Radio Local Area Network (RLAN) to Fixed Service (FS) Microwave Interference in the 6 GHz Band

Analysis of Select Real World Scenarios

Context

- RLAN advocates seek to eliminate automatic frequency coordination (AFC) requirements for "low power" indoor and "very low power" devices
  - These devices are not "low"/"very low" power—the "low power" RLAN devices operate with the ***same*** maximum power limit (EIRP) as handsets in the ***licensed*** AWS service
  - RLAN advocates have completely failed to make a technical non-interference case—Boeing admits "***interference events inevitably will occur for some fixed links***" (Boeing Nov. 1 *ex parte*)
  - RLAN advocates are now arguing that even though interference is inevitable, the "statistical probability is low (although how low is in dispute)," *id.*, and FS operations can mitigate any interference that results
    - Primary licensees cannot be required to accept interference from unlicensed users and should not bear the cost of implementing costly upgrades to remediate interference
    - The probability of interference is not low—AT&T's examples herein are not "worst case" and were identified by reviewing only a couple dozen out of thousands of FS links in its portfolio
    - The changes in uptime reliability for these links is many times larger than, for example, in MVDDS, a secondary service with superior rights than unlicensed RLANs, where the FCC found that a percentage uptime availability change for DBS (a consumer service) of 10% constituted "harmful interference"

Objectives

- Analyses to date have relied upon unrealistic parameters
  - Statistical analyses discount potential impacts to situations outside the mean, even though real world scenarios exist in those categories
  - Unrealistic simplification of Building Entry Loss—attenuation of RLAN interference to FS resulting from indoor operation
- AT&T has modeled the impact of RLAN operation to actual FS facilities operated by AT&T
  - RLAN operating assumptions are realistic—actual buildings selected for modeling are locations where RLAN use would be anticipated
  - AT&T's modeling utilizes conservative assumptions, but also factors in a more rigorous analysis of potential Building Entry Loss effects
- AT&T's real world deployment scenarios demonstrate that RLAN interference to FS links is a significant problem and that RLANs require Automatic Frequency Control (AFC) to avoid harmful interference to incumbent FS systems

Analysis Overview

- FS data reflects properties of links licensed and operating in AT&T’s communications network
- The Interference Power to the victim FS receiver is calculated as:

$$I = P_{TX} - L_P + G_{RX} - L_D - L_{WG} + Adj_{BW\&Adj}$$

- The RLAN EIRP limit from an outdoor RLAN is then defined by the following equation with the interference power I set to its maximum permissible level

$$P_{TX} = I + L_P - G_{RX} + L_D + L_{WG} + Adj_{BW\&Adj}$$

I: Received Interference power in dBm

P_{TX}: RLAN EIRP in direction of the victim in dBm

L_P: Propagation Loss in dB

G_{RX}: Victim Antenna Gain in dBi

L_D: Victim Antenna Discrimination in dB

L_{WG}: Any Waveguide Loss and polarization loss in dB

$Adj_{BW\&Adj}$: Adjustments for bandwidth correction accounting for adjacent channel interference in dB

- Sensitivity analysis on building loss for traditional and thermal efficient windows is shown based on 25%, 50% and 75 % probability distribution.

Analysis Overview (Cont'd)

- The theoretical minimum noise floor of a 30 MHz channel is given by

$$-173.8\ \text{dBmTHz} + 10\log_{10}(30 \times 10^6)\ \text{Hz} = -99.0\ \text{dBm}$$

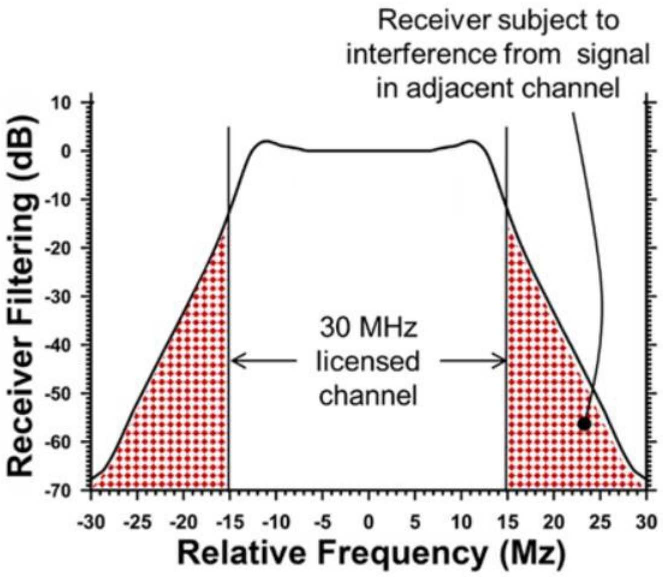
- Assuming a receiver noise figure of 3.0 dB and an I/N requirement of -12.0 dB results in a maximum permissible interference level of:

$$-99.0\ \text{dBm} + 3.0\ \text{dB} - 12.0\ \text{dB} = -108.0\ \text{dBm}$$

  - For I/N requirements of -6 dB and -9 dB, the maximum permissible interference levels would be, respectively, -102 dBm and -105 dBm
  - AT&T has argued the appropriate I/N should be -12 dB, but has provided other I/N values for informational purposes

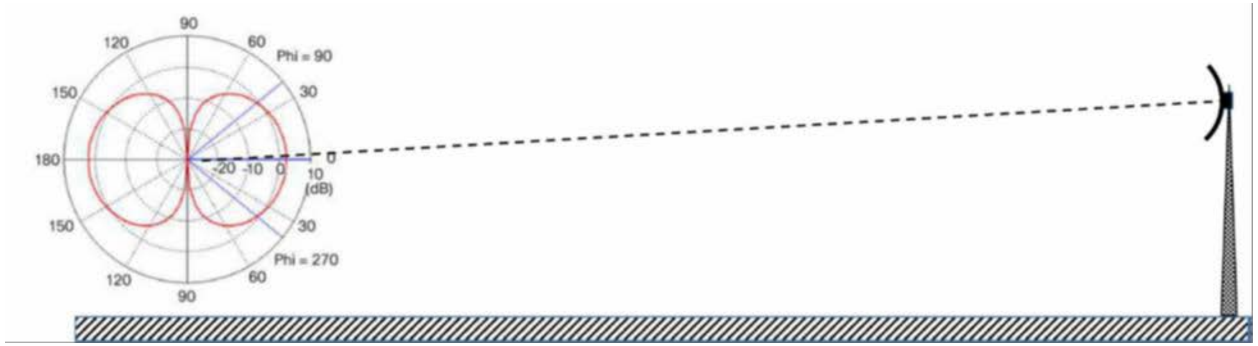
Analysis Assumptions

- Line of sight, free space propagation
  - Can be validated from photographs in scenarios analyzed
- Conservative 3 dB polarization mismatch adjustment
  - CTIA has argued—correctly—that "polarization discrimination is predictable **only for systems that can guarantee antenna placement and orientation**" (CTIA *Ex Parte*, filed Oct. 22, 2019)
  - Although an RLAN antenna is adjustable and its orientation cannot be guaranteed, AT&T has nonetheless applied a 3 dB polarization mismatch adjustment to be conservative
- Conservative 3 dB bandwidth mismatch adjustment
  - Considers impact of RLAN use of 80 MHz channels while FS systems under analysis have 30 MHz channelization
  - While RLAN proponents have used a larger adjustment factor, they are ignoring that FS receivers will still be affected by RLAN emissions from "adjacent" FS channels
  - In other words, inability to filter reception of out-of-band signals gives FS systems a wider "virtual" bandwidth
  - AT&T believes the appropriate adjustment is thus only 3 dB



Analysis Assumptions (Cont'd)

- The analysis factors in RLAN antenna pattern mismatch, *i.e.*, reduces the RLAN antenna gain when the interference path is above or below the horizontal (azimuth) plane directly in front of the RLAN antenna
  - Because most RLAN access points will have near-zero antenna attenuation in the direction of the FS, the reduction in gain is generally not significant



