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VIA ELECTRONIC FILING

July 15, 2013

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

Re: Notice of *Ex Parte* Presentation*; IB Docket No. 11-109; DA 12-1863, IB Docket No. 12-340; IBFS File Nos. SATMOD-20101118-00239; SAT-MOD-20120928-00160; SAT-MOD-20120928-00161; SES-MOD-20121001-00872; RM-11681; WT Docket No. 12-327*

Dear Ms. Dortch:

On Thursday, July 11, 2013, Doug Smith, Chairman of the Board and Chief Executive Officer of LightSquared Subsidiary LLC ("LightSquared"); Jeffrey Carlisle, Executive Vice President for Regulatory Affairs and Public Policy of LightSquared; Geoff Stearn, Vice President, Spectrum Development; Maqbool Aliani, Vice President, Spectrum Management; Michael Tseytlin, Vice President, Engineering; and the undersigned of Latham & Watkins LLP, outside counsel to LightSquared met with the staff identified below. The attached presentation formed the basis for the discussion.

Respectfully submitted,

/s/ John P. Janka
John P. Janka

cc: Michael Ha
Robert Nelson
Ronald Repasi
Mark Settle
Janet Young

LightSquared Assessment of Uplinks in the 1626.5-1660.5 MHz band

In early 2012, LightSquared began to seek a path forward to resolve the GPS issue and create a new deployment plan in cooperation with government and military stakeholders. As part of this process, the company sought feedback so that it could construct a plan that dealt effectively with all important issues. This paper provides an overview of the assessments that recently have been made with a view toward clearing the use of LightSquared's authorized uplink channels in the 1626.5-1660.5 MHz band for uplinks from terrestrial wireless user terminals. This paper includes a focused response to the questions raised by several government agencies.

1. Terrestrial Use of the 1626.5-1660.5 MHz for Handset Uplink Transmissions

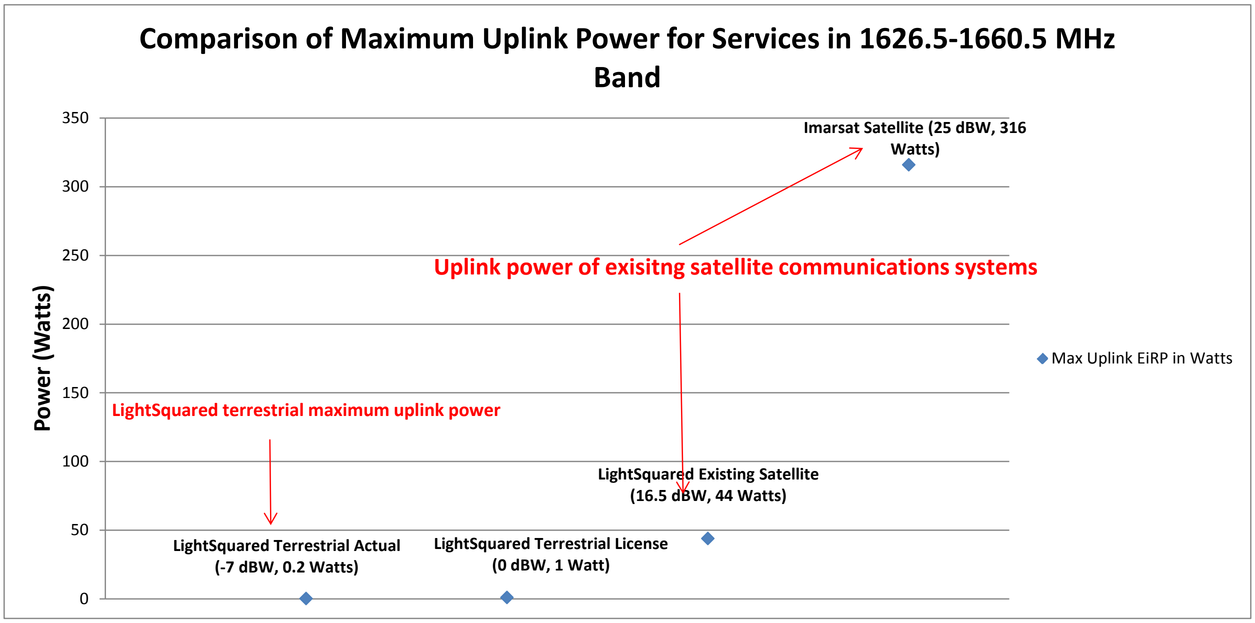
LightSquared currently uses the 1626.5-1660.5 MHz band for uplink transmissions from its customers' mobile earth terminals ("METs") to its geosynchronous satellites. These uplink channels have been in use by LightSquared since it first began satellite operations in the mid-1990s. This band is also currently used by Inmarsat for its customers' METs and other devices whose uplinks communicate with its L-Band satellite constellation. This same spectrum band will be used for uplinks by LightSquared customers' terrestrial devices, but at far lower maximum power (over 300x less power) than today's satellite METs, and under stricter out of band emissions ("OOBE") limits than those that apply to today's satellite METs. Significantly, there are no known compatibility problems with the operation of today's satellite METs in the immediate vicinity of GPS devices, even at those higher permitted power levels.

Element	Licensed Maximum Power
LightSquared MSS Uplink – MET to Satellite	16.5 dBW EiRP[1]
Inmarsat MSS Uplink – User Device to Satellite	25 dBW EiRP[2]
LightSquared Terrestrial Uplink – User Device to Cell Site/Satellite	0 dBW EiRP[3]

Note: The actual maximum transmit power of the LightSquared terrestrial devices will be -7 dBW EiRP; as such, the company would have no objection to its terrestrial authorization being modified to reflect this limit.

[1] File No. SES-MOD-20100510-00582 (Call Sign E980179).
[2] File No. SES-RWL-20110914-01080 (Call Sign E000180).
[3] *In the Matter of SkyTerra Subsidiary LLC Application for Modification Authority for an Ancillary Terrestrial Component*, Order and Authorization, 25 FCC Rcd 3043 (2010).

Figure 1: Relative Power Levels of Existing and Future Uplinks



1.1. Use of ATC Handsets On-Ground

The following section analyzes the potential interaction between LightSquared terrestrial devices and GPS receivers operating at or near ground level.

1.1.1. Impact on General Location/Navigation GPS Devices

1.1.1.1. Use Case Analyses

In order to assess the potential interaction between LightSquared's uplink operation and general location/navigation ("GLN") GPS devices, use-cases were constructed to represent the likely device operational scenarios in order to gauge the potential for devices to be impacted by LightSquared transmissions. The analysis was constructed in order to "stress" GPS devices by assuming a very high LightSquared device power level. In order to accomplish this, LightSquared used two independent variables which affect the power of LightSquared transmissions that are present at the GLN device antenna; each variable was set at the 90th percentile value of its cumulative distribution function (CDF). Because these are independent random variables, their sum is at a point on its CDF curve that is greater than 90% (actual values were 94% and 96% for GLN and high precision devices respectively, based on actual probability density functions).

In other words, 94% or 96% of the time (depending on the GPS device type), the actual LightSquared device uplink power level encountered by the GPS device will be lower than what is assumed in this analysis; thus providing in this analysis a worst-case view from the perspective of the GPS device.

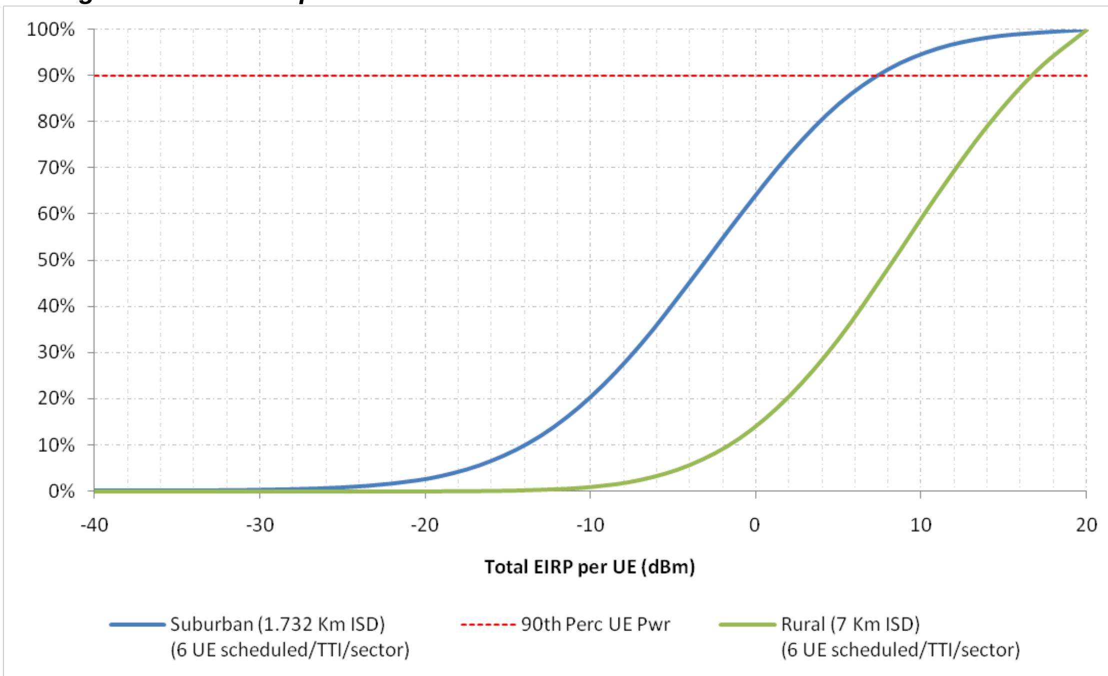
1.1.1.1.1. Uplink Power Control – 90th Percentile of CSMAC Power Levels

LightSquared terrestrial devices will be deployed in a 4G LTE network. Like all commercial wireless voice and data networks, its devices will utilize uplink power control. The purpose of this is to both minimize intra-system interference and maximize device battery life by requiring the device to operate at the lowest power necessary for its signal to reach the nearest cell site. As a result, wireless devices only operate at full power in extreme situations where there is significant path loss between the device and the cell site (such as at the edge of the network coverage or deep inside of a building).

This attribute was recognized by the Commerce Spectrum Management Advisory Committee ("CSMAC") working group that was formed in order to study the potential for interference from LTE wireless devices operating in 1695-1710 MHz to incumbent users[4]. The CSMAC working group in its simulations generated a CDF curve of device uplink EIRP levels for both suburban/urban and rural morphologies. LightSquared used the 90th percentile value for uplink power control for this analysis in order to be conservative (see Figure 2). Furthermore, in assessing the device PA output, a 3 dB positive adjustment was made to this curve to compensate for a -3 dBi average antenna gain assumed by CSMAC. The device (UE) antenna gain was accounted for separately in the antenna coupling analysis performed by LightSquared. Thus, in the use case analyses, LightSquared devices were modeled as having a PA that could operate at a maximum EIRP of 23 dBm, with a 90th percentile value of 11 dBm in urban and suburban environments and 19.6 dBm in rural environments.

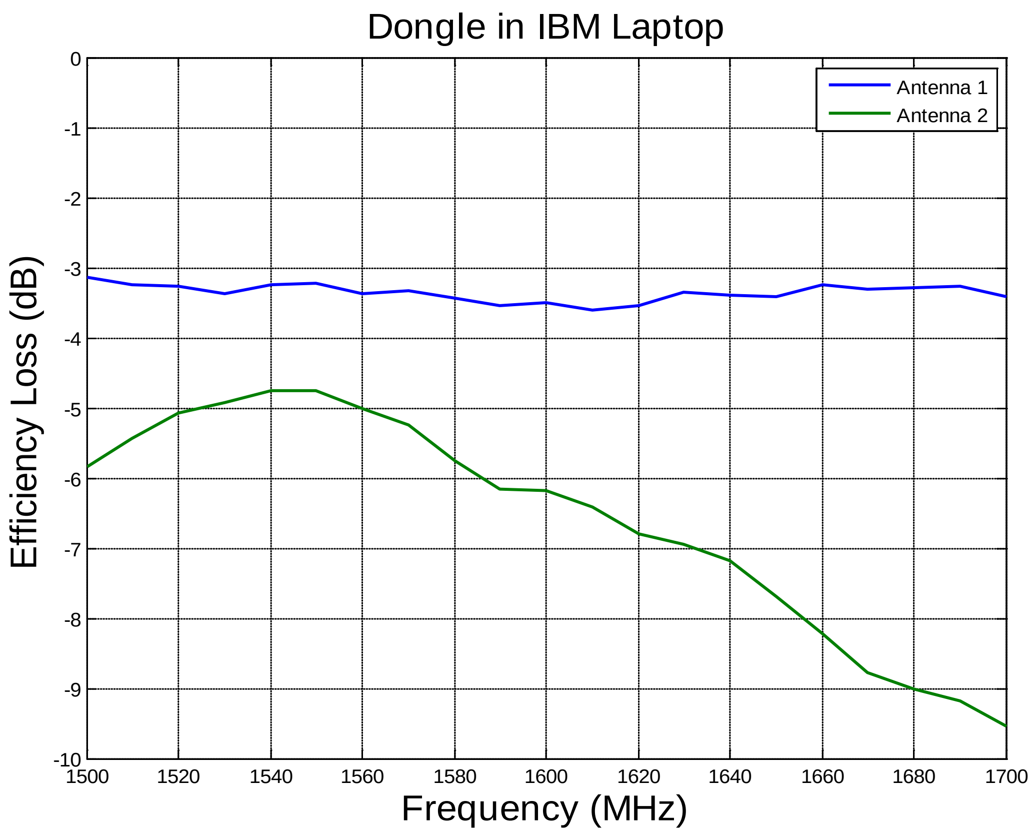
[4] Commerce Spectrum Management Advisory Committee, Final Report, Working Group 1 – 1695-1710 MHz Meteorological-Satellite (January 22, 2013), *available at* http://www.ntia.doc.gov/files/ntia/publications/wg-1_report_v2.pdf.

Figure 2: CSMAC Uplink EIRP CDF Curve – 90th Percentile



Understanding the actual power being emitted from a LightSquared device is critical in performing interference analysis. This analysis takes into account the essential variables to provide a view of the highest practical LightSquared uplink power levels, without overstating this level and thus improperly skewing the results of the analysis.

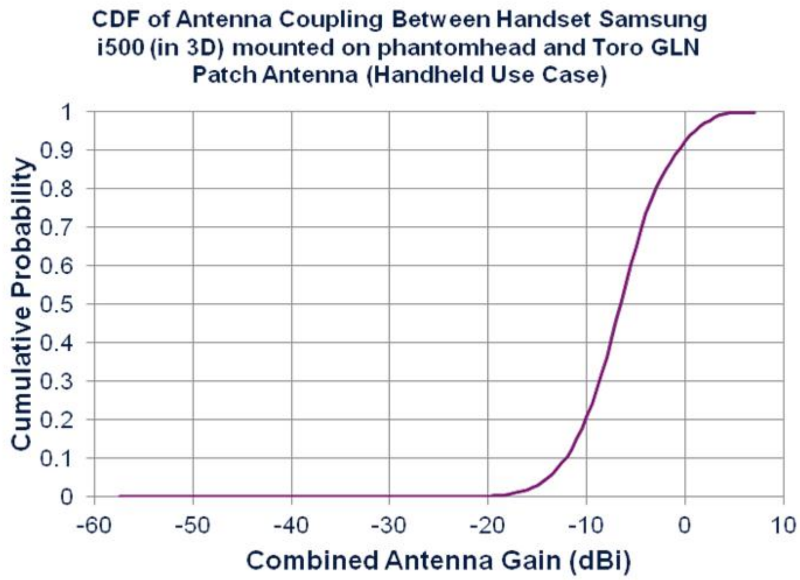
Figure 3: Measured antenna efficiency of L-band USB dongles connected to laptop computers



1.1.1.1.2. Antenna Coupling Loss – 90th Percentile of Cumulative Distribution Function

Compact antennas typical of those found in LTE devices have highly irregular antenna patterns, with antenna peaks and nulls occurring in arbitrary directions. A GLN antenna pattern was chosen which is typical of the type used in automotive and handheld devices. Thus the amount of power received at a GPS device depends on the orientation of both its own antenna as well as that of the LightSquared device that is transmitting. A CDF was constructed that accounts for all possible transmit and receive power levels for devices with these typical antenna patterns. Similar to the method employed for uplink power control, the 90th percentile value for antenna coupling loss was chosen (see Figure 4).

Figure 4: Antenna Coupling CDF



As stated above, by utilizing the 90th percentile of two independent variables, the result is a received power level that is at the 94th percentile point of its CDF curve when both variables are considered. In order to calculate this value, CDFs are converted into probability density functions which are then convolved and converted back to CDF form. It should also be noted that LightSquared has evaluated only two variables which would serve to reduce the total received power from the theoretical maximum, but this is by no means exhaustive. Other elements such as device shielding (due to body, structure, foliage, etc.) and uplink duty cycle were not considered, but both would serve to further reduce the LightSquared power levels received by the GPS device.

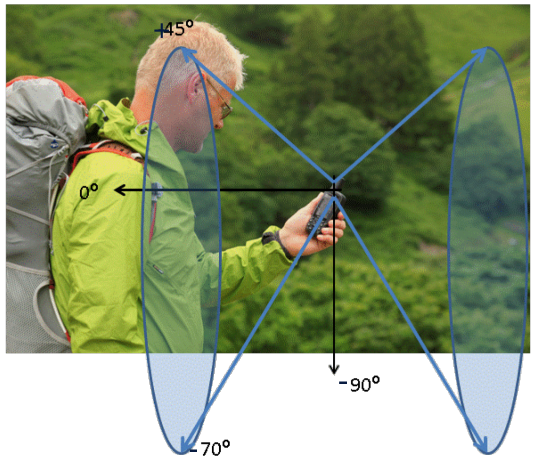
For the above analysis, the antenna pattern was a key input. Details of individual GPS antenna patterns are not available from GPS manufacturers, so a typical pattern as provided in the catalogs of the GPS antenna suppliers for GLN receivers was utilized. The antenna pattern for a typical high precision GPS receiver (for analysis discussed later in this document) was obtained from a publicly available Novatel catalog (Novatel GPS-703-GGG).

The power levels calculated through this process are key inputs into the use-case analysis which is summarized below and detailed in Appendix 1.

1.1.1.2. Handheld Use Case

The following two use cases represent handheld as well as in-car use of GLN GPS devices and utilize a LightSquared/GPS device separation distance of 1 meter.

Figure 5: Outdoor Handheld GLN GPS Receiver in Use



Most likely angle of arrival (AoA) of handheld general location/navigation (GLN) GPS receiver. AOAs are selective in elevation (as shown) but non-selective (equiprobable) in azimuth

To illustrate the compatibility of its terrestrial operations, LightSquared's cases use a 1 meter separation distance, which is more conservative than the assumptions underlying the previous agreements with the US GPS Industry Council and FCC orders that use a 3 – 4.5 meter[5] separation distance as the relevant point of reference. LightSquared is not aware of any FCC or other regulatory precedent for using a separation distance of less than one meter for any service.

The 94th percentile power levels were then compared to the point at which all devices that were selected and tested by manufacturers at the White Sands Missile Range ("WSMR") in November of 2011 (see Tables 1 and 2 below) experienced a 1 dB change in C/N_0. This use-case analysis does not take into account other relevant mitigating factors (such as transmit duty cycle). Only a very small number of GPS devices could potentially experience a 1 dB change in C/N_0 due to the presence of a nearby LightSquared user device, with the received power at a level that would be reached or exceeded with only 6 percent probability. Significantly, no correlation has been established between a 1 dB reduction in C/N_0 and a loss of GPS positioning accuracy. Moreover, none of the GPS devices would have experienced interference due to OOBE at these power levels.

As mentioned above, this analysis is a "worst case," not a typical use scenario. Specifically, LightSquared did not include any transmit power reduction due to transmitter duty cycle, which in an LTE environment rarely exceeds 50%. Stated another way, a transmitter utilizing a 50%

[5] *See* Letter to FCC from Mobile Satellite Ventures L.P. and the U.S. GPS Industry Council, IB Docket No. 01-185, at 4-5 (July 17, 2002); *see also Letter* to FCC from USGIC and SkyTerra Subsidiary LLC, IBFS File Nos. SAT- MOD-20090429-00046 at 1 (Aug. 13, 2009).

duty cycle transmits at only half the average power of a theoretical transmitter operating at 100% duty cycle.

An uplink user transmission may approach 100% duty cycle only if the following conditions both occur simultaneously:

- The cell site sector is lightly loaded, or unloaded, meaning that the user has virtually all of the capacity from that site dedicated to him or her
- The user is uploading a very large data file that requires dedication of this level of cell site resource

For purposes of comparison, LightSquared has calculated that a typical LTE user on a voice call would experience a duty cycle of 10%[6] to 20%[7] which would reduce the uplink EIRP by 10 to 7 dB, respectively. A 50% duty cycle, which is rarely exceeded, would reduce the EIRP by 3 dB. This 3 dB reduction in power would reduce the received power utilized in this analysis to -31.7 dBm.

