Number of T1 Channels in Use	0	Interface: (•) T1 ( ) E1	
Antenna List: ( ) by Gain (•) by Vendor / Type			
Antenna, Site A	Gabriel 2' Dish, GFD2-49-N, 27.7dBi	0	Alternative Antenna Gain (dBi)
Antenna, Site B	Gabriel 2' Dish, GFD2-49-N, 27.7dBi	0	Alternative Antenna Gain (dBi)
Transmission Line Type, Site A	Andrew 5/8-inch Heliax, LDF4.5-50 (4.2dB/100 ft)	0	Alternative Transmission Line Loss (dB/100 ft)
Transmission Line Length (ft) Site A	75	Line Loss, Site A	3.2dB
Transmission Line Type, Site B		0	Alternative Transmission Line Loss (dB/100 ft)
Transmission Line Length (ft) Site B	50	Line Loss, Site B	2.8dB
Transmission Line Length Units: (•) Feet ( ) Meters			

	Site A		Site B	
Lightning Protection Loss (dB)	0		0	typical loss = 0.2 dB / device
Connector Loss (dB)	0.5		0.5	typical loss = 0.25 dB / connector
Additional Jumper Loss (dB)	0.5		0.5	
Maximum Legal Transmitter Power Output (dBm)	22.0		22.0	(for reference only)

Mode-1 (QPSK) Results

	Site A		Site B	
Radio Transmit Power Setting (dBm)	22.0		22.0	
Additional Transmit Power Reduction (dB)	18		18	(enter value for Mode 1 only)
EIRP (dBm)	27.6		28.0	
Received Signal Level (dBm)	-68.4		-68.4	
Receiver Sensitivity (dBm)		-86		
Interference Factor (dBm)		-95		
Fade Margin (dB)	16.6		16.6	
Predicted One-Way Annual Outage (minutes)	1.0		1.0	
Predicted Annual One-Way Availability (percent)	99.9998%		99.9998%	
Aggregate Ethernet Throughput (Mbps)		11.2 Mbps		
Full-Duplex Throughput		5.6 Mbps		
One-way TDM Latency (ms)		1.4 ms		

Mode-2 (16QAM) Results

	Site A		Site B	
Radio Transmit Power Setting (dBm)	21.0		21.0	
Additional Transmit Power Reduction (dB)	11		11	(enter value for Mode 2 only)
EIRP (dBm)	33.6		34.0	
Received Signal Level (dBm)	-62.4		-62.4	
Receiver Sensitivity (dBm)		-78		
Interference Factor (dBm)		-95		
Fade Margin (dB)	15.6		15.6	
Predicted One-Way Annual Outage (minutes)	1.2		1.2	
Predicted Annual One-Way Availability (percent)	99.9998%		99.9998%	
Aggregate Ethernet Throughput (Mbps)		22.5 Mbps		
Full-Duplex Throughput		11.25 Mbps		
One-way TDM Latency (ms)		1.2 ms		

Pit River Bridge Link distance 3 mi

Pit River Bridge Throughput 11.3 Mbps

Note: These calculations are provided in order to assist with the design of a wireless link using an EX-4.9 and are not a guarantee of link performance. They assume an unobstructed line-of-site radio path with appropriate antenna height clearance above terrain and obstructions, using standard factors for terrain and climate conditions, assuming no unusual or multipath propagation. The availability and outage predictions are based on industry-standard formulae. The calculated performance may be useful for comparison with the actual system when installed.

Exalt™
EX-4.9 Calculator
v3.4.1

Project Title	Exalt 4.9GHz Microwave Link		
	Other - enter to right----->	50	Alternative Max EIRP (dBm)
Frequency Band (GHz)	4.9		
Path Length	8.9	Units: (●) Miles ( ) Kilometers	
Free Space Path Loss (dB)	129.4	(for reference only)	
Climate	0.25 (Average)	0	Alternative Climate Factor
Terrain	1.00 (Average)	0	Alternative Terrain Factor
RF Noise Value	-95dB (Average)	0	Alternative RF Noise Value (-dBm)
Channel Bandwidth Setting	10MHz	1 ms	TDD Frame Size
Number of T1 Channels in Use	0	Interface: (●) T1 ( ) E1	

Antenna List: ( ) by Gain (●) by Vendor / Type

Antenna, Site A	Gabriel 2.5' Dish, QFD2.5-49-N, 29.7dBi	0	Alternative Antenna Gain (dBi)
Antenna, Site B	Gabriel 4' Dish, QFD4-49-N, 33.7dBi	0	Alternative Antenna Gain (dBi)
Transmission Line Type, Site A	Andrew 1/2-inch Heliax, LDF4-50 (5.5dB/100 ft)	0	Alternative Transmission Line Loss (dB/100 ft)
Transmission Line Length (ft) Site A	75	Line Loss, Site A	4.1dB
Transmission Line Type, Site B	[illegible]	0	Alternative Transmission Line Loss (dB/100 ft)
Transmission Line Length (ft) Site B	60	Line Loss, Site B	3.3dB

Transmission Line Length Units: (●) Feet ( ) Meters

	Site A	Site B	
Lightning Protection Loss (dB)	0	0	typical loss = 0.2 dB / device
Connector Loss (dB)	0.5	0.5	typical loss = 0.25 dB / connector
Additional Jumper Loss (dB)	0.5	0.5	
Maximum Legal Transmitter Power Output (dBm)	22.0	20.6	(for reference only)

Mode-1 (QPSK) Results

	Site A		Site B	
Radio Transmit Power Setting (dBm)	22.0		20.5	
Additional Transmit Power Reduction (dB)	1		1	(enter value for Mode 1 only)
EIRP (dBm)	45.6		48.9	
Received Signal Level (dBm)	-55.9		-54.4	
Receiver Sensitivity (dBm)		-86		
Interference Factor (dBm)		-95		
Fade Margin (dB)	29.1		30.6	
Predicted One-Way Annual Outage (minutes)	1.4		1.0	
Predicted Annual One-Way Availability (percent)	99.9997%		99.9998%	
Aggregate Ethernet Throughput (Mbps)		7.4 Mbps		
Full-Duplex Throughput		3.7 Mbps		
One-way TDM Latency (ms)		1.4 ms		

Mode-2 (16QAM) Results

	Site A		Site B	
Radio Transmit Power Setting (dBm)	21.0		20.5	
Additional Transmit Power Reduction (dB)	0		0	(enter value for Mode 2 only)
EIRP (dBm)	45.6		49.9	
Received Signal Level (dBm)	-54.9		-54.4	
Receiver Sensitivity (dBm)		-78		
Interference Factor (dBm)		-95		
Fade Margin (dB)	23.1		23.6	
Predicted One-Way Annual Outage (minutes)	5.6		5.0	
Predicted Annual One-Way Availability (percent)	99.9989%		99.9990%	
Aggregate Ethernet Throughput (Mbps)		18.8 Mbps		
Full-Duplex Throughput		9.4 Mbps		
One-way TDM Latency (ms)		1.2 ms		

Obrien
Link distance 9 mi

Obrien
Throughput 9.4 Mbps

Note: These calculations are provided in order to assist with the design of a wireless link using an EX-4.9 and are not a guarantee of link performance. They assume an unobstructed line-of-site radio path with appropriate antenna height clearance above terrain and obstructions, using standard factors for terrain and climate conditions, assuming no unusual or multipath propagation. The availability and outage predictions are based on industry-standard formulae. The calculated performance may be useful for comparison with the actual system when installed.

Licensed Field Radio Upgrade

- Exalt link testing results
  - A couple more things to remember about TDD link design
    1. Link distance has a significant impact on throughput
    2. Complex synchronization is required between terminals collocated within the same building to reduce co-channel interference, the synchronization ensures all frames on all terminals are sent at the same time

Licensed Field Radio Upgrade

- After the Exalt testing we were willing to accept the TDD limitations as we had very limited options for an IDU radio

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- Reviewed the spec for the NX-GEN-S and it met all of our requirements

NX-GEN-S

Digital Microwave Radio

- All Indoor Architecture (1+0, 1+1, 2+0)
- 5 - 13 GHz
- Modulates QPSK to 256 QAM
- Software Selected Bandwidth 3.5 - 56 MHz
- 2 - 700 Mbps Data Rates
- Powerful ATPC, XPIC, Adaptive Modulation
- Full-featured Advanced Ethernet
- Comprehensive Network Management, Web Server, & SNMP
- All Interfaces Nx E1/T1, Gigabit Ethernet, 2 x OC3, DS3, NxDS3, Integrated Add/Drop Mux, OC3
- Up to 37 dbm Output Power
- Standard TDM and Ethernet Mix Programmable
- Ring and Consecutive Point Architecture

The NX-GEN-S is an advanced software-defined digital microwave radio that offers scalable configurations and the highest value in the point-to-point microwave marketplace.

This carrier class product transports a programmable mix of native TDM and IP traffic separately, ensuring a seamless transition from legacy TDM networks to an all-IP network.

The integrated "Add and Drop" multiplexer allows DS3/28DS1, SDH/63E1, add/drop operation. The advanced QoS / Ethernet features deliver secure LAN / WLAN networks.

The comprehensive NMS / Web Server / SNMP features enable the NX-GEN-S to be integrated with existing managed networks.

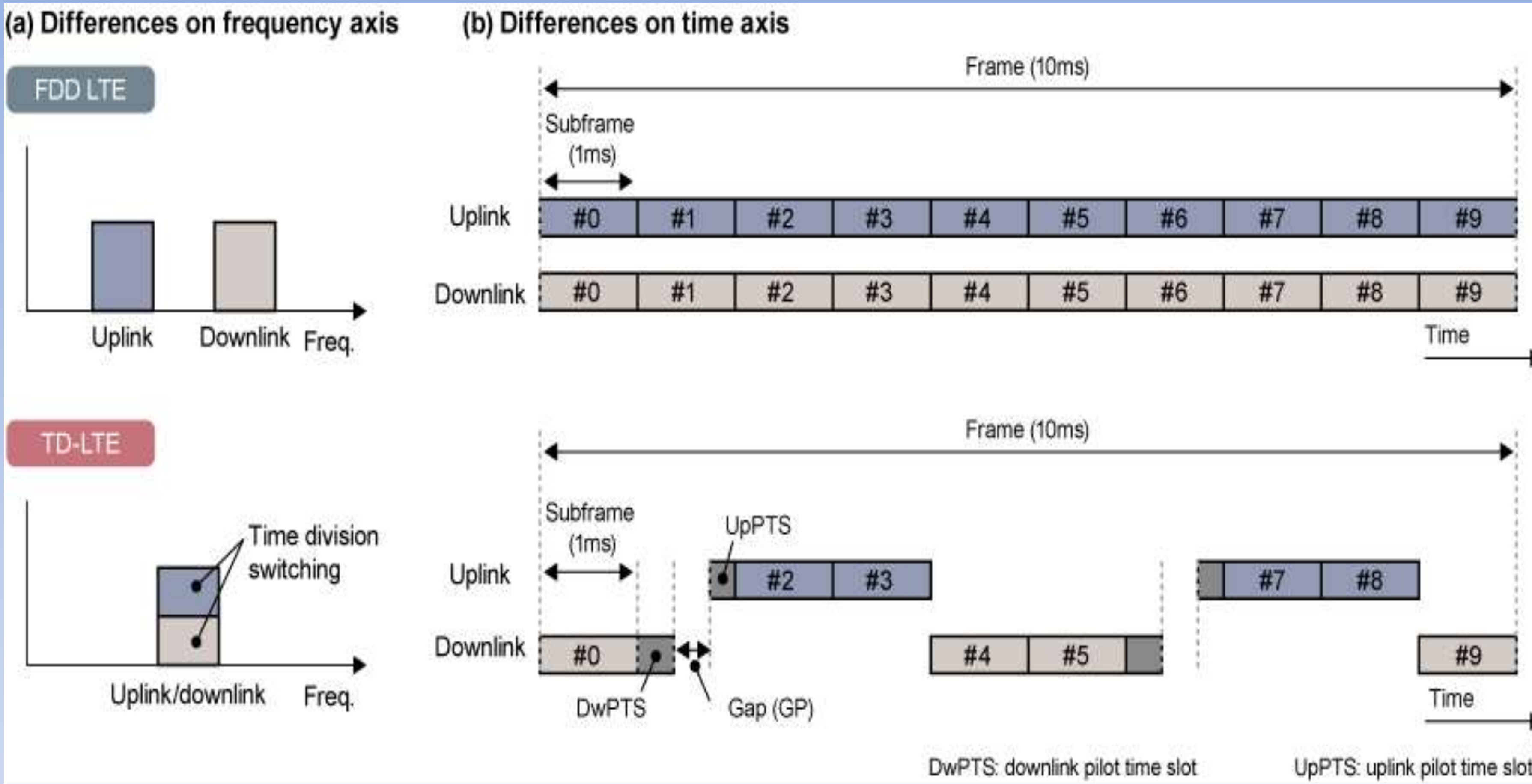
Moseley

Licensed Field Radio Upgrade

- After the Exalt testing we were willing to accept the TDD limitations as we had very limited options for an IDU radio
- Received a call from a sales rep for Moseley Broadcast
- Reviewed the spec for the NX-GEN-S and it met all of our requirements
- Requested a link from Moseley to test