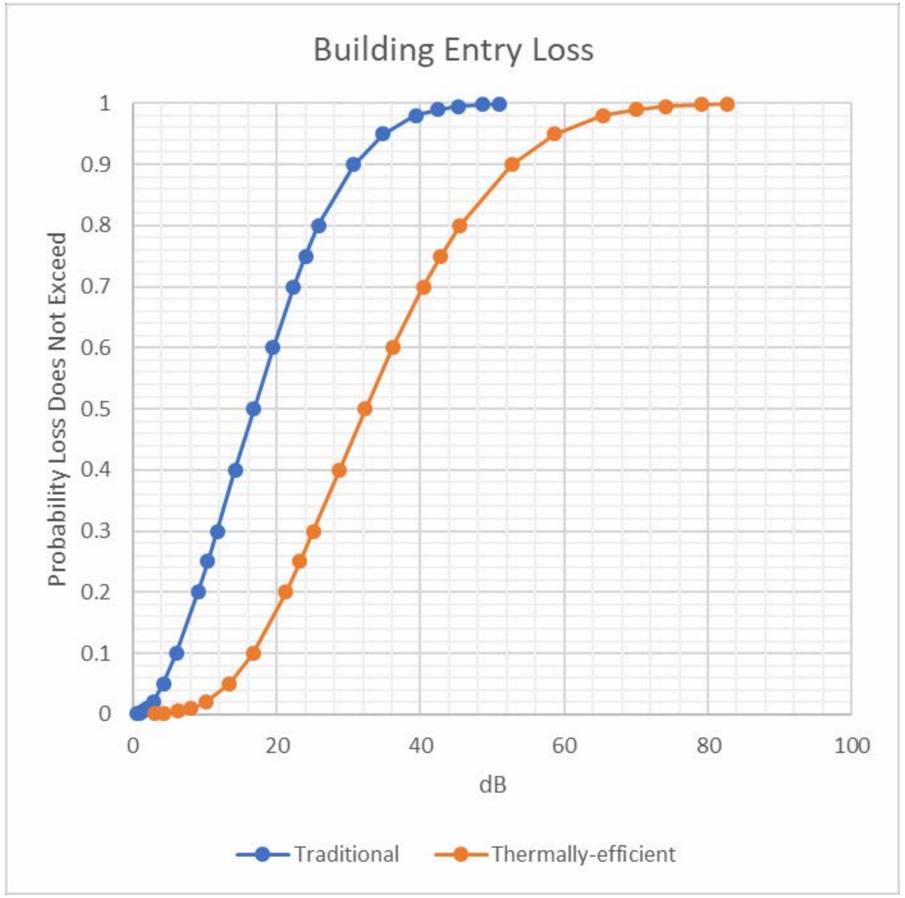
- The analysis considers FS receiver feeder loss, *i.e*., adjusts for the loss between the FS receive antenna and the input to the FS receiver
  - This information is not in the ULS database and is therefore an estimate
  - Not all sites have feeder loss in the link budget

Modeling Building Entry Loss

- Prior RLAN analyses oversimplify Building Entry Loss (BEL), which must be modeled as a distribution function rather than a simple average
  - As CTIA notes "ITU-R Rec. P.2109-0 on BEL requires sharing studies to use the **full distribution**, not a single level of loss" (CTIA *Ex Parte*, filed Oct. 22, 2019)
  - Building Entry Loss is dependent upon a variety of factors that include, among other things, RLAN location in the building relative to materials with differing attenuation, the attenuation range of the building materials, and the transmission angle in relation to the windows
- ITU-R P.2109 provides a distribution of Building Entry Loss as a function of frequency and elevation angle for two classes of building construction
  - The building construction classes are "thermally-efficient" and "traditional"
  - Thermally-efficient buildings typically use metalized glass windows and metal foil backed insulation which provide significantly different radio frequency shielding
  - AT&T has modeled both types of buildings even though in some scenarios it is clear from visual inspection that the building would not have thermally-efficient construction

Modeling Building Entry Loss (Cont'd)

- The chart shows BEL for 6.5 GHz and zero elevation
  - Different curves for traditional v. thermally efficient construction
  - Curves represent probability that loss **does not exceed** the attenuation shown
    - In other words, there is a 75% probability that BEL will not be greater than 24 dB for traditional construction—a 25% probability attenuation will be at least 24 dB
    - The higher probability the analysis reflects, the lower the attenuation that can be assumed—being 100% sure requires assuming 0 dB attenuation
- AT&T's analysis calculates elevation for the RLAN signals to the FS victim receiver and adjusts the BEL probabilities accordingly



Modeling Building Entry Loss (Cont'd)

- Table 1 below shows the impact of elevation on the BEL, showing the impact at 25%, 50% and 75% probabilities for dB values *not* exceeded

Elevation [deg]	Traditional Construction			Thermally-efficient		
	25%	50%	75%	25%	50%	75%
0	10.4	16.8	24.0	23.2	32.3	42.8
5	11.1	17.8	25.0	23.8	33.2	43.8
10	11.9	18.7	26.1	24.4	34.1	44.8
15	12.8	19.7	27.1	25.1	35.0	45.9
20	13.7	20.7	28.2	25.8	36.0	46.9

- There is a 25% chance that the BEL is less than 10.4 dB, and consequently a 75% chance it is greater than 10.4 dB
- There is a 75% chance the BEL is less than 24.0 dB, and consequently only a 25% chance it is greater than 24.0 dB
- ITU-R Rec. P2109 conservatively assumes transmitters are randomly distributed
  - In situations where the user is motivated to provide coverage to outside areas next to the building from inside, the deployment of the transmitter will not be random
  - For example, if a residential user wishes to cover an outside deck, pool, disconnected garage or shed from inside they will likely select an indoor transmitter location that provides as much signal outdoors as possible
  - In these situations, the BEL is likely to be significantly less than the predicted median value

