QUALCOMM Incorporated

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May 2, 2013

Ms. Marlene Dortch
Secretary
Federal Communications Commission
445 12th Street, SW
Washington, DC 20554

Re: Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions -- GN Docket No. 12-268

Dear Ms. Dortch:

On April 30, 2013, Dean Brenner, Sumit Verma, Kent Walker, and the undersigned of QUALCOMM Incorporated ("Qualcomm") discussed the *Notice of Proposed Rulemaking* in the above-referenced proceeding with Commissioner Ajit Pai, his Chief of Staff Matthew Berry, his legal advisors Courtney Reinhard and Nicholas Degani, and intern Benjamin Tarbell. Qualcomm presented the attached slides, discussing the technical issues relating to 600 MHz band plans covered therein.

On May 1, 2013, Dean Brenner also briefly discussed the slide presentation with Gary Epstein, Chief of the Commission's Incentive Auction Task Force. Following this conversation, Mr. Brenner provided Mr. Epstein with a copy of the attached slides.

Respectfully submitted,

John W. Kuzin

John W. Kuzin
Senior Director, Government Affairs – Regulatory

Att.

cc (w/ Att.) Commissioner Ajit Pai
(via email) Matthew Berry
Nicholas Degani
Courtney Reinhard
Ben Tarbell
Gary Epstein

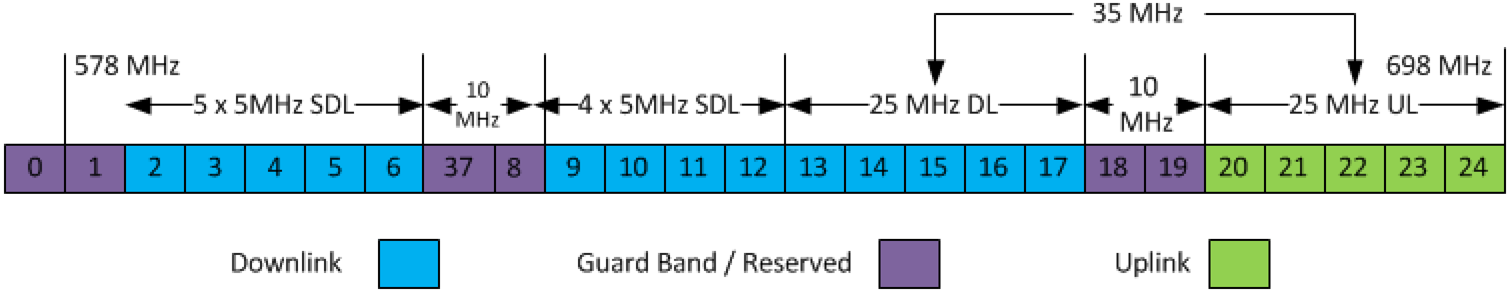
FCC 600 MHz Band Technical Discussion

Agenda

- Key Findings
- Technical Issues
  - Background and Analysis Method
  - Harmonic Analysis
  - Spurious Analysis
  - Antenna Considerations
  - Filter Findings
  - White Space in Guardbands
  - Back Up

Key Findings (page 1 of 2)

- A 2 x 25 MHz plan is technically feasible and can be readily implemented with minimal increase in components, antenna costs, and device size, while maintaining performance
- Mobile uplink should start at Channel 51, immediately adjacent to existing mobile uplink on Channel 52
- Below the 2 x 25 MHz pair, all additional spectrum recovered in the auction should be allocated for Supplemental Downlink (SDL)
- This flexible allocation can address scenarios in which different amounts of bandwidth are available in the forward auction



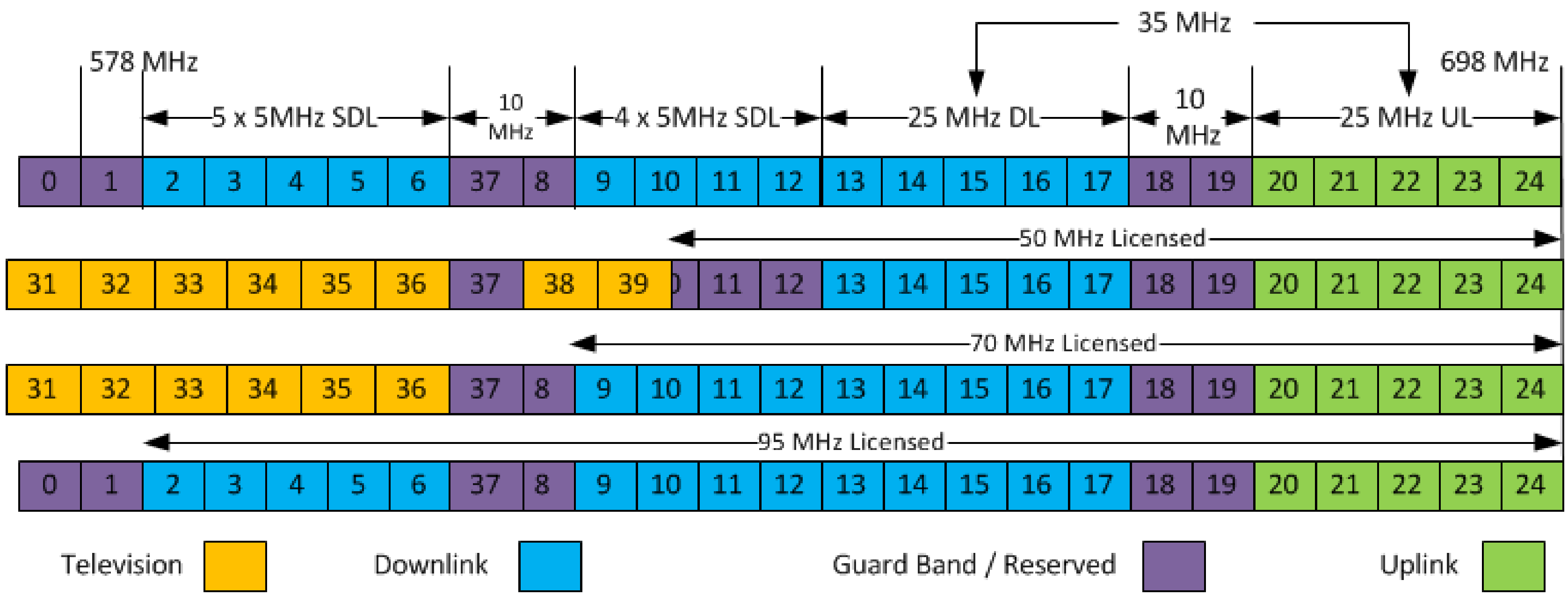
Each block is 5 MHz except channel 37, which is 6 MHz wide and provided as a frame of reference

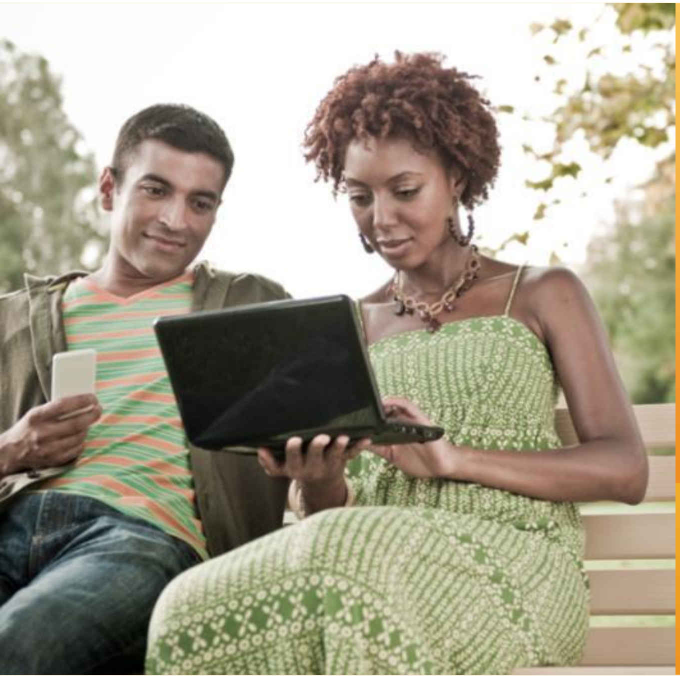
Key Findings (page 2 of 2)