Licensed Field Radio Upgrade

- Moseley Nx-Gen-S is a full duplex radio



FDD vs. TDD

- An FDD link will use up more spectrum, but the upside is much higher throughput

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- Moseley Nx-Gen-S is a full duplex radio
- With the Moseley radio’s, the frequency, channel size and assignment are customizable

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- Moseley Nx-Gen-S is a full duplex radio
- With the Moseley radio’s, the frequency, channel size and assignment are customizable
- The FCC allowed for a 5 MHz channel size, none of the TDD radio’s I looked at went lower than 10 MHz

Licensed Field Radio Upgrade

- Moseley Nx-Gen-S is a full duplex radio
- With the Moseley radio’s, the frequency, channel size and assignment are customizable
- The FCC allowed for a 5 MHz channel size, none of the TDD radio’s I looked at went lower than 10 MHz
- With the Moseley radio, we get a true full-duplex connection with a slightly higher throughput using the same amount of spectrum, while sacrificing about 2 dB of receiver sensitivity

Items to change Highlighted with Pull down menu options

RS Error Correction = 1.1

Digital Roll of Filter = 1.2

Bandwidth 5 MHz Bandwidth System

Trellis Code	Modulation Type	Efficiency (Bit / Hz)	Change based on Factory Information Over Head for Radio (Mbps)	Data Rate (Mbps)	Change based on Factory Information Duplexer Losses (dB)	Threshold in dBm at Receiver	Change number based on Factory Tx Power dBm	System Gain dB	Co Channel 3dB Interference Signal	Co Channel 3dB degradation on Threshold	1st Adjacent
7/8	QPSK	2	0.5	6.50	5	-91	27	118	-100	-9	8
3/4	16QAM	4	0.5	11.50	5	-84	27	111	-102	-18	8
4/5	32QAM	5	0.5	15.50	5	-80	27	107	-101	-21	8
5/6	64QAM	6	0.5	19.50	5	-75	27	102	-102	-27	8
6/7	128QAM	7	0.5	23.50	5	-70	27	97	-103	-33	8
15/16	256QAM	8	0.5	29.50	5	-65	27	92	-104	-39	8

Moseley Throughput and Receiver Threshold Calculator

Microwave Link Analysis

		Site A	Repeater	Site B
Site Name	:	Bass		Fawndale
Location	:	Bass Mtn		I5 South at Fawndale O
Call Sign	:	n/a		n/a
Latitude	:	40° 43' 58.14" N	40° 43' 14.85" N	40° 43' 51.00" N
Longitude	:	122° 22' 01.57" W	122° 19' 36.40" W	122° 19' 13.54" W
Elevation	ft/m:	2785.0 / 848.9	948.2 / 289.0	976.0 / 297.5
Azimuth	deg:	111.3901	291.4164 / 25.69049	205.6946
Distance to Repeater	mi/km:	2.3 / 3.7		0.8 / 1.2
Frequency	MHz:	4952.50000		4977.50000
Equipment	:	Moseley NX-GEN-S		Moseley NX-GEN-S
Tx Antenna Height	ft:	45.00		30.00
Tx Antenna Type	:	Radio Waves HP2-4.7		Radio Waves HP2-4.7
Tx Antenna Size / Polarization	ft:	2 / H		2 / H
Tx Transmission Line Length	ft:	89.99		60.01
Tx Transmission Line Type	:	LDF5-50A		LDF4-50A
Rx Antenna Height	ft:	45.00		30.00
Rx Antenna Type	:	Radio Waves HP2-4.7		Radio Waves HP2-4.7
Rx Antenna Size / Polarization	ft:	2 / H		2 / H
Rx Transmission Line Length	ft:	60.01		60.01
Rx Transmission Line Type	:	LDF5-50A		LDF4-50A
Effective Isotropic Radiated Power	dBm:	41.74		41.80
System Gains		**Site A to B**		**Site B to A**
Tx Antenna Gain	dBi:	28.50		28.50
Rx Antenna Gain	dBi:	28.50		28.50
Transmitter Power	dBm:	18.00		18.00
Total System Gain	dB:	165.77		165.77
System Losses		**Site A to B**		**Site B to A**
Free Space Path Loss	dBi:	117.62 \ 108.19	117.66 \ 108.24	
Diffraction Loss	dB:	0.00		0.00
Atmospheric Absorption	dB:	0.04		0.04
Foliage Loss	dB:	0.00		0.00
Tx Jumper Loss	dB:	0.40		0.40
Tx Radome Loss	dB:	0.00		0.00
Tx Connector Loss	dB:	0.74		0.50
Tx Transmission Line Loss	dB:	3.12		3.30
Tx Standby Switch Loss	dB:	0.00		0.00
Tx Power Splitter Loss	dB:	0.00		0.00
Tx RF Branching Loss	dB:	0.00		0.00
Tx Attenuator Pad Loss	dB:	0.00		0.00
Tx Miscellaneous & Safety Loss	dB:	0.50		0.50
Rx Connector Loss	dB:	0.50		0.74
Rx Transmission Line Loss	dB:	3.27		2.11
Rx Jumper Loss	dB:	0.40		0.40
Rx Radome Loss	dB:	0.00		0.00
Rx Hybrid Loss	dB:	0.00		0.00
Rx RF Branching Loss	dB:	0.00		0.00
Rx Attenuator Pad Loss	dB:	0.00		0.00
Rx Miscellaneous & Safety Loss	dB:	0.50		0.50
Repeater Loss	dB:		0.00	
Total System Loss	dB:	235.28		234.39
Path Calculations		**Site A to B**		**Site B to A**
Unfaded Receive Signal Level	dBm:	-69.51		-68.62
Rx Threshold Level	dBm:	-84.00		-84.00
Fade Margin	dB:	14.49		15.38
Outage	sec/year:	31.36		25.68
Rain Outage	sec/year:	0.00		0.00
Propagation Reliability	%:	99.99990056		99.99991856

Outage Parameters: Vigants - Digital

Climate Factor (c)	0.262	Terrain Factor (w)	140.0	Average Temperature	15.56°C / 60.0°F
CFM	15.38	DFM	0.000	TFM	15.382
BER	1x10E-6	AIFM	0.000	EIFM	0.000

Microwave Link Analysis

		Site A	Site B
Site Name	:	Sugarloaf	Obrien
Location	:	Sugarloaf Peak	I5 South at Obrien exit
Call Sign	:	n/a	n/a
Latitude	:	40° 54' 51.50" N	40° 49' 33.09" N
Longitude	:	122° 26' 42.10" W	122° 19' 13.02" W
Elevation	ft/m:	3859.8 / 1176.5	1614.0 / 491.9
Azimuth	deg:	133.004	313.0856
Distance	mi/km:	8.942 / 14.4	8.942 / 14.4
Frequency	MHz:	4962.50000	4987.50000
Equipment	:	Moseley NX-GEN-S	Moseley NX-GEN-S
Tx Antenna Height	ft:	25.00	30.00
Tx Antenna Type	:	Radio Waves HP2-4.7	Radio Waves HP3-4.7
Tx Antenna Size / Polarization	ft:	2 / V	3 / V
Tx Transmission Line Length	ft:	50.00	75.00
Tx Transmission Line Type	:	LDF4-50A	LDF4-50A
Rx Antenna Height	ft:	25.00	30.00
Rx Antenna Type	:	Radio Waves HP2-4.7	Radio Waves HP3-4.7
Rx Antenna Size / Polarization	ft:	2 / V	3 / V
Rx Transmission Line Length	ft:	50.00	75.00
Rx Transmission Line Type	:	LDF4-50A	LDF4-50A
Effective Isotropic Radiated Power	dBm:	42.38	42.77

System Gains		Site A to B	Site B to A
Tx Antenna Gain	dBi:	28.50	29.30
Rx Antenna Gain	dBi:	29.30	28.50
Transmitter Power	dBm:	18.00	19.00
Total System Gain	dB:	75.80	76.80

System Losses		Site A to B	Site B to A
Free Space Path Loss	dB:	129.523	129.567
Diffraction Loss	dB:	0.00	0.00
Atmospheric Absorption	dB:	0.11	0.11
Foliage Loss	dB:	0.00	0.00
Tx Jumper Loss	dB:	0.40	0.40
Tx Radome Loss	dB:	0.00	0.00
Tx Connector Loss	dB:	0.50	0.50
Tx Transmission Line Loss	dB:	2.73	4.13
Tx Standby Switch Loss	dB:	0.00	0.00
Tx Power Splitter Loss	dB:	0.00	0.00
Tx RF Branching Loss	dB:	0.00	0.00
Tx Attenuator Pad Loss	dB:	0.00	0.00
Tx Miscellaneous & Safety Loss	dB:	0.50	0.50
Rx Connector Loss	dB:	0.50	0.74
Rx Transmission Line Loss	dB:	4.09	2.75
Rx Jumper Loss	dB:	0.40	0.40
Rx Radome Loss	dB:	0.00	0.00
Rx Hybrid Loss	dB:	0.00	0.00
Rx RF Branching Loss	dB:	0.00	0.00
Rx Attenuator Pad Loss	dB:	0.00	0.00
Rx Miscellaneous & Safety Loss	dB:	0.50	0.50
Total System Loss	dB:	139.24	139.6

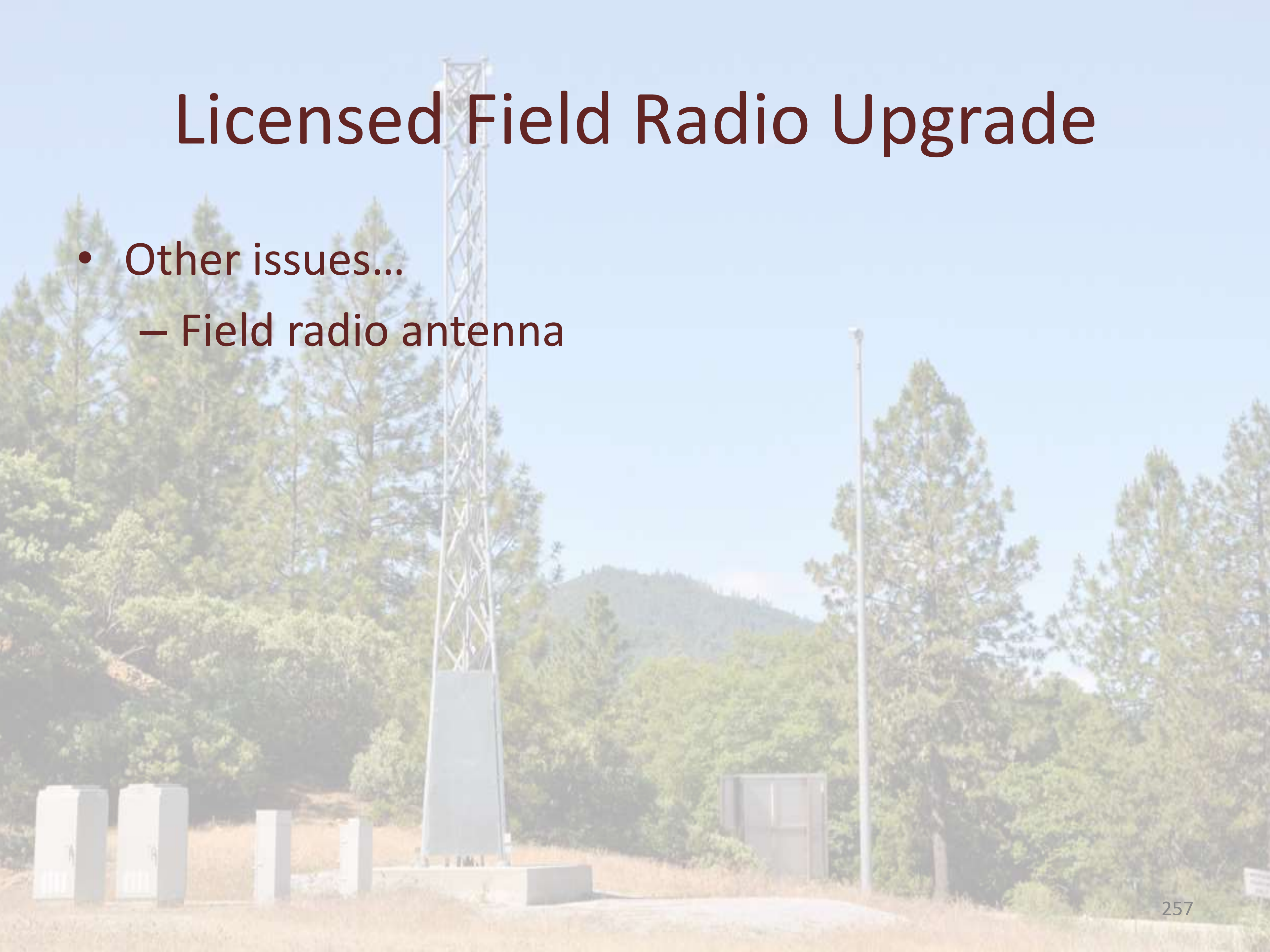
Path Calculations		Site A to B	Site B to A
Unfaded Receive Signal Level	dBm:	-63.44	-62.80
Rx Threshold Level	dBm:	-84.00	-84.00
Fade Margin	dB:	20.56	21.20
Outage	sec/year:	197.47	171.16
Rain Outage	sec/year:	0.00	0.00
Propagation Reliability	%:	99.99937381	99.99945725