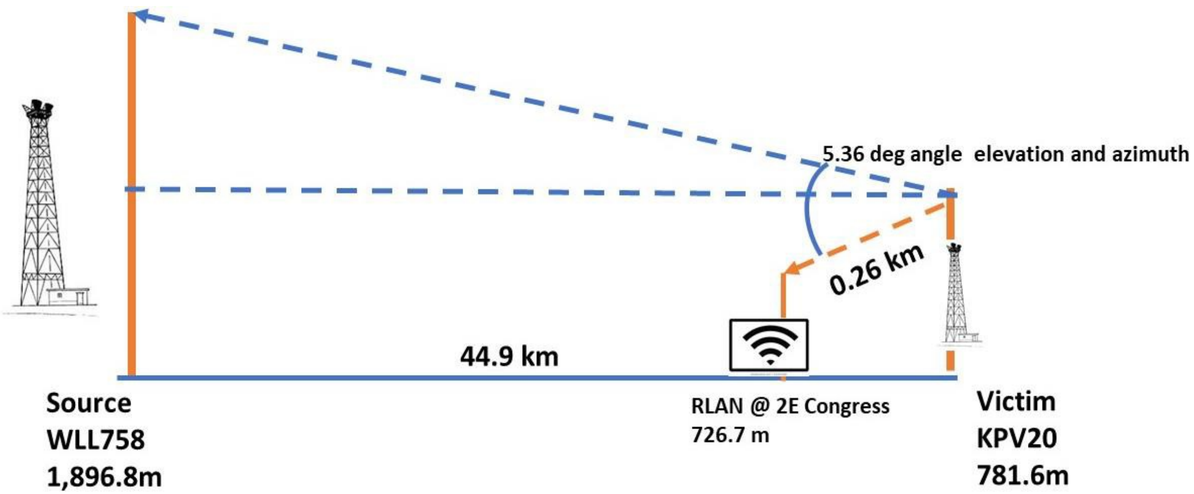
RLAN to FS Interference Examples

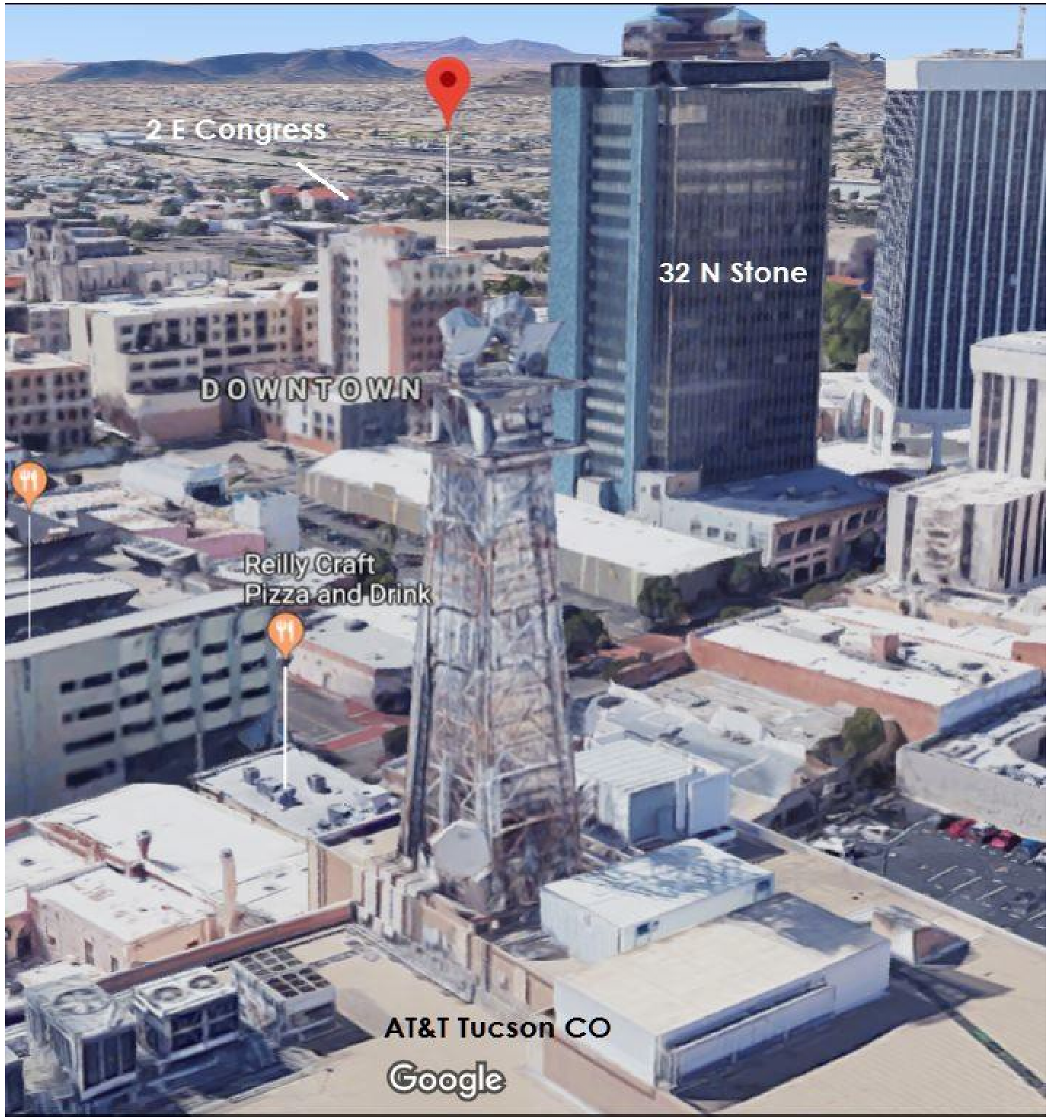
- Example 1A, 1B: KPV20 Tucson, AZ
  - Urban area, high buildings in FS link path; close distances but high discrimination angle
  - Example 1A has more detail—other examples use similar calculations but are not shown
- Example 2: WQPJ679 Batavia, NY
  - Longer distance between RLAN and FS, but RLAN closer to main beam
- Example 3: WQXC429 Sun Tan Valley, AZ
  - Longer distance, but RLAN on naturally higher ground and closer to main beam
- Example 4: WLU230 Lynnwood, WA
  - Short distance, high RLAN antenna discrimination factor
- Example 5: WQWA497 Gehring, NE
  - Very short distance, very high RLAN antenna discrimination factor

All examples show very high potential—based on BEL probabilities—of causing interference to FS incumbents

Example 1A: WLL758 > KPV20, RLAN at 2 E. Congress

- FS link to AT&T's CO in Tucson, AZ
  - Low Path loss – 0.26 km between RLAN and victim FS receiver
  - High FS antenna discrimination factor (36 dB) between RLAN and victim FS receiver
- RLAN at 36m AGL with transmit power of 30 dBm





Example 1A: WLL758 > KPV20, RLAN at 2 E. Congress

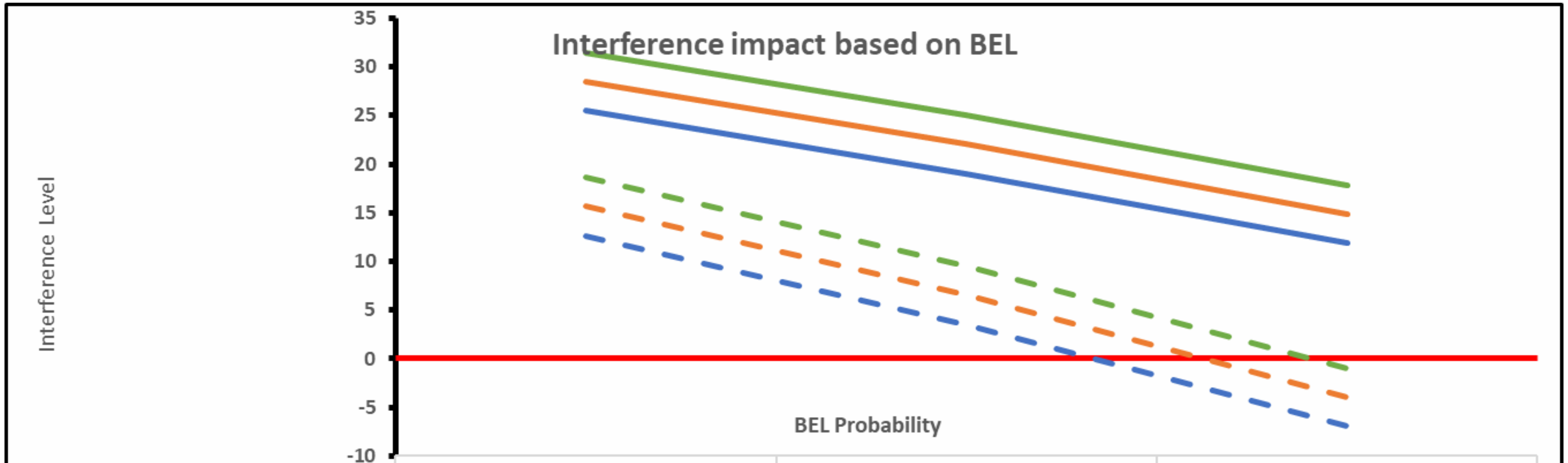
		Victim	Source	2 E Congress
		KPV20	WLL758	
Height AGL	m	54.9	19.8	36
Height ASL	m	781.6	1896.8	762.7
Lat		32.2	31.9	32.22
Lon		-111.0	-111.2	-110.97
$\theta_{Elevation}$ *	deg		1.27	-4.09
$\theta_{Azimuth}$	deg		211.14	211.13

* Adjusted for Earth Curvature

	Units	Derived Figures		
$\theta_{Elevation}$ *	deg	5.36		
$\theta_{Azimuth}$	deg	0.00		
$\Delta\theta$	deg	5.36		
Dist. Source > Victim	km	0.00		
Dist. RLAN > Victim	m	265.22		
Path Loss	dB	96.45		
Antenna Gain	dBi	43.20		
Antenna Discrimination	dB	36.00		
Other losses incl Pol	dB	5.00		
RLAN Transmit Pwr	dBm	30.00		
Bandwidth mismatch	dB	3.00		
RX interference power	dB	-102.00	-105.00	-108.00
I/N	dB	-6.00	-9.00	-12.00
Allowable RLAN Power	dBm	-4.75	-7.75	-10.75

Example 1A: RLAN Impact on KPV20

- Chart graphs interference level for I/N of -6 dB, -9 dB and -12 dB for traditional and thermally efficient construction at 25%, 50% and 75% probabilities for BEL "not to exceed" values