The fact that such a small number of the GLN devices tested are likely even able to detect the presence of a nearby LightSquared user device operating on the LightSquared uplink channel closest to the GPS band demonstrates the resiliency of legacy GPS devices. Again, there is no correlation between being able to *detect* the presence of a LightSquared user device and a loss of GPS positioning accuracy.

Table 1: GLN Overload Analysis

GPS Rx: GLN
Standoff Distance: 1 meter

Parameter	**Value**	**Comments**
Device Tx Power (dBm)	11.0	Based on CSMAC simulations: 90% point of UE power CDF
Pathloss (dB)	36.7	Free Space
GPS Rx Power (dBm)	-25.7	Calculated
Number of simultaneously on Tx devices	1.0	ATC spec for device OOBE is based on 1 user with 4.8 m separation
Power gain/loss (dB) owing to no. of Tx devices	0.0	Calculated
GPS Rx Power (dBm)	-25.7	Calculated
GPS Antenna Gain Normalization Factor (dB)	-3.0	Based on measured/specified GPS antenna gains; includes normalization for peak gain of GPS antenna
Normalized power at GPS Rx input connector(dBm)	-28.7	Calculated
% of devices experiencing 1 dB change in C/N_0 for UL-1	10.0 %	Look up of WSMR table
% of devices experiencing 1 dB change in C/N_0 for UL-2	4.65 %	Look up of WSMR table

[6] Using AMR 5.9 kbps vocoder with 2-TTI bundling.
[7] Using AMR 12.2 kbps vocoder with 4-TTI bundling.

Table 2: Comparison to WSMR Overload Test Results

	GLN TE3 and TE12 (10L UL)			GLN TE4 and TE13 (10H UL)		
Handset Power at receiver	Receivers Degraded	Percentage Degraded	Cumulative Percentage	Receivers Degraded	Percentage Degraded	Cumulative Percentage
-55 to -45	0	0%	0%	0	0%	0.00%
-45 to -40	0	0%	0%	0	0%	0.00%
-40 to -35	0	0%	0%	0	0%	0.00%
-35 to -30	4	4%	4%	1	1%	1.16%
-30 to -25	5	5%	10%	3	3%	4.65%
-25 to -20	4	4%	14%	2	2%	6.98%
-20 to -15	5	5%	20%	5	6%	12.79%
-15 to -10	24	26%	46%	13	15%	27.91%
> -10	49	54%	100%	62	72%	100.00%

The results discussed in this paper are generally for the uplink channel that is closest to the GNSS band. As noted in Table 1 above, test results for the other uplink channel are even more favorable given the larger spectrum separation distance between it and the GNSS band.

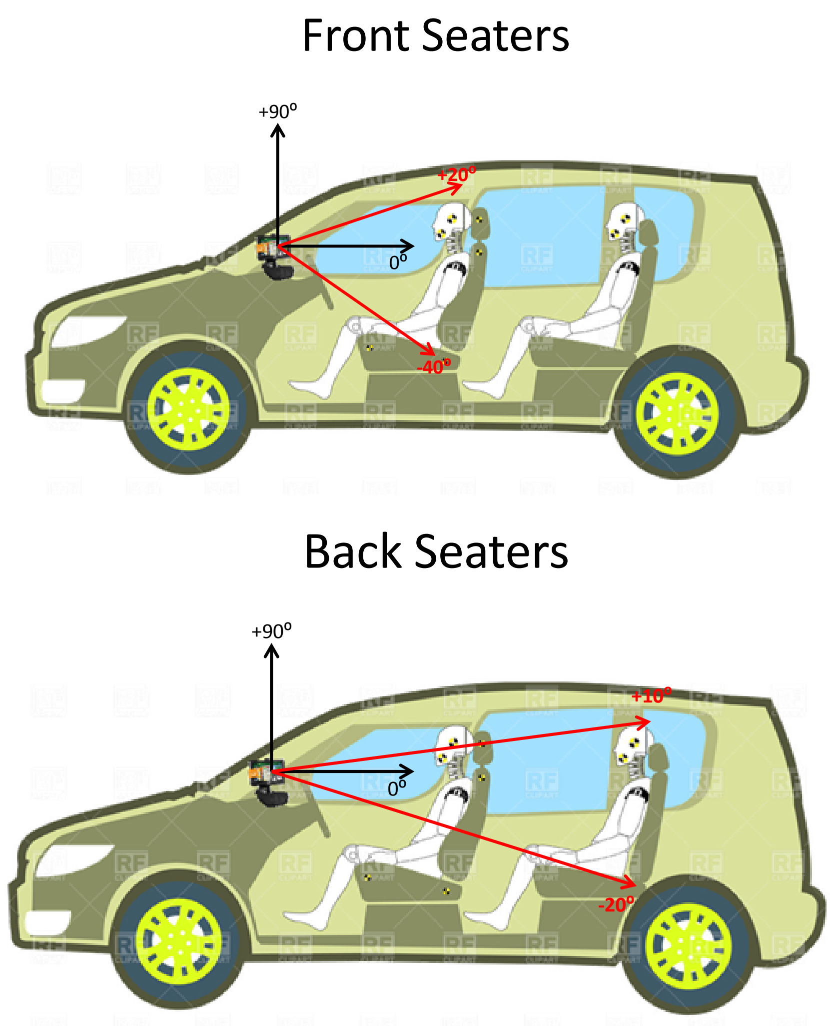
It should be noted that at the time of the WSMR testing, GPS manufacturers declined to provide any sales or market-share information regarding the devices that were tested. However, reviewing the identities of the of devices that were least resilient, none appear to be mass-market devices, so it is very possible that the actual current market share of this group of devices is significantly less than the percentage that experienced a 1 dB change in C/N_0. Due to the confidentiality agreement that LightSquared was required to execute in order to have access to these test results, the company does not believe it is able to discuss specific test results relative to individual devices.

The details of this analysis may be found in Appendix 1.

1.1.1.3. Automotive Use Case

Figure 6 illustrates this use case, which comprises four users inside a car, simultaneously using four LightSquared devices, and a GPS receiver mounted on the dashboard.

Figure 6 Automotive Use Case Involving Four Simultaneous Users



The analysis shows that, based purely on the angles of arrival of the signals relative to the GPS receiver, illustrated in Figure 6 above, and the assumed antenna patterns of the devices and the GPS receiver, the 90% point of CDF of the 4 antenna couplings has a value of approximately –2dBi[8]. This is 2.5 dB lower than the 0.5 dBi coupling factor calculated for a single proximate user in the previous outdoor GLN use case. Thus, the automotive case results in a lower LightSquared received power by the GLN device than would exist for the outdoor use case.

[8] This is an equivalent coupling value, where the 4 transmitters are replaced by a single transmitter with the stated coupling value. The 4 transmitters are assumed to be transmitting simultaneously with the power at the receiver being 100% cumulative.

It is noteworthy that the above analysis assumes that the power from the 4 transmitters will be completely additive, which will not be the case due to the fact that the LTE resource block assignments of the 4 transmitters will not be 100% synchronous. Additional margin will exist due to this effect.

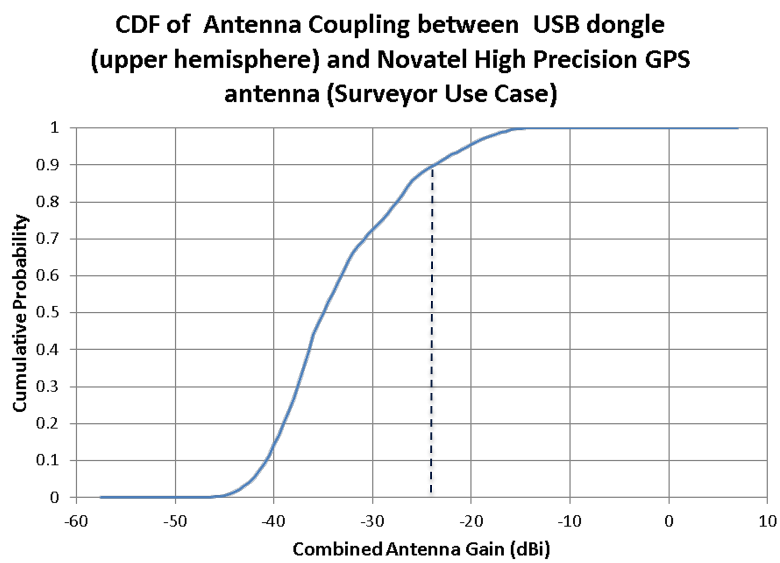
More details about this case may be found in Appendix 1.

1.1.2. Impact on High Precision GPS Devices

High precision GPS devices are generally those that include a system where any kind of information is obtained by a subject GPS receiver from another (reference) receiver and that information is used to improve the accuracy of solutions provided by the subject receiver.

In a manner similar to that employed for the GLN devices, high precision devices were analyzed using the 90^{th} percentile values for both uplink power control (using the CSMAC CDF curve for the rural case) and antenna coupling loss (see figure 7) in order to produce a value that represents the 96^{th} percentile of possible power levels received by a GPS device antenna.

Figure 7: High Precision Antenna Coupling



90% of time the coupling factor relative to isotropic tx and rx antennas is less than -24 dB.

The analysis considered both survey and agricultural use cases which are the most widely used applications for high precision GPS.

The analysis concluded that only one of the devices tested by commercial manufacturers at WSMR in November of 2011 which were believed to have been high precision devices would have experienced a 1 dB change in C/N_0 due to the effect of LightSquared uplink transmissions in an adjacent band from LightSquared devices operating at distances between 1 and 10 meters from the GPS device (see Tables 3 and 4). None of the devices would have been adversely affected by OOBE.

Table 3: High Precision Overload Analysis

Standoff distance	Variable UE position, anywhere inside a circular domain: 1 m below GPS antenna with radius of 10 m from base of GPS antenna.		UE at fixed distance of 1 m from GPS antenna and below it. Variable AoA relative to Rx and AoD relative to Tx.	
Device Tx. Power (dBm)	19.6	UE power assumed based on CSMAC simulations: 90% point of UE power CDF for rural case.	19.6	UE power assumed based on CSMAC simulations: 90% point of UE power CDF for rural case.
Integrated coupling loss (Tx/Rx antenna gains + distance loss) (dBi)	58.3	90% point on CDF of {Sum of Tx/Rx antenna gains (dBi) + Free Space loss (dB)} with UE 1 m below GPS antenna and 0 - 10 from base of GPS antenna	61	90% point on CDF of {Sum of Tx/Rx antenna gains} (dBi) of GPS antenna with UE at a fixed distance of 1 m from the GPS antenna
Rx. Power (dBm)	-38.7	Calculated	-41.4	Calculated
No. of simultaneously on devices	1	ATC spec for device OOBE is based on 4.8 m separation.	1	ATC spec for device OOBE is based on 4.8 m separation.
Power gain/loss (dB) owing to no. of devices	0.00	Calculated	0.00	Calculated
GPS Antenna Gain Normalization Factor (dB)	3.00	Based on Measured/Specified antenna gain; includes normalization of peak gain of GPS antenna	3.00	Based on Measured/Specified antenna gain; includes normalization of peak gain of GPS antenna
Normalized power at GPS Rx input connector (dBm)	-41.7	Calculated	-44.4	Calculated

Note that the Integrated Coupling Loss value in the second column of Table 3 is a variable that is correlated with the angle-of-arrival (AoA) of the incident ray at the GPS antenna; therefore, the separation distance is integrated into a joint, antenna-coupling-loss-cum-distance-loss term while evaluating the CDF.

It should also be noted that the GPS Antenna Gain Normalization Factor in the sixth row of Table 3 was inserted in order to normalize for the fact that the GPS device antennas at the WSMR facility were oriented so that their direction of maximum gain faced the LightSquared downlink transmit antenna. It was calculated that, for GLN devices, the location of the LightSquared uplink transmit antenna relative to this direction required a 3.5 dB correction in order to normalize for the 0 dBi GPS antenna assumed in the test results. For HP devices, the correction factor was 3.0 dB. These corrections were based on the GPS antennas' gains at 45^0 from boresight, which was the approximate direction of arrival of the uplink signal in the NPEF tests. For the GLN case, the -3.5 dB normalization factor, when combined with a +0.5 dB antenna coupling factor, resulted in a net antenna-coupling/normalization factor of -3.0 dB. Diagrams showing GPS antenna gains at 45° are included in Appendices 1 and 2.

Table 4: High Precision OOBE Analysis

Currently specified OOBE PSD in ATC Order	**-95 dBW/MHz**	
	-125 dBm/Hz	
Permitted OOBE PSD at GPS Rx based on USGIC/MSV Letter to FCC		
Maximum allowed Interference Spectral Density (I_0)	**-174.5 dBm/Hz**	GPS Receiver Interference Susceptibility based on USGIC/MSV letter to FCC [1]
Integrated coupling loss for unconstrained user, 1 m below and 10 m around HP GPS antenna (90% point of CDF)	**58.3 dB**	Calculated
Polarization Mismatch	**1.5 dB**	Polarization mismatch between linearly polarized dongle and circularly polarized GPS antenna.
Power control for 90% point of CDF from CSMAC rural case	**3.4 dB**	Here, OOBE PSD is assumed to vary linearly (dB-for-dB) with UE output power. However measured data shows 3.5 dB OOBE variation for 1 dB power variation, making this is an overly conservative assumption. Significant margin exists regardless.
Total Margin	**13.7 dB**	Calculated

As was the case with GLN devices, additional margin would exist due to environmental factors such as body shielding, vehicle shielding and uplink duty cycle, though none was evaluated for the purpose of this analysis.

The details of the high precision analysis may be found in Appendix 2.

1.2. Aviation

Based on previous discussions with the FAA, LightSquared constructed four use cases and compared these results to applicable limits established in RTCA/FAA standards. These have also been compared to the existing Standards and Recommended Practices ("SARPs") that have been established by International Civil Aeronautics Organization ("ICAO") for GLONASS aviation receivers as well. LightSquared is not aware of any aviation standards that have been established for other GNSS services.

LightSquared notes that in the aviation analysis, it did not assume any uplink power control for the baseline of use cases where an aircraft is in flight, thus providing an inherent additional margin for safety-of-life applications. Uplink power control is assumed for the two use cases below where an aircraft is parked at the gate.

As detailed below, these cases cover (i) passengers using LightSquared devices inside an aircraft, (ii) the impact of hundreds of LightSquared devices operating at ground level on aircraft in flight overhead, (iii) numerous LightSquared devices operating simultaneously near an aircraft parked at the gate, and (iv) the operation of a LightSquared device at the top of the stairs leading from the tarmac to an aircraft. In all cases, compliance with the parameters established in existing FAA/RTCA/ICAO standards for aviation GPS is assured. Thus, LightSquared's uplink emissions would have no impact on existing or emerging GNSS systems, and are no more of an issue to aviation than the over 100 million devices currently operating in the nearby PCS band today.

1.2.1. Users Inside Aircraft

LightSquared evaluated the potential for its devices utilized by passengers to exceed applicable parameters previously established by the FAA and RTCA in aviation GPS standards. This analysis differed from that employed in the other use cases as it assumed the maximum transmit power from a LightSquared device and did not make any reduction for uplink power control. This is consistent with FAA procedure which typically considers only worst-case values in calculations involving safety-of-life applications, such as an aircraft in-flight.

Instead of using a statistical distribution for the antenna coupling loss, LightSquared utilized a fixed Tx/Rx antenna coupling loss of 3 dB and pathloss values from a previous analysis conducted by NASA[9] which measured actual pathloss between users and the GPS antenna mounted on the exterior of the aircraft. For the purpose of this analysis, LightSquared assumed that all 63 passengers in window seats (with the least amount of pathloss to the aviation GPS antenna) were operating LightSquared devices at full power.

Table 5: Excerpt of In-Cabin Overload and OOBE Analysis

Window Location (Right side)	Path Loss to GPS antenna @ 1575 MHz (dB)	Adjacent band power received (Tx Power = 23 dBm)	Unit	Received OOBE	Unit	Adjacent band power received (mW)	Received OOBE (mW/Hz)
1	68.5	-45.5	dBm	-223.5	dBW/Hz	2.81838E-05	4.46684E-23
2	69.9	-46.9	dBm	-224.9	dBW/Hz	2.04174E-05	3.23594E-23
- - -							
31	74.7	-51.7	dBm	-229.7	dBW/Hz	6.76083E-06	1.07152E-23
32	82.9	-59.9	dBm	-237.9	dBW/Hz	1.02329E-06	1.62181E-24
	Aggregate Power	-29.7	dBm	-207.7	dBW/Hz	0.001067926	1.69255E-21
	Tx/Rx Coupling loss	3	dB	3	dB	Conservative Estimate	
	MOPS Limit	-16.7	dBm	-206.5	dBW/Hz	RTCA - 229D	
	Margin (with 64 Tx)	16.0	dB (O/L)	4.2	dB (OOBE)		

Note: The received OOBE level of -223.5 dBW/Hz is computed by subtracting 68.5 dB path loss from the transmitted OOBE (PSD) -95 dBW/MHz in the GNSS band, and converting PSD for 1 MHz to 1 Hz BW. (-95 dBW/MHz – 68.5 dB – 60 dB = -223.5 dBW/Hz).

For OOBE, the analysis shows that the aggregate level will not exceed -207.7 dBW/Hz. Accounting for the coupling loss between user devices and the GPS antenna at a very conservative level of 3 dB, there is excess margin of 4.2 dB compared to the RTCA limit of -206.5 dBW/Hz (as shown in Table 5, above).

For receiver overload, the analysis calculates the aggregate power level of LightSquared devices will not exceed -29.7 dBm. Accounting for the same 3 dB coupling loss provides an excess margin of 16.0 dB against the RTCA limit of -16.7 dBm (as shown in Table 5, above). Using similar analysis compared to the

[9] RTCA, Inc., *Assessment of Radio Frequency Interference Relevant to the GNSS L1 Frequency* Band, Document No. DO-235B, Appendix E, at Section E.6.3 (Mar. 13, 2008).

ICAO SARPs for GLONASS receivers, produces a margin of 10 dB against the GLONASS overload threshold of -22.7 dBm.

This analysis concluded that even with these extreme values, the emissions received by the GPS antenna would not exceed the limits established in existing FAA/RTCA/ICAO standards.

The details of this analysis are provided in Appendix 3.

1.2.2. Aircraft In-Flight/ Users On-Ground

This use case assessed the potential impact of hundreds of LightSquared devices operating at ground level on an aircraft in flight overhead. This use case was previously studied by the RTCA in DO-327 which at the time concluded that the effect of OOBE in the extreme case of 1,000 LightSquared users per cell was 0.4 dB assuming a LightSquared OOBE limit of -95 dBW/MHz at 1605 MHz. While this amount was considered to be de minimis, even this small value is likely overstated as it is not possible for this many devices inside of a single cell site to be transmitting simultaneously. For example, CSMAC assumed a maximum number of only six simultaneous users per sector per 10 MHz channel.

Furthermore, the analysis assumed that all devices would be transmitting at their maximum rated power with no uplink power control, which is just not physically possible. Invoking the CSMAC model, more than 15 dB of power backoff would exist for the average[10] power value relative to the maximum value. This would contribute even more positive margin to the RTCA analysis, providing added assurance that the aggregate emissions from LightSquared devices operating at ground level would not impact the aviation use of GPS.

Nevertheless, this assertion is made only to demonstrate that additional margin is available beyond the already accepted levels if these added factors were to be considered.

The details of this analysis are provided in Appendix 4.

1.2.3. Aircraft At-Gate/Users Nearby

This use case assessed the potential impact of numerous LightSquared devices operating simultaneously near an aircraft parked at the gate. While this use case does not have direct safety-of-life implications, it was requested by the FAA since it could impact the pre-flight testing of GPS equipment prior to aircraft departure.

This case assumed a total of 30 LightSquared users transmitting simultaneously inside the terminal gate area and jetway leading to a parked aircraft. 30 simultaneous users is actually five times the number that CSMAC estimated could be supported by a single LTE cell site sector, but is used for this purpose in order to

[10] Where a use case involves a large number (N) of transmitting devices, it is appropriate to use the *average value* of each device as the probability of the net power exceeding (N times average value) rapidly becomes very small as N becomes large.

be consistent with the conservative analytical approach guiding this process. The analysis assumes a maximum LightSquared device EIRP of 20 dBm with a 9.5 dB power reduction due to uplink power control (which is the 95th percentile value of the CSMAC CDF curve for suburban environments).[11] Additionally a GPS receive antenna coupling loss of 3 dB is booked for elevation angles lower than 45 degrees relative to the horizon. This is because aircraft GPS antennas are oriented so that their point of maximum gain looks upward, not toward the horizon. As the elevation angle decreases to be more horizontal with respect to the aircraft's GPS antenna (as would occur when the LightSquared user is at or below the level of top of the plane), greater coupling loss occurs.

[11] Suburban morphology was assumed for airport locations by the RTCA in its analyses of LightSquared scenarios. RCTA, Inc., *Assessment of the LightSquared Ancillary Terrestrial Component Radio Frequency Interference Impact on GNSS L1 Band Airborne Receiver Operations*, Document No. DO-327 (June 3, 2011).