Outage Parameters: Vigants - Digital

Climate Factor (c)	0.262	Terrain Factor (w)	140.0	Average Temperature	15.56°C / 60.0°F
CFM	21.2	DFM	0.000	TFM	21.198
BER	1x10E-6	AIFM	0.000	EIFM	0.000

Licensed Field Radio Upgrade

- Other issues…
  - Field radio antenna



Licensed Field Radio Upgrade

- Other issues…
  - Field radio antenna
  - Need a 2’, 3’, and a 4’ parabolic antenna, preferably a High Performance Parabolic

Licensed Field Radio Upgrade

- Other issues…
  - Field radio antenna
  - Need a 2’, 3’, and a 4’ parabolic antenna, preferably a High Performance Parabolic
  - Found three parabolic dishes that met our needs
    1. Andrew – Not enough selection, 3’ and 4’ dishes recently discontinued, unhappy with quality recently, only standard parabolic dishes available

Licensed Field Radio Upgrade

- Other issues…
  - Field radio antenna
  - Need a 2’, 3’, and a 4’ parabolic antenna, preferably a High Performance Parabolic
  - Found three parabolic dishes that met our needs
    1. Andrew
    2. Gabriel – Difficult to order, link alignment mechanism undesirable, only standard parabolic dishes available

Licensed Field Radio Upgrade

- Other issues…
  - Field radio antenna
  - Need a 2’, 3’, and a 4’ parabolic antenna, preferably a High Performance Parabolic
  - Found three parabolic dishes that met our needs
    1. Andrew
    2. Gabriel
    3. Radio Waves – Offers a variety of High Performance parabolic dishes, mount and alignment mechanism look good, easy to buy

Public Safety Band

4.940 - 4.990 GHz Spread Spectrum UNII Band

Device Specifications

- Gabriel "Best In Class" Quality & Dependability
- **New** Innovative Feed Designs
- Type "N" Female connector, 50 ohm, standard.
- CPR 137 Available on Parabolic
- QuickFire feeds allow for easy installation & inspection.
- Gabriel antennas meet or exceed standards EIA/TIA-195-C and EIA/TIA-222-F.
- 2-foot (0.6-m) models are supplied with Gabriel's Patented Quick Align Mount
- The Feed assembly on 2-ft. models is front insertable

Technical Specifications

Model Number	Size Ft. (in)	Gain at dBi Low	Gain at dBi Mid	Gain at dBi High	Nominal Beam Width (deg)	XPD dB	F/B ratio dB	VSWR Max. (R.L. dB)	Connector Type	Weight Pounds
Panels										
EPD1-49	1 (0.3)	21.9	22.4	22.9	9.0	26	35	1.7 (11.7)	N-Type	7
EPD2-49	2 (0.6)	26.5	27.0	27.5	4.6	26	40	1.4 (15.6)	or SMA 6" Cable	21
Parabolics										
QF2-49-N*	2(0.6)	27.6	27.7	27.8	7.0	35	35	1.30(17.7)	N-Type	35
QF2.5-49-N*	2.5(0.8)	29.6	29.7	29.8	5.6	35	38	1.30(17.7)	N-Type	40
QF4-49-N*	4(1.2)	33.6	33.7	33.7	3.5	35	42	1.30(17.7)	N-Type	100
QF6-49-N	6(1.8)	37.2	37.2	37.3	2.4	35	46	1.30(17.7)	N-Type	200

** Also available in RK (radome included) configurations.*

GENERAL DYNAMICS
C4 Systems

RADIOWAVES
THE LEADER IN MICROWAVE ANTENNA INNOVATION™

High Performance Series for 4.4-5.0 GHz Frequencies

Key Features

- **High Performance antennas minimize interference as they have more stringent radiation side lobe and front-to-back suppression characteristic**
- **Lightweight and rugged design**
- **Easily installed with our superior mounting system included with the antenna**
- **RF connector: "N" female connector. Some models are available with 7/16 DIN Connector. Please call the factory for availability**
- **Our industry leading 7-year warranty**
- **Radome is included**
- **Single (HP) and Dual (HPD) polarization are available**

Antenna Specifications, Electrical **(typical)**

Model Number	Diameter ft. (m)	Frequency GHz	Gain (dBi) Low	Mid	High	3dB BW degs	X-Pol Rejection. dB	F/B Ratio dB	VSWR, Max (R.L., dB)	Antenna Weight
HP2-4.7	2 (0.6)	4.4-5.0	25.8	26.4	29.6	7.1 deg.	28 dB	48 dB	1.5:1 (14.0)	27 lbs. (12.3 kg)
HP3-4.7	3 (0.9)	4.4-5.0	29.2	29.8	30.3	4.7 deg.	30 dB	52 dB	1.5:1 (14.0)	50 lbs. (22.7 kg)
HP4-4.7	4 (1.2)	4.4-5.0	31.8	32.4	32.9	3.6 deg.	30 dB	54 dB	1.5:1 (14.0)	85 lbs. (38.3 kg)
HP6-4.7	6 (1.8)	4.4-5.0	34.8	35.4	35.3	2.6 deg.	30 dB	57 dB	1.5:1 (14.0)	251 lbs. (113.0 kg)
HP8-4.7	8 (2.4)	4.4-5.0	48.2	38.8	39.3	1.8 deg.	30 dB	61 dB	1.5:1 (14.0)	424 lbs. (194.5 kg)
HPLPD1-4.7	1 (0.3)	4.4-5.0	20.2	20.8	21.1	13.1 deg.	20 dB	40 dB	1.5:1 (14.0)	27 lbs. (12.3 kg)
HPD2-4.7	2 (0.6)	4.4-5.0	25.8	26.4	26.9	7.1 deg.	28 dB	48 dB	1.5:1 (14.0)	27 lbs. (12.3 kg)
HPD3-4.7	3 (0.9)	4.4-5.0	29.2	29.8	30.3	4.7 deg.	30 dB	52 dB	1.5:1 (14.0)	50 lbs. (22.7 kg)
HPD4-4.7	4 (1.2)	4.4-5.0	31.8	32.4	32.9	3.6 deg.	30 dB	54 dB	1.5:1 (14.0)	85 lbs. (38.3 kg)
HPD6-4.7	6 (1.8)	4.4-5.0	34.8	35.4	35.9	2.6 deg.	30 dB	57 dB	1.5:1 (14.0)	251 lbs. (113.0 kg)
HPD8-4.7	8 (2.4)	4.4-5.0	38.2	38.8	39.3	1.8 deg.	30 dB	61 dB	1.5:1 (14.0)	424 lbs. (194.5 kg)

Note: Side Struts available from Radio Waves

Radio Waves, Inc. • 495 R Billerica Avenue • N. Billerica, MA 01862 USA • Tel: (978) 459-8800 • Fax: (978) 459-3310 / 8810
www.radiowavesinc.com

HPX4.7 Rev. A

sales@radiowavesinc.com

Licensed Field Radio Upgrade

- Other issues…
  - Network changes
    - Not desirable to have a flat switched network, want to segment the backbone network from the field radio networks

Licensed Field Radio Upgrade

- Other issues…
  - Network changes
    - Not desirable to have a flat switched network, want to segment the backbone network from the field radio networks
    - Using a Cisco Layer 3, 16-port switch Service Module to aggregate Ethernet interfaces from field radios at Mtn Top locations

Licensed Field Radio Upgrade

- Other issues…
  - Network changes
    - Decided to use the existing router at the Mtn Top, rather than routing off the layer 3 backbone switch

Licensed Field Radio Upgrade

- Other issues…
  - Network changes
    - Decided to use the existing router at the Mtn Top, rather than routing off the layer 3 backbone switch
    - A Router gives us some extra flexibility if we ever needed to use a serial or T1 interface at the Mtn Top

Licensed Field Radio Upgrade

- Other issues…
  - Network changes
    - Decision to use Ethernet interface on field radios requires us to replace legacy Cisco 2509-ET routers at ITS Nodes with Cisco 1841 or 1921 routers, the 2509-ET had only one native Ethernet port, the upgrade will require two Ethernet ports on the router

Licensed Field Radio Upgrade

- Other issues…
  - Network changes
    - Decision to use Ethernet interface on field radios requires us to replace legacy Cisco 2509-ET routers at ITS Nodes with Cisco 1841 or 1921 routers, the 2509-ET had only one native Ethernet port, the upgrade will require two Ethernet ports on the router
    - Upgrade will require an extra 4-port switch module for our field switch to accommodate the NMS port on the radio

Licensed Field Radio Upgrade

- Pit River Bridge Link Turn-up
  - Discuss…

Sac River Canyon Rigid Towers Project

Sac River Canyons Rigid Towers

- Project initiated due to antenna requirements for Licensed Field Radio Upgrade project when it was coordinated to 900 MHz

KATHREIN
SCALA DIVISION

RY-900B
Radome Protected Yagi Antenna

The Kathrein-Scala RY series are rugged broadband yagi antennas housed in rugged fiberglass radomes, fabricated of 6061/T6 aluminum rod and seamless drawn pipe, anodized for maximum reliability and corrosion resistance. The radome protects the antenna against snow, ice and other adverse environmental conditions which can degrade performance and cause damage. The hardware and fastenings are stainless steel. The internal balun, coax feed and connector are sealed in a foam potting system to prevent moisture penetration and assure long service life in severe environmental conditions. The heavy aluminum mounting casting allows installation for V or H polarization.

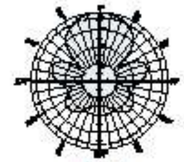
- The RY-900B is specifically designed for professional fixed-station applications in the 890–960 MHz band.

(Shown vertically polarized)

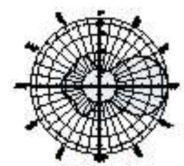
Specifications:

Frequency range	890–960 MHz
Gain	12 dBi
Impedance	50 ohms
VSWR	< 1.5:1 maximum (1.35:1 typical)
Polarization	Horizontal or vertical
Front-to-back ratio	>20 dB
Maximum input power	100 watts (at 50°C)
H-plane beamwidth	48 degrees (half-power)
E-plane beamwidth	40 degrees (half-power)
Connector	N female
Weight	16.0 lb (7.3 kg)
Dimensions	29 x 17 x 12 inches (737 x 432 x 305 mm)
Equivalent flat plate area	2.78 ft² (0.258 m²)
Wind survival rating*	120 mph (200 kph)
Shipping dimensions	31 x 20 x 14.5 inches (787 x 508 x 368 mm)
Shipping weight	28.0 lb (12.7 kg)
Mounting	Mounting kits available for masts of 2.375 to 4.5 inch (60 to 114 mm) OD.

See reverse for order information.



H-plane
Horizontal pattern – V-polarization
Vertical pattern – H-polarization



E-plane
Horizontal pattern – H-polarization
Vertical pattern – V-polarization

* Mechanical design is based on environmental conditions as stipulated in EIA-222-F (June 1996) and/or ETS 300 019-1-4 which include the static mechanical load imposed on an antenna by wind at maximum velocity. See the Engineering Section of the catalog for further details.

RoHS
Lead-Free
10064-G

Kathrein Inc., Scala Division Post Office Box 4580 Medford, OR 97501 (USA) Phone: (541) 779-6500 Fax: (541) 779-3991
Email: communications@kathrein.com Internet: www.kathrein-scala.com

Sac River Canyons Rigid Towers

- Project initiated due to antenna requirements for Licensed Field Radio Upgrade project when it was coordinated to 900 MHz
- Frequency coordination showed extensive use of the 900 MHz band by the railroad, FCC required tighter tolerances on antenna spec

Sac River Canyons Rigid Towers

- Project initiated due to antenna requirements for Licensed Field Radio Upgrade project when it was coordinated to 900 MHz
- Frequency coordination showed extensive use of the 900 MHz band by the railroad, FCC required tighter tolerances on antenna spec
- Realized our intent to install Yagis on existing CCTV poles wasn’t going to work

Sac River Canyons Rigid Towers

- Specified a gridded half parabolic, Scala PR-950, based on FCC requirements

KATHREIN
SCALA DIVISION

PR-950
High-Gain Half-Parabolic Antenna

The Kathrein-Scala Paraflector® is a high-gain half-parabolic antenna used in broadcast and communications systems around the world.

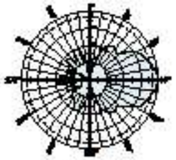
- High front-to-back ratio for point-to-point relay system applications, as well as GSM cellular repeaters and MAS and ISM systems.
- Fabricated from seamless drawn aluminum tubing and extruded pipe and heavy aluminum castings, gold anodized for corrosion protection, plus stainless steel hardware and fastenings. Foam-filled broadband feed assembly requires no pressurization and can be easily replaced if necessary.