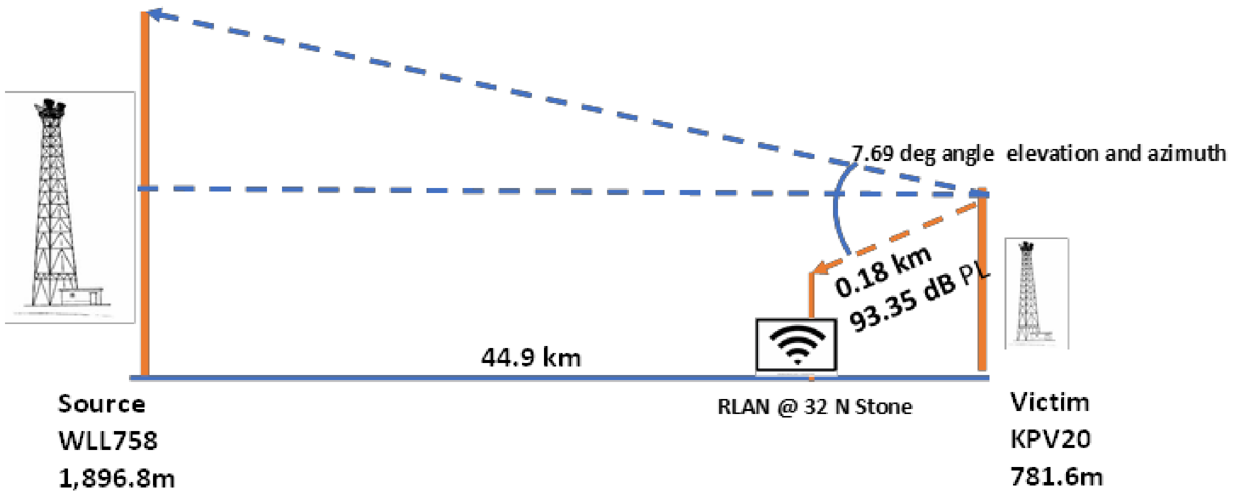


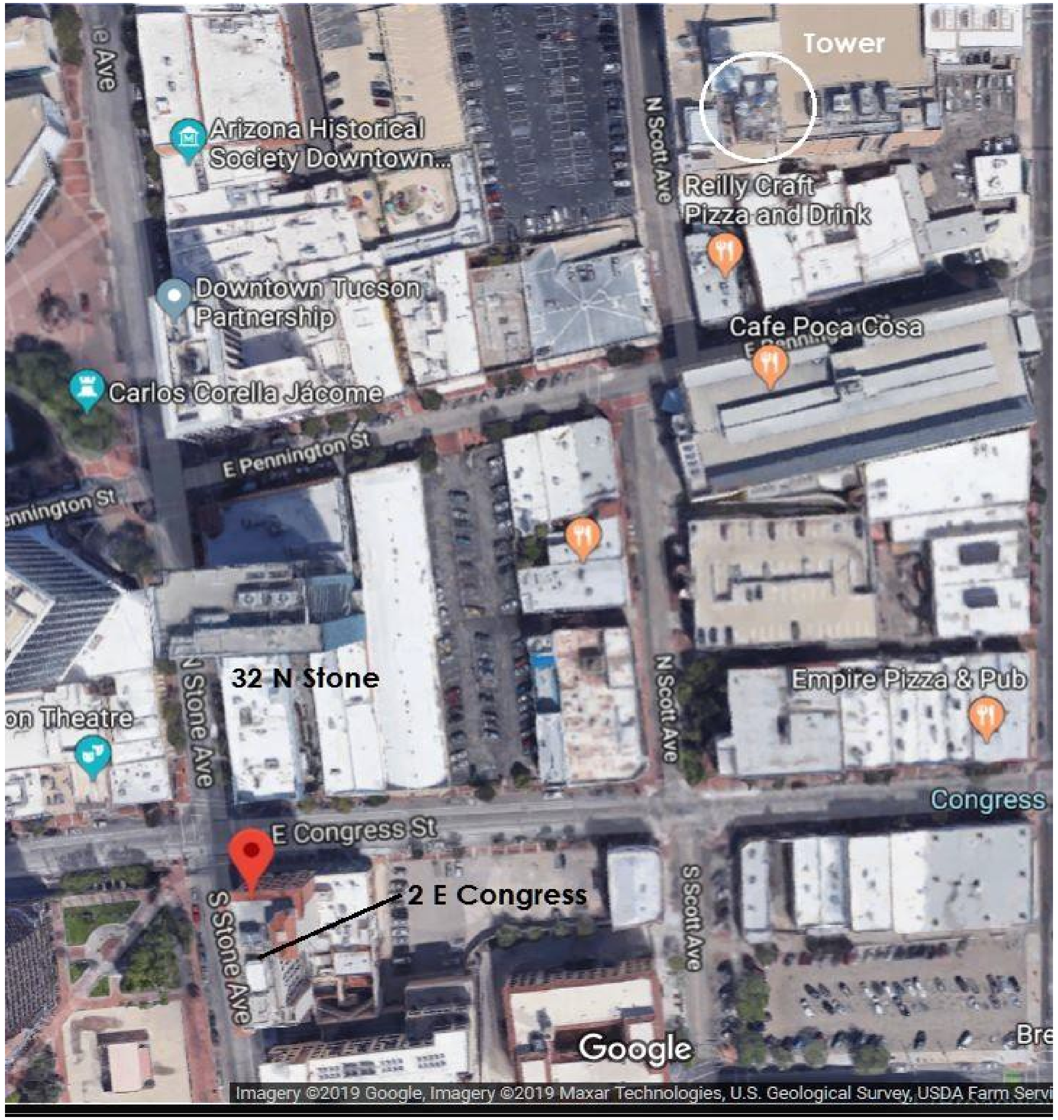
	25%	50%	75%
Traditional Window I/N -6 dB	25	19	12
Traditional Window I/N -9 dB	28	22	15
Traditional Window I/N -12 dB	31	25	18
Thermal window I/N -6 dB	13	4	-7
"Thermal Window I/N -9 dB"	16	7	-4
"Thermal Window I/N -12 dB"	19	10	-1

- RLAN will almost certainly exceed interference threshold in both cases

Example 1B: WLL758 > KPV20, RLAN at 32 N. Stone

- Same FS link to AT&T's CO in Tucson, AZ used in Example 1A
  - Low Path loss – 0.19 km between RLAN and victim FS receiver
  - High FS antenna discrimination factor (38 dB) between RLAN and victim FS receiver
- RLAN at 59m AGL with transmit power of 30 dBm





Example 1A: WLL758 > KPV20, RLAN at 32 N. Stone

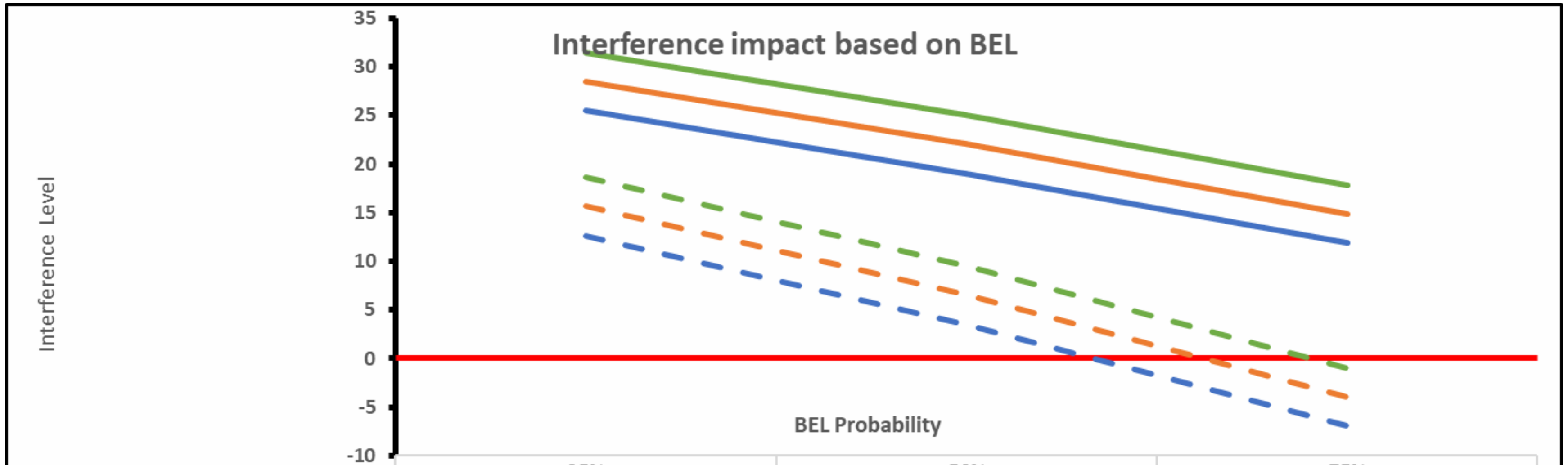
	Units	Victim	Source	32 N Stone
		KPV20	WLL758	
Height AGL	m	54.9	19.8	59
Height ASL	m	781.6	1896.8	785.7
Lat		32.2	31.9	32.22
Lon		-111.0	-111.2	-110.97
$\theta_{Elevation}$ *	deg		1.27	1.27
$\theta_{Azimuth}$	deg		211.14	218.83