Table 6: Aviation "Nearby Emitters" Use Case Calculations

Parameter	Value	Unit	Note
Max UE Tx EIRP	20	dBm	Maximum as per CSMAC simulation (-3 dBi average UE antenna gain)
UE OOBE (select)	-95	dBW/MHz	ATC Order minimum requirement after 5 years
Uplink power control factor	9.5	dB	95% point of CSMAC CDF
Jetway User # 1 Path loss	48.8	dB	(1) Power addition for multiple users is extremely unlikely owing to strong TDMA component in LTE uplink (2) Assumes dB-for-dB reduction of OOBE PSD with fundamental Tx power
Jetway User # 1 Rx ant Coupling loss	6.17	dB	
OOBE received by GPS antenna	-222.4	dBW/Hz	
Adjacent band power received	-44.4	dBm	
Jetway User # 2 Path loss	51.5	dB	
Jetway User # 2 Rx ant Coupling loss	5.83	dB	
OOBE received by GPS antenna	-224.8	dBW/Hz	
Adjacent band power received	-46.8	dBm	
Jetway User # 3 Path loss	53.6	dB	
Jetway User # 3 Rx ant Coupling loss	5.67	dB	
OOBE received by GPS antenna	-226.8	dBW/Hz	
Adjacent band power received	-48.8	dBm	
Jetway User # 4 Path loss	55.3	dB	
Jetway User # 4 Rx ant Coupling loss	5.5	dB	
OOBE received by GPS antenna	-228.3	dBW/Hz	
Adjacent band power received	-50.3	dBm	
Jetway User # 5 Path loss	56.7	dB	
Jetway User # 5 Rx ant Coupling loss	5.5	dB	
OOBE received by GPS antenna	-229.7	dBW/Hz	
Adjacent band power received	-51.7	dBm	
OOBE received by GPS antenna from all Jet way UEs (5)	-218.6	dBW/Hz	
Adjacent band power received from all Jet way UEs (5)	-40.6	dBm	
Number of UE transmitting simultaneously in terminal, all spaced at 10 meters from GPS antenna	10	#	Power addition for multiple users is extremely unlikely owing to strong TDMA component in LTE uplink
Mean Path loss to GPS antenna	56.7	dB	Free Space propagation
Rx antenna Coupling loss	3.0	dB	
OOBE received by GPS antenna from all Terminal UEs (5)	-217.2	dBW/Hz	Assumes dB-for-dB reduction of OOBE PSD with fundamental tx power
Adjacent band power received from all Terminal UEs (5)	-39.2	dBm	
Number of UE transmitting simultaneously in terminal, evenly spaced 10 - 25 meters from GPS antenna	15	#	Power addition for multiple users is extremely unlikely owing to strong TDMA component in LTE uplink
Mean Path loss to GPS antenna	62.0	dB	Free Space propagation
Rx antenna Coupling loss	3.0	dB	
OOBE received by GPS antenna from all Terminal UEs (15)	-220.7	dBW/Hz	Assumes dB-for-dB reduction of OOBE PSD with fundamental tx power
Adjacent band power received from all Terminal UEs (15)	-42.7	dBm	
Total OOBE received by GPS antenna	-213.8	dBW/Hz	
Total Adjacent band power received	-35.8	dBm	
MOPS OOBE limit	-206.5	dBW/Hz	RTCA DO-229D
OOBE Margin	7.3	dB	
Overload limit	-16.7	dBm	RTCA DO-229D
Overload margin	19.1	dB	

Note: above table contains a 3 dB reduction in "OOBE received by GPS antenna" value to account for transmit coupling loss.

As a result of these calculations (shown in Table 6, above), it is shown that the aircraft GPS system will not exceed the limits for either OOBE or overload established by RTCA DO-229D. Specifically, the total LightSquared user OOBE would not exceed -213.8 dBW/Hz at the aircraft GPS antenna, which results in 7.3 dB of positive margin relative to the RTCA limit of -206.5 dBW/Hz. For the overload case, the total LightSquared adjacent-band received power would not exceed -35.8 dBm, which provides 19.1 dB of positive margin relative to the RTCA overload limit of -16.7 dBm. This also provides 13.1 dB of positive margin relative to the ICAO overload limit of -22.7 dBm for GLONASS.

It should also be noted that the LightSquared OOBE limits of -95 dBW/MHz are over 158,000 times more stringent than the OOBE limits established for wireless devices operating in the 1.9 GHz PCS band. Even though PCS devices operate at a considerable distance in the spectrum band away from GNSS, the much higher PCS emissions very likely still exceed those of LightSquared entering into the upper end of the GNSS band.

Details of this analysis are provided in Appendix 5.

1.2.4. Aircraft At-Gate/User On Stairs

This scenario assumes a single user at the top of the stairs leading from the tarmac to a regional jet. This analysis was selected due to the user's proximity to the GPS antenna (assumed to be approximately 3 meters) and the potential that the user has clear line-of-sight to the GPS antenna. Only a single user is assumed for this calculation as it is not possible for more than one user to occupy the space at the top of the aircraft stairs.

This use case assumes a maximum uplink EIRP of 20 dBm, with a 9.5 dB backoff due to uplink power control (CSMAC CDF plot for the suburban case). An additional 10 dB of loss is booked using the representative aviation GPS antenna pattern provided in RTCA DO-235B, which is the value for elevation angles lower than -30 degrees relative to the horizon.

Table 7: Aviation "Single User/Commuter Jet" Use Case Calculation

Parameter	Value	Unit	Note
Max UE Tx EIRP	20	dBm	Maximum as per CSMAC simulation (-3 dBi average UE antenna gain)
UE Maximum OOBE PSD (select)	-95	dBW/MHz	ATC Order minimum requirement after 5 years
Uplink power control factor	9.5	dB	95% point of CSMAC CDF
Rx Antenna Coupling loss	10	dB	-10 dBi gain of GPS antenna
Tx/Rx Distance	3	Meters	Minimum plausible distance for use case
Path loss to GPS antenna	46.2	dB	Free Space
OOBE received by GPS antenna	-223.7	dBW/Hz	Assumes dB-for-dB reduction of OOBE PSD with fundamental tx power
MOPS OOBE limit	-206.5	dBW/Hz	RTCA DO-229D
OOBE Margin	17.2	dB	
Adjacent band power received	-45.7	dBm	
Overload limit	-16.7	dBm	RTCA DO-229D
Overload margin	29.0	dB	

Note: above table contains a 3 dB reduction in "OOBE received by GPS antenna" value to account for transmit coupling loss.

The results of this analysis show that the OOBE and overload limits established in RTCA DO-229D are not exceeded due to the operation of the LightSquared device assumed in this use case (see Table 7, below). Specifically, the total LightSquared user OOBE would not exceed -223.7 dBW/Hz at the aircraft GPS antenna, which results in 17.2 dB of positive margin relative to the RTCA limit of -206.5 dBW/Hz. For the overload case, the total LightSquared adjacent-band received power would not exceed -45.7 dBm, which provides 29.0 dB of positive margin relative to the RTCA overload limit of -16.7 dBm. This also results in 23.0 dB of positive margin relative to the ICAO overload limit of -22.7 dBm for GLONASS.

As with the use case discussed above, the controlling factor in this scenario was OOBE and not receiver overload. As noted above, the OOBE from LightSquared devices would not cause any disruption to the aviation GPS equipment, which apparently are also unaffected by the significantly higher OOBE from existing PCS communications devices.

Details of this analysis are provided in Appendix 5.

1.3. Current and Emerging GNSS Systems

LightSquared and Inmarsat both utilize uplinks from METs and other devices to their existing satellites in the 1626.5-1660.5 MHz band as they have for over twenty years. These satellite uplinks are not affected by the current regulatory review process and operate at significantly higher power than the maximum power currently authorized for devices that would transmit to terrestrial base stations. The current devices that transmit to LightSquared and Inmarsat satellites are also governed by less stringent OOBE limits of -70 dBW/MHz, which emit 316 times more energy into the GNSS than would be allowed for devices transmitting terrestrially.

LightSquared has not seen any evidence that the lower power and more stringent emissions under which its terrestrial devices would operate would impact any of the current or emerging GNSS systems including Galileo, BeiDou, GLONASS or QZSS.

In the absence of empirical receiver data by which to evaluate these other GNSS bands, it is not possible to further analyze the potential vulnerability of other GNSS receivers for use cases other than aviation. For aviation receivers, all systems either have, or plan to have in the future, Minimum Operational Standards which define the vulnerability of the receivers to adjacent band CW emissions. Analyses for GLONASS are provided here based on ICAO SARPs. For Galileo, formal MOPS comparable to RTCA DO-229D have not been published.

Additionally, LightSquared's long-term emissions limits of -95 dBW/MHz are similar to those recently adopted by the FCC that apply to the terrestrial operations of Dish Network and Globalstar; limits that were agreed to by the US GPS industry in a letter to the FCC on September 27, 2012. Finally, as discussed in the aviation section above, LightSquared's emissions in the GNSS band are over 158,000 times more stringent than emissions from devices operating in the PCS band of -43 dBW/Hz. Thus, not only would LightSquared's uplink emissions have no impact on existing or emerging GNSS systems, they even pose less of a risk than the over 100 million devices currently operating in the PCS band today.

2. Conclusions

LightSquared has engaged with government stakeholders wherever possible in order to build use cases to properly evaluate the potential for conflict between LightSquared's proposed modified operation and those of existing users in other bands. The work performed to date has been very valuable in validating LightSquared's proposed plan to allow it to proceed with the modified deployment of its terrestrial network. Specifically, these use-case analyses have demonstrated the following areas of compatibility relative to LightSquared's uplink transmissions in the L-band:

- Handheld GLN Equipment in close proximity to LightSquared devices
- In-car GLN equipment in close proximity to LightSquared devices
- High precision survey equipment in close proximity to LightSquared devices
- High precision agriculture equipment in close proximity to LightSquared devices
- Certified aviation devices with LightSquared devices operating in-cabin while airborne
- Certified aviation devices with LightSquared devices operating at ground level with aircraft overhead
- Certified aviation devices on aircraft parked at gate with LightSquared devices in terminal and on jetway
- Certified aviation device on commuter jet parked on tarmac with LightSquared user at top of aircraft stairs

Appendix 1
LightSquared Uplink Analysis Relative to General Location/Navigation Devices

Compatibility of LightSquared's L-band Uplinks with General Location/Navigation GPS Receivers

Analytical Approach to Uplinks

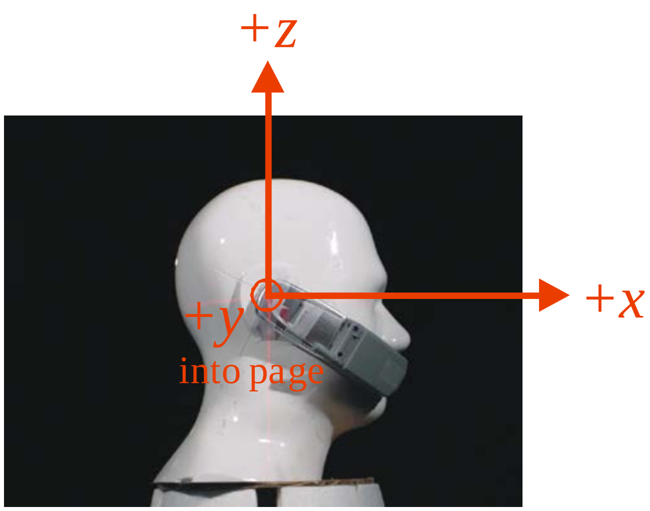
- Analysis focuses on use cases typical of general location/navigation (GLN) devices
- Quantifies expected power levels at the GPS receiver from a single LightSquared user operating user equipment (UE) at a variety of orientations relative to the GPS antenna at a distance of 1 meter
- Includes adjustments to received power due to
  - Transmit and receive antenna coupling loss
  - Reduction in UE transmit power caused by uplink power control
  - Sets conservative assumptions (90th percentile values) for each independent variable.
- Compares these power levels to 1 dB C/N_0 desense thresholds measured for GLN devices during WSMR device testing in 2011

Antenna Coupling Loss

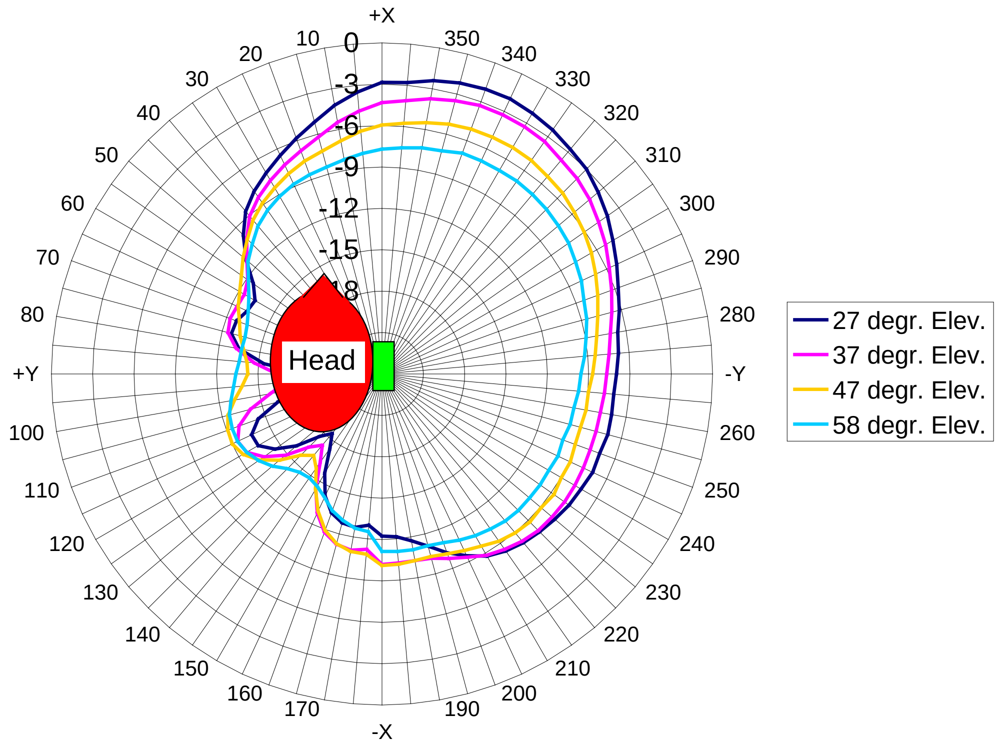
- It is generally acknowledged that real world antennas are not isotropic radiators (which have a gain of 0 dBi in all directions in 3D)
- Compact antennas found in both USB dongles and cellular handsets have highly irregular patterns with peaks and nulls in arbitrary directions
- Antenna Coupling Loss = - (Tx antenna gain + Rx antenna gain) dB
- A statistical analysis of antenna coupling loss was performed using angle-of-arrival (AoA) at the GPS receiver and angle-of-departure (AoD) values at the LightSquared transmitter, following certain assumed probability distributions based on use-case assumptions
- Cumulative distribution functions were generated for the coupling losses considering both USB dongles and handsets transmitting on LightSquared uplink channels

Typical PCS Band Handset Antenna Patterns

Data obtained from Satimo Labs in 2006 testing on CDMA handset



Handset orientation with respect to phantom head

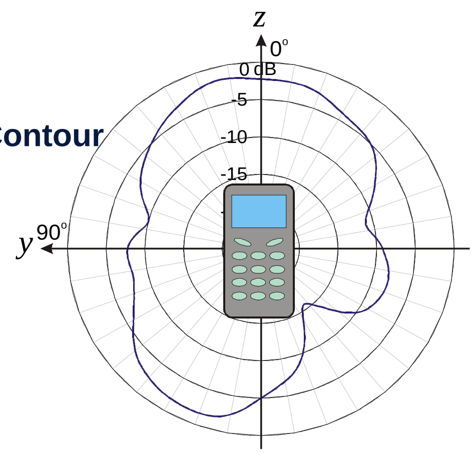


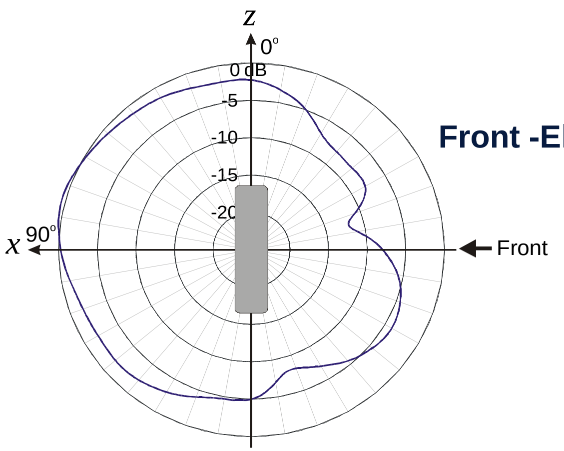
Transmit Gain (dBi) vs. Azimuth Angle w/ patch (internal) antenna for 4 discrete elevation angles (27^0 , 37^0, 47^0 , 58^0)

Example Handset Antenna Patterns

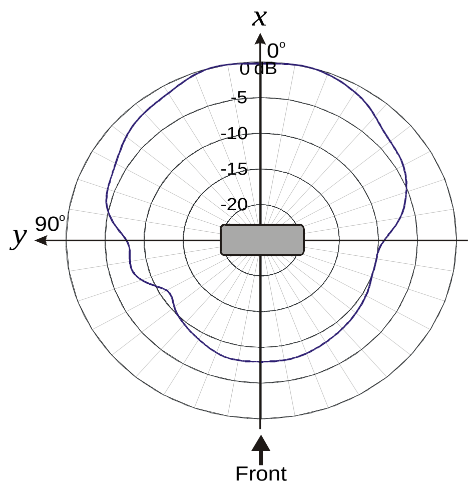
Provided to MSV by Ericsson (MSV’s FCC Filing, June 2003)

Side-Elevation Gain Contour





Front -Elevation Gain Contour



Azimuth Gain Contour

Based on this filing, MSV claimed and FCC allowed booking an <u>average handset antenna gain of – 4dBi</u>

Distribution of Measured Handset Antenna Gains

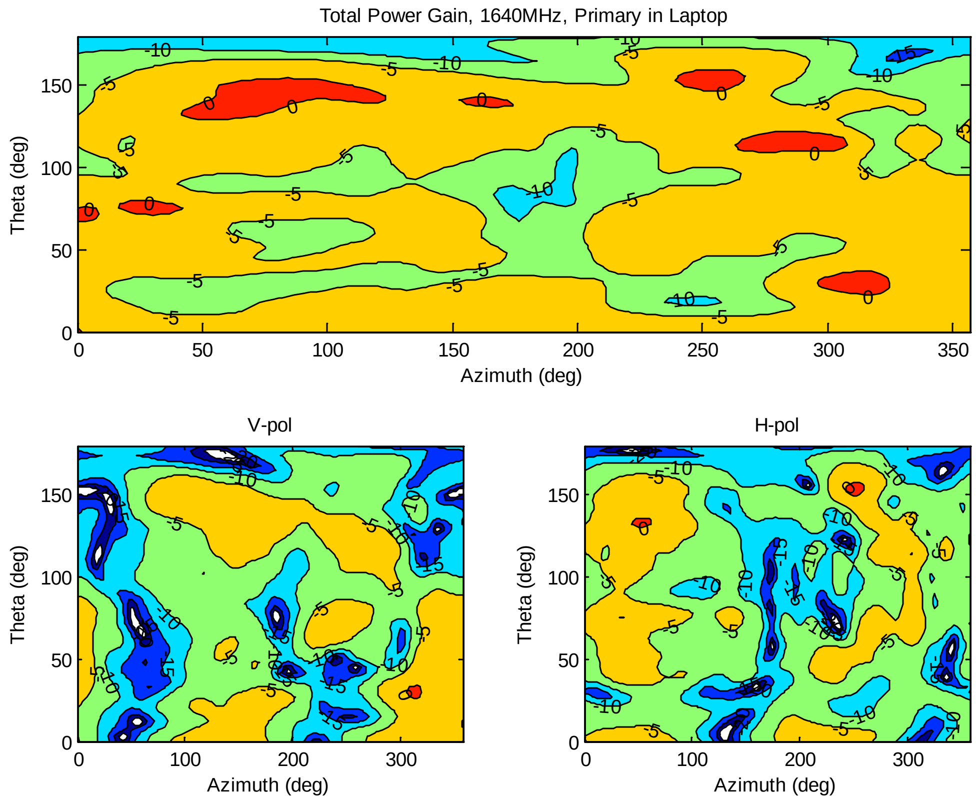
Used by TWG Cellular Subgroup

Handset-based GPS antenna coupling loss relative to an isotropic (0 dBi gain) antenna

	CD-A	CD-B	CD-C
max	-5.6	2.4	-10.5
min	-16.7	-19.7	-22.8
average	-9.9	-8.3	-14.2
median	-10.1	-9.7	-13.8
90%tile	-7.0	1.0	-12.0
75%tile	-8.0	-5.0	-13.0

The Cellular subgroup used an antenna coupling loss value of -5 dB.