Specifications:

Frequency range	940–960 MHz
Gain	18 dBi (16 dBd)
Impedance	50 ohms
VSWR	< 1.2:1
Polarization	Horizontal or vertical
Front-to-back ratio	>25 dB
Maximum input power	100 watts (at 50°C)
H-plane beamwidth	12 degrees (half-power)
E-plane beamwidth	24 degrees (half-power)
Connector	N female
Weight	38 lb (17.2 kg)
Dimensions	68 x 36 x 18 inches (1727 x 914 x 457 mm)
Equivalent flat plate area	6.35 ft² (.595 m²)
Wind survival rating*	100 mph (160 kph)
Shipping dimensions	40 x 36 x 7 inches (1016 x 914 x 178 mm)
Shipping weight	47 lb (21.3 kg)
Mounting	Mounting kits available for masts of 2.375 to 4.5 inches (60 to 114 mm) OD.

See reverse for order information.

H-plane
Horizontal pattern – V-polarization
Vertical pattern – H-polarization



E-plane
Horizontal pattern – H-polarization
Vertical pattern – V-polarization

*Mechanical design is based on environmental conditions as stipulated in EIA-222-F (June 1996) and/or ETS 300 019-1-4 which include the static mechanical load imposed on an antenna by wind at maximum velocity. See the Engineering Section of the catalog for further details.

RoHS
Lead-Free
10056-H

Kathrein Inc., Scala Division Post Office Box 4580 Medford, OR 97501 (USA) Phone: (541) 779-6500 Fax: (541) 779-3991
Email: communications@kathrein.com Internet: www.kathrein-scala.com

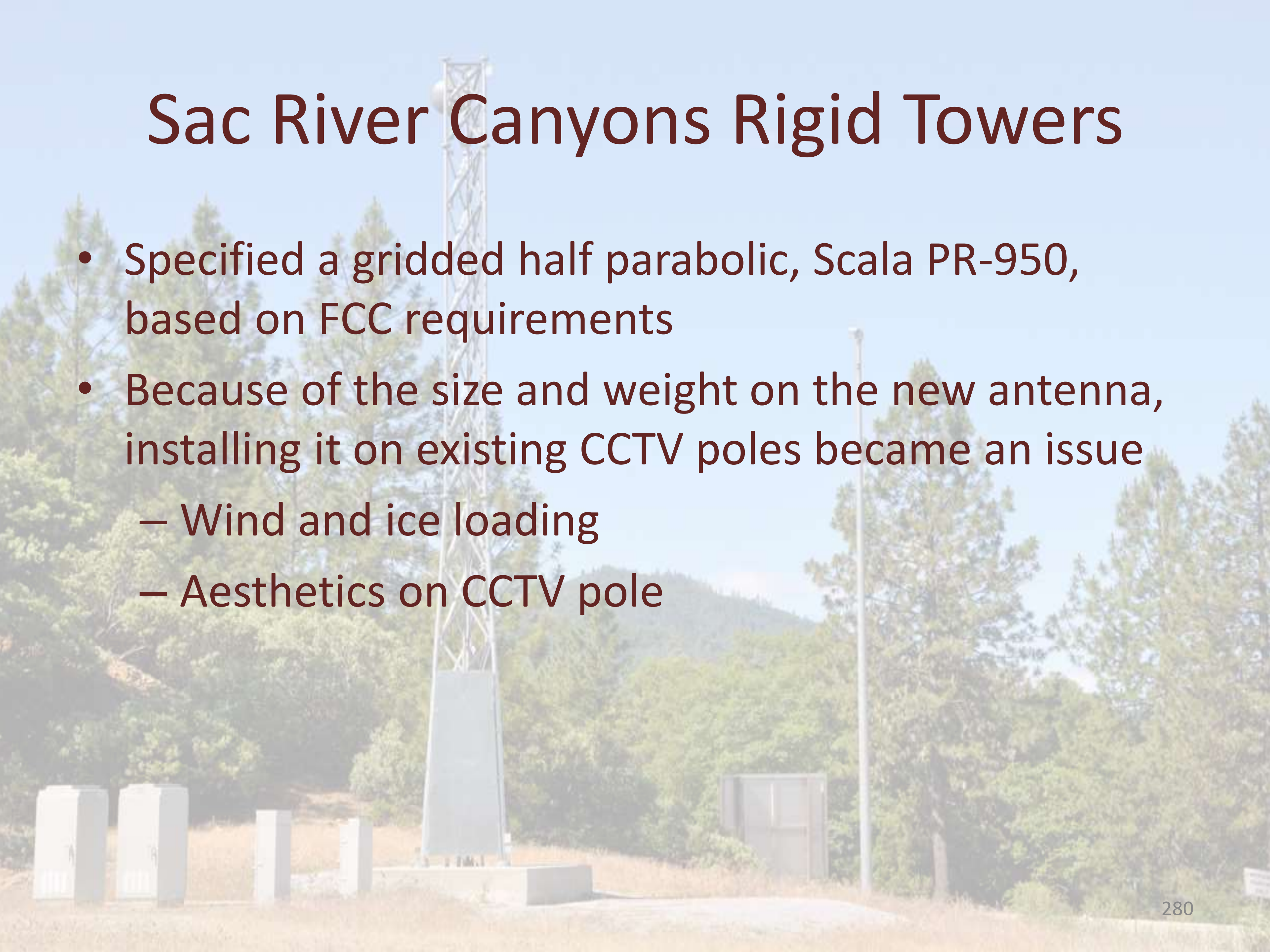
Sac River Canyons Rigid Towers

- Specified a gridded half parabolic, Scala PR-950, based on FCC requirements
- Because of the size and weight on the new antenna, installing it on existing CCTV poles became an issue

Sac River Canyons Rigid Towers

- Specified a gridded half parabolic, Scala PR-950, based on FCC requirements
- Because of the size and weight on the new antenna, installing it on existing CCTV poles became an issue
  - Wind and ice loading

Sac River Canyons Rigid Towers



- Specified a gridded half parabolic, Scala PR-950, based on FCC requirements
- Because of the size and weight on the new antenna, installing it on existing CCTV poles became an issue
  - Wind and ice loading
  - Aesthetics on CCTV pole

Sac River Canyons Rigid Towers

- Specified a gridded half parabolic, Scala PR-950, based on FCC requirements
- Because of the size and weight on the new antenna, installing it on existing CCTV poles became an issue
  - Wind and ice loading
  - Aesthetics on CCTV pole
- Also, this project was meant to set a precedence for taller towers further up canyon in densely forested areas where trees can reach 60 – 80 ft tall

Sac River Canyons Rigid Towers

- Project Scope
  - Install 35’ and 45’ galvanized steel lattice towers at five existing ITS nodes (originally seven sites)
  - Towers need anti-climb panels
  - Install conduit up the tower for cables
  - Install tower ground system
  - Interconnect to existing facilities
  - Remove existing CCTV poles

DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS
02	Sha	5	Var	1	25

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

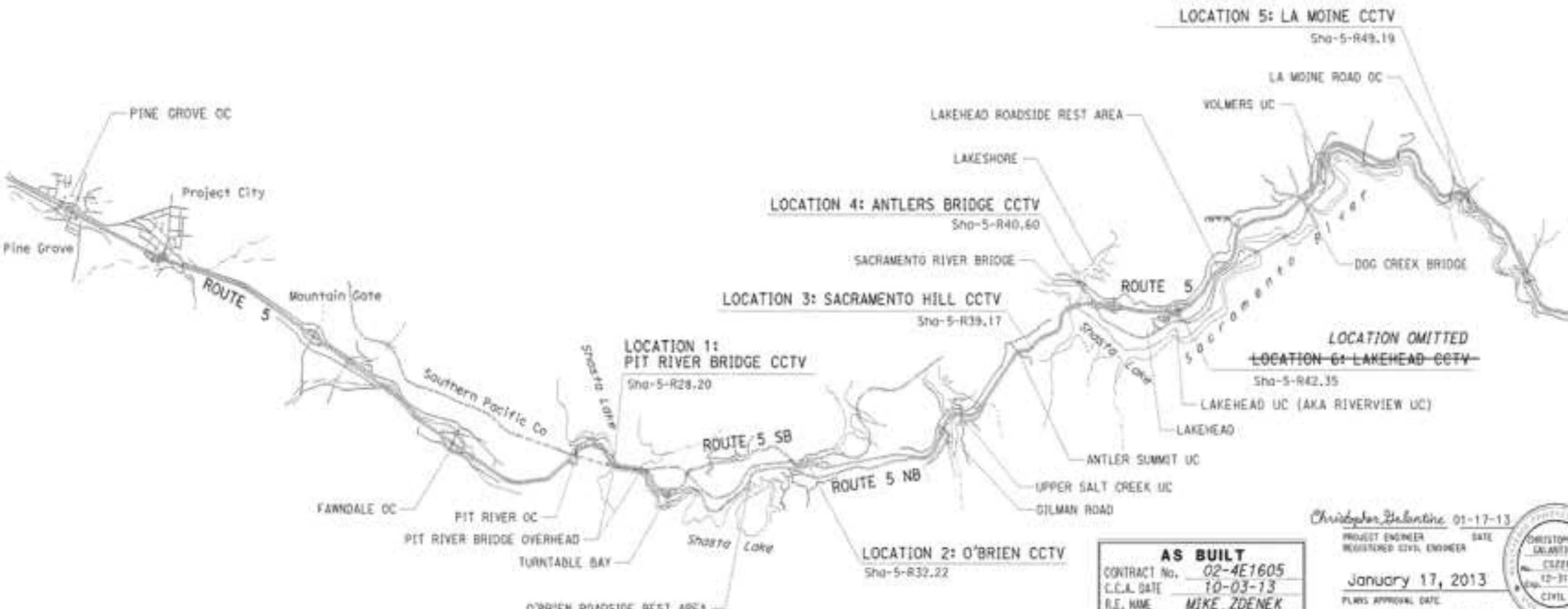
PROJECT PLANS FOR CONSTRUCTION ON
STATE HIGHWAY
IN SHASTA COUNTY AT VARIOUS LOCATIONS FROM PIT RIVER BRIDGE OVERHEAD TO 0.1 MILE NORTH OF LA MOINE ROAD OVERCROSSING

TO BE SUPPLEMENTED BY STANDARD PLANS DATED MAY 2006

INDEX OF PLANS

SHEET No.	DESCRIPTION
1	TITLE AND LOCATION MAP
2-3	CONSTRUCTION DETAILS
4-14	CCTV / ANTENNA TOWER (ELECTRICAL SUPPORT)
15-16	STRUCTURAL / ELECTRICAL DETAILS
17-25	REVISED STANDARD PLANS

THE STANDARD PLANS LIST APPLICABLE TO THIS CONTRACT IS INCLUDED IN THE NOTICE TO BIDDERS AND SPECIAL PROVISIONS BOOK.



NO SCALE

THE CONTRACTOR SHALL POSSESS THE CLASS (OR CLASSES) OF LICENSE AS SPECIFIED IN THE "NOTICE TO BIDDERS."

AS BUILT
CONTRACT No. 02-4E1605
C.C.A. DATE 10-03-13
R.E. NAME MIKE ZDENEK
R.E. Signature for final approval of As-built information

Christopher Galantine 01-17-13
PROJECT ENGINEER DATE
REGISTERED CIVIL ENGINEER

January 17, 2013
PLANS APPROVAL DATE

THE STATE OF CALIFORNIA OR ITS OFFICERS OR AGENTS SHALL NOT BE RESPONSIBLE FOR THE ACCURACY OR COMPLETENESS OF SCANNED COPIES OF THIS PLAN SHEET.