* Adjusted for Earth Curvature

	Units	Derived Figures		
$\theta_{Elevation}$ *	deg	0.00		
$\theta_{Azimuth}$	deg	-7.69		
$\Delta\theta$	deg	7.69		
Dist. Source > Victim	km	44.92		
Dist. RLAN > Victim	m	185.10		
Path Loss	dB	93.35		
Antenna Gain	dBi	43.20		
Antenna Discrimination	dB	38.00		
Other losses incl Pol	dB	5.00		
RLAN Transmit Pwr	dBm	30.00		
Bandwidth mismatch	dB	3.00		
RX interference power	dB	-102.00	-105.00	-108.00
I/N	dB	-6.00	-9.00	-12.00
Allowable RLAN Power	dBm	-5.85	-8.85	-11.85

Example 1B: RLAN Impact on KPV20

- Chart graphs interference level for I/N of -6 dB, -9 dB and -12 dB for traditional and thermally efficient construction at 25%, 50% and 75% probabilities for BEL “not to exceed” values

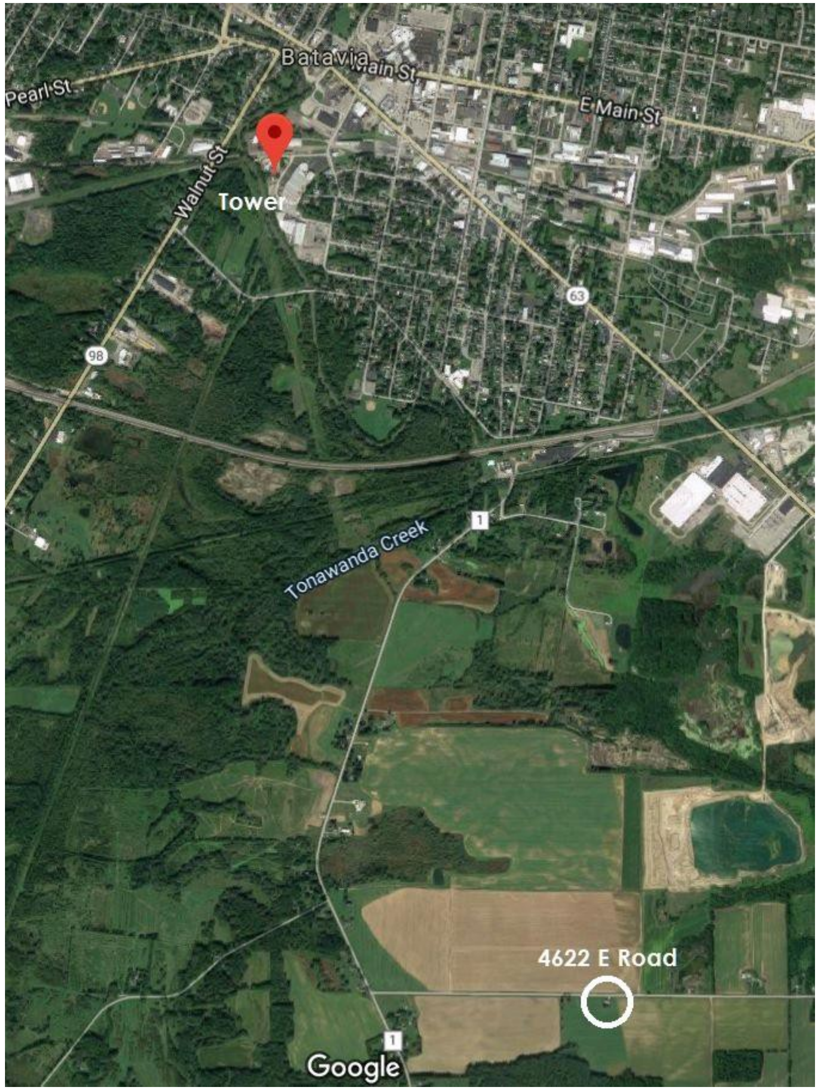


	25%	50%	75%
Traditional Window I/N -6 dB	25	19	12
Traditional Window I/N -9 dB	28	22	15
Traditional Window I/N -12 dB	31	25	18
Thermal window I/N -6 dB	13	4	-7
"Thermal Window I/N -9 dB"	16	7	-4
"Thermal Window I/N -12 dB"	19	10	-1

- RLAN will almost certainly exceed interference threshold in both cases

Example 2: WQPJ677 > WQPJ679, RLAN at 4622 E. Rd

- FS link in Batavia, NY
  - 3.5 km between RLAN and victim FS receiver
  - Low FS antenna discrimination factor (1.5 dB) between RLAN and victim FS receiver
- RLAN at 1.5m AGL with transmit power of 30 dBm



Example 2: WQPJ677 > WQPJ679, RLAN at 4622 E. Rd

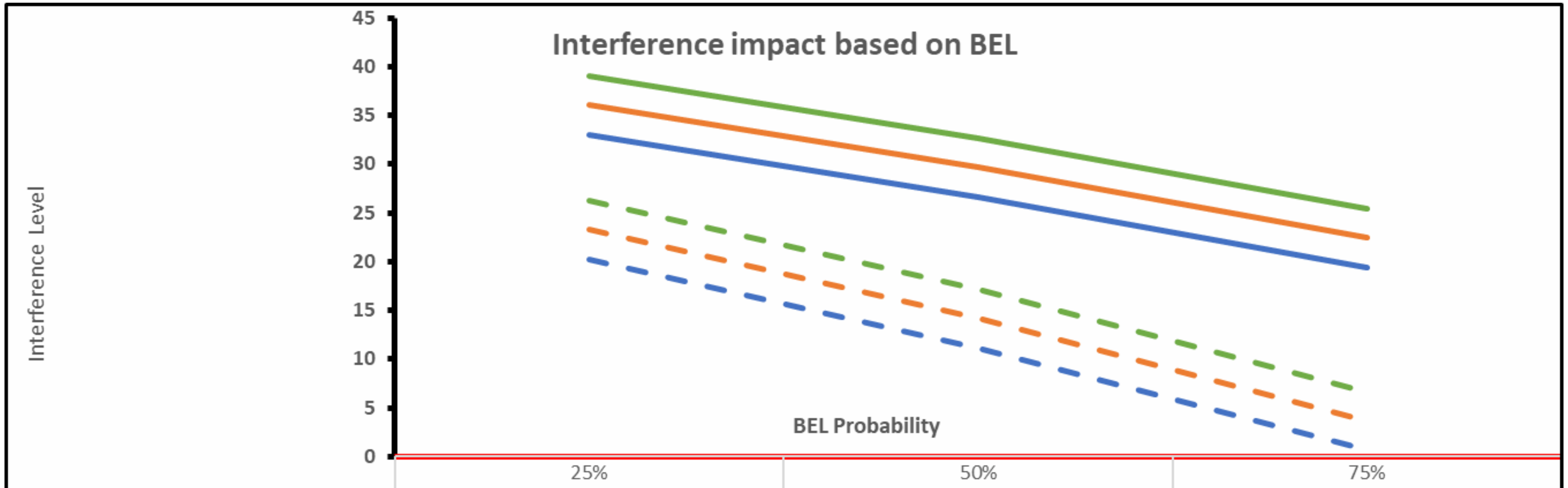
	Units	Victim	Source	4622 E Rd
		WQPJ679	WQPJ677	
Height AGL	m	27.4	42.7	1.5
Height ASL	m	299.3	406.9	276.5
Lat		43.0	42.9	42.96
Lon		-78.2	-78.1	-78.17
$\theta_{Elevation}$ *	deg		0.55	-0.38
$\theta_{Azimuth}$	deg		157.71	157.81