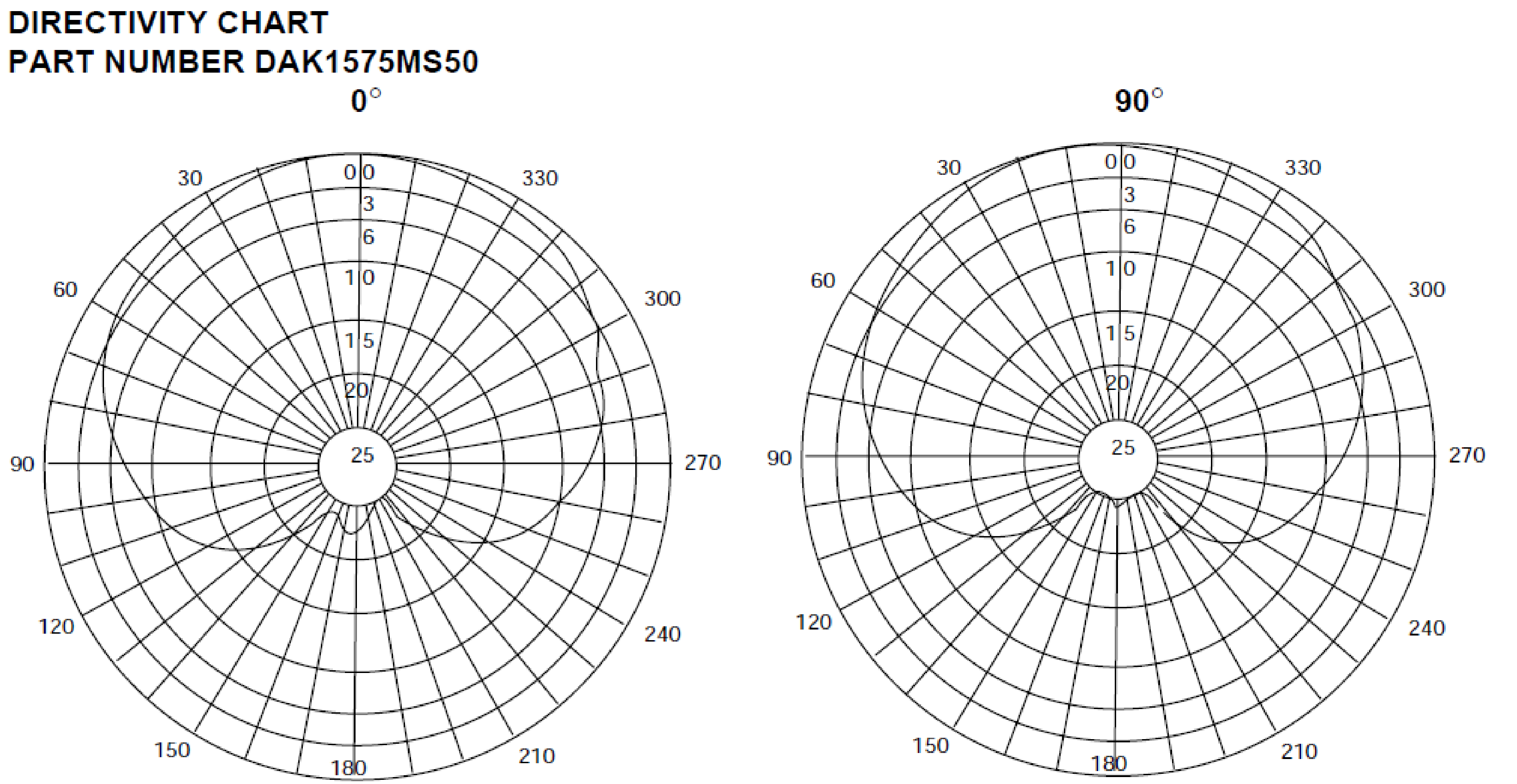
Typical Antenna Gain Contour Maps of L-band USB Dongle



In most directions, the antenna gain is less than -5 dBi

Example Handheld GLN GPS Rx Antenna Patterns

(elevation patterns for orthogonal azimuth cuts)

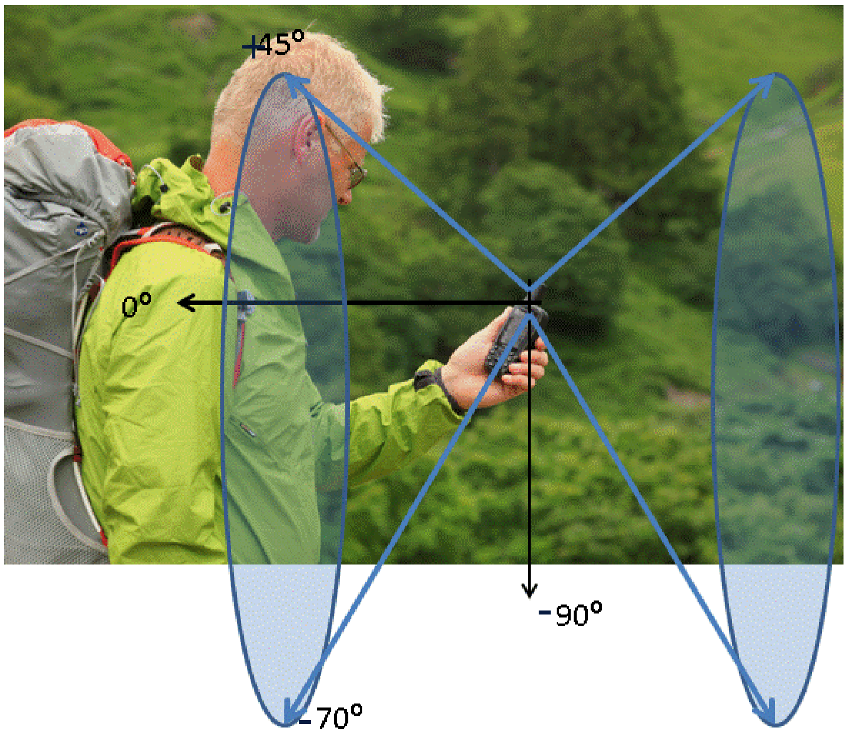


Peak Gain = 5 dBi from product spec sheet

Statistical Analyses of Antenna Coupling Loss

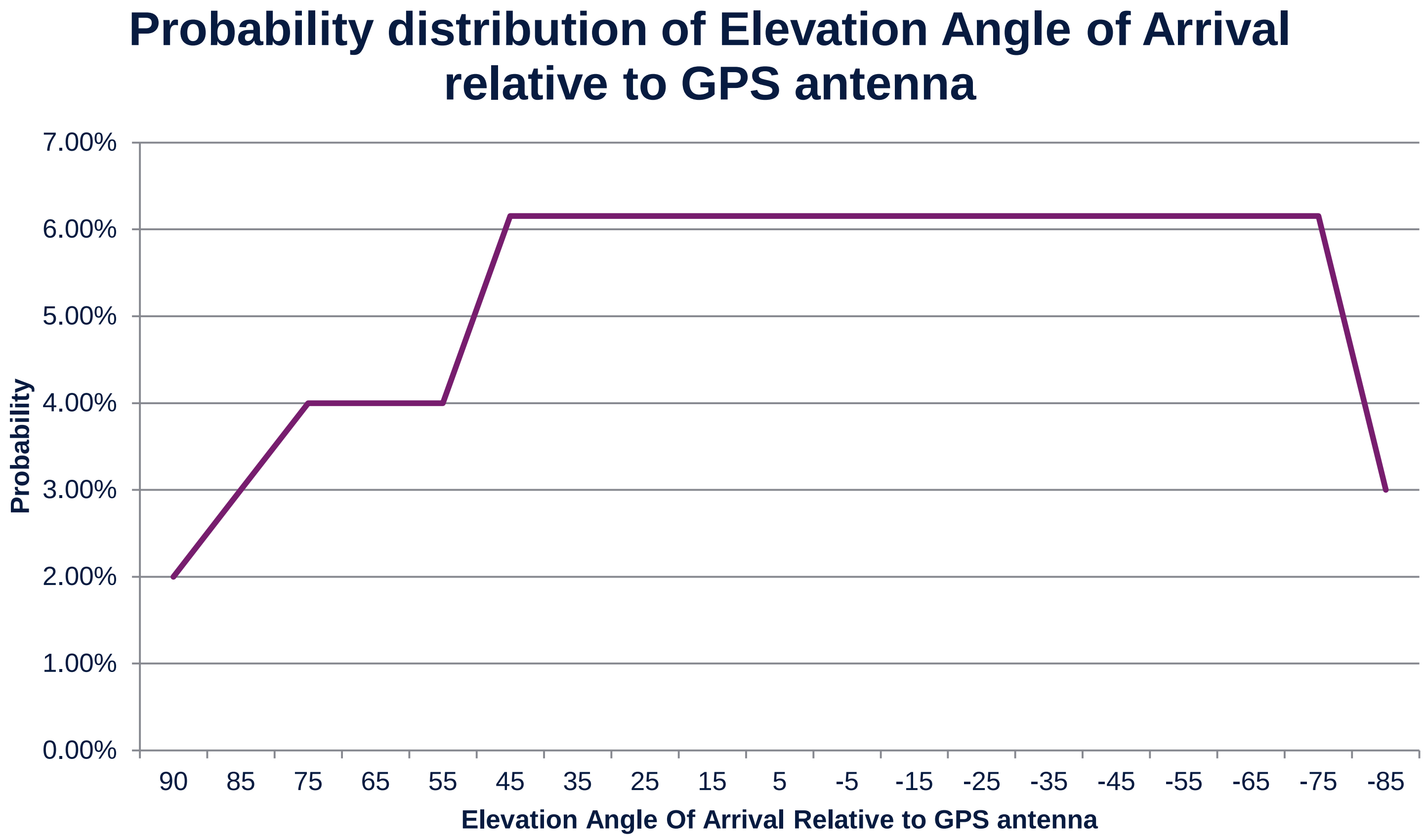
- Device Orientation Assumptions
  - Handset Tx
    - Relative to the handset, the ray launch angles (AoD) are assumed to be uniformly and randomly distributed in 3D (all device orientations are equally likely)
  - USB dongle Tx:
    - Relative to a dongle plugged into a laptop computer, the ray AoDs are assumed to be uniformly distributed in azimuth and over 0 to 90 degrees in elevation (upper hemisphere)
  - Handheld GLN Rx:
    - Relative to the GPS device, the ray arrival angles (Angles of Arrival, AoA) are assumed to be distributed in 3D

Example Use Case for Handheld GLN Receiver

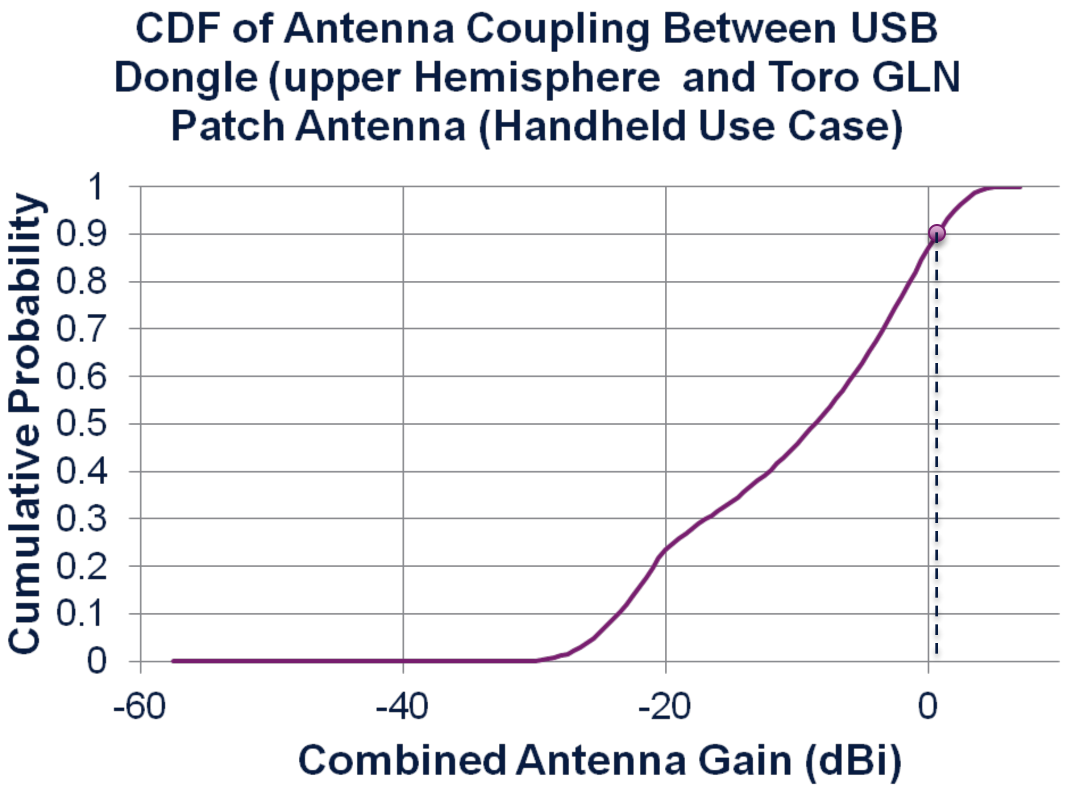


Most likely angle of arrival (AoA) of handheld general location/navigation (GLN) GPS receiver. AOAs are selective in elevation (as shown) but non-selective (equiprobable) in azimuth

Assumed Probability Distribution - GLN

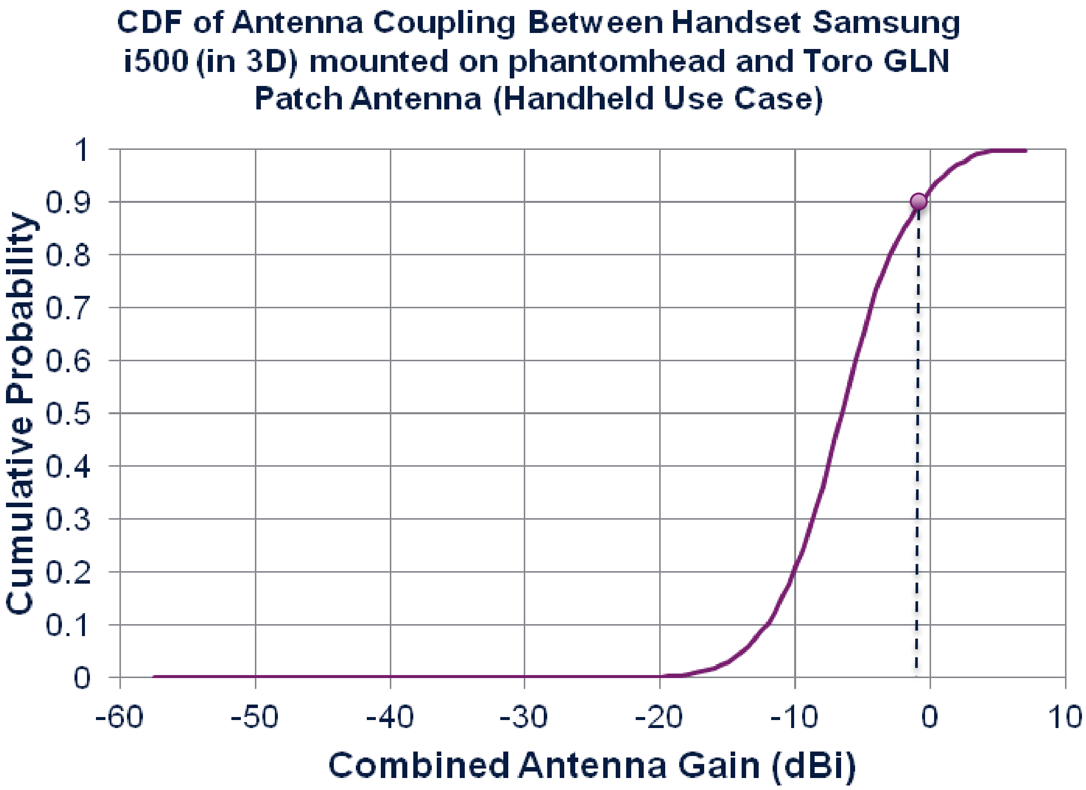


Results for USB Dongle Emitting Towards Handheld GLN GPS Receiver



90% of time the coupling factor relative to isotropic Tx and Rx antennas is less than 0.5 dB.

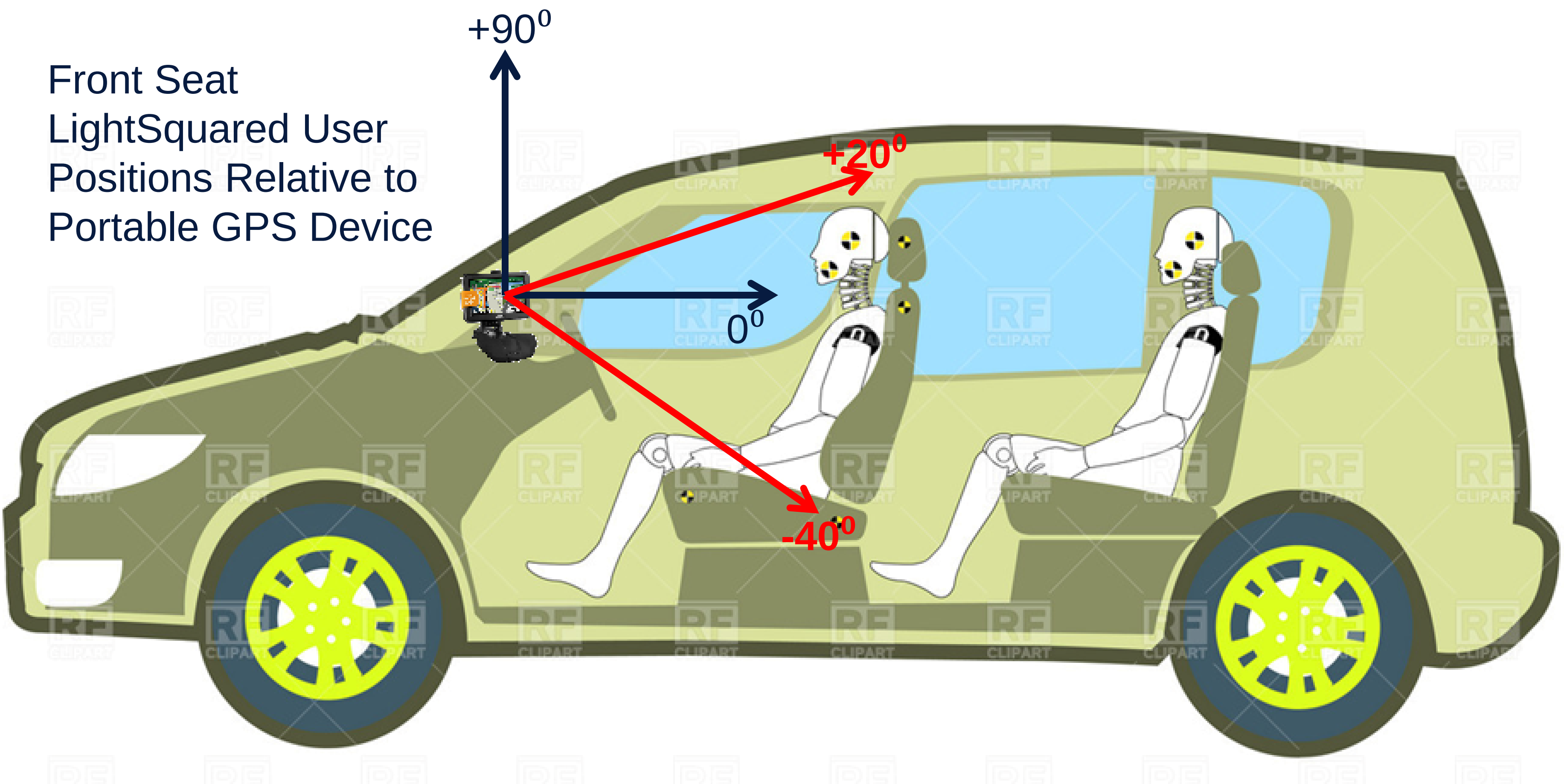
Results for Handset Emitting Towards Handheld GLN GPS Antenna



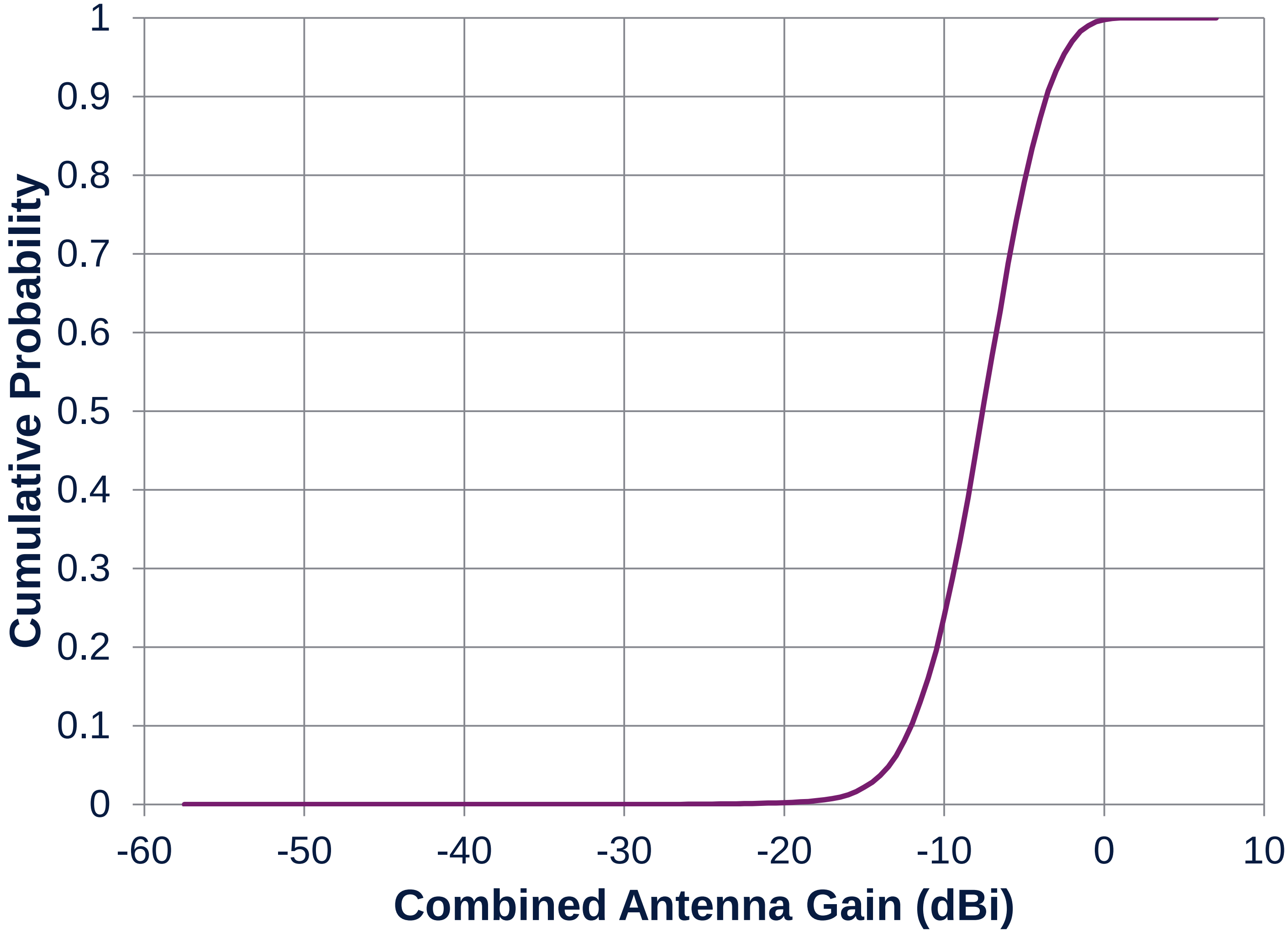
90% of time the coupling factor relative to isotropic Tx and Rx antennas is less than -0.5 dB.