CHRISTOPHER GALANTINE No. C52697 Exp. 12-31-14 CIVIL

DESIGN ENGINEER MARK MILLER
PROJECT MANAGER MARK MILLER

CONTRACT No. 02-4E1604
PROJECT ID 0200020226

Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS
02	Sha	5	Var	6	25

01-17-13
REGISTERED ELECTRICAL ENGINEER DATE
01-17-13
PLANS APPROVAL DATE

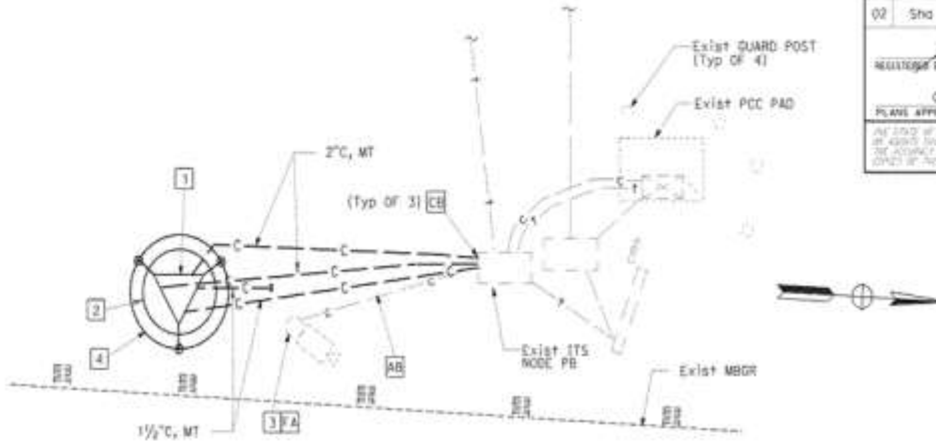
JEREMIAH PEARCE
No. E19475
Exp. 9-30-13
ELECTRICAL

NOTES:

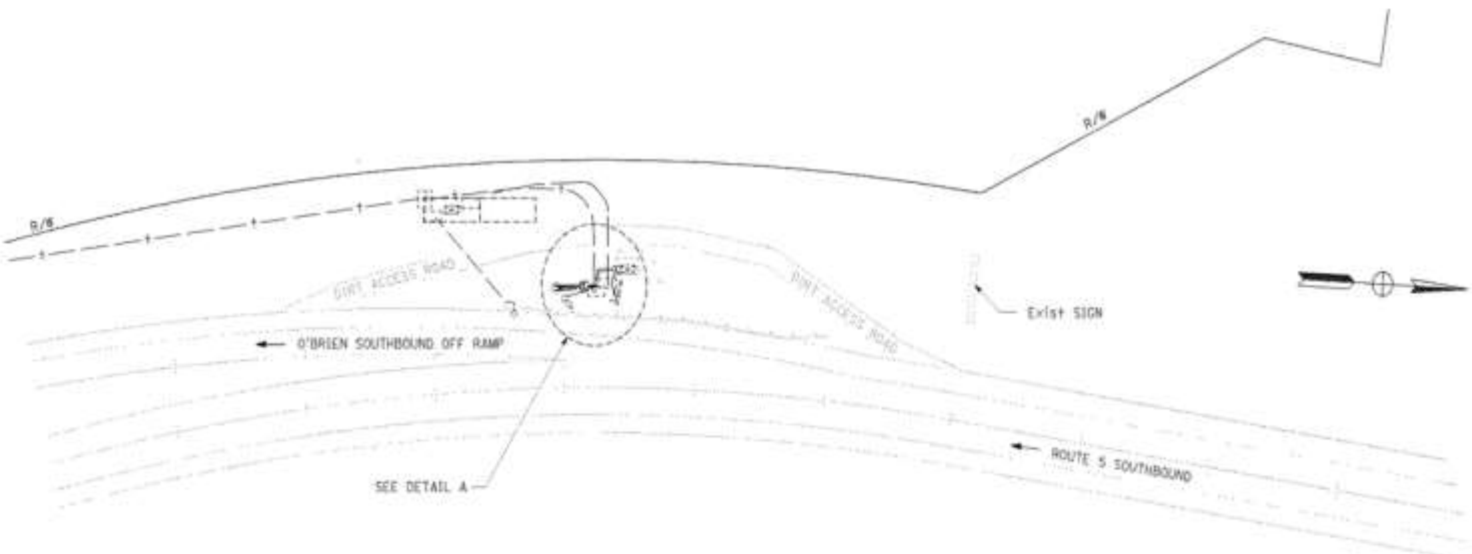
1. FOR ACCURATE RIGHT OF WAY AND ACCESS DATA, CONTACT RIGHT OF WAY ENGINEERING AT THE DISTRICT OFFICE.
2. VERIFY LOCATION OF ALL EXISTING CONDUITS BEFORE DRILLING FOR CIDH PILE FOUNDATION.

NOTES (THIS SHEET):

1. 35' CCTV TOWER, SEE CCTV/ANTENNA TOWER ELEVATION AND FOUNDATION DETAILS ON SHEET SES-1 AND SES-2.
2. EXACT LOCATION AND ORIENTATION OF TOWER FOUNDATION TO BE DETERMINED BY THE ENGINEER.
3. RS EXISTING CCTV POLE, CAMERA, 2' DISH ANTENNA AND CABLES.
4. SEE CONDUIT AND GROUNDING DETAIL ON SHEET E-4.



DETAIL A
NO SCALE



AS BUILT
CONTRACT No. 02-4E1605
C.C.A. DATE 10-03-13
R.E. NAME MIKE ZDENEK

CCTV/ANTENNA TOWER (ELECTRICAL SUPPORT) (LOCATION 2) O'BRIEN CCTV
NO SCALE

E-3

APPROVED FOR ELECTRICAL WORK ONLY

STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION
Caltrans ELECTRICAL DESIGN
FUNCTIONAL SUPERVISOR: IAN TURNBULL
CALCULATED-DESIGNED BY: JEREMIAH PEARCE
CHECKED BY: KEITH KOEPPEN
REVISED BY: J P
DATE REVISED: 01/03/13

UNIT 0151 | PROJECT NUMBER & PHASE | 02000202261

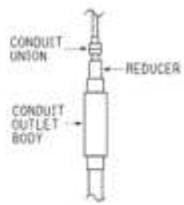
DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS
02	Sha	5	Var	7	25

01-17-13
REGISTERED ELECTRICAL ENGINEER DATE
01-17-13
PLANS APPROVAL DATE

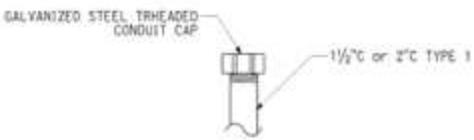
JEREMIAH PEARCE
No. E19475
Exp. 9-30-13
ELECTRICAL

NOTES (THIS SHEET):

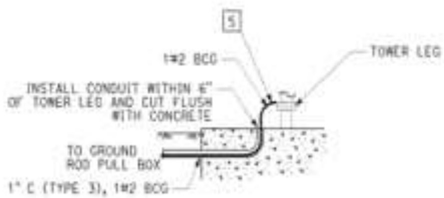
1. SECURE CONDUIT TO INSIDE OF TOWER FACE PER MANUFACTURER'S RECOMMENDATIONS.
2. SEE DETAIL A: INSTALL CONDUIT OUTLET BODY, REDUCER, AND CONDUIT UNION APPROXIMATELY 24" ABOVE FOUNDATION.
3. TERMINATE CONDUIT 12" ABOVE FOUNDATION. SEE DETAIL B THIS SEET
4. EXOTHERMIC WELD ALL CONNECTIONS TO GROUND RODS.
5. TOWER GROUND CONNECTION METHOD PER MANUFACTURER'S RECOMMENDATIONS (Typ OF 3).



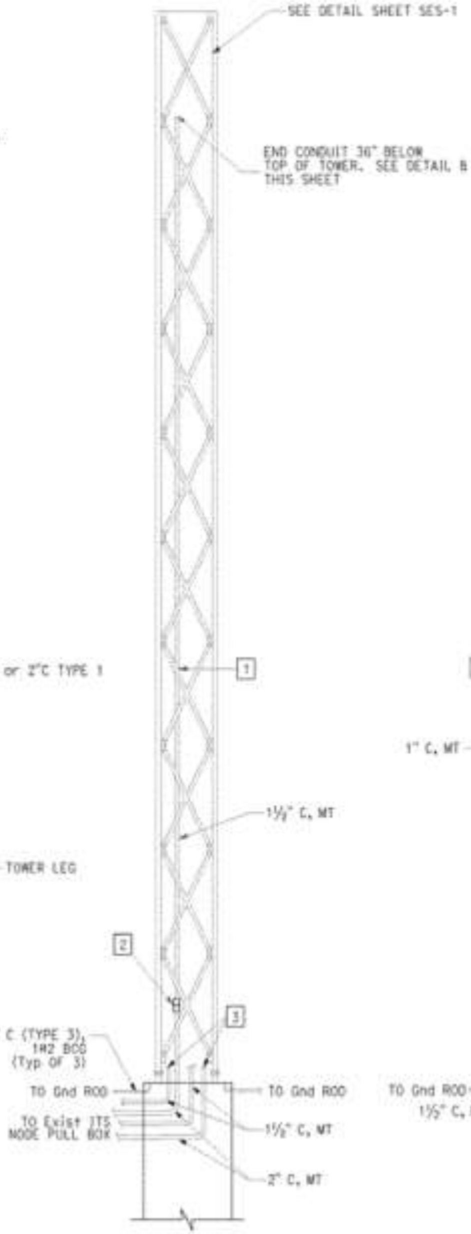
DETAIL A
SEE NOTE 2



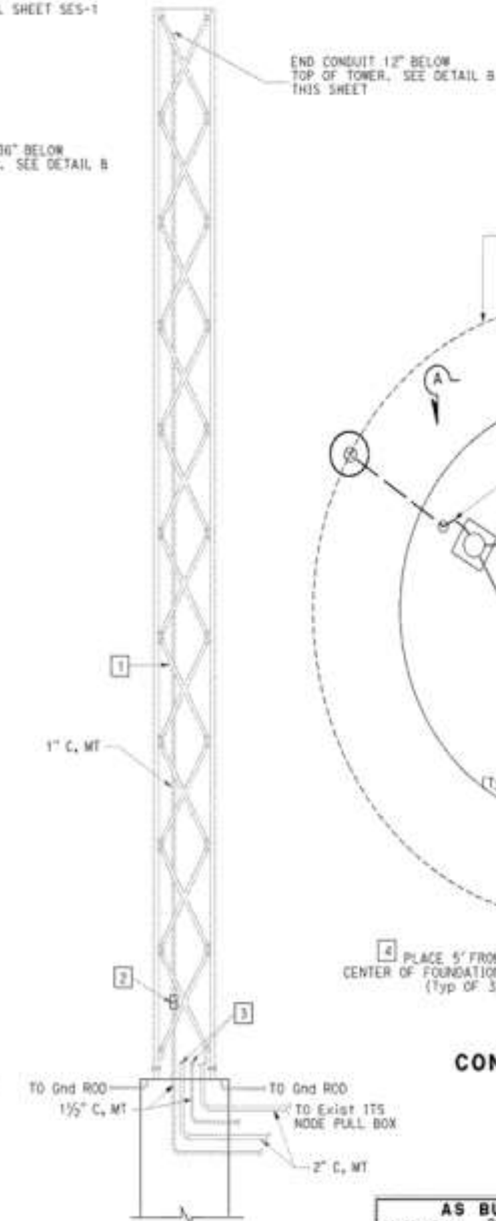
DETAIL B



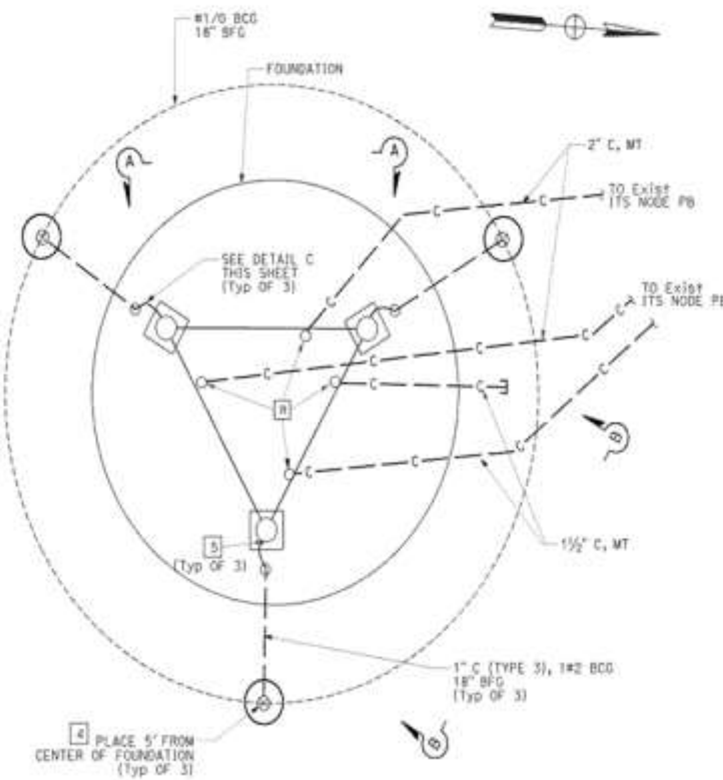
DETAIL C



ELEVATION
SECTION A-A



ELEVATION
SECTION B-B



PLAN VIEW
CONDUIT AND GROUNDING DETAIL

AS BUILT	
CONTRACT No.	02-4E1605
C.C.A. DATE	10-03-13
R.E. NAME	MIKE ZDENEK

CCTV/ANTENNA TOWER (ELECTRICAL SUPPORT) (LOCATION 3) O'BRIEN CCTV

NO SCALE

E-4

APPROVED FOR ELECTRICAL WORK ONLY

STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION
Caltrans ELECTRICAL DESIGN
JEREMIAH PEARCE
KEITH KOEPPEN
IAN TURNBULL

BORDER LAST REVISED 7/2/2010 | UNIT 0151 | PROJECT NUMBER & PHASE 02000202261

DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No	TOTAL SHEETS
02	Sha	5	Var	15	25

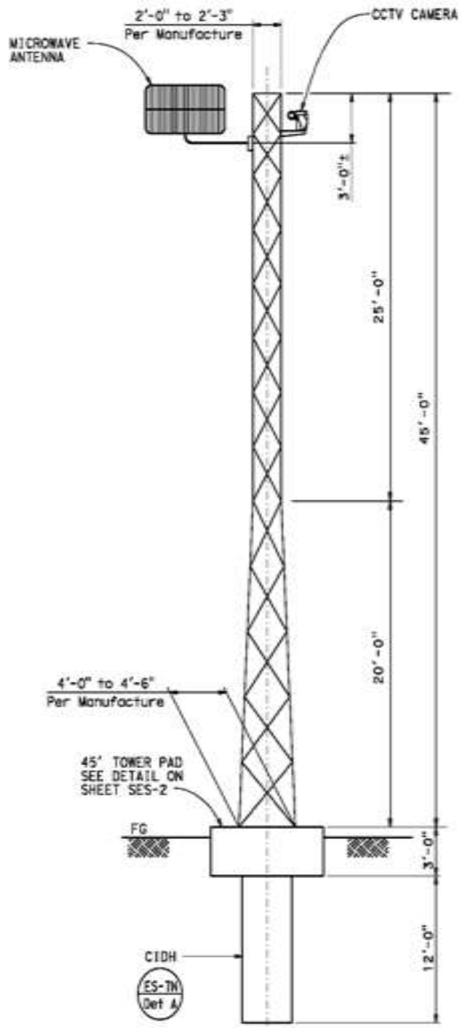
REGISTERED CIVIL ENGINEER 1-17-13 DATE

1-17-13
PLANS APPROVAL DATE

The State of California or its officers or agents shall not be responsible for the accuracy or completeness of electronic copies of this plan sheet.