* Adjusted for Earth Curvature

	Units	Derived Figures		
$\theta_{Elevation}$ *	deg	0.93		
$\theta_{Azimuth}$	deg	-0.10		
$\Delta\theta$	deg	0.94		
Dist. Source > Victim	km	10.53		
Dist. RLAN > Victim	m	3528.14		
Path Loss	dB	118.96		
Antenna Gain	dBi	37.90		
Antenna Discrimination	dB	1.50		
Other losses incl Pol	dB	3.00		
RLAN Transmit Pwr	dBm	30.00		
Bandwidth mismatch	dB	3.00		
RX interference power	dB	-102.00	-105.00	-108.00
I/N	dB	-6.00	-9.00	-12.00
Allowable RLAN Power	dBm	-13.44	-16.44	-19.44

Example 2: WQPJ677 > WQPJ679, RLAN at 4622 E. Rd

- Chart graphs interference level for I/N of -6 dB, -9 dB and -12 dB for traditional and thermally efficient construction at 25%, 50% and 75% probabilities for BEL "not to exceed" values

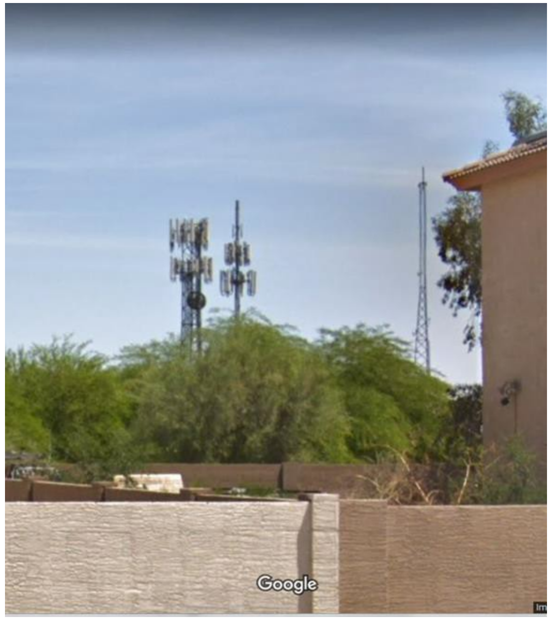


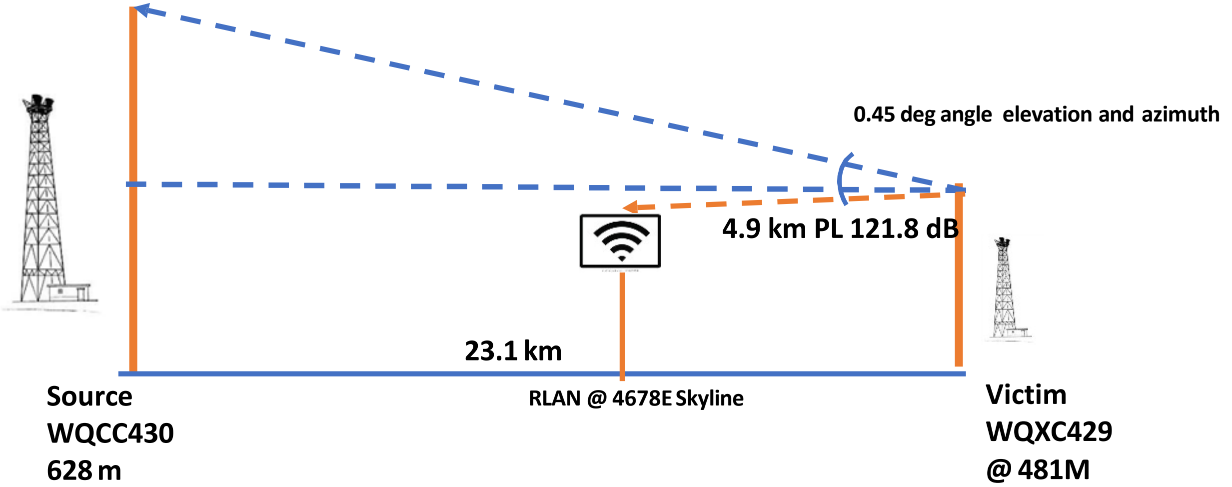
	25%	50%	75%
Traditional Window I/N -6 dB	33	27	19
Traditional Window I/N -9 dB	36	30	22
Traditional Window I/N -12 dB	39	33	25
Thermal window I/N -6 dB	20	11	1
"Thermal Window I/N -9 dB"	23	14	4
"Thermal Window I/N -12 dB"	26	17	7

- RLAN exceeds interference threshold in both cases

Example 3: WQXC430 > WQXC429, RLAN at 4678 E. Skyline

- FS link in Sun Tan Valley, AZ
  - Almost 5 km between RLAN and victim FS receiver
  - Low FS antenna discrimination factor (0.9 dB) between RLAN and victim FS receiver
- RLAN at 2m AGL with transmit power of 30 dBm
  - GL is 21.3m at victim, but 472m at RLAN





Example 3: WQXC430 > WQXC429, RLAN at 4678 E. Skyline

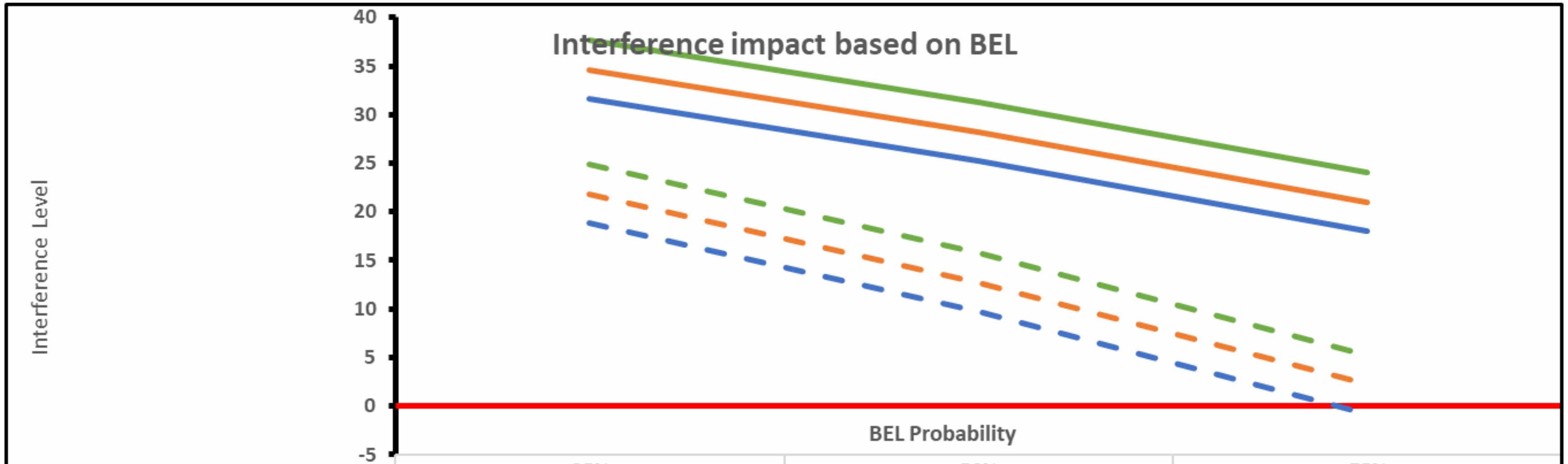
	Units	Victim WQXC429	Source WQXC430	4678 E Skyline
Height AGL	m	21.3	51.8	2
Height ASL	m	481.6	628.5	472
Lat		33.2	33.3	33.19
Lon		-111.6	-111.3	-111.52
$\theta_{Elevation}$*	deg		0.29	-0.13
$\theta_{Azimuth}$	deg		65.04	64.85