- Duplex gap must be a minimum of 10 MHz and need not be more than 12 MHz to prevent interference within the licensed mobile spectrum
- Guard band between TV and mobile downlink should be 10 MHz to avoid harmful interference
- A TDD allocation is not advisable because the usable bandwidth is limited by harmonic and spurious interference and would require a guard band below Channel 52, which would consume a substantial amount of the bandwidth best suited for uplink
- Unlicensed operation in the duplex gap and guard band would cause interference to mobile downlink
- Unlicensed service in the duplex gap and guard band would suffer interference from mobile uplink

Potential Solution

- The figure below shows a family of band plans that meets all the described desirable characteristics:
  - No impaired spectrum, due to harmonics, spurious, or whitespace operations
  - Can be supported with a single UE design in all markets with no overlapping or otherwise duplicative filters
  - Antennas compatible with a smartphone form factor

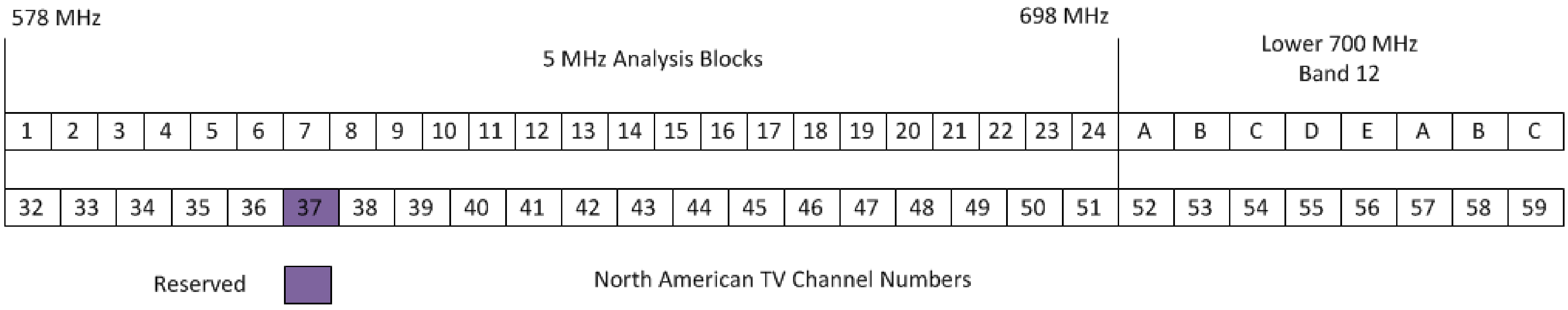


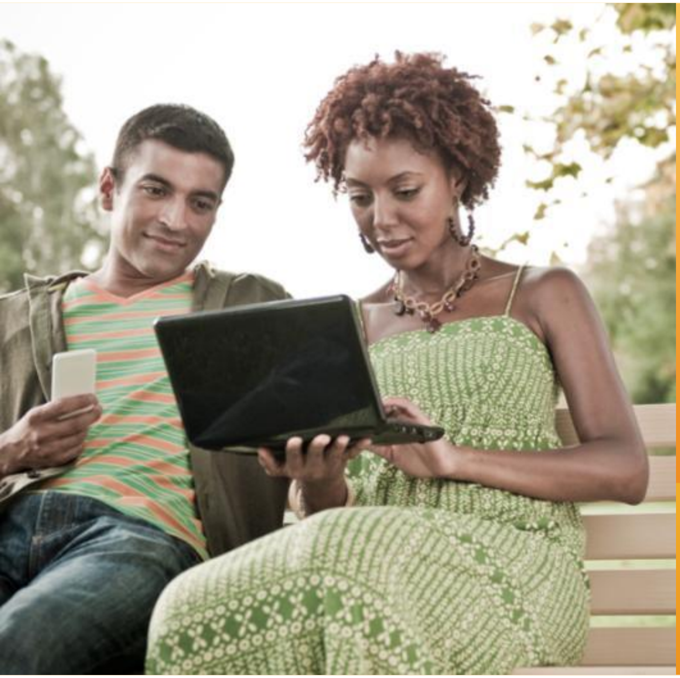


Technical Analysis

Background

- The 600 MHz spectrum is depicted below labeled along with the historical 6 MHz TV channel assignments and FCC’s 5 MHz analysis blocks
- A total of 120 MHz is located immediately below old Channel 52 i.e. the uplink portion of the Lower 700 MHz A block
- Channel 37 is reserved for radio astronomy and intra-hospital radio communications



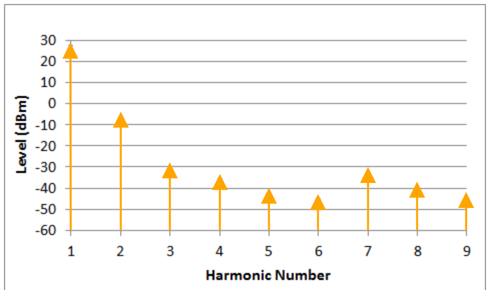


UE Transmit Harmonics

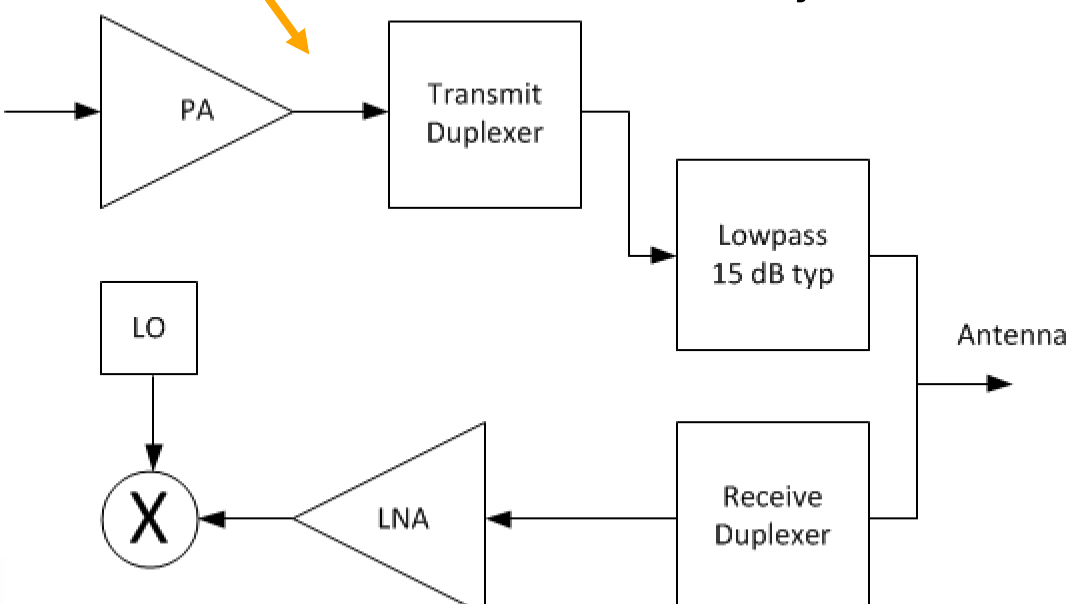
North American Victim Receive Bands

Band	Uplink (MHz)		Downlink (MHz)		BW (MHz)	TX-RX (MHz)
2	1850	1910	1930	1990	60	80
4	1710	1755	2110	2155	45	400
5	824	849	869	894	25	45
12	698	716	728	746	18	30
13	777	787	746	756	10	-31
14	788	798	758	768	10	-30
17	704	716	734	746	12	30
23	2000	2020	2180	2200	20	180
25	1850	1915	1930	1995	65	80
41	2496	2690	2496	2690	194	
CH55_56			716	728	12	
Public Safety			769	775	6	
3_5G_US	3550	3650	3550	3650	100	
WCS	2305	2320	2345	2360	15	40
600M_US	500	698	500	698	198	
WLAN 2.4G	2400	2484	2400	2484	84	
WLAN 5G	5170	5330	5170	5330	160	
	5490	5835	5490	5835	345	
	5850	5920	5850	5920	70	
WLAN 900M	902	928	902	928	26	
GNSS L1			1559.052	1605.886	46.834	
GNSS L2			1226.577	1249.136	22.559	