Assessment of Automotive Use Case: Portable GLN Device Inside Passenger Compartment

Front Seat LightSquared User Positions Relative to Portable GPS Device

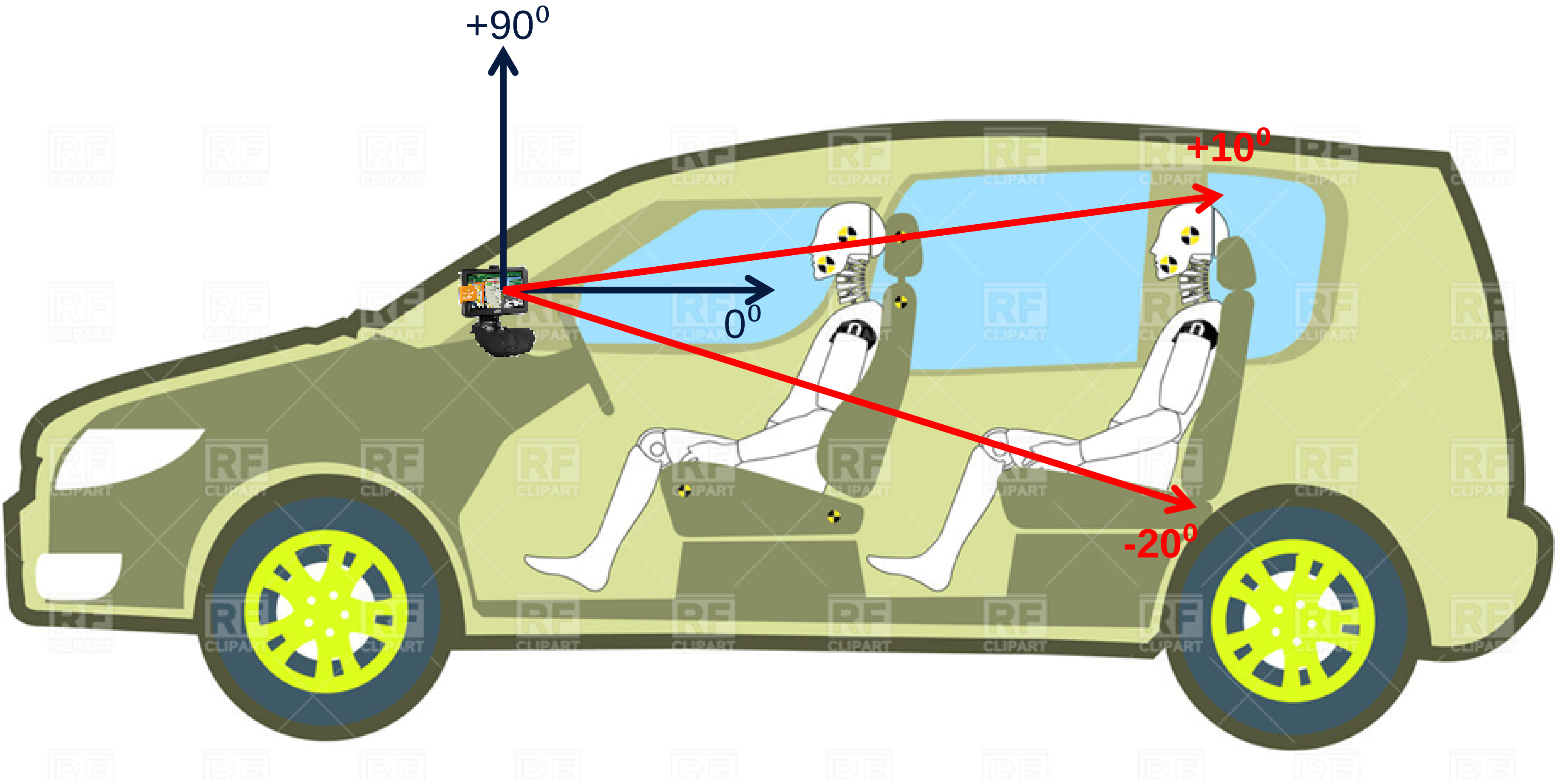


CDF of Antenna Coupling Between USB Dongle and Toro GLN Patch Antenna (Automotive Use Case) for front seat occupants Probability is equally distributed between $+20^0$ and -40^0



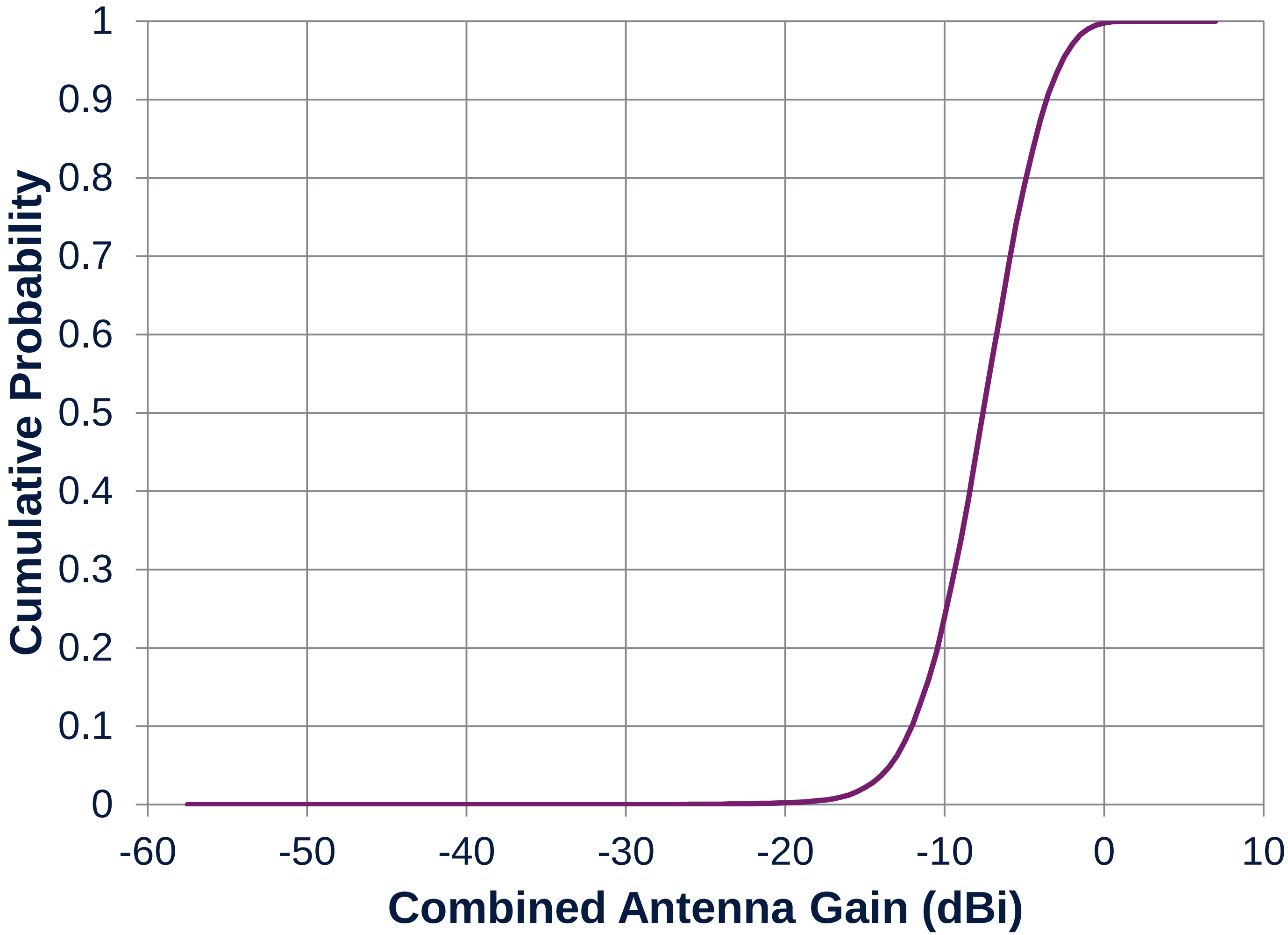
Front Seaters – 90% shows -5 dBi antenna coupling

Back Seat Users



CDF of Antenna Coupling Between USB Dongle and Toro GLN Patch Antenna (Automotive Use Case) for back seaters

Probability is equally distributed between -10^0 and $+20^0$



Back Seaters – 90% shows -3.5 dBi antenna coupling

Combined antenna coupling for four users in the car

Users in Front Seat	2	
90 % Antenna Coupling	-5	dBi
Users in Back Seat	2	
90 % Antenna Coupling	-3.5	dBi
Distance between front to back	1	m
Pathloss (free space)	36.7	dB
Combined Antenna Coupling	-1.98877	dBi

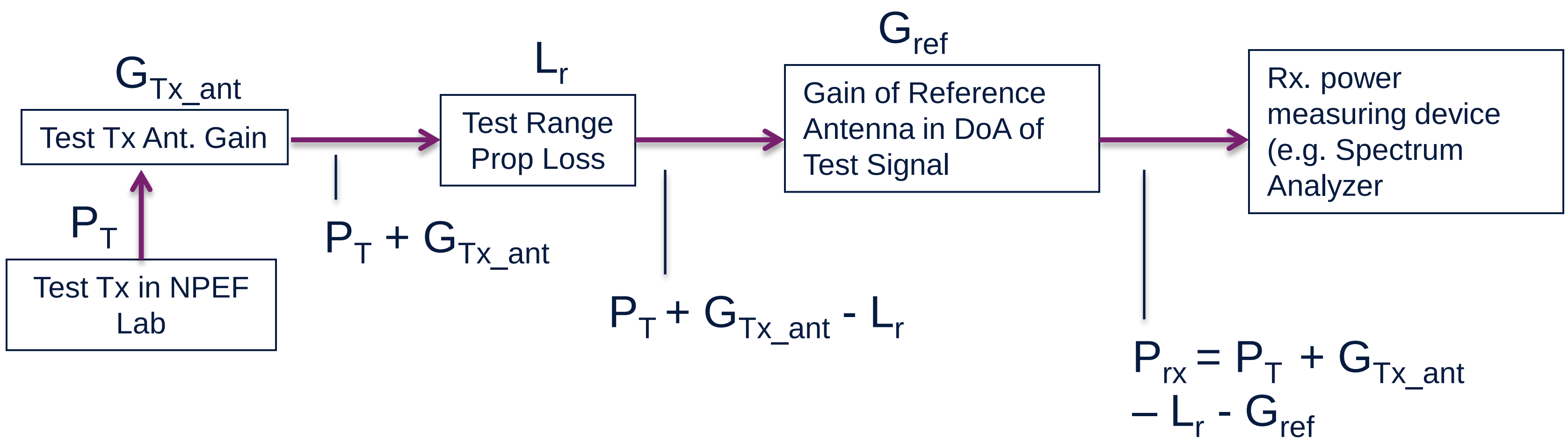
Conclusions from Antenna Coupling Analyses

	GLN Device
USB Dongle	0.5 dB
Handset	-0.5 dB

- Controlling coupling factor is for USB dongle
- In order to normalize the NPEF results to isotropic (0 dBi) GPS receive antennas, the coupling factors are reduced by 3.5 dB
- Maximum (among Handset and Dongle) normalized coupling factor for GLN device: -3.0 dB

Scaling of NPEF Results

The NPEF test range was calibrated (by NPEF staff) as shown below. The NPEF results re: received power are actually P_T values projected to the receiver input based on the equations shown below.



By calibration, power levels reported in NPEF lab were normalized to remove the effect of the reference antenna gain, G_{ref}. Thus, powers reported were the powers that would be reported by a 0 dBi GPS receive antenna.

During testing, the peak gain of GPS devices was pointed towards the transmit antenna in the test range.

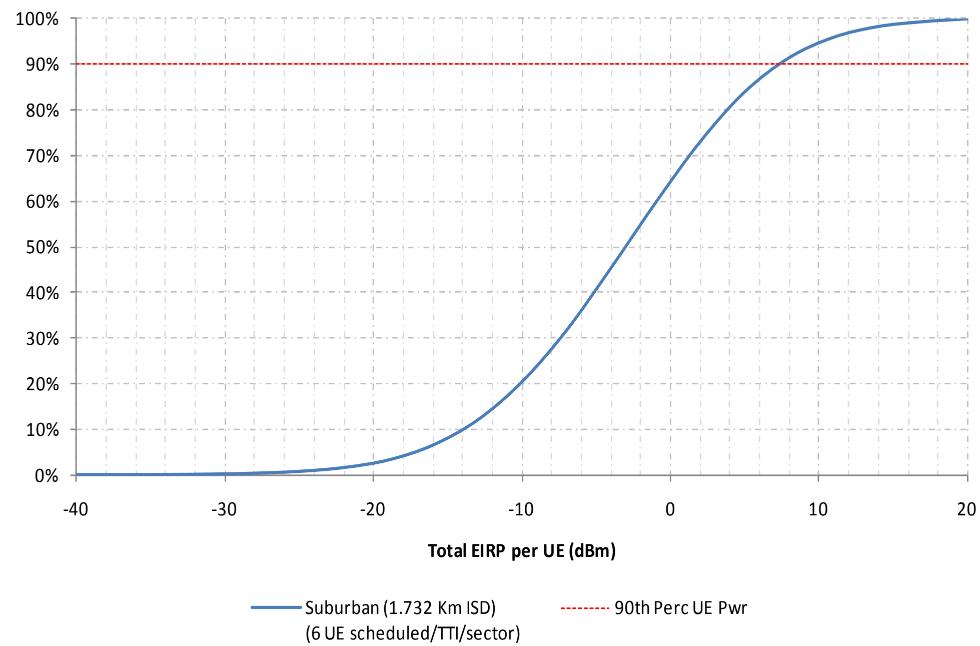
To compare the Rx power (so determined) to the NPEF overload results, the latter need to be scaled up by the peak gain of the GPS Rx antenna.

UE Power Reduction

- In order to manage battery/power consumption and balance network parameters, mobile devices rarely operate at full power
- When full power operation does occur, it is usually the result of a device being operated deep indoors, with multiple obstructions between the user device and the cell site
- To objectively quantify the assumed power level, LightSquared used analyses from CSMAC (the Department of Commerce Spectrum Management Advisory Committee)
- The CSMAC simulations conclude that UE power will be less than 8 dBm in suburban environments in 90% of cases, which is the value used in the present analysis
- Independent simulations performed by ITU show that CSMAC results are credible (median values are of similar order, even lower in some instances)

CSMAC Data

	Urban/Suburban (1.732 Km ISD) (6 UE scheduled/TTI/sector)		Rural (7 Km ISD) (6 UE scheduled/TTI /sector)
UE EIRP (dBm)	**PDF**	**CDF**	**CDF**
-40	0.0000	0.0000	0.0000
-37	0.0001	0.0001	0.0000
-34	0.0002	0.0003	0.0000
-31	0.0008	0.0011	0.0000
-28	0.0020	0.0031	0.0000
-25	0.0040	0.0071	0.0000
-22	0.0083	0.0154	0.0002
-19	0.0166	0.0320	0.0006
-16	0.0327	0.0647	0.0013
-13	0.0547	0.1194	0.0039
-10	0.0839	0.2033	0.0099
-7	0.1128	0.3160	0.0252
-4	0.1370	0.4530	0.0577
-1	0.1429	0.5959	0.1152
2	0.1338	0.7297	0.2062
5	0.1094	0.8390	0.3307
8	0.0753	0.9143	0.4843
11	0.0450	0.9594	0.6448
14	0.0236	0.9830	0.7920
17	0.0106	0.9936	0.9123
20	0.0064	1.0000	1.0000



	Suburban (100% Outdoor UEs)
Avg UE Pwr	5.4 dBm
90th Perc UE Pwr	8 dBm

Overload Analysis for GLN Devices (Outdoor Use Case)

GPS Rx: GLN
Standoff Distance: 1 meter

Parameter	Value	Comments
Device Tx Power (dBm)	11.0	Based on CSMAC simulations: 90% point of UE power CDF
Pathloss (dB)	36.7	Free Space
GPS Rx Power (dBm)	-25.7	Calculated
Number of simultaneously on Tx devices	1.0	ATC spec for device OOBE is based on 1 user with 4.8 m separation
Power gain/loss (dB) owing to no. of Tx devices	0.0	Calculated
GPS Rx Power (dBm)	-25.7	Calculated
Maximum, normalized coupling factor for GLN device (dB)	-3.0	Based on measured/specified GPS antenna gains; includes normalization for peak gain of GPS antenna
Normalized power at GPS Rx input connector(dBm)	-28.7	Calculated
% of devices experiencing 1 dB change in C/N_0 for UL-1	10.0 %	Look up of WSMR table
% of devices experiencing 1 dB change in C/N_0 for UL-2	4.65 %	Look up of WSMR table

NPEF Reported Overload Levels

Uplink transmissions for exclusively GLN devices (unnormalized with respect to peak gain of GPS antenna) [NPEF Report, p. 31-32, Table 7, 8]

	GLN TE3 and TE12 (10L UL)			GLN TE4 and TE13 (10H UL)		
Handset Power at receiver	Receivers Degraded	Percentage Degraded	Cumulative Percentage	Receivers Degraded	Percentage Degraded	Cumulative Percentage
-55 to -45	0	0%	0%	0	0%	0.00%
-45 to -40	0	0%	0%	0	0%	0.00%
-40 to -35	0	0%	0%	0	0%	0.00%
-35 to -30	4	4%	4%	1	1%	1.16%
-30 to -25	5	5%	10%	3	3%	4.65%
-25 to -20	4	4%	14%	2	2%	6.98%
-20 to -15	5	5%	20%	5	6%	12.79%
-15 to -10	24	26%	46%	13	15%	27.91%
> -10	49	54%	100%	62	72%	100.00%

OOBE Assessment

- OOBE vulnerability was also analyzed using the above model including
  - A single user within 1 meter of the GPS Receiver
  - Empirical antenna coupling data
  - Uplink power control data from CSMAC simulations and dB-for-dB reduction of OOBE level with output power. This is supported by device measurements, which show even greater variation.
- Performing an analysis similar to that used for determining power levels for overload susceptibility, significant positive margin exists for OOBE as well

OOBE Vulnerability Analysis for GLN Devices
(At 1 Meter Separation Distance)

Currently specified OOBE PSD in ATC Order	**-95 dBW/MHz**	
	-125 dBm/Hz	
Permitted OOBE PSD at GPS Rx based on USGIC/MSV Letter to FCC		
Maximum allowed Interference Spectral Density (I_0)	**-174.5 dBm/Hz**	GPS Receiver Interference Susceptibility based on USGIC/MSV letter to FCC [1]