* Adjusted for Earth Curvature

	Units	Derived Figures		
$\theta_{Elevation}$*	deg	0.41		
$\theta_{Azimuth}$	deg	0.19		
$\Delta\theta$	deg	0.46		
Dist. Source > Victim	km	23.17		
Dist. RLAN > Victim	m	4938.09		
Path Loss	dB	121.88		
Antenna Gain	dBi	38.80		
Antenna Discrimination	dB	0.90		
Other losses incl Pol	dB	3.00		
RLAN Transmit Pwr	dBm	30.00		
Bandwidth mismatch	dB	3.00		
RX interference power	dB	-102.00	-105.00	-108.00
I/N	dB	-6.00	-9.00	-12.00
Allowable RLAN Power	dBm	-12.02	-15.02	-18.02

Example 3: WQXC430 > WQXC429, RLAN at 4678 E. Skyline

- Chart graphs interference level for I/N of -6 dB, -9 dB and -12 dB for traditional and thermally efficient construction at 25%, 50% and 75% probabilities for BEL "not to exceed" values

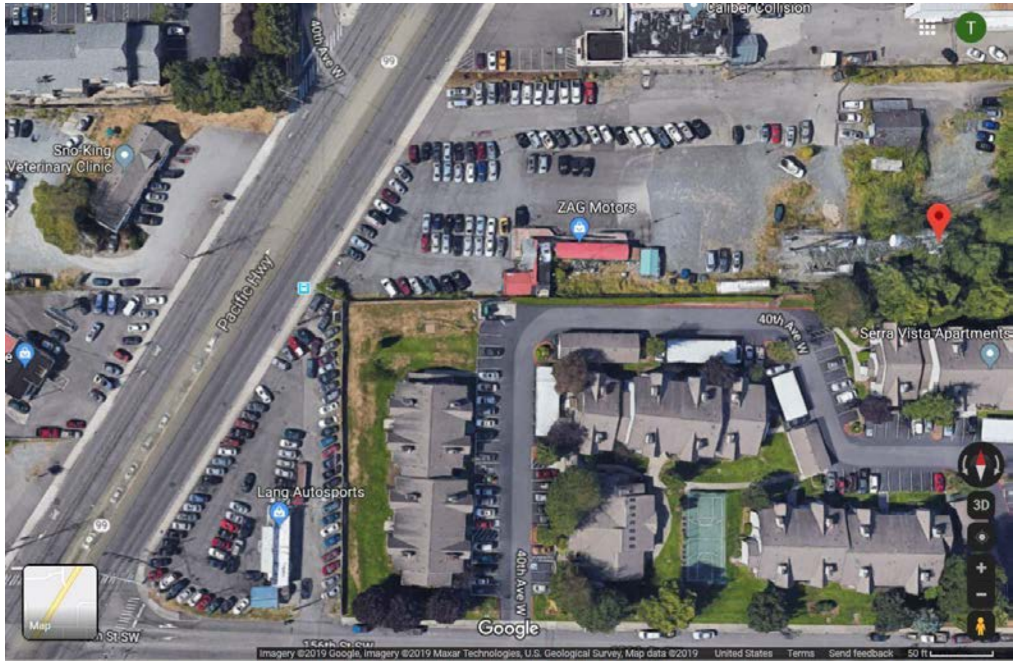


	25%	50%	75%
Traditional Window I/N -6 dB	32	25	18
Traditional Window I/N -9 dB	35	28	21
Traditional Window I/N -12 dB	38	31	24
Thermal window I/N -6 dB	19	10	-1
"Thermal Window I/N -9 dB"	22	13	2
"Thermal Window I/N -12 dB"	25	16	5

- RLAN will exceed interference threshold in both cases

Example 4: WPTX494 > WLU230, RLAN at Vet Clinic

- FS link in Lynnwood, WA
  - Low Path loss – 0.17 km between RLAN and victim FS receiver
  - High FS antenna discrimination factor (38 dB) between RLAN and victim FS receiver
- RLAN at 2m AGL with transmit power of 30 dBm



Example 4: WPTX494 > WLU230, RLAN at Vet Clinic

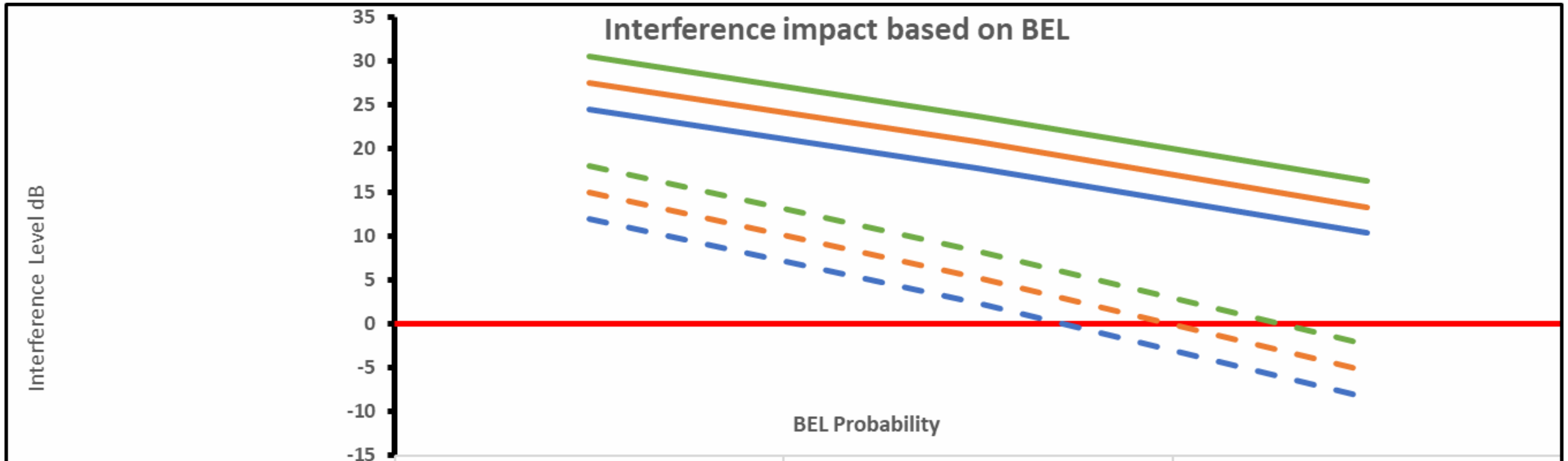
	Units	Victim	Source	Vet Clinic
		WLU230	WPTX494	
Height AGL	m	44.5	43.3	2
Height ASL	m	236.2	202.1	193.7
Lat		47.9	47.9	47.86
Lon		-122.3	-122.7	-122.29
$\theta_{Elevation}$ *	deg		-0.17	-14.10
$\theta_{Azimuth}$	deg		273.95	275.58

* Adjusted for Earth Curvature

	Units	Derived Figures		
$\theta_{Elevation}$ *	deg	13.93		
$\theta_{Azimuth}$	deg	-1.63		
$\Delta\theta$	deg	14.02		
Dist. Source > Victim	km	0.00		
Dist. RLAN > Victim	m	174.43		
Path Loss	dB	92.84		
Antenna Gain	dBi	41.30		
Antenna Discrimination	dB	38.00		
Other losses incl Pol	dB	3.00		
RLAN Transmit Pwr	dBm	30.00		
Bandwidth mismatch	dB	3.00		
RX interference power	dB	-102.00	-105.00	-108.
I/N	dB	-6.00	-9.00	-12.0
Allowable RLAN Power	dBm	-6.46	-9.46	-12.4

Example 4: WPTX494 > WLU230, RLAN at Vet Clinic

- Chart graphs interference level for I/N of -6 dB, -9 dB and -12 dB for traditional and thermally efficient construction at 25%, 50% and 75% probabilities for BEL "not to exceed" values