Harmonic Self Jamming



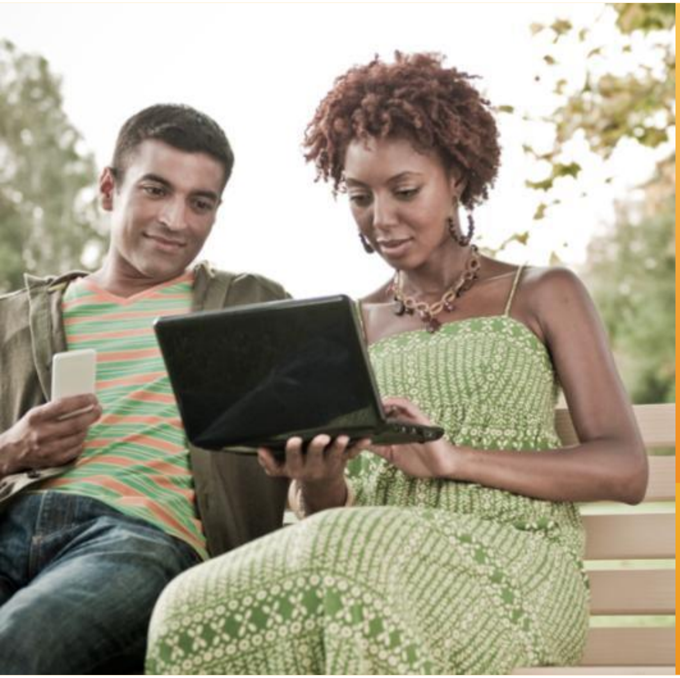
- The output of the transmit PA has harmonic that falls in band for another land mobile receive band
- Combination of filters, antenna return loss and layout do not provide sufficient attenuation
- Reception in the harmonically related band is jammed



UE Transmit Harmonic Victims North America

- A primary concern is the number of mobile, positioning, and Wifi receive bands that are potentially jammed by harmonics of an uplink within the 600 MHz band
- This has significant negative impact on carrier aggregation (CA), an important LTE Advanced feature
- Only the impacted bands for North America are shown below
- The top 5 analysis blocks, i.e. 25 MHz, have only one 5 GHz Wifi victim, an 8th harmonic

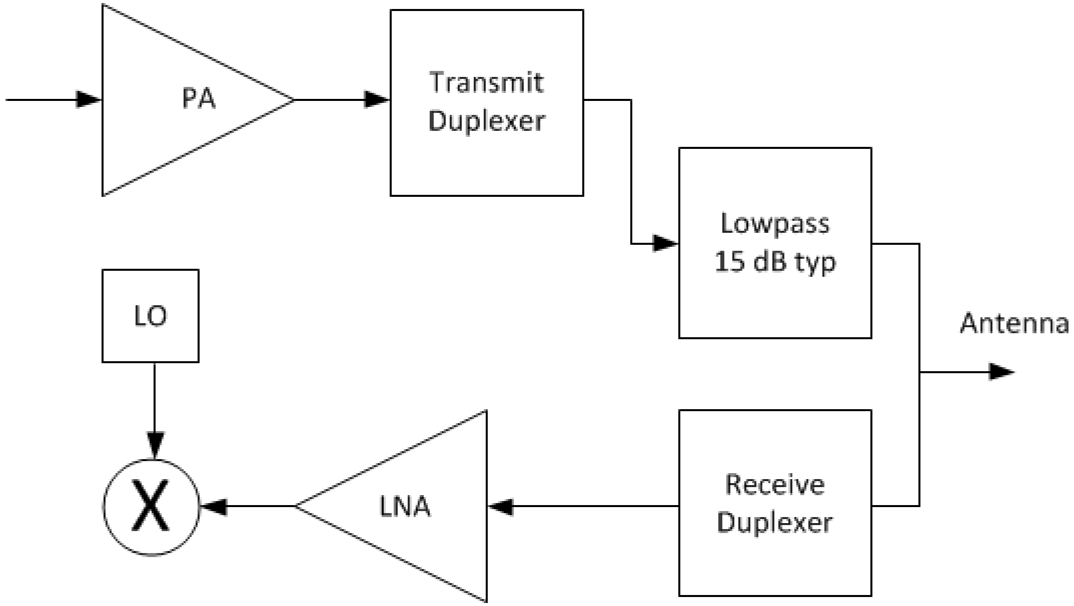
Analysis Block	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Victim Band																								
B2														H3	H3	H3	H3	H3						
B25														H3	H3	H3	H3	H3						
B41										H4	H4	H4	H4	H4	H4	H4	H4	H4	H4					
GNSS-L2						H2	H2	H2	H2															
WLAN_2400_2484					H4	H4	H4	H4	H4															
3.5G_US			H6	H6	H6	H6	H6																	
WCS		H4	H4																					
WLAN_5170_5920	H9 H10	H9 H10	H9 H10	H9	H9	H9	H9	H9	H9	H9	H9	H9	H9	H8 H9	H8H9	H8 H9	H8	H8	H8	H8	H8	H8	H8	H8
GNSS-L5	H2	H2	H2	H2																				