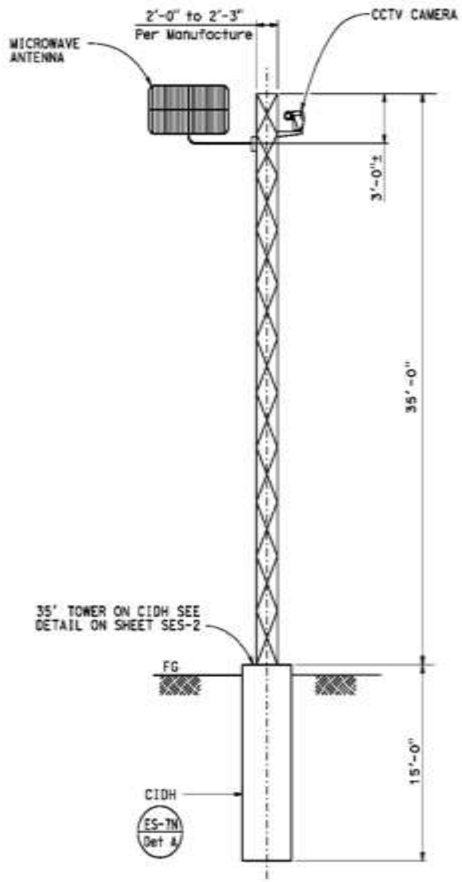
REGISTERED PROFESSIONAL ENGINEER JEFFREY B. WOODY No. C41260 Exp. 3/31/13 CIVIL STATE OF CALIFORNIA

To get to the Caltrans web site, go to: http://www.dot.ca.gov



ELEVATION

1/4" = 1'-0"



ELEVATION

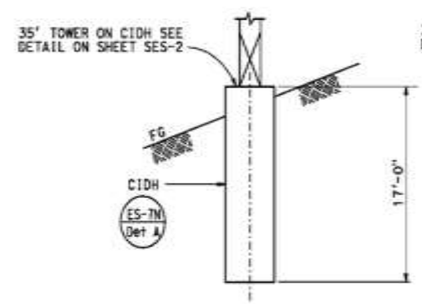
1/4" = 1'-0"

GENERAL NOTES:

1. Locale and topographic information for design shall be based on using the location coordinates listed below provided in D-M-S format. From south to north the tower locations are all along I-5 in California. The associated tower height at each location is shown in parenthesis.

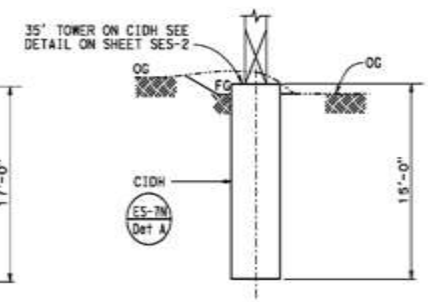
LOCATION 1: Pit River : 40°45'27.10"N, 122° 19'09.60"W (45')
LOCATION 2: Obrien : 40°49'33.10"N, 122°19'13.00"W (35')
LOCATION 3: Sacramento Hill : 40°52'15.90"N, 122°22'02.50"W (35')
LOCATION 4: Antlers Bridge : 40°53'06.13"N, 122°23'01.68"W (45')
LOCATION 5: Lamoine : 40°56'46.13"N, 122°25'54.40"W (35')

2. Microwave antenna and CCTV camera to be installed by others.
3. Tower pads shall be structural concrete.
4. Concrete: f'_c = 3,600 psi @ 28 days.



LOCATION 5
SLOPED FINISH GRADE
ELEVATION

1/4" = 1'-0"



LOCATION 3 (CUT BANK)
FINISH GRADE
ELEVATION

1/4" = 1'-0"

THE CONTRACTOR SHALL VERIFY ALL CONTROLLING FIELD DIMENSIONS BEFORE ORDERING OR FABRICATING ANY MATERIAL.

BRANCH CHIEF JEFFREY B WOODY	DESIGN	BY J WOODY	CHECKED J DATILES
	DETAILS	BY ARD/DWJJ	CHECKED J WOODY
	QUANTITIES	BY J DATILES	CHECKED D VORA

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

DIVISION OF ENGINEERING SERVICES
DESIGN AND TECHNICAL SERVICES
SPECIAL DESIGNS BRANCH **A**

BRIDGE NO. N/A
POST MILE

CCTV/ANTENNA TOWER
ELEVATION DETAILS

SES-1

UNIT: 3619
PROJECT NUMBER & PHASE: 0200020226-1
CONTRACT NO.: 02-4E1601

FILE => spec_des_br_prj/2011sd/02-4E1601/02-4e1601_ses-1.dgn


Sacramento Hill
CCTV 35’ tower

Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS
02	Sha	5	Var	10	25

REGISTERED ELECTRICAL ENGINEER 01-08-13 DATE

PLANS APPROVAL DATE 01-17-13

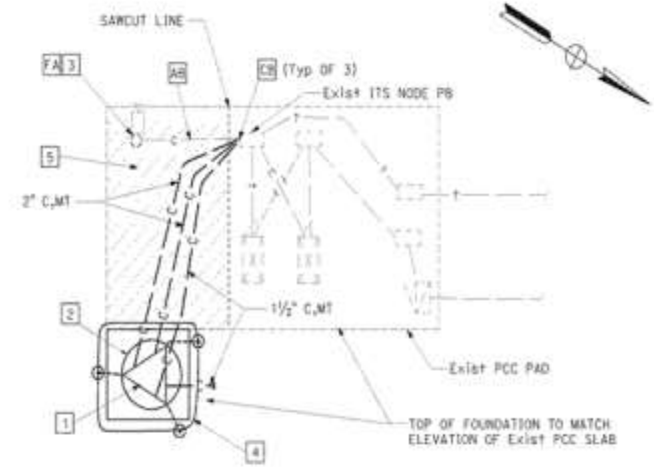
JEREMIAH PEARCE No. E19475 Exp. 6-30-13 ELECTRICAL

NOTES:

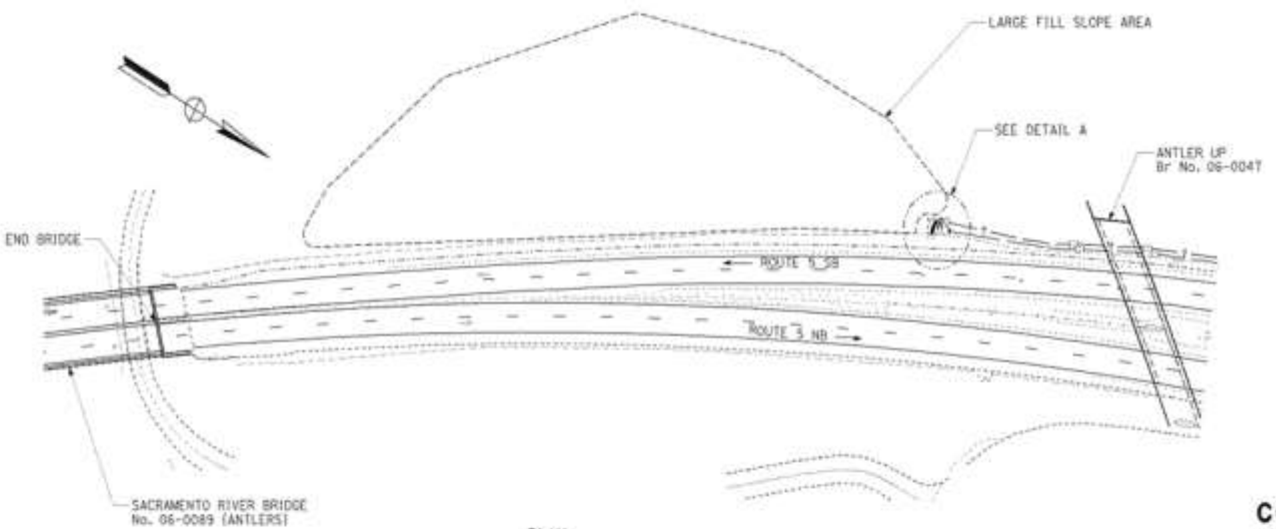
1. FOR ACCURATE RIGHT OF WAY AND ACCESS DATA, CONTACT RIGHT OF WAY ENGINEERING AT THE DISTRICT OFFICE.
2. VERIFY LOCATION OF ALL EXISTING CONDUITS BEFORE DRILLING FOR CIDH PILE FOUNDATION.

NOTES (THIS SHEET):

1. 45' CCTV TOWER, SEE TOWER AND FOUNDATION CONSTRUCTION DETAILS ON SHEET SES-1 AND SES-2.
2. EXACT LOCATION AND ORIENTATION OF TOWER FOUNDATION TO BE DETERMINED BY THE ENGINEER.
3. HS EXISTING CCTV POLE, CAMERA, 2' DISH ANTENNA AND CABLES.
4. SEE CONDUIT AND GROUNDING DETAIL ON SHEET E-8.
5. SEE Const DETAILS FOR REMOVAL AND REPLACEMENT OF CONCRETE SLAB.



DETAIL A
NO SCALE



PLAN

AS BUILT	
CONTRACT No.	02-4E1605
C.C.A. DATE	10-03-13
R.E. NAME	MIKE ZDENEK

CCTV/ANTENNA TOWER (ELECTRICAL SUPPORT) (LOCATION 4) ANTLERS BRIDGE CCTV
NO SCALE

E-7

APPROVED FOR ELECTRICAL WORK ONLY

STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION
Caltrans ELECTRICAL DESIGN
FUNCTIONAL SUPERVISOR: IAN TURNBULL
CALCULATED-DESIGNED BY: JEREMIAH PEARCE
CHECKED BY: KEITH KOEPPEN
REVISED BY: J.P.
DATE REVISED: 01/03/13

BORDER LAST REVISED 7/2/2010 | UNIT 0151 | PROJECT NUMBER & PHASE 02000202261

DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS
02	Sha	5	Var	11	25

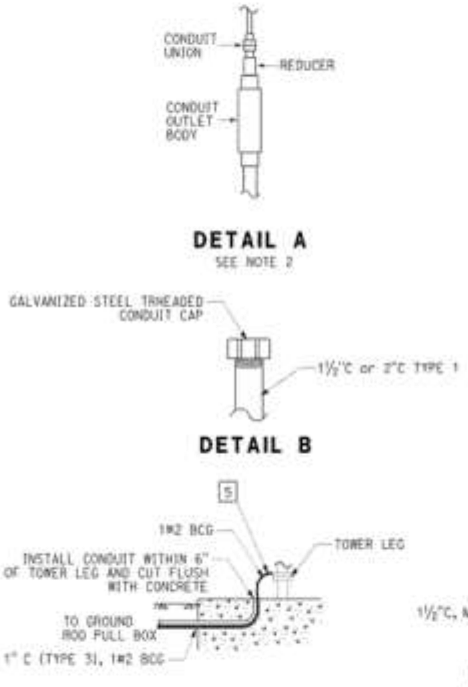
REGISTERED ELECTRICAL ENGINEER DATE 01-08-13