Free Space Loss for 1 m separation	**37 dB**	Free space propagation at 1631 MHz
Required Tx - Rx coupling loss	**12.4 dB**	Calculated
Antenna Coupling Loss at 90% point of CDF	**-0.5 dB**	From simulation using handheld GLN and USB dongle pattern data
Polarization Mismatch	**1.5 dB**	Polarization mismatch between linearly polarized dongle and circularly polarized GPS antenna.
Power control for 90% point of CDF	**12 dB**	Here, OOBE PSD is assumed to vary linearly (dB-for-dB) with UE output power. However measured data shows 3.5 dB OOBE variation for 1 dB power variation, making this is an overly conservative assumption. However, significant margin exists regardless.
Total Margin	**0.5 dB**	

[1] **Interference Analysis of Out-of-Band Emissions (OOBE) Limits to GPS from Ancillary Terrestrial Mobile Satellite Services in the L-Band (IB Docket No. 01-185), August 8, 2002, Table 2**

Factors Capable of Contributing Additional Margin

- For simplicity, this analysis only considered two primary variables: antenna coupling loss and UE power control

- Many other real world factors, which would further increase margin, were not included in this analysis, including
  - Uplink duty cycle, which is rarely 100% in an operational LTE network
  - User body loss re: LightSquared uplink transmitter
  - Vehicle shielding loss (when a GPS receiver is outside a vehicle and the LightSquared device is inside)

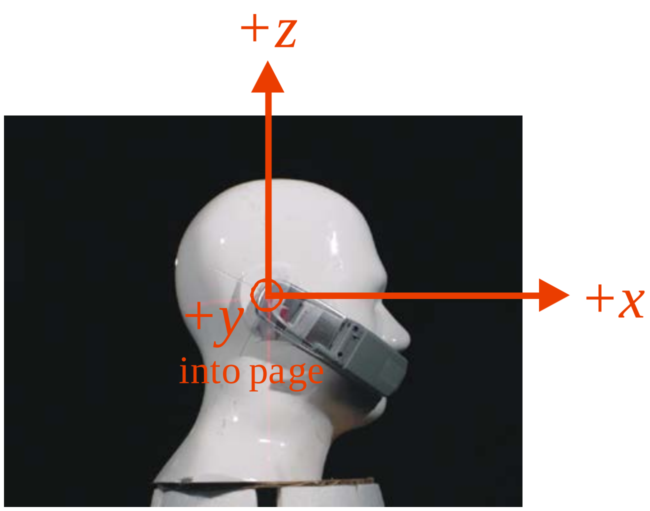
Appendix 2
LightSquared Uplink Analysis Relative to High Precision GPS Devices

Compatibility of LightSquared's L-band Uplinks with High Precision GPS Receivers

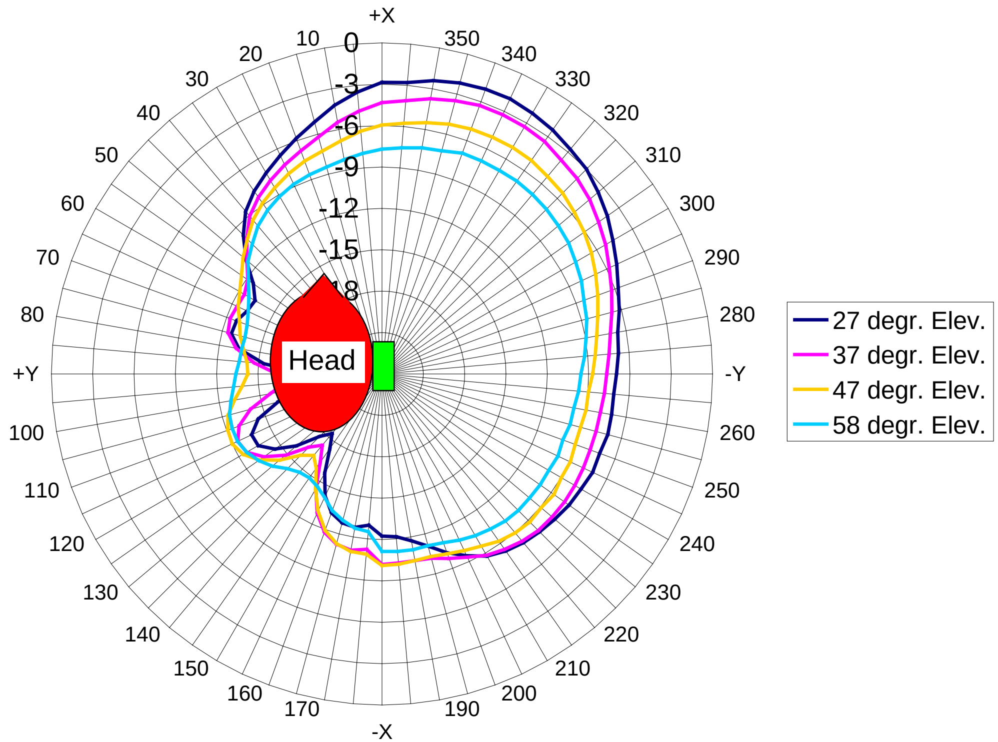
Antenna Coupling Loss/Antenna Pattern Analysis

Typical PCS Band Handset Antenna Patterns (Satimo data)

Data obtained by Satimo Labs in 2006 on CDMA handset



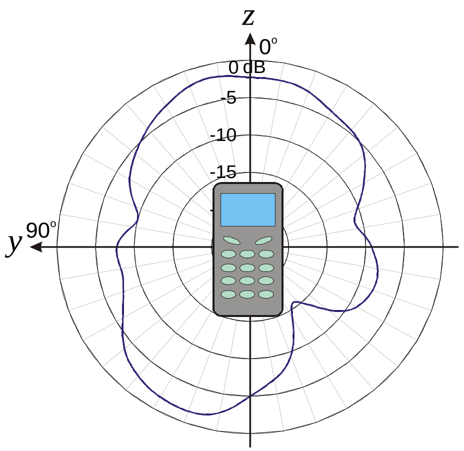
Handset orientation wrt phantom head



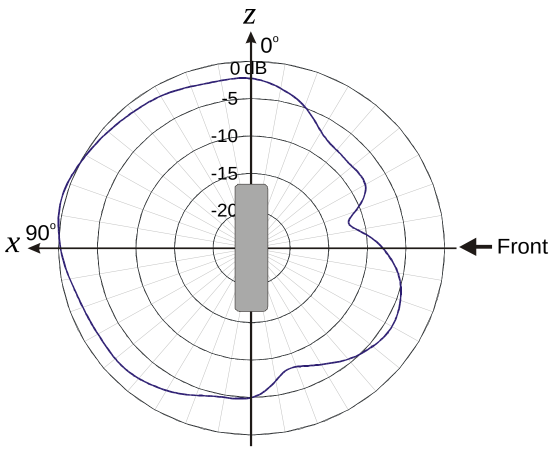
Transmit Gain (dBi) vs. Azimuth Angle w/ patch (internal) antenna for 4 discrete elevation angles (27^0 , 37^0, 47^0 , 58^0)

Example Handset Antenna Patterns provided to MSV by Ericsson (MSV's FCC Filing, June 2003)

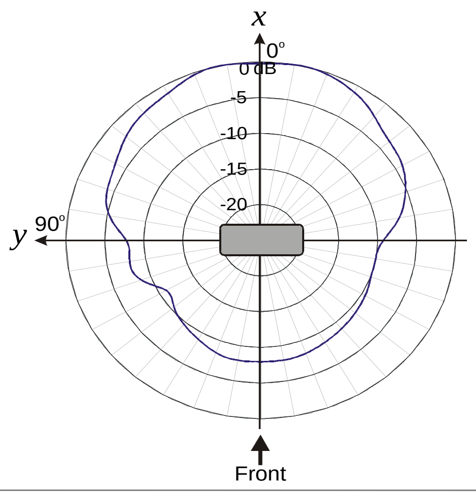
Side-Elevation Gain Contour



Front -Elevation Gain Contour



Azimuth Gain Contour



Based on this filing, MSV claimed and FCC allowed booking an <u>average handset antenna gain of – 4dBi</u>

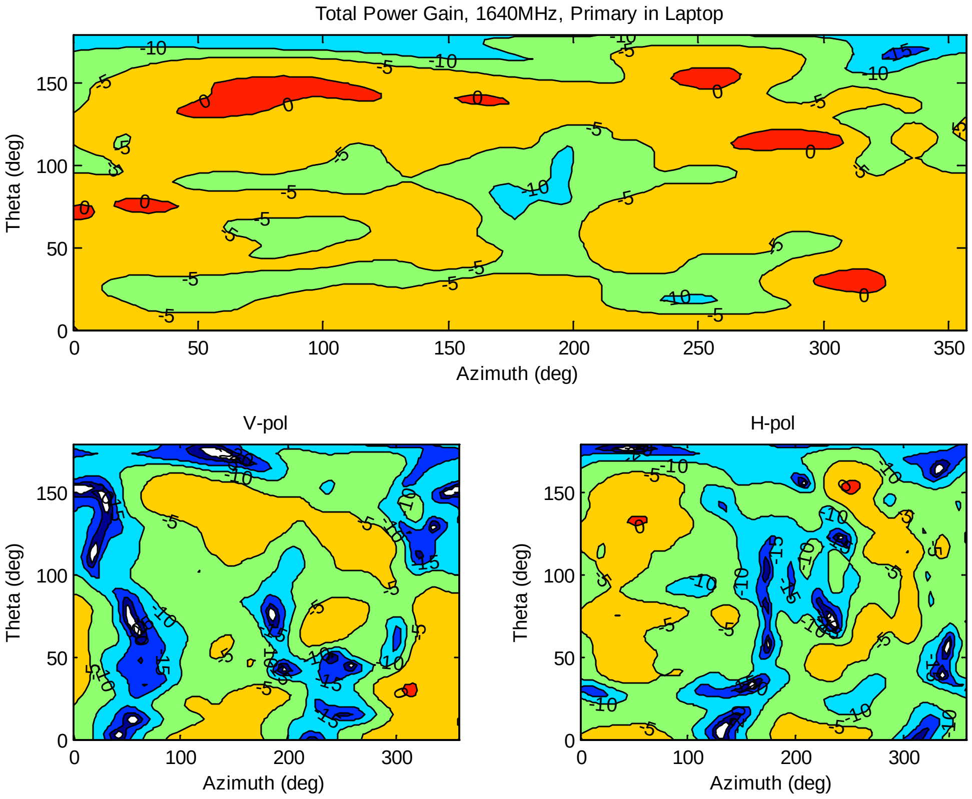
Distribution of measured handset antenna gains considered by TWG Cellular Subgroup

Handset-based GPS antenna coupling loss relative to an isotropic (0 dBi gain) antenna

	CD-A	**CD-B**	**CD-C**
max	-5.6	2.4	-10.5
min	-16.7	-19.7	-22.8
avg	-9.9	-8.3	-14.2
median	-10.1	-9.7	-13.8
90%tile	-7.0	1.0	-12.0
75%tile	-8.0	-5.0	-13.0

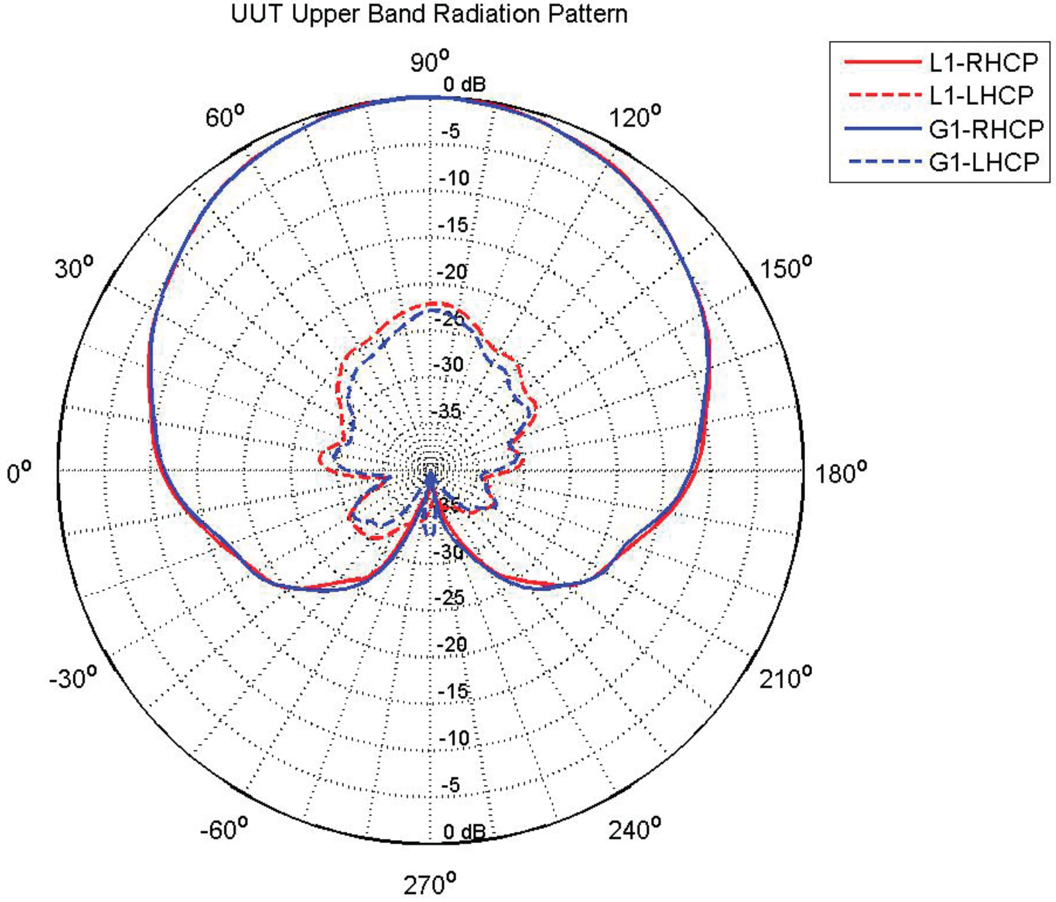
The Cellular subgroup used an antenna coupling loss value of -5 dB.

Typical antenna gain contour maps of L-band USB dongle



In most directions, the antenna gain is less than -5 dBi

Typical Normalized Pattern of High Precision GPS Antenna [Novatel GPS-703-GGG spec sheet]

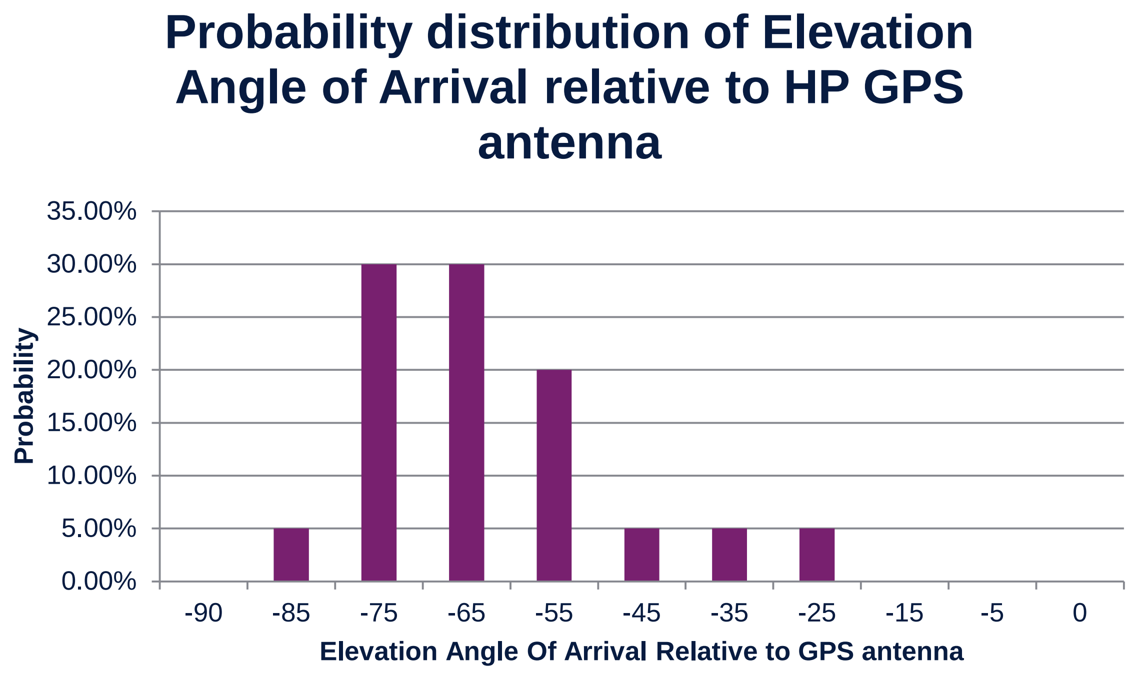


Peak Gain = 5 dBi from product spec sheet

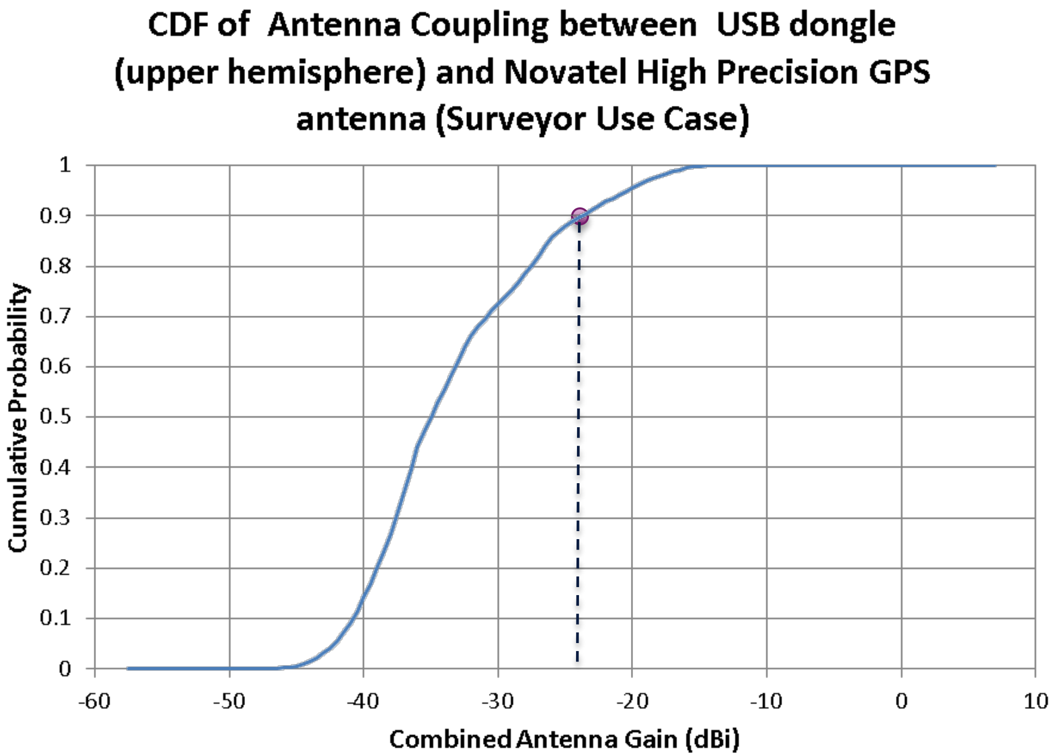
Use Case for High Precision GPS

- The antenna is typically above the user's head; coupling with a user operated transmitting device occurs through the lower hemisphere (back lobe) of the GPS antenna

Assumed probability distribution of Elevation Angle of Arrival relative to HP GPS antenna