Spurious Analysis

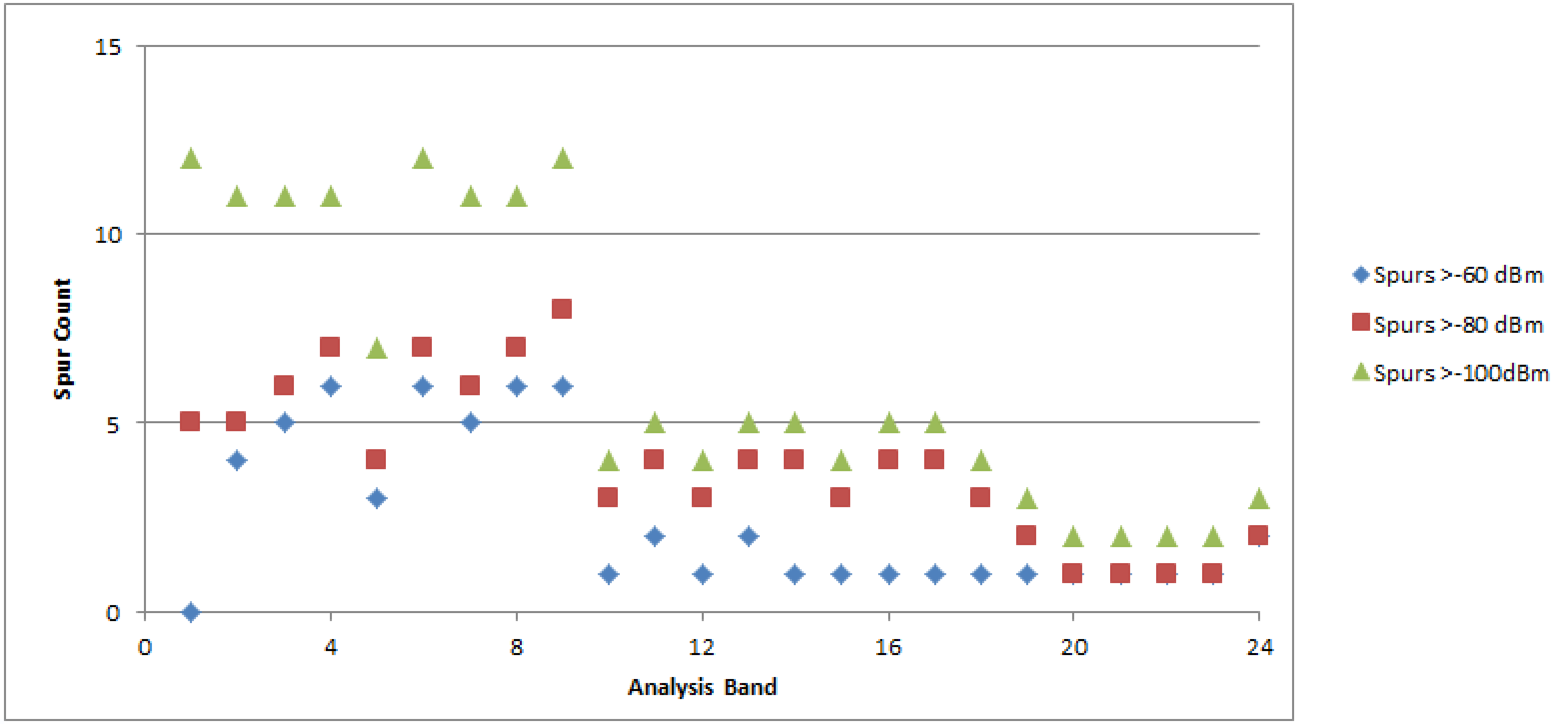
Self Jamming Spurious Response

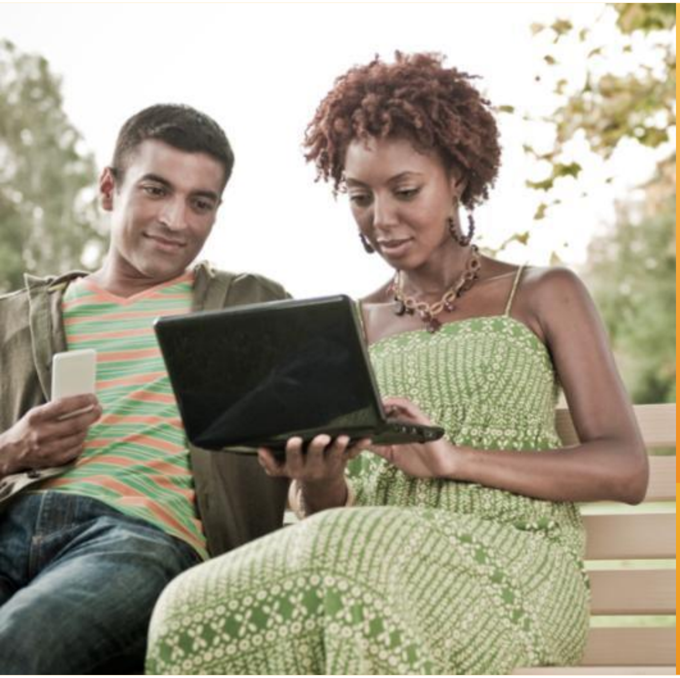
- Similar to the harmonic analysis, except complicated by the presence of harmonic responses in the receive chain
- M•F(tx) ± N•F(rx) = Victim Receive Band Frequency
- Level of the spurs in the subsequent slide are referenced to conducted input level, so they may be easily evaluated



Spurious Results for 24 Analysis Blocks

- Figure shows the number of US bands with spur(s) greater than -100, -80 or -60 dBm per analysis block
- This figure confirms the harmonic analysis, all uplinks should be in the upper 25 MHz of the band





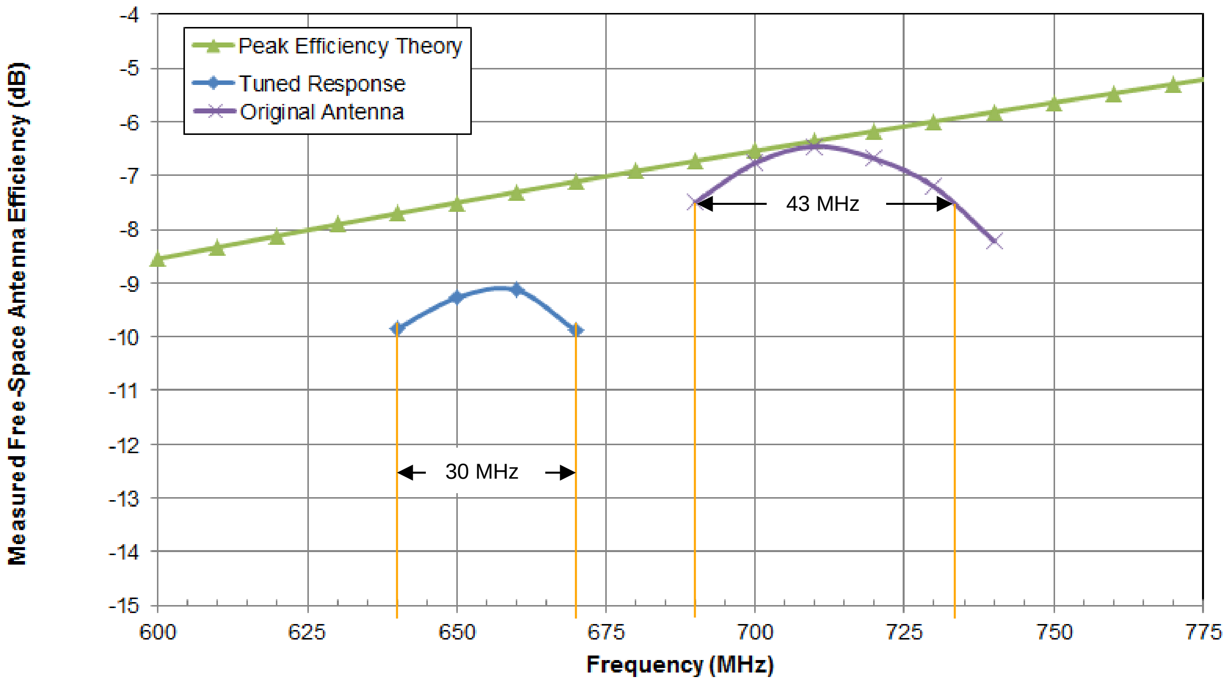
Antenna Considerations

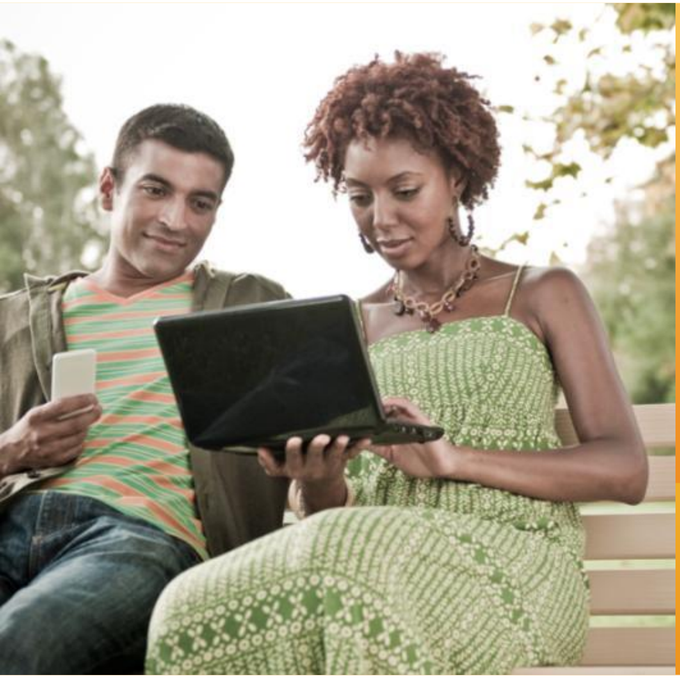
Antenna Considerations for 600 MHz

- Mobile devices will continue to be space constrained
- Adding a new low frequency band either requires an additional relatively large antenna system or the use of an existing antenna system with a tuner
- It would be preferable to reuse a 700 MHz antenna for the 600 MHz band
- Impedance match is a requirement for every concurrently active band, for both transmit and receive, i.e., the real time antenna bandwidth
- For a given device type, i.e., a defined antenna volume and frequency, there is a percentage bandwidth that can be matched
  - A current design at 710 MHz achieves 6%, 1dB efficiency bandwidth
    - Theoretical efficiency for constant antenna volume varies as f^3 for electrically small antennas
    - Re-tuning to 655 MHz the 1 dB efficiency bandwidth is reduced to ~4.7%
- It is possible to achieve another simultaneous match on the same antenna structure approximately an octave distant in frequency, but not much closer

Impact of Antenna Tuning

- The measured results below show the impact of retuning a fixed volume antenna to a lower band
- This particular antenna is somewhat worse than theory for peak efficiency
- Even with a 2 x 25 MHz plan, which requires 60 MHz of bandwidth, either the antenna volume will need to increase somewhat or antenna performance will be degraded
- The bound on antenna volume is proportional to the [bandwidth x efficiency] product