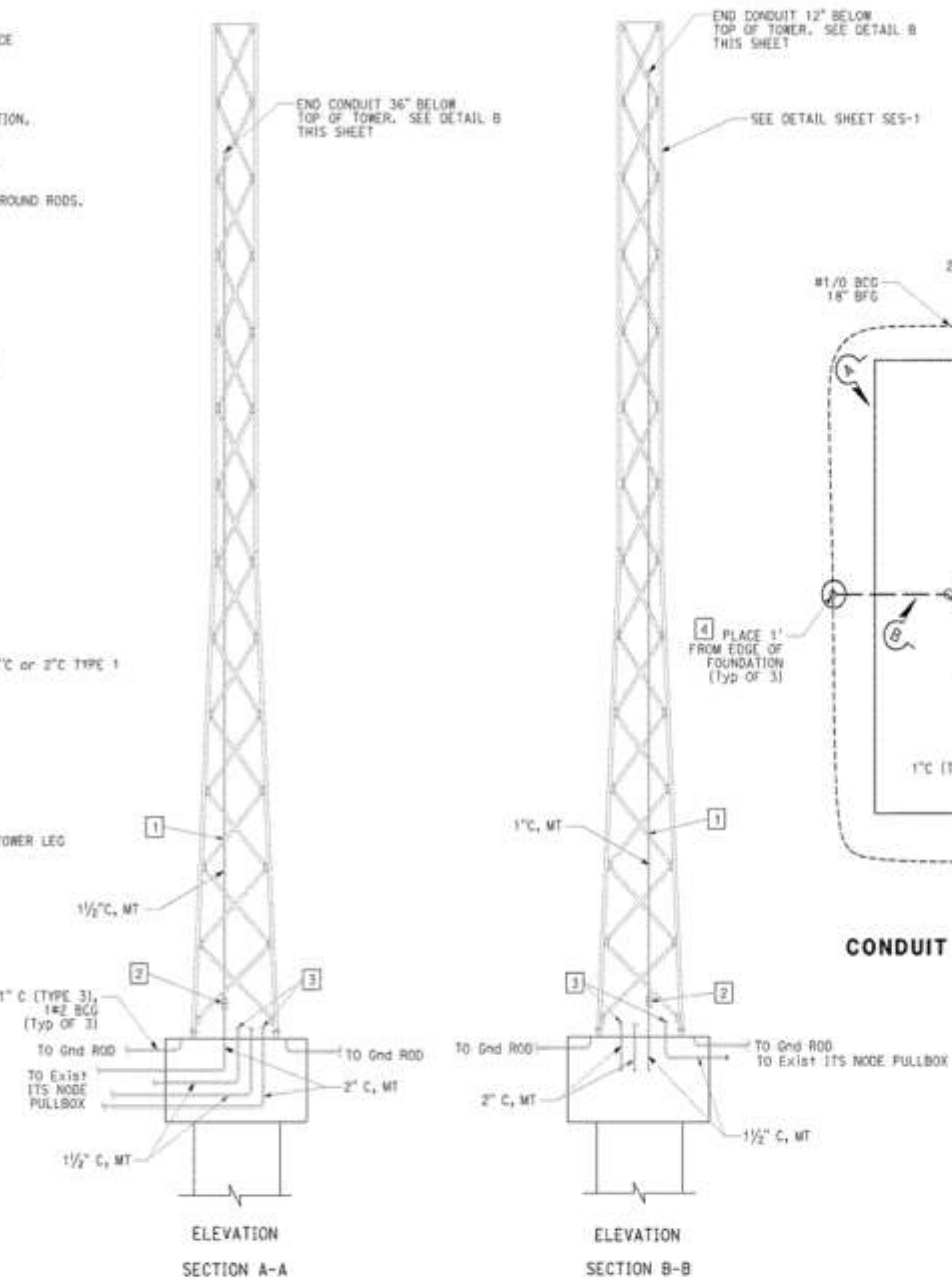
PLANS APPROVAL DATE 01-17-13

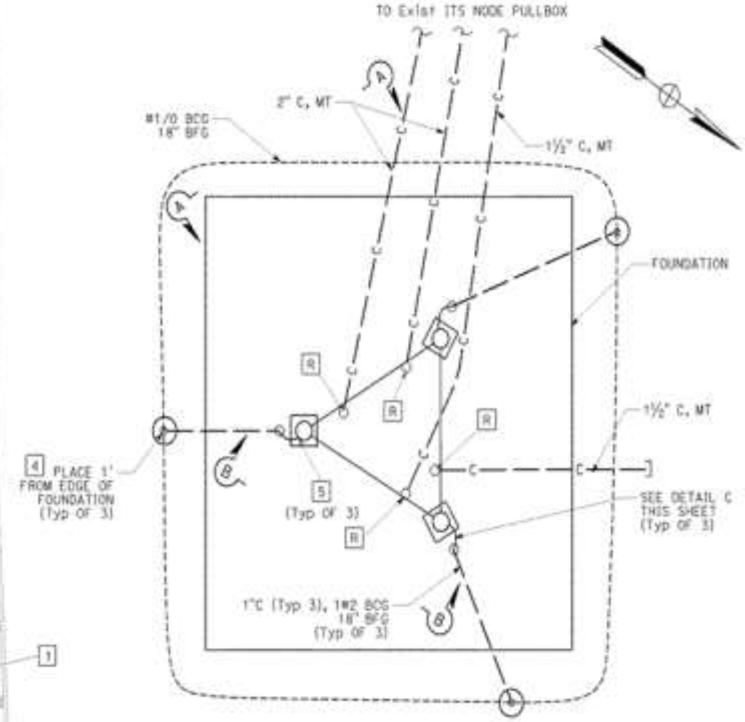
JEREMIAH PEARCE No. E19475 Exp. 6-30-13 ELECTRICAL

NOTES (THIS SHEET):

1. SECURE CONDUIT TO INSIDE OF TOWER FACE PER MANUFACTURER'S RECOMMENDATIONS.
2. SEE DETAIL A: INSTALL CONDUIT OUTLET BODY, REDUCER, AND CONDUIT UNION APPROXIMATELY 24" ABOVE FOUNDATION.
3. TERMINATE CONDUIT 12" ABOVE FOUNDATION. SEE DETAIL B THIS SHEET.
4. EXOTHERMIC WELD ALL CONNECTIONS TO GROUND RODS.
5. TOWER GROUND CONNECTION METHOD PER MANUFACTURER'S RECOMMENDATIONS.







PLAN VIEW

CONDUIT AND GROUNDING DETAIL

AS BUILT	
CONTRACT No.	02-4E1605
C.C.A. DATE	10-03-13
R.E. NAME	MIKE ZDENEK

CCTV/ANTENNA TOWER (ELECTRICAL SUPPORT) (LOCATION 4) ANTLERS BRIDGE CCTV

NO SCALE

E-8

APPROVED FOR ELECTRICAL WORK ONLY

STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION

Caltrans ELECTRICAL DESIGN

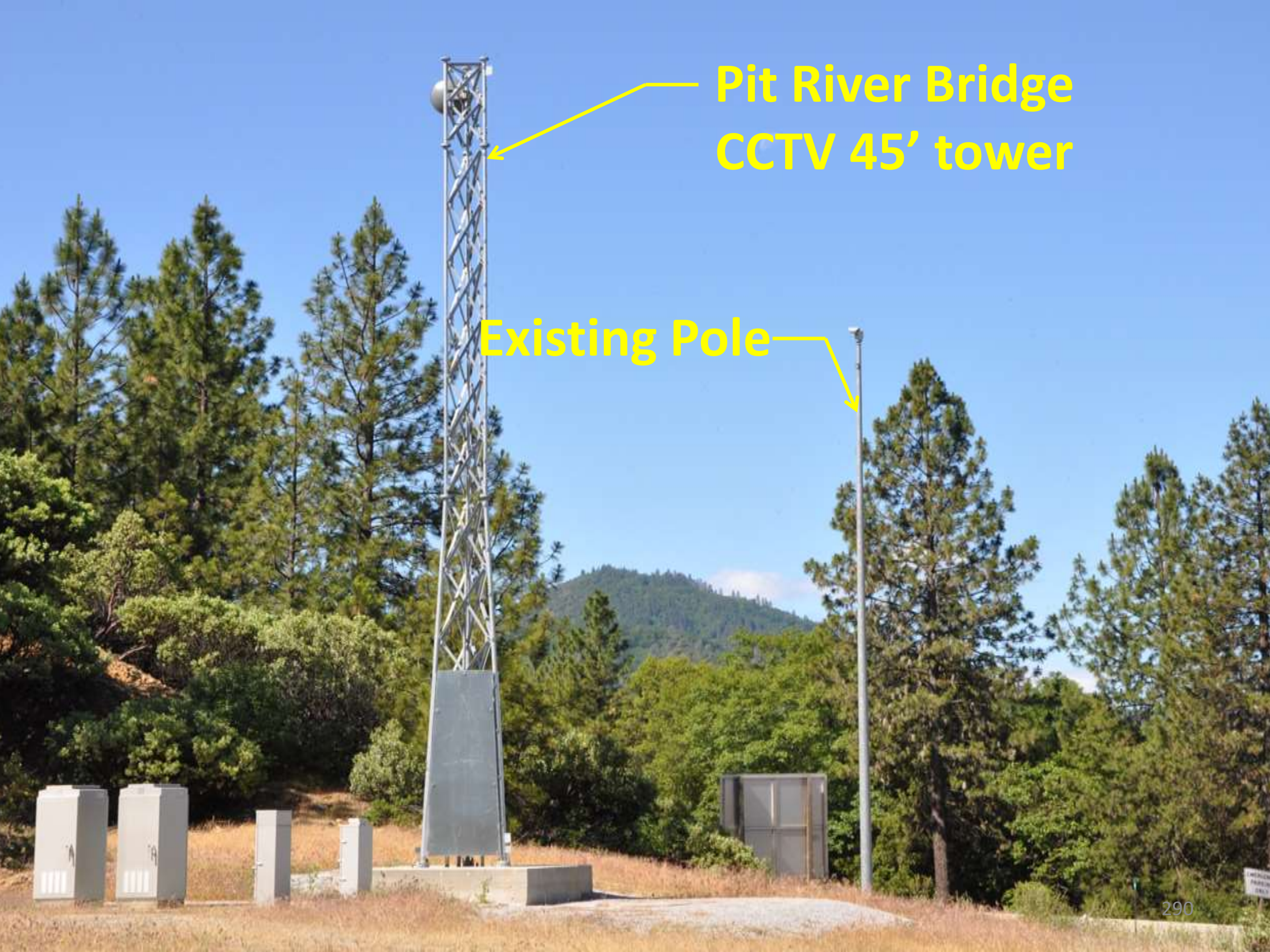
FUNCTIONAL SUPERVISOR JAN TURNBULL

CALCULATED-DESIGNED BY JEREMIAH PEARCE

CHECKED BY KEITH KOEPPEN

REVISED BY J P DATE REVISED 01/03/13

UNIT 0151 PROJECT NUMBER & PHASE 02000202261


Pit River Bridge
CCTV 45' tower
Existing Pole

Connection Details

Tower Ground Details

Sac River Canyons Rigid Towers

- Issues during construction
  - Foundation issues and conflict with Railroad

Sac River Canyons Rigid Towers

- Issues during construction
  - Foundation issues and conflict with Railroad
  - Conduit hangers


a Lake

Sac River Canyons Rigid Towers

- Issues during construction
  - Foundation issues and conflict with Railroad
  - Conduit hangers
  - Anti-climb panels

Sac River Canyons Rigid Towers

- Project complete August of 2013

Sac River Canyons Rigid Towers

- Project complete August of 2013
- Project was a success, however…

Sac River Canyons Rigid Towers

- Project complete August of 2013
- Project was a success, however…
- Revisited Licensed Field Radio Upgrade project
  - Requirements changed, needed more bandwidth to the roadside
  - Equipment became available on the 4.9GHz band