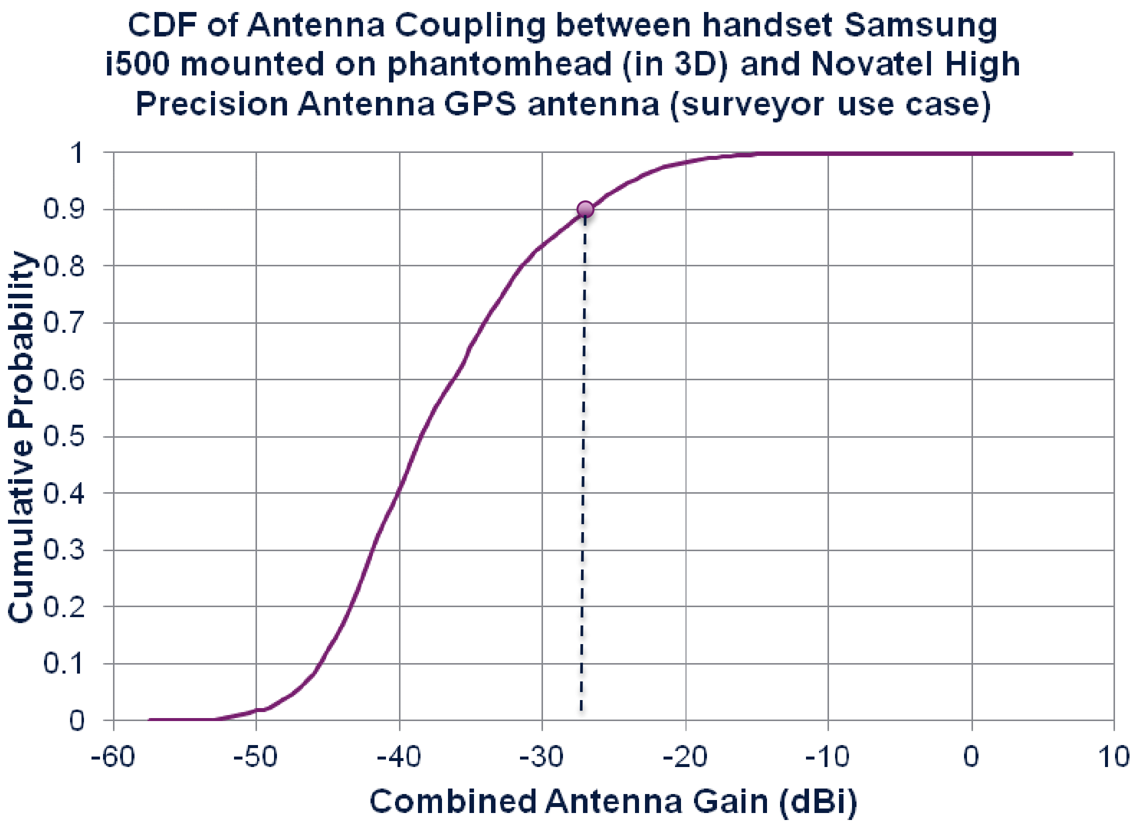


Results for USB dongle emitting towards HP GPS antenna



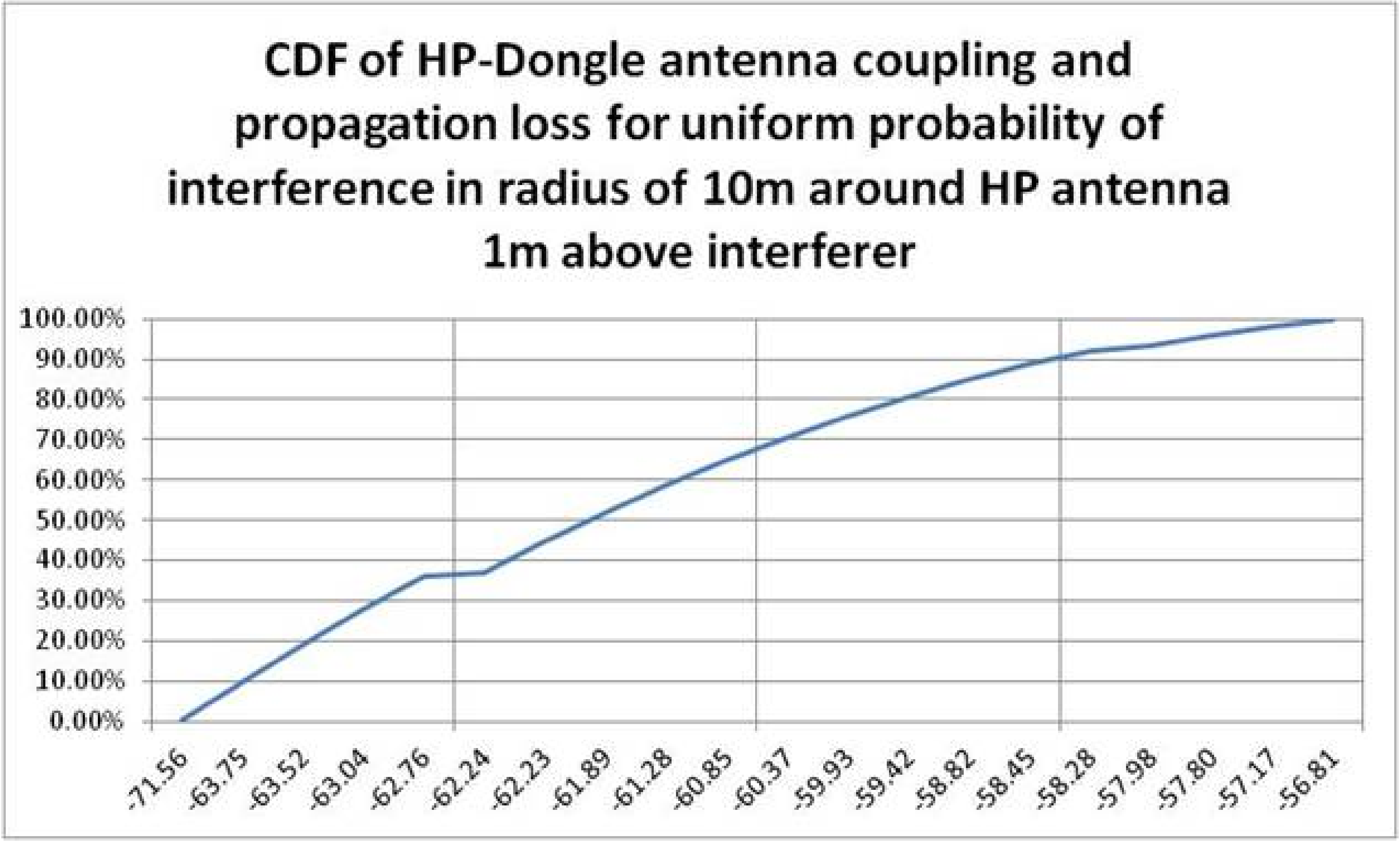
90% of time the coupling factor relative to isotropic tx and rx antennas is less than -24 dB.

Results for Handset emitting towards HP GPS antenna



90% of time the coupling factor relative to isotropic tx and rx antennas is less than -27 dB.

CDF of Integrated Coupling Factor



90% of the time, the integrated coupling factor is lower than -58.3 dBi

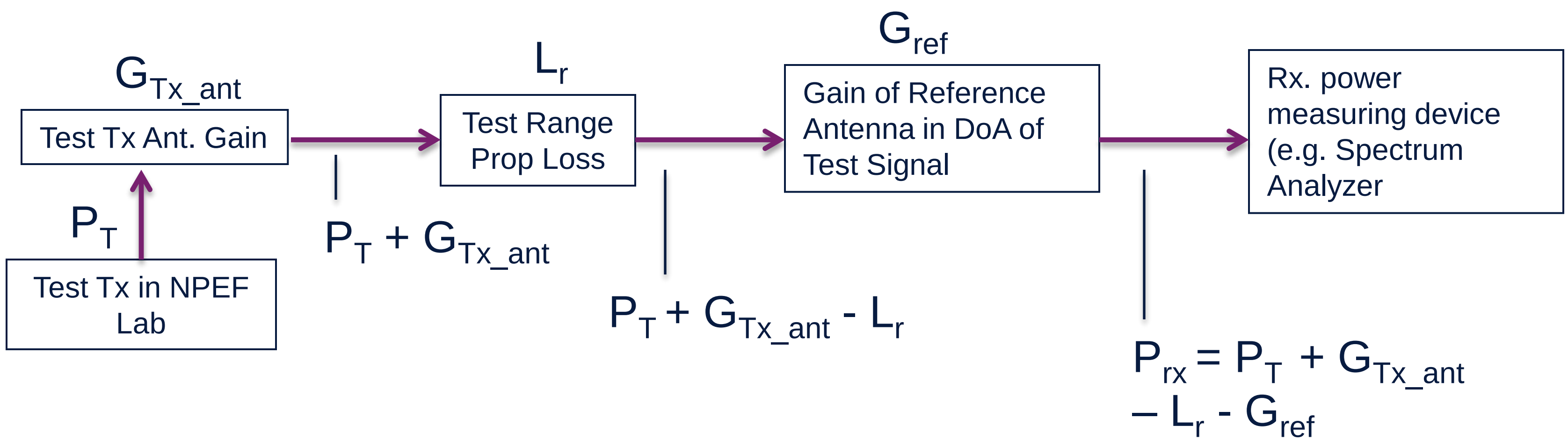
Conclusions from antenna coupling analyses

	HP Device
USB Dongle	-24 dB
Handset	-27 dB

- Controlling coupling factor is for USB dongle
- In order to normalize the NPEF results to isotropic (0 dBi) GPS receive antennas, the coupling factors are reduced by 5 dB (peak gain of HP antenna)
- Maximum coupling factor for HP device: -29 dB

Scaling of NPEF Results

The NPEF test range was calibrated (by NPEF staff) as shown below. The NPEF results re: received power are actually P_T values projected to the receiver input based on the equations shown below.



By calibration, power levels reported in NPEF lab were normalized to remove the effect of the reference antenna gain, G_{ref}. Thus, powers reported were the powers that would be reported by a 0 dBi GPS receive antenna.

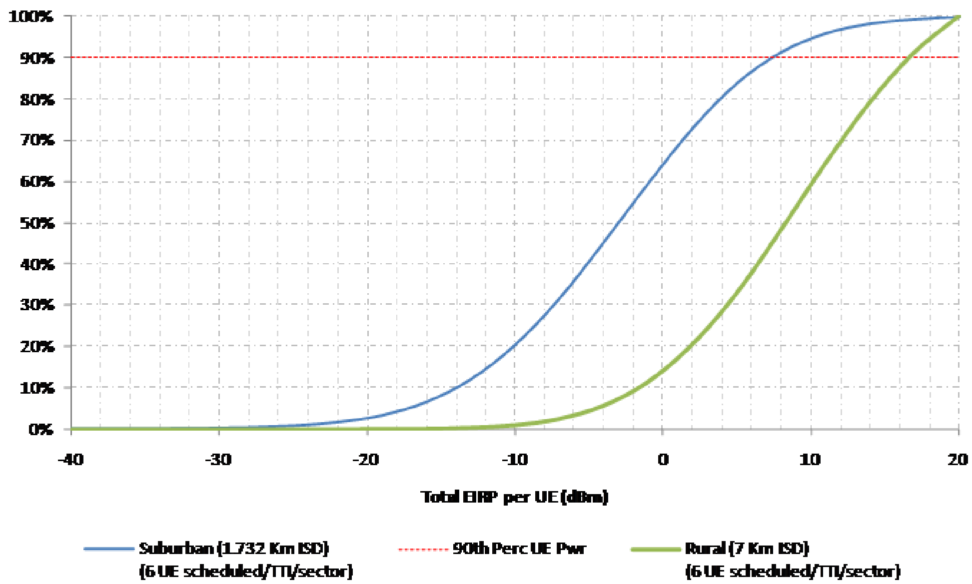
During testing, the peak gain of GPS devices was pointed towards the transmit antenna in the test range.

To compare the rx power (so determined) to the NPEF overload results, the latter need to be scaled up by the peak gain of the GPS rx antenna.

Uplink Power Control Factor

CSMAC Data

	Urban/Suburban (1.732 Km ISD) (6 UE scheduled/TTI/sector)		Rural (7 Km ISD) (6 UE scheduled/TTI /sector)
UE EiRP (dBm)	PDF	CDF	CDF
-40	0.0000	0.0000	0.0000
-37	0.0001	0.0001	0.0000
-34	0.0002	0.0003	0.0000
-31	0.0008	0.0011	0.0000
-28	0.0020	0.0031	0.0000
-25	0.0040	0.0071	0.0000
-22	0.0083	0.0154	0.0002
-19	0.0166	0.0320	0.0006
-16	0.0327	0.0647	0.0013
-13	0.0547	0.1194	0.0039
-10	0.0839	0.2033	0.0099
-7	0.1128	0.3160	0.0252
-4	0.1370	0.4530	0.0577
-1	0.1429	0.5959	0.1152
2	0.1338	0.7297	0.2062
5	0.1094	0.8390	0.3307
8	0.0753	0.9143	0.4843
11	0.0450	0.9594	0.6448
14	0.0236	0.9830	0.7920
17	0.0106	0.9936	0.9123
20	0.0064	1.0000	1.0000



	Suburban	Rural
Avg UE EIRP Power	5.4 dBm	13.4 dBm
90th perc UE EIRP power	8 dBm	16.6 dBm
Back off from max EIRP power	12 dB	3.4 dB

Overload Analysis for HP Devices

Standoff distance	Variable UE position, anywhere inside a circular domain: 1 m below GPS antenna with radius of 10 m from base of GPS antenna.		UE at fixed distance of 1 m from GPS antenna and below it. Variable AoA relative to Rx and AoD relative to Tx.	
Device Tx. Power (dBm)	19.6	UE power assumed based on CSMAC simulations: 90% point of UE power CDF for rural case.	19.6	UE power assumed based on CSMAC simulations: 90% point of UE power CDF for rural case.
Integrated coupling loss (Tx/Rx antenna gains + distance loss) (dBi)	58.3	90% point on CDF of {Sum of Tx/Rx antenna gains (dBi) + Free Space loss (dB)} with UE 1 m below GPS antenna and 0 - 10 from base of GPS antenna	61	90% point on CDF of {Sum of Tx/Rx antenna gains} (dBi) of GPS antenna with UE at a fixed distance of 1 m from the GPS antenna
Rx. Power (dBm)	-38.7	Calculated	-41.4	Calculated
No. of simultaneously on devices	1	ATC spec for device OOBE is based on 4.8 m separation.	1	ATC spec for device OOBE is based on 4.8 m separation.
Power gain/loss (dB) owing to no. of devices	0.00	Calculated	0.00	Calculated
GPS Antenna Gain Normalization Factor (dB)	3.00	Based on Measured/Specified antenna gain; includes normalization of peak gain of GPS antenna	3.00	Based on Measured/Specified antenna gain; includes normalization of peak gain of GPS antenna
Normalized power at GPS Rx input connector (dBm)	-41.7	Calculated	-44.4	Calculated

OOBE Analysis

Vulnerability to OOBE

- OOBE vulnerability was also analyzed using the above model including
  - A single user within 1 m of the GPS Receiver
  - Empirical antenna coupling data
  - Uplink power control data from CSMAC simulations and dB-for-dB reduction of OOBE level with output power. This is a very conservative assumption as OOBE at close frequency separations is caused by transmit intermod products which vary approximately 3x with input power per measured data.
  - Probabilistic analysis

OOBE vulnerability analysis for HP devices

Currently specified OOBE PSD in ATC Order	**-95 dBW/MHz**	
	-125 dBm/Hz	
Permitted OOBE PSD at GPS Rx based on USGIC/MSV Letter to FCC		
Maximum allowed Interference Spectral Density (I_0)	**-174.5 dBm/Hz**	GPS Receiver Interference Susceptibility based on USGIC/MSV letter to FCC [1]

Integrated coupling loss for unconstrained user, 1 m below and 10 m around HP GPS antenna (90% point of CDF)	**58.3 dB**	Calculated
Polarization Mismatch	**1.5 dB**	Polarization mismatch between linearly polarized dongle and circularly polarized GPS antenna.
Power control for 90% point of CDF from CSMAC rural case	**3.4 dB**	Here, OOBE PSD is assumed to vary linearly (dB-for-dB) with UE output power. However measured data shows 3.5 dB OOBE variation for 1 dB power variation, making this is an overly conservative assumption. Significant margin exists regardless.
Total Margin	**13.7 dB**	Calculated

[1] **Interference Analysis of Out-of-Band Emissions (OOBE) Limits to GPS from Ancillary Terrestrial Mobile Satellite Services in the L-Band (IB Docket No. 01-185), August 8, 2002, Table 2**

Appendix 3

Potential for Interference to Aviation GPS from LightSquared User Equipment (UE):

In-Cabin Usage

Potential for Interference to Aviation GPS from LightSquared User Equipment (UE):
In-Cabin Usage

Summary

LightSquared has analyzed the potential for LightSquared devices operating on board an aircraft to exceed the FAA's specified limits for both overload and OOBE to certified aviation receivers. Using models published by RTCA and NASA, the analysis demonstrates that LightSquared devices, even in extreme use cases, will not exceed the FAA's specified limits.

1.0 Problem Statement

The scenario analyzed here involves usage of LightSquared UE's (such as mobile phones) inside an aircraft. The analysis methodology is based on [1], which is itself based on an investigation by NASA on the coupling loss between a UE near a window inside the passenger area of a plane and antennas mounted on the body of the plane. The investigation included measurements on a Boeing 737-200 aircraft. The coupling factors yielded by the above measurement, as reported in [1, Table E-10], were used to determine the potential for both OOBE and overload interference to a GPS receiver. The scenario involved the following assumptions.

1.1 UE Power

The UE power was assumed to be 23 dBm, which is the maximum power of a device according to the 3GPP standard for LTE. This is an extremely conservative assumption for the *operational power*, which will be backed off from the maximum value owing to uplink power control. The CSMAC [2] simulations have shown that, in suburban environments, the power is less than 10 dBm with a probability greater than 95% for an individual device.

1.2 UE antenna coupling loss

A device antenna coupling loss of 3 dB, relative to an isotropic radiator, was used. This value, which includes both antenna deficiency and directive gain, is intended to replicate a handset when averaged over all directions. This is consistent with the value used by the CSMAC working group and is slightly more conservative than the 4 dB value which was accepted by the FCC in the 2003 ATC Order, based on measurements performed by Ericsson on a GSM handset. The TWG cellular subgroup assumed an even higher antenna coupling loss of 5 dB for a GPS antenna on a cellphone.

1.3 Number of simultaneously transmitting devices

Two cases are shown: (a) seven simultaneous users, each with an IPL (interference path loss) corresponding to the average IPL; and (b) all 63 window seats (as per the aircraft model in [1]) occupied with simultaneously transmitting users. It will be recognized that (b) is an implausible scenario and is presented here as an alternate way (alternative to dBs of margin for a more likely number of devices) to demonstrate the significant positive margin inherent in the use case in general. It is further noted that, as per the LTE protocol, owing to the strong TDMA component in the air interface, simultaneous uplink usage does not typically result in power addition at the GPS receiver. Nevertheless, for simplicity and conservatism, power addition is assumed in this analysis.

1.4 OOBE PSD from UE

The numerical example shown assumes -95 dBW/MHz.

1.5 OOBE threshold at the GPS receiver

The OOBE threshold used is -206.5 dBW/Hz, as per RTCA DO-229D.

1.6 Overload threshold at the GPS receiver

The overload threshold used is -16.7 dBm, as per RTCA DO-229D for a CW signal at 1626.5 MHz.

2.0 Conclusions

The first use case shows that 7 window-seated users randomly distributed throughout the passenger cabin, simultaneously using LightSquared phones, would leave over 17 dB margin relative to the threshold for 1 dB C/N_0 desensitization, considering either OOBE or overload.

The second use case shows that 63 users, seated next to the window, could be talking simultaneously on LightSquared phones and still leave over 4 dB margin relative to the OOBE interference threshold (the risk of overload is clearly insignificant). If the UE OOBE level were -90 dBW/MHz, instead of -95 dBW/MHz as assumed here, the margin would still be slightly positive.