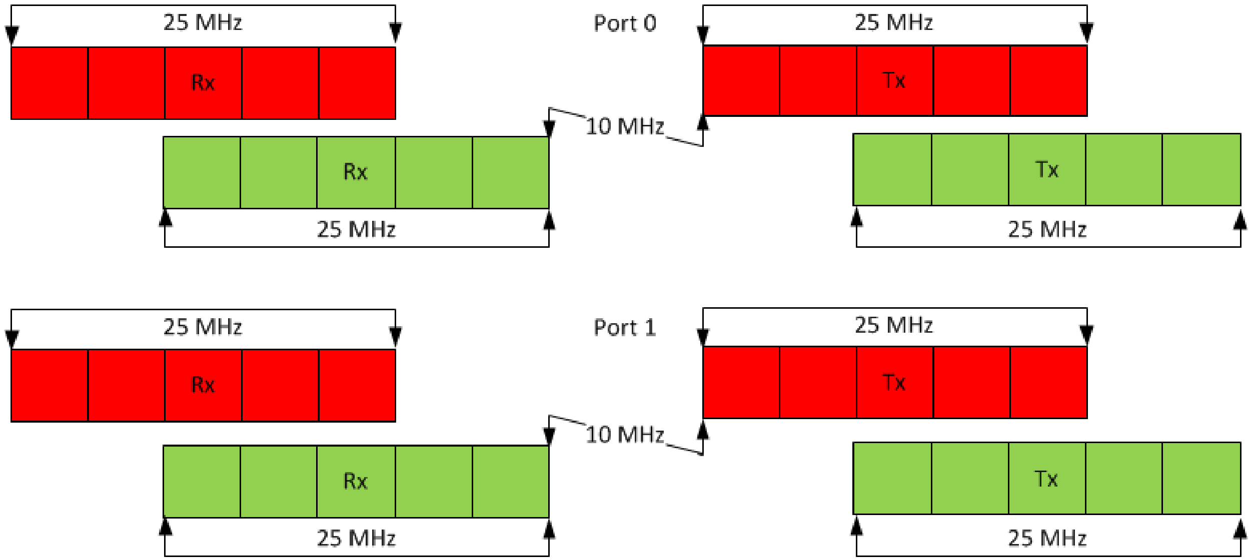


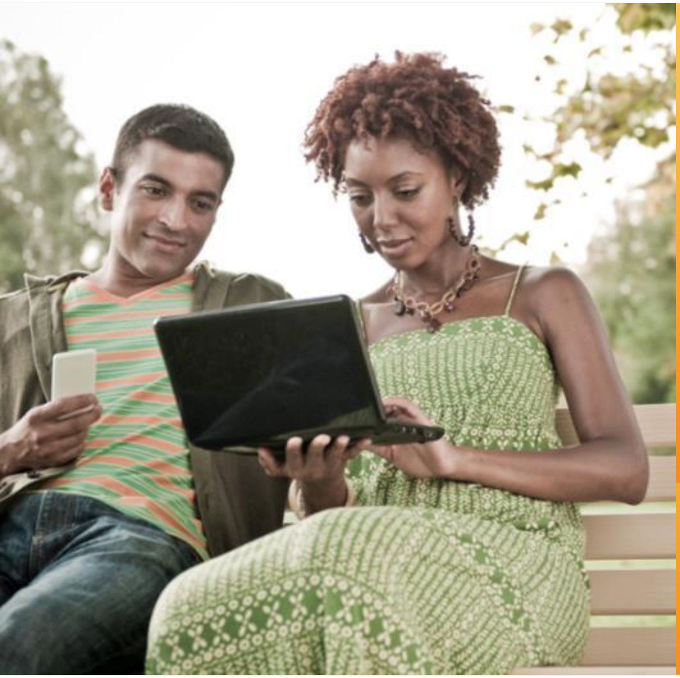


Filter Topics

Filter Findings 600 MHz

- Multiple vendors were polled on achievable 600 MHz filter characteristics
  - The results were consistent: no for 30 MHz, yes for 20 and 25 MHz
  - The maximum filter bandwidth that can meet the desired specs is 4% of center frequency
- Duplex gap and guard bands
  - 10 MHz is the minimum sufficient for the duplex gap, no benefit beyond 12 MHz
  - 10 MHz is sufficient for broadcast TV rejection
- The most efficient filter design is achieved by utilizing non-overlapping 25 MHz blocks of uplink and downlink
- Increasing the paired bandwidth to 35 MHz requires 4 additional filters for the FDD pair





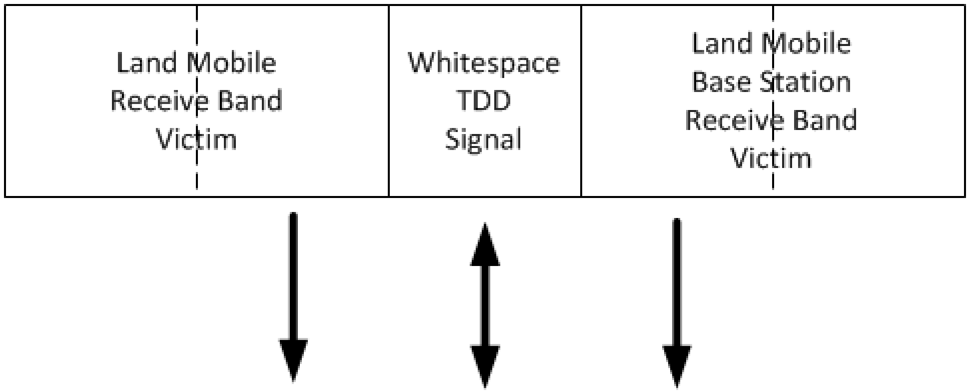
White Space in Duplex Gap

Assumptions

- Whitespace signals (WS) are similar to WiFi, a TDD OFDM waveform
  - Not too dissimilar to full carrier bandwidth TDD LTE as an interferer
- In band radiation is governed by existing FCC Rules 15.701 to 15.717
  - Max base station power 6 dBW EIRP with maximum antenna gain of 6 dBi
  - Max base station height, 30m AGL
  - Maximum mobile radiated power 100 mW per 6 MHz
- Good electromagnetic compatibility is operation to within 1m radial distance

Use Cases to Consider

- LTE UE receiver blocking victim due to WS base station adjacent channel power
- WS UE receiver desense victim due to LTE UE Out of Band Emissions (OOBE)
- LTE UE receiver desense due to WS mobile Out of Band Emissions (OOBE)

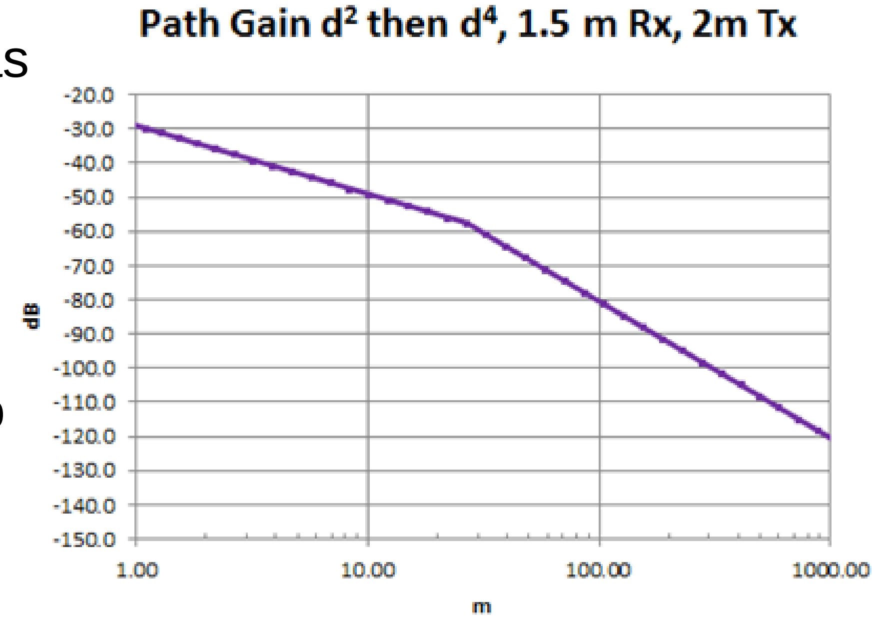


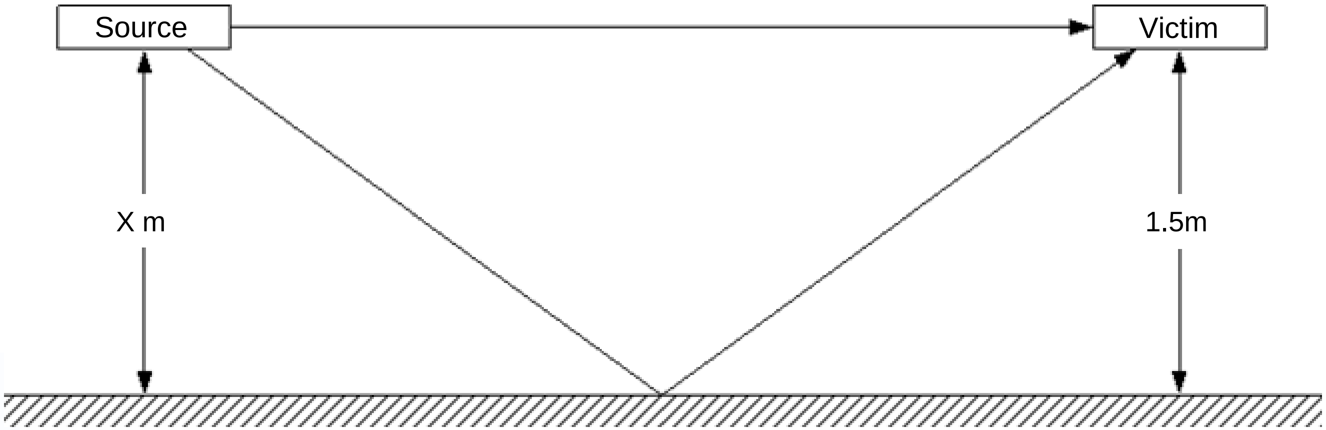
Propagation Model for White Space <–> LTE

- For the analysis of LTE device interference the path loss is modeled as n=2 (free space) and then n=4
- The transition distance is defined as

$$\frac{4 h_b h_m}{\lambda}$$

- The heights of the two devices is set to 1.5 m (UE) and X m respectively
- See ITU-R 1411-2 Sec 4.1 or ITU-R P.341 for more details





Blocking and Desense Limits and Method

- WS Base Station Blocking of LTE UE
  - LTE UE minimum specification for blocking
    - Desired signal level set to REFSEN + 6 dB
    - In band Blocker is set to -56 dBm
    - REFSEN for band 12 is defined as -97 dBm for 5 MHz [1]
  - Assume LTE device meets this requirement
    - Calculate blocked area around WS base station

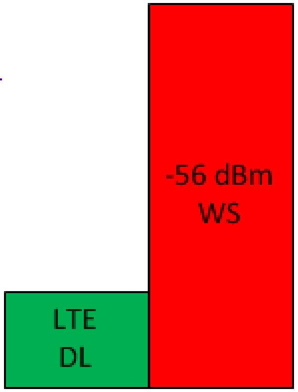
- LTE UE Desense of WS UE
  - OOBE calculation based typical LTE UE performance adjacent channel OOBE ~30 dB below desired, and average filter attenuation of 3 dB at 10 MHz offset
    - Calculate radius for which WS UE is degraded by 3 dB or more

- WS UE Desense of LTE UE
  - OOBE calculation based on typical UE performance adjacent channel OOBE -55 dB below desired, and average filter attenuation of 3 dB at 10 MHz offset
    - Calculate radius for which WS UE is degraded by 3 dB or more

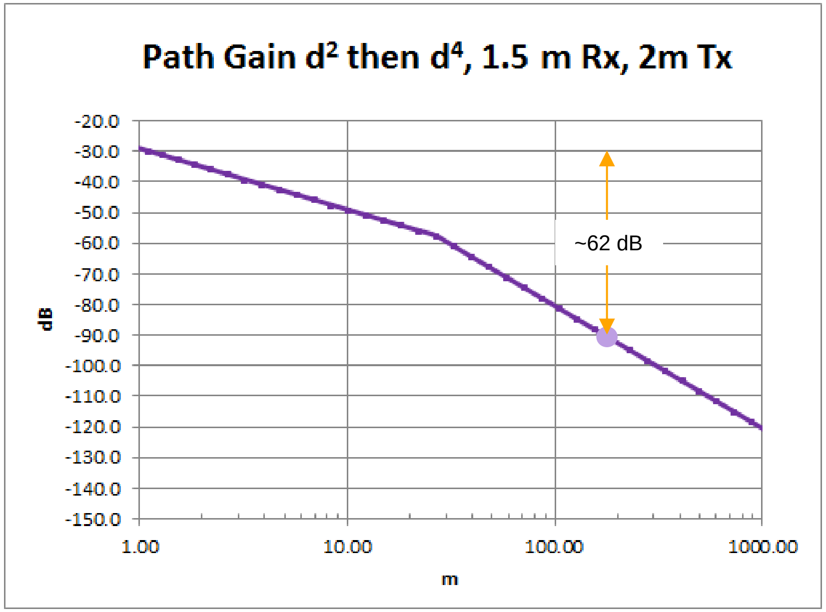
1. 3GPP T S 36.101 V11.2.0 (2012-09) 89 Release 11

WS Base Station Block of LTE UE

- WS base station may block a LTE UE 155m away
- Potentially blocked radius is defined as area with received signal strength greater than that defined as blocking in the LTE specification Case 1,[1] suitable to an indoor use case



Parameter	Value	Units
Transmit Height	2	m
Receive Height	1.5	m
RF Frequency	668	MHz
Refsens for 5 MHz Band 12	-97.0	dBm
UE Desired Refsens + 6 dB	-91	dBm
WS Blocking Level	-56	dBm
Adjacent Channel Integrated Loss	3.0	dB
WS Base Station EIRP	36.0	dBm
Blocking Path Loss	92	dB
Distance to Path Loss	155	m

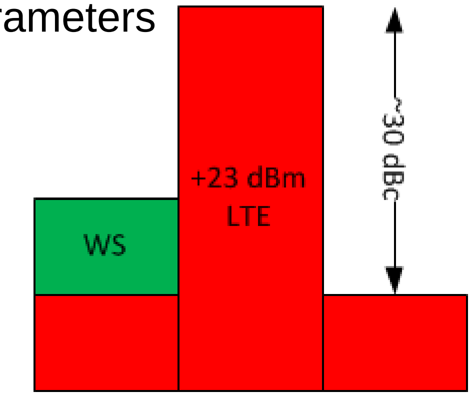


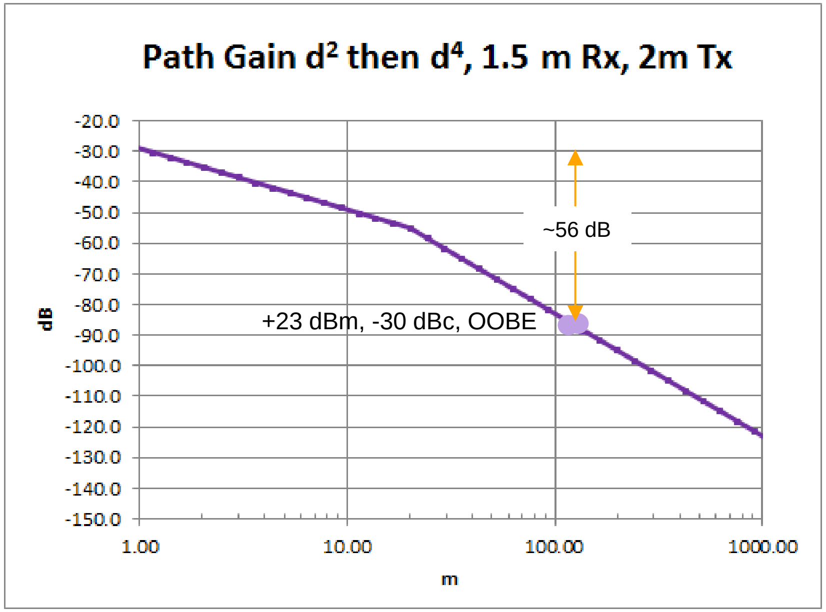
1. 3GPP T S 36.101 V11.2.0 (2012-09) 89 Release 11

LTE UE Desense of WS UE

- Distance to path loss is 123m @ 200 mW radiated power, -30 dB shoulder
- Defined criteria is 3 dB of sensitivity loss for a typical WS UE
  - WS portable is assumed to be similar to LTE UE in terms of RF parameters

Parameter	Value	Units
RF Frequency	668	MHz
Transmit Height	1.5	m
Receive Height	1.5	m
System Temperature	290	K
Boltzman's constant	1.38E-23	J/K
Receiver Bandwidth	4.5	MHz
Reference Noise Power (kTB)	-107.5	dBm
0 C/N Conducted	-101.5	dBm
Desense	3	dB
Interference Input level 3 dB loss	-98.5	dBm
Antenna Efficiency	-5	dB
Radiated Power 3dB Sensitivity Loss	-93.5	dBm
Radiated Power LTE UE	23	dBm
First Side Lobe Level	-30	dB Carrier Density
Integrated Loss in Adjacent Channel	3	dB
Radiated Power In Receive Bandwidth	-10	dBm
Path Loss to Achieve 3 dB Desense	86.5	dB
Distance to 3 dB Desense due to OOBE	123	m

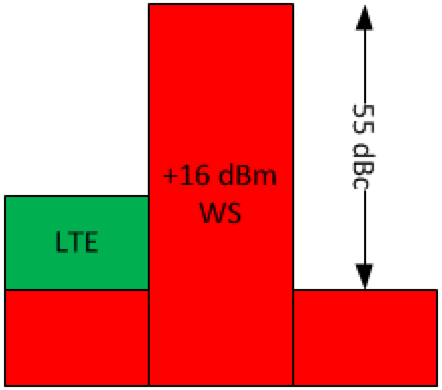


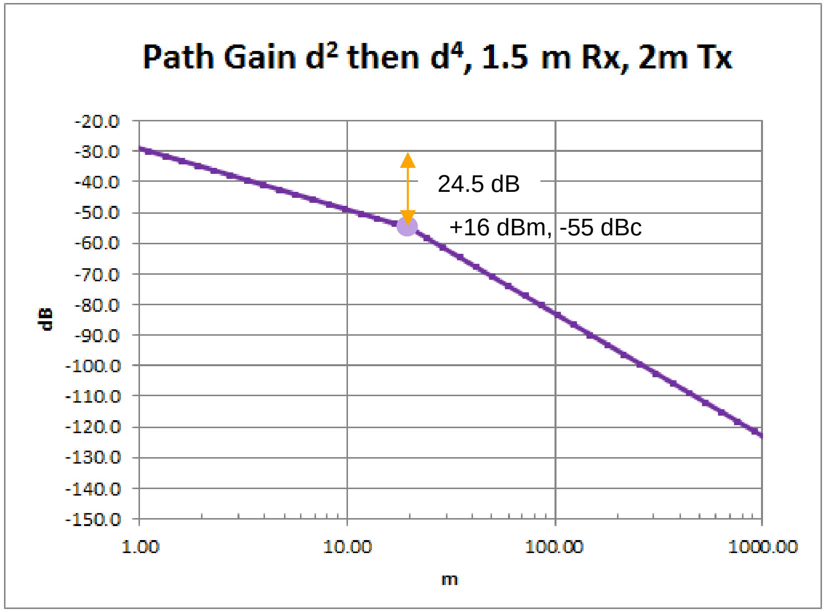


WS UE Desense of LTE UE

- WS UE may desense an LTE UE at 19m (+16 dBm, -55 dBc OOBE)
- Defined criteria is 3dB of sensitivity loss for a typical LTE UE receiver

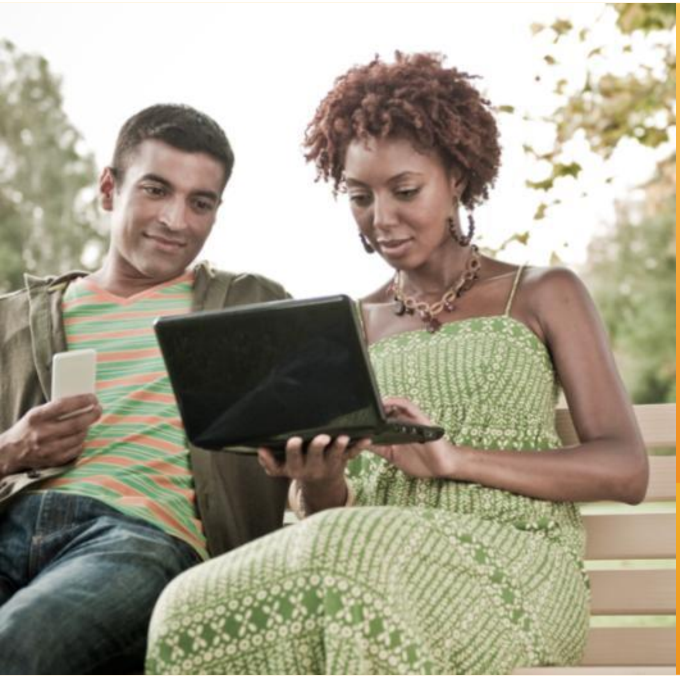
Parameter	Value	Units
RF Frequency	668	MHz
Transmit Height	1.5	m
Receive Height	1.5	m
System Temperature	290	K
Boltzman's constant	1.38E-23	J/K
Receiver Bandwidth	4.5	MHz
Reference Noise Power (kTB)	-107.5	dBm
0 C/N Conducted	-101.5	dBm
Desense	3	dB
Interference Input level 3 dB loss	-98.5	dBm
Antenna Efficiency	-5	dB
Radiated Power 3dB Sensitivity Loss	-93.5	dBm
Radiated Power WS UE	20	dBm
First Side Lobe Level	-55	dB Carrier Density
Integrated Loss in Adjacent Channel	0	dB
Radiated Power In Receive Bandwidth	-39	dBm
Path Loss to Achieve 3 dB Desense	54.5	dB
Distance to 3 dB Desense due to OOBE	19	m





Comments

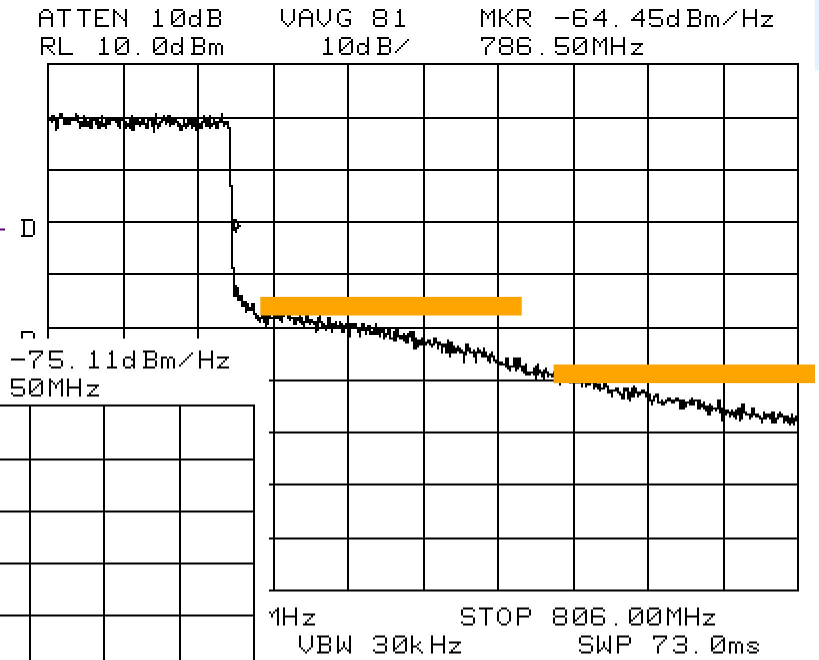
- Whitespace base station operation in an adjacent guard band can cause LTE downlink blocking within a 155m radius around each base station
- Whitespace portable device operation in an adjacent guard band will suffer 3 dB or greater downlink desense within a 123m radius around each active LTE device
- A WS UE, operating under the most restrictive FCC rules, will cause desense to a LTE UE within 19 m
- The required attenuation to get to 1m are ~62 dB, ~56 dB, and ~25 dB
- The only means to achieve the required attenuation is to add additional guard band on either side of white space allocation of approximately 10 MHz per side
- Use of guard band spectrum for white space communications is not recommended
- Spectrum blocks auctioned for licensed use that are adjacent to White Space operations will be impaired and, thus, not fungible with non-adjacent blocks, thereby adversely impacting auction value and design

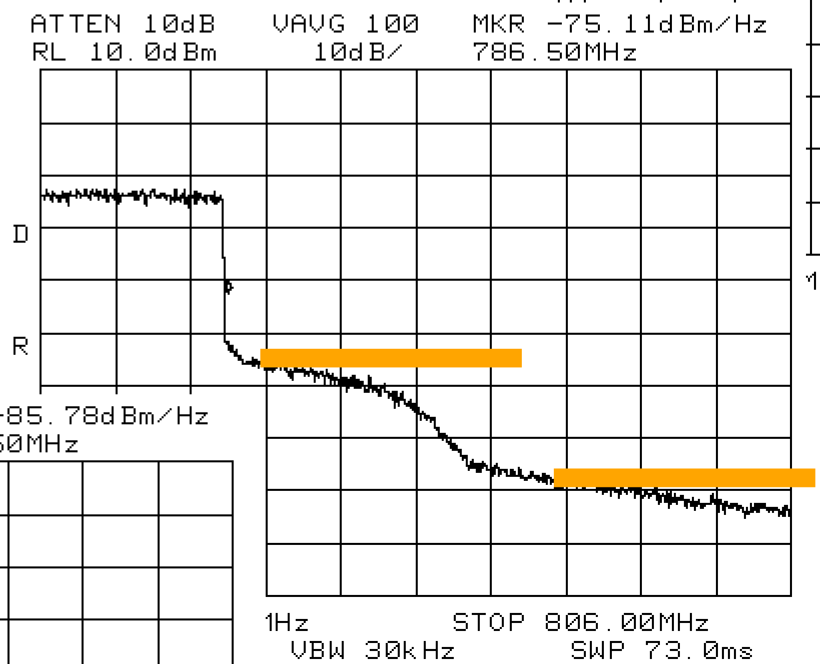


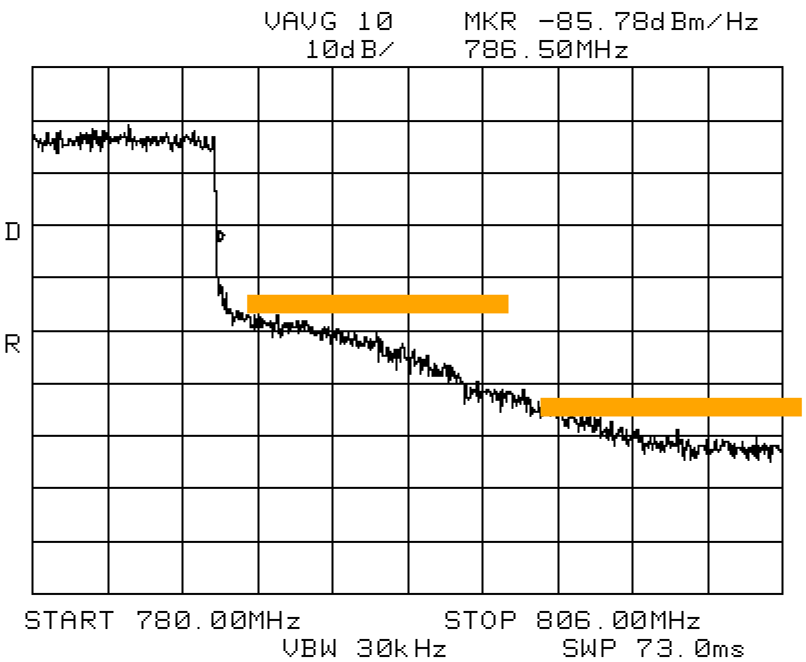
Back Up

Mobile Power Amplifier Performance (10 MHz)

- PA Output Spectrum at Antenna
  - + 26 dBm
  - +13 dBm
  - +3 dBm

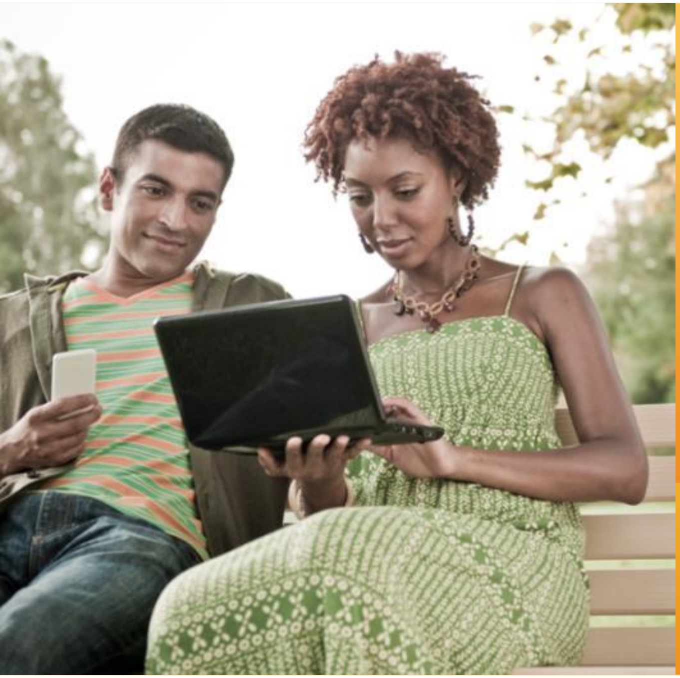






Listing of Spurious Frequencies

3GPP Band/ Analysis Block	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
B2														R1+T2 R2+T1	R1+T2 R2+T1	R1+T2 R2+T1	R1+T2 R2+T1	R1+T2 R2+T1						
B25														R1+T2 R2+T1	R1+T2 R2+T1	R1+T2 R2+T1	R1+T2 R2+T1	R1+T2 R2+T1						
B41										R1+T3 R2+T2 R3+T1	R1+T3 R2+T2 R3+T1	R1+T3 R2+T2 R3+T1	R1+T3 R2+T2 R3+T1	R1+T3 R2+T2 R3+T1	R1+T3 R2+T2 R3+T1	R1+T3 R2+T2 R3+T1	R1+T3 R2+T2 R3+T1	R1+T3 R2+T2 R3+T1	R1+T3 R2+T2 R3+T1					
GNSS-L2						R1+T1	R1+T1	R1+T1	R1+T1															
WLAN_2.4_2.48					R1+T3 R2+T2 R3+T1	R1+T3 R2+T2 R3+T1	R1+T3 R2+T2 R3+T1	R1+T3 R2+T2 R3+T1	R1+T3 R2+T2 R3+T1															
3.5GHz			R1+T5 R2+T4 R3+T3 R4+T2 R5+T1	R1+T5 R2+T4 R3+T3 R4+T2 R5+T1	R1+T5 R2+T4 R3+T3 R4+T2 R5+T1	R1+T5 R2+T4 R3+T3 R4+T2 R5+T1	R1+T5 R2+T4 R3+T3 R4+T2 R5+T1																	
WCS		R1+T3 R2+T2 R3+T1	R1+T3 R2+T2 R3+T1																					
WLAN_5.17_5.92	R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1 R1+T9 R2+T8 R3+T7 R4+T6 R5+T5 R6+T4 R7+T3 R8+T2 R9+T10	R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1 R1+T9 R2+T8 R3+T7 R4+T6 R5+T5 R6+T4 R7+T3 R8+T2 R9+T10	R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1 R1+T9 R2+T8 R3+T7 R4+T6 R5+T5 R6+T4 R7+T3 R8+T2 R9+T10	R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1	R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1	R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1	R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1	R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1	R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1	R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1	R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1	R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1	R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1	R1+T7 R2+T6 R3+T5 R4+T4 R5+T3 R6+T2 R7+T1 R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1	R1+T7 R2+T6 R3+T5 R4+T4 R5+T3 R6+T2 R7+T1 R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1	R1+T7 R2+T6 R3+T5 R4+T4 R5+T3 R6+T2 R7+T1 R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1	R1+T7 R2+T6 R3+T5 R4+T4 R5+T3 R6+T2 R7+T1	R1+T7 R2+T6 R3+T5 R4+T4 R5+T3 R6+T2 R7+T1	R1+T7 R2+T6 R3+T5 R4+T4 R5+T3 R6+T2 R7+T1	R1+T7 R2+T6 R3+T5 R4+T4 R5+T3 R6+T2 R7+T1	R1+T7 R2+T6 R3+T5 R4+T4 R5+T3 R6+T2 R7+T1	R1+T7 R2+T6 R3+T5 R4+T4 R5+T3 R6+T2 R7+T1	R1+T7 R2+T6 R3+T5 R4+T4 R5+T3 R6+T2 R7+T1	R1+T7 R2+T6 R3+T5 R4+T4 R5+T3 R6+T2 R7+T1
GNSS-L5	R1+T1	R1+T1	R1+T1	R1+T1																				



Thank You