Sac River Canyons Rigid Towers

- Large half parabolic 900 MHz antennas no longer required

Sac River Canyons Rigid Towers

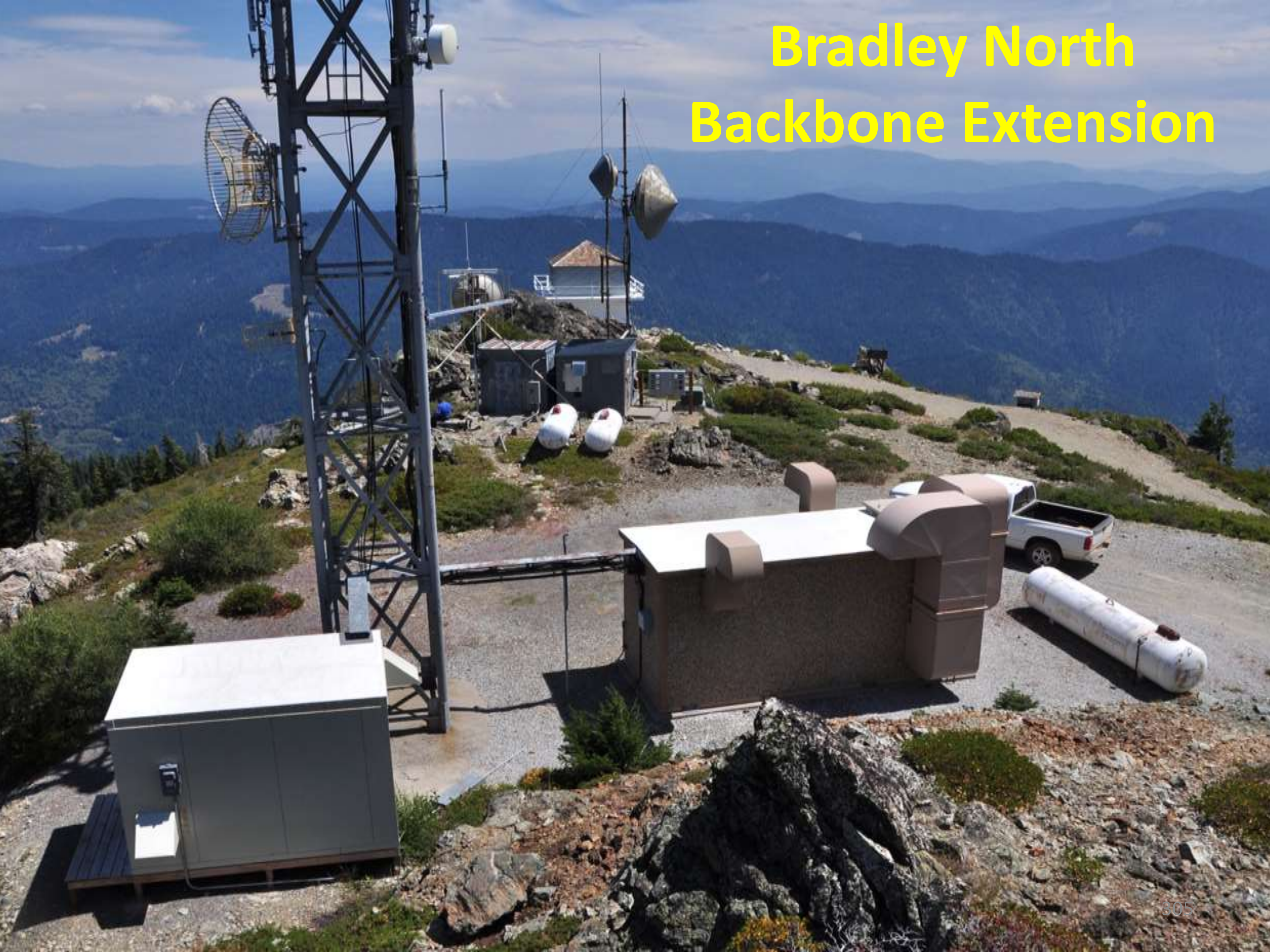
- Large half parabolic 900 MHz antennas no longer required
- Link reliability with new licensed field radio’s and 2’ high performance parabolic dishes calculated at 99.999%, however there is approximately 10 dB less margin than there was with our old radios

Sac River Canyons Rigid Towers

- Large half parabolic 900 MHz antennas no longer required
- Link reliability with new licensed field radio’s and 2’ high performance parabolic dishes calculated at 99.999%, however there is approximately 10 dB less margin than there was with our old radios
- The new towers allow us to install 3’ dishes at the roadside to increase margin.

Sac River Canyons Rigid Towers

- Towers also set a precedence with our Headquarters Steel Structures unit to allow us to install 80’ towers further up the canyon where trees obstruct line-of-site paths
- So far no one has complained about the aesthetics, I think they look good


Bradley North
Backbone Extension

Bradley North Backbone Extension

- Ongoing project to extend microwave backbone network north up the I-5 corridor based on our deployment strategy

Bradley North Backbone Extension

- Ongoing project to extend microwave backbone network north up the I-5 corridor based on our deployment strategy
- Good example of our deployment strategy

Bradley North Backbone Extension

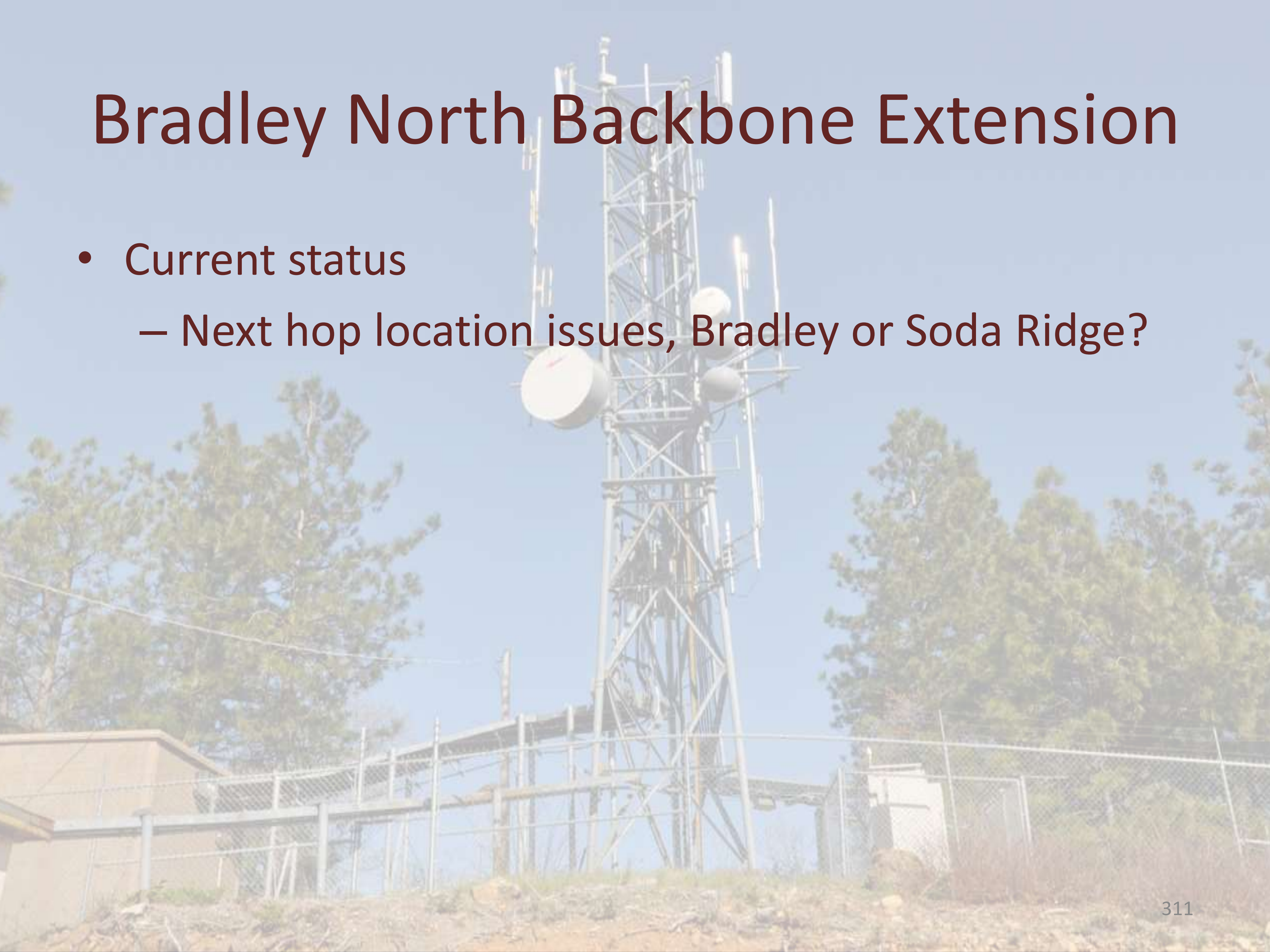
- Ongoing project to extend microwave backbone network north up the I-5 corridor based on our deployment strategy
- Good example of our deployment strategy
  - Field elements in this area are turned up with Telco services while we initiate a presence at a mountain top facility

Bradley North Backbone Extension

- Ongoing project to extend microwave backbone network north up the I-5 corridor based on our deployment strategy
- Good example of our deployment strategy
  - Field elements in this area are turned up with Telco services while we initiate a presence at a mountain top facility
  - When we get into the facility, we will be using ISM band equipment while we initiate license requests for the new links

Bradley North Backbone Extension

- Current status



Bradley North Backbone Extension

- Current status
  - Next hop location issues, Bradley or Soda Ridge?

Bradley North Backbone Extension

- Current status
  - Next hop location issues, Bradley or Soda Ridge?
  - Still investigating which site has a better view of the interstate and other state highways


From Bradley looking
North


From Bradley looking
North East


From Bradley looking
East

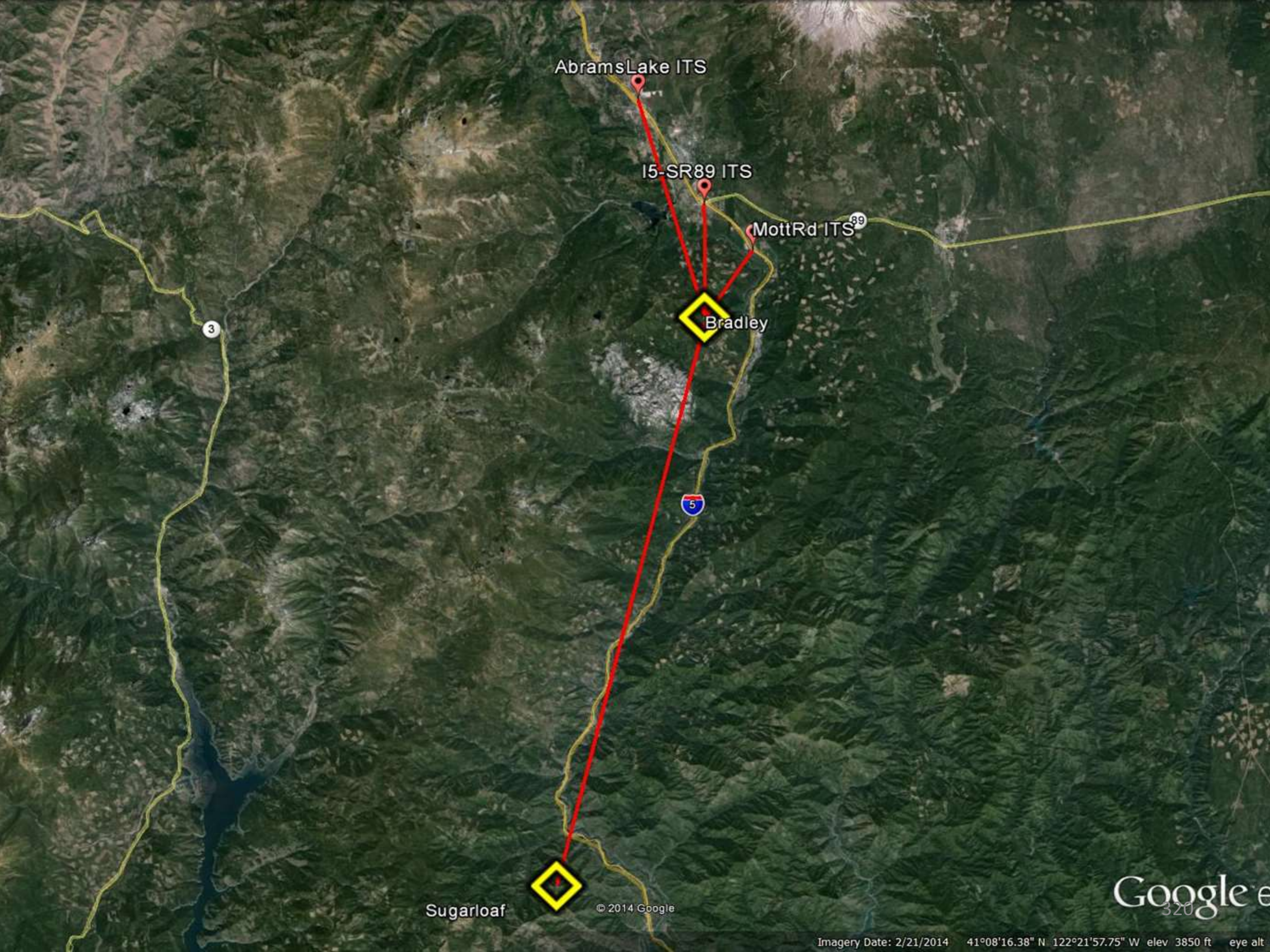

From Bradley looking
South East

Bradley North Backbone Extension

- Current status
  - Next hop location issues, Bradley or Soda Ridge?
  - Still investigating which site has a better view of the interstate and other state highways
  - Winter conditions and access issues compared to existing sites


Photo Courtesy of
Mike Birdsill


Photo Courtesy of
Mike Birdsill


AbramsLake ITS
I5-SR89 ITS
MottRd ITS
89
3
Bradley
5
Sugarloaf
© 2014 Google
Google earth
Imagery Date: 2/21/2014 41°08'16.38" N 122°21'57.75" W elev 3850 ft eye alt

Conclusions

- Deployment Strategy
  - Field: Telco services -> ISM band microwave if available -> Licensed microwave
  - Backbone: Initiate presence -> ISM band microwave -> Licensed microwave
- Deployment strategy proven effective for our network for 10+ years
- Has made it possible to seamlessly migrate from one level of service to another


Questions?