Results

7 users transmitting simultaneously

Select Number of simultaneous Tx's	Average Path Loss to GPS antenna @ 1575 MHz (dB)	Aggregate Adjacent band power received (Tx Power = 23 dBm)	Unit	Aggregate Received OOBE	Unit
7	74.0	-42.6	dBm	-220.6	dBW/Hz
	Tx/Rx Coupling loss	3	dB	3	dB
	Margin (with 7 Tx)	28.9	dB (O/L)	17.1	dB (OOBE)

63 users transmitting simultaneously (p. 1 of 2)

Window Location (Left side)	Path Loss to GPS antenna @ 1575 MHz (dB)	Adjacent band power received (Tx Power = 23 dBm)	Unit	Received OOBE	Unit	Adjacent band power received (mW)	Received OOBE (mW/Hz)
1	69.3	-46.3	dBm	-224.3	dBW/Hz	2.34423E-05	3.71535E-23
2	65	-42	dBm	-220	dBW/Hz	6.30957E-05	1E-22
3	66.2	-43.2	dBm	-221.2	dBW/Hz	4.7863E-05	7.58578E-23
4	65.6	-42.6	dBm	-220.6	dBW/Hz	5.49541E-05	8.70964E-23
5	70.4	-47.4	dBm	-225.4	dBW/Hz	1.8197E-05	2.88403E-23
6	64.2	-41.2	dBm	-219.2	dBW/Hz	7.58578E-05	1.20226E-22
7	66.2	-43.2	dBm	-221.2	dBW/Hz	4.7863E-05	7.58578E-23
8	68.5	-45.5	dBm	-223.5	dBW/Hz	2.81838E-05	4.46684E-23
9	72.1	-49.1	dBm	-227.1	dBW/Hz	1.23027E-05	1.94984E-23
10	75.8	-52.8	dBm	-230.8	dBW/Hz	5.24807E-06	8.31764E-24
11	74.9	-51.9	dBm	-229.9	dBW/Hz	6.45654E-06	1.02329E-23
12	73.9	-50.9	dBm	-228.9	dBW/Hz	8.12831E-06	1.28825E-23
13	75.7	-52.7	dBm	-230.7	dBW/Hz	5.37032E-06	8.51138E-24
14	76.2	-53.2	dBm	-231.2	dBW/Hz	4.7863E-06	7.58578E-24
15	78.1	-55.1	dBm	-233.1	dBW/Hz	3.0903E-06	4.89779E-24
16	73.6	-50.6	dBm	-228.6	dBW/Hz	8.70964E-06	1.38038E-23
17	82.8	-59.8	dBm	-237.8	dBW/Hz	1.04713E-06	1.65959E-24
18	82.2	-59.2	dBm	-237.2	dBW/Hz	1.20226E-06	1.90546E-24
19	81.8	-58.8	dBm	-236.8	dBW/Hz	1.31826E-06	2.0893E-24
20	78.5	-55.5	dBm	-233.5	dBW/Hz	2.81838E-06	4.46684E-24
21	84.6	-61.6	dBm	-239.6	dBW/Hz	6.91831E-07	1.09648E-24
22	79.7	-56.7	dBm	-234.7	dBW/Hz	2.13796E-06	3.38844E-24
23	N/A						
24	82.4	-59.4	dBm	-237.4	dBW/Hz	1.14815E-06	1.8197E-24
25	85.7	-62.7	dBm	-240.7	dBW/Hz	5.37032E-07	8.51138E-25
26	86.4	-63.4	dBm	-241.4	dBW/Hz	4.57088E-07	7.24436E-25
27	81.5	-58.5	dBm	-236.5	dBW/Hz	1.41254E-06	2.23872E-24
28	86.4	-63.4	dBm	-241.4	dBW/Hz	4.57088E-07	7.24436E-25
29	90.1	-67.1	dBm	-245.1	dBW/Hz	1.94984E-07	3.0903E-25
30	85.3	-62.3	dBm	-240.3	dBW/Hz	5.88844E-07	9.33254E-25
31	82.4	-59.4	dBm	-237.4	dBW/Hz	1.14815E-06	1.8197E-24
32	83.9	-60.9	dBm	-238.9	dBW/Hz	8.12831E-07	1.28825E-24

63 users transmitting simultaneously (p. 2 of 2)

Window Location (Right side)	Path Loss to GPS antenna @ 1575 MHz (dB)	Adjacent band power received (Tx Power = 23 dBm)	Unit	Received OOBE	Unit	Adjacent band power received (mW)	Received OOBE (mW/Hz)
1	68.5	-45.5	dBm	-223.5	dBW/Hz	2.81838E-05	4.46684E-23
2	69.9	-46.9	dBm	-224.9	dBW/Hz	2.04174E-05	3.23594E-23
3	71.8	-48.8	dBm	-226.8	dBW/Hz	1.31826E-05	2.0893E-23
4	70.1	-47.1	dBm	-225.1	dBW/Hz	1.94984E-05	3.0903E-23
5	73.9	-50.9	dBm	-228.9	dBW/Hz	8.12831E-06	1.28825E-23
6	66.8	-43.8	dBm	-221.8	dBW/Hz	4.16869E-05	6.60693E-23
7	65	-42	dBm	-220	dBW/Hz	6.30957E-05	1E-22
8	67.4	-44.4	dBm	-222.4	dBW/Hz	3.63078E-05	5.7544E-23
9	69.2	-46.2	dBm	-224.2	dBW/Hz	2.39883E-05	3.80189E-23
10	68.5	-45.5	dBm	-223.5	dBW/Hz	2.81838E-05	4.46684E-23
11	69.2	-46.2	dBm	-224.2	dBW/Hz	2.39883E-05	3.80189E-23
12	66.5	-43.5	dBm	-221.5	dBW/Hz	4.46684E-05	7.07946E-23
13	67.5	-44.5	dBm	-222.5	dBW/Hz	3.54813E-05	5.62341E-23
14	68.4	-45.4	dBm	-223.4	dBW/Hz	2.88403E-05	4.57088E-23
15	74.3	-51.3	dBm	-229.3	dBW/Hz	7.4131E-06	1.1749E-23
16	70	-47	dBm	-225	dBW/Hz	1.99526E-05	3.16228E-23
17	74.3	-51.3	dBm	-229.3	dBW/Hz	7.4131E-06	1.1749E-23
18	69.2	-46.2	dBm	-224.2	dBW/Hz	2.39883E-05	3.80189E-23
19	71.4	-48.4	dBm	-226.4	dBW/Hz	1.44544E-05	2.29087E-23
20	69.4	-46.4	dBm	-224.4	dBW/Hz	2.29087E-05	3.63078E-23
21	71.2	-48.2	dBm	-226.2	dBW/Hz	1.51356E-05	2.39883E-23
22	70.7	-47.7	dBm	-225.7	dBW/Hz	1.69824E-05	2.69153E-23
23	72.2	-49.2	dBm	-227.2	dBW/Hz	1.20226E-05	1.90546E-23
24	71	-48	dBm	-226	dBW/Hz	1.58489E-05	2.51189E-23
25	70.1	-47.1	dBm	-225.1	dBW/Hz	1.94984E-05	3.0903E-23
26	74	-51	dBm	-229	dBW/Hz	7.94328E-06	1.25893E-23
27	72.3	-49.3	dBm	-227.3	dBW/Hz	1.1749E-05	1.86209E-23
28	74.4	-51.4	dBm	-229.4	dBW/Hz	7.24436E-06	1.14815E-23
29	75.6	-52.6	dBm	-230.6	dBW/Hz	5.49541E-06	8.70964E-24
30	74.6	-51.6	dBm	-229.6	dBW/Hz	6.91831E-06	1.09648E-23
31	74.7	-51.7	dBm	-229.7	dBW/Hz	6.76083E-06	1.07152E-23
32	82.9	-59.9	dBm	-237.9	dBW/Hz	1.02329E-06	1.62181E-24
	Aggregate Power	-29.7	dBm	-207.7	dBW/Hz	0.001067926	1.69255E-21
	Tx/Rx Coupling loss	3	dB	3	dB	Conservative Estimate	
	MOPS Limit	-16.7	dBm	-206.5	dBW/Hz	RTCA - 229D	
	Margin (with 64 Tx)	16.0	dB (O/L)	4.2	dB (OOBE)		

References

[1] RTCA DO-235B, Appendix E, Section E.6.3.

[2] Commerce Spectrum Management Advisory Committee Final Report, Working Group 1 – 1695-1710 MHz Meteorological-Satellite, January 22, 2013.

Appendix 4

Analysis of potential for uplink interference to Aviation GPS from the collection of all LightSquared mobile stations on the ground within the radio horizon

Analysis of potential for uplink interference to Aviation GPS from the collection of all LightSquared mobile stations on the ground within the radio horizon

Summary

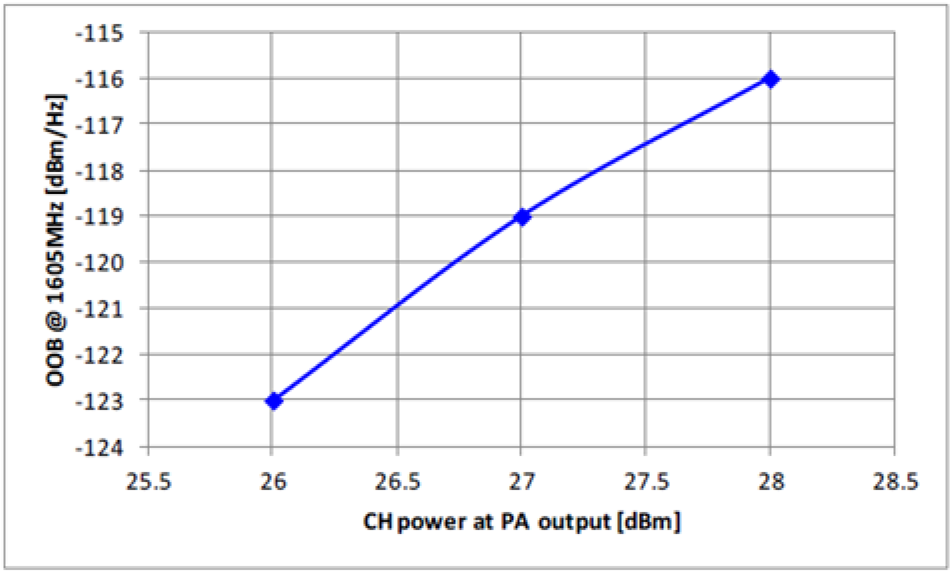
RTCA/DO-327 [1] analyzed the potential interference impact of a large number of LightSquared mobile stations on the ground to an airborne aviation GPS receiver. The results of the analyses and simulations reported therein showed that the effect was de minimis -- the OOBE from ATCt mobile stations caused a 0.4 dB rise in noise floor in the (assumed) nominal case of 300 mobile stations per cell and 1.2 dB in the extreme case of 1000 mobile stations per cell. Furthermore, the RTCA results were calculated based on a LightSquared out of band emission level of -90 dBW/MHz at 1605 MHz. The noise floor is increase is further abated when an OOBE value of -95 dBW/MHz is considered. This reduces the rise in the noise floor to 0.1 dB and 0.4 dB for 300 and 1000 mobiles respectively.

This paper supplements the above analysis with measurement information not available at the time of writing [1]. It is shown that the new information leads to an additional margin of 32 dB relative to the analysis in [1].

1.0 Re: Section 2.4.1.2 ATCt Mobile Station (User Equipment, UE) Emission Parameters

In [1, Section 2.4.1.2] it is acknowledged that there will be an average, UE transmit power backoff of 10 dB owing to power control. However, no consequent reduction of the UE OOBE was allowed, based on the assumption that, because the spectral separation of the GPS frequency from the UE's fundamental frequency was more than 52 MHz, the UE's spurious emissions would be independent of UE output power. Since the issuance of [1], measurements performed on actual UEs have shown that, not only is the OOBE power spectral density (PSD) dependent on the UE output power, the dependence is more than dB-for-dB, as shown in Figure 1. This is to be expected where the OOBE PSD is dominated by transmit intermodulation (IM) components. Such IM products would be expected to have a non-linear power relationship to the fundamental power.

Figure 1 UE output PSD variation with output power



The validity of the assumed 10 dB backoff has been independently corroborated (approximately) by [2], where the power backoff in suburban environments was estimated to be 9 dB for 95% probability. Where a large number of UEs are concerned, it is more appropriate to use the mean power, which was estimated to be 5.4 dBm. This corresponds to a backoff of 14.6 dB relative to the maximum operational power of 20 dBm. Conservatively assuming a dB-for-dB reduction of OOBE PSD tracking the fundamental EIRP, the OOBE PSD levels used in [1] should be reduced by 14.6 dB.

2.0 Re: Section 2.4.3.2 ATCt Mobile Station Location and Concentration Parameters

It was assumed by RTCA that all mobile stations visible to a GPS antenna are emitting OOBE with a constant PSD, regardless of whether they have been commanded by the base station to transmit or are idling (while camped on the base station's forward control channel). This is an erroneous assumption, as it has been confirmed by LightSquared's UE platform vendor that the UE's PA will be commanded into the sleep mode when idling (to minimize battery drain), in which mode the emissions are insignificant. This means that the interference model should only consider UEs that have been commanded to transmit. In a given cell, this is typically less than 3x6=18 for LTE[1]. Thus, the interference is overestimated by a factor of approximately 10log(300/18) = 17 dB, noting that 300 is the nominal number of UEs assumed in a cell.

3.0 Re: 4.7 Summary Results

In [1, Table 4-12], the estimated values of OOBE PSD from ATCt mobile stations are shown for three use cases (Cat. II DH, Cat. I DH, FAF WP). Results are shown for the cases with and without LightSquared UEs

[1] The CSMAC study [2] assumed that the number of simultaneously transmitting UE's was 6 in a given sector for a 10 MHz channel. The number of sectors is assumed to be 3. While there may be some random variation around this typical value, where a large number of base stations are involved (as in the present scenario) it is appropriate to use the typical (median) value as all base stations are unlikely to simultaneously support a significantly larger value.

present. The received interference PSD is highest in the case of Cat. II DH. In this case, for 300 UE/cell, the received OOBE PSD is -165.21 dBW/MHz with LightSquared operating under an OOBE limit of -95 dB/MHz (-160.21 dBW/MHz was derived by RTCA assuming LightSquared OOBE limit of -90 dBW/MHz) whereas the baseline noise floor established by other sources of noise and interference is -149.86 dBW MHz. Thus, there is a difference of approximately 15 dB, which would increase the extant background noise floor by 0.1 dB. Even if one assumes the upper limit case of 1000 UE/cell, the minimum difference is approximately 10 dB, which would increase the background noise floor by 0.4 dB.

4.0 Conclusions

One could conclude from the above that, even before any new margin-enhancing factors are considered, the impact of UE OOBE in the present interference model (described in DO-327) is already *de minimis*.

This paper shows that the DO-327 interference model overestimated the received PSD by approximately 15 dB by not accounting for the reduction of OOBE caused by UE power control, and 17 dB by assuming that all UEs active (powered on) in a cell, whether idling or transmitting, are emitting OOBE at the maximum PSD level of -90 dBW/MHz. Thus there is an approximately 32 dB overestimation of the OOBE PSD in the present interference model. In other words, significant additional margin exists beyond the initial analysis performed by RTCA. This margin would be increased by an additional 5 dB if the OOBE level were -95 dBW/MHz, rather than the -90 dBW/MHz assumed in DO-327.

References

[1] RTCA DO-327, Assessment of LightSquared Ancillary Component Radio Frequency Interference Impact on GNSS L1 Band Airborne Receiver Operations, June 3, 2011.

[2] Commerce Spectrum Management Advisory Committee Final Report, Working Group 1 – 1695-1710 MHz Meteorological-Satellite, January 22, 2013.

Appendix 5

Potential for Interference to Aviation GPS from LightSquared User Equipment:

Nearby Users Scenario

Potential for Interference to Aviation GPS from LightSquared User Equipment: *Nearby Users Scenario*

1.0 Problem Statement

The scenarios analyzed here involve use of LightSquared user equipment (UE), such as mobile phones, close to an aircraft with the minimal likely (based on real world usage) pathloss to a GPS antenna. Two such scenarios were identified, as illustrated in Figures 1 and 2 below.

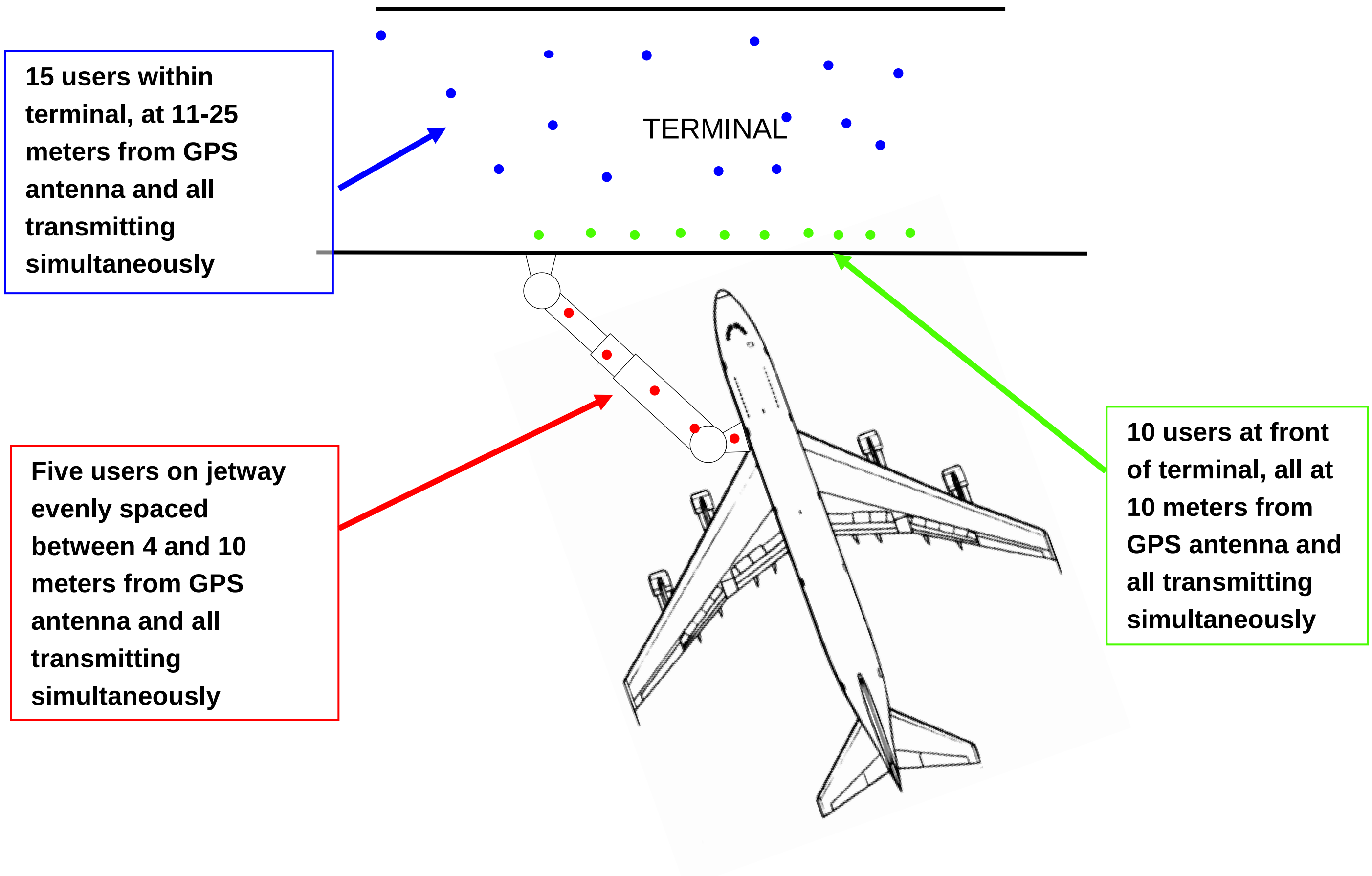
In Figure 1, a user at the top of the aircraft stairs is about to enter the passenger cabin and is utilizing a LightSquared UE.

Figure 1 Single user operating UE at the top of aircraft stairs

The user is assumed to be in clear line of sight of the GPS antenna, although this may not always be the case, given the locations of the antenna relative to the door, the overall height of the aircraft as well as the height of the user and location and orientation of the UE. Nevertheless, a minimum separation distance of 3 m from the GPS antenna is postulated. Only a single user is considered in this situation, as other users could not have line of sight to the GPS antenna at such a short distance.

Figure 2 shows the second scenario analyzed. Here, multiple users (represented as dots) are located at various distances from an aircraft parked at the gate.

Figure 2 Thirty users operating UEs at various distances from aircraft (Note: diagram is not to scale)



2.0 Analysis

2.1 Single User at Top of Aircraft Stairs

The scenario assumptions and link calculations are given below.

2.1.1 Maximum UE Power

The maximum operational UE power was assumed to be 20 dBm. This corresponds to the CSMAC assumption [2], which is based on 23 dBm as the maximum rated PA power (as per 3GPP LTE specifications) and an assumed, average UE antenna gain of – 3dBi. It is noteworthy that the value is slightly more conservative than the -4dBi average UE antenna gain allowed by the FCC in the 2003 ATC Order and the 5 dB coupling loss assumed by the TWG cellular subgroup for GPS antennas in handsets.

2.1.2 Uplink power control

The 95% point of the CDF curve for suburban environments is 10.5 dBm. This corresponds to a 9.5 dB power control backoff relative to the maximum operational UE power of 20 dBm.

2.1.3 Antenna coupling loss

A net antenna coupling loss of 10 dB relative to isotropic transmit and receive antennas is booked. The rationale is provided below in Sections 2.1.3.1 and 2.1.3.2.

2.1.3.1 UE antenna gain towards GPS antenna

A device antenna coupling loss of 3 dB, relative to an isotropic radiator, is built into the CSMAC UE power distribution, so is not counted again.

2.1.3.2 GPS antenna gain towards UE

Using the representative pattern of an aviation GPS antenna provided in RTCA DO-235B, Fig. G-13, a gain of -10 dBi is booked conservatively for elevation angles lower than -30^0 relative to the horizon. It is noteworthy that this is the gain for vertical polarization; the gain for horizontal polarization is much lower. Depending on how the phone is held by the user and owing to multipath reflections, some of the radiated power will be received with horizontal polarization.

2.1.4 Number of simultaneously transmitting devices

This scenario involves a single user at the top of the aircraft stairs. It does not appear possible to have more than a single user at this particular location.

2.1.5 Separation distance from UE to GPS receiver

The separation distance was assumed to be 3 m. It will be noted that this is conservative as, in many cases, the GPS antenna will not be located so close to the cabin door on an aircraft. Further, it is not clear how frequently a user operating a UE at this location would have line of sight to the aircraft's GPS antenna. However, the statistical improbability of such an occurrence is not factored into the use-case analysis.

2.1.6 OOBE PSD from UE

The example in Table 1 assumes -95 dBW/MHz.

2.1.7 OOBE threshold at the GPS receiver

The OOBE threshold used is -206.5 dBW/Hz, as per RTCA DO-229D.

2.1.8 Overload threshold at the GPS receiver

The overload threshold used is -16.7 dBm, as per RTCA DO-229D for a CW signal at 1626.5 MHz.

2.1.9 Link Calculations

Table 1 shows the link calculations for the single user case.

Table 1 Link calculations: single user at the top of aircraft stairs (illustrated in Fig. 1)

Parameter	Value	Unit	Note
Max UE Tx EIRP	20	dBm	Maximum as per CSMAC simulation (