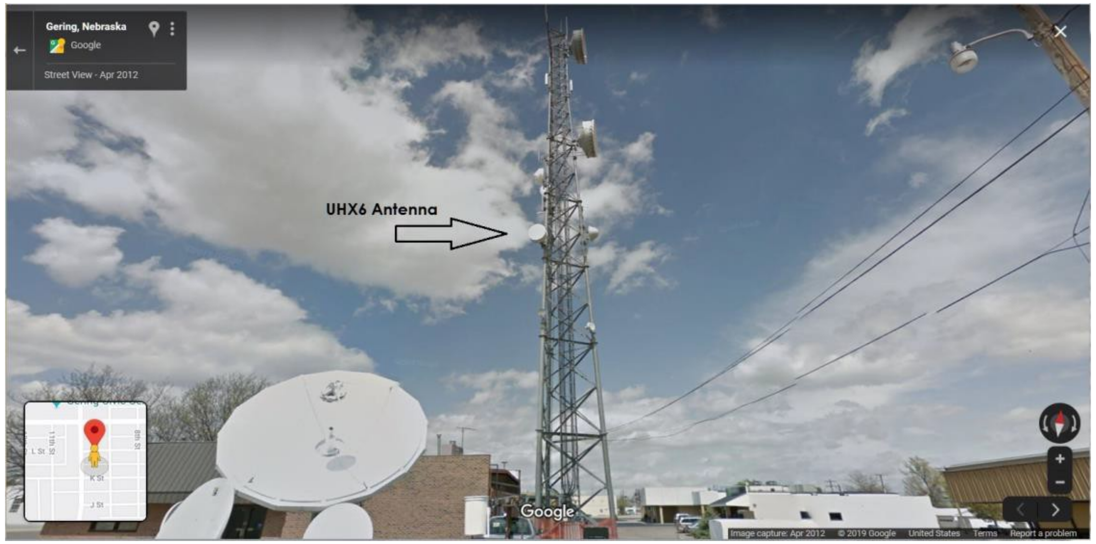


	75%	50%	25%
Traditional Window I/N -6 dB	25	18	10
Traditional Window I/N -9 dB	28	21	13
Traditional Window I/N -12 dB	31	24	16
Thermal window I/N -6 dB	12	2	-8
"Thermal Window I/N -9 dB"	15	5	-5
"Thermal Window I/N -12 dB"	18	8	-2

- RLAN will almost certainly exceed interference threshold in both cases

Example 5: WWWA496 > WQWA497, RLAN at K St Home

- FS link to AT&T's CO in Gering, NE
  - Low Path loss – only 50m between RLAN and victim FS receiver
  - High FS antenna discrimination factor (38.8 dB) between RLAN and victim FS receiver
- RLAN at 1.5m AGL with transmit power of 30 dBm



Example 5: WWWA496 > WQWA497, RLAN at K St Home

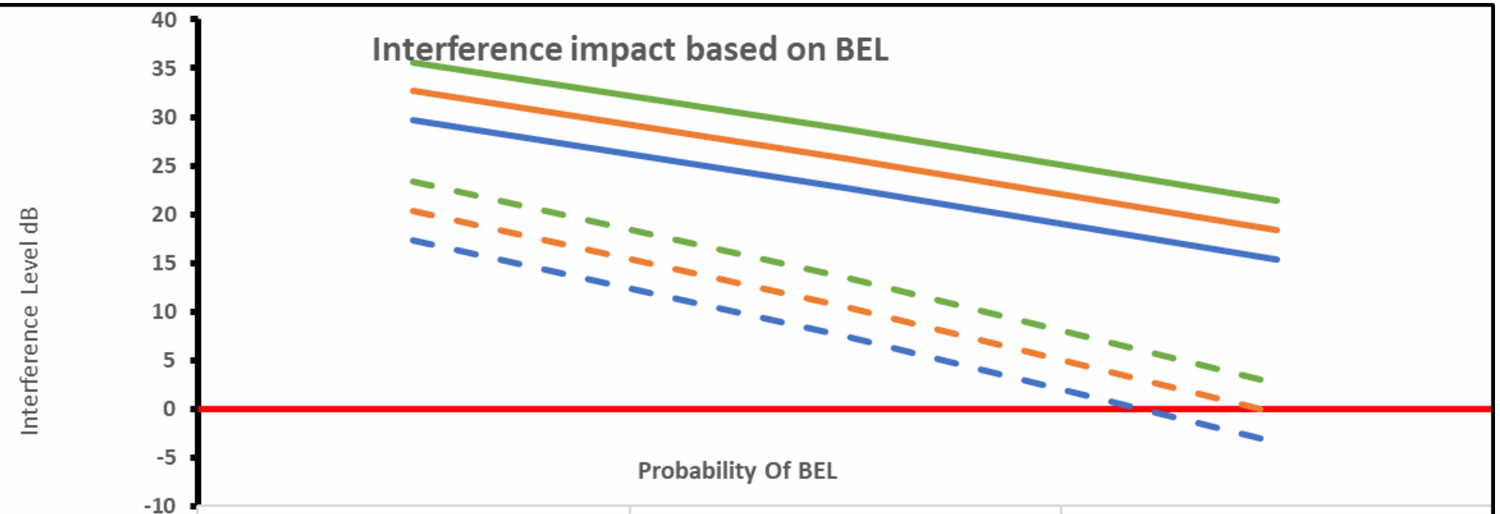
	Units	Victim WQWA497	Source WQWA496	K St Home
Height AGL	m	15.2	19.8	1.5
Height ASL	m	1207.6	1464.6	1193.9
Lat		41.8	41.7	41.82
Lon		-103.7	-103.7	-103.66
$\theta_{Elevation}$*	deg		1.07	-15.23
$\theta_{Azimuth}$	deg		188.77	179.14

* Adjusted for Earth Curvature

	Units	Derived Figures		
$\theta_{Elevation}$*	deg	16.30		
$\theta_{Azimuth}$	deg	9.63		
$\Delta\theta$	deg	18.68		
Dist. Source > Victim	km	0.00		
Dist. RLAN > Victim	m	52.15		
Path Loss	dB	82.35		
Antenna Gain	dBi	38.80		
Antenna Discrimination	dB	40.00		
Other losses incl Pol	dB	3.00		
RLAN Transmit Pwr	dBm	30.00		
Bandwidth mismatch	dB	3.00		
RX interference power	dB	-102.00	-105.00	-108.00
I/N	dB	-6.00	-9.00	-12.00
Allowable RLAN Power	dBm	-12.45	-15.45	-18.45

Example 5: WWWA496 > WQWA497, RLAN at K St Home

- Chart graphs interference level for I/N of -6 dB, -9 dB and -12 dB for traditional and thermally efficient construction at 25%, 50% and 75% probabilities for BEL “not to exceed” values



	75%	50%	25%
Traditional Window I/N -6 dB	30	23	15
Traditional Window I/N -9 dB	33	26	18
Traditional Window I/N -12 dB	36	29	21
Thermal window I/N -6 dB	17	7	-3
"Thermal Window I/N -9 dB"	20	10	0
"Thermal Window I/N -12 dB"	23	13	3

- RLAN will almost certainly exceed interference threshold in both cases

Impact on AT&T links based on 14 dBm outdoor devices

AT&T Scenario	I/N [dB]	Outdoor Max EIRP [dBm]	Delta @ max (14 dBm) [dB]
KPV20 (Case 1)	-6	-5	18.7
	-9	-8	21.7
	-12	-11	24.7
KPV20 (Case 2)	-6	-6	19.8
	-9	-9	22.8
	-12	-12	25.8
WQPJ679	-6	-13	27.4
	-9	-16	30.4
	-12	-19	33.4
WQXC429	-6	-12	26
	-9	-15	29
	-12	-18	32
WLU230	-6	-6	20.5
	-9	-9	23.5
	-12	-12	26.5
WQWA497	-6	-12	26.4
	-9	-15	29.4
	-12	-18	32.4

- Table shows interference above acceptable I/N (“Delta @ max”) levels of -6 dB, -9 dB, and -12 dB based on proposed 14 dBm outdoor RLAN EIRP limit
- Analysis is based on actual RLAN and FS receiver geometry, including path loss, bandwidth mismatch, polarization loss, antenna discrimination, feeder losses, etc
- Does not include inappropriate “body loss” adjustment
  - Use case/orientation dependent
  - If applicable, misleading to use single loss value
- Mobility will add further uncertainty to interference detection and avoidance
- Outdoor RLAN without AFC control will almost certain exceed interference thresholds in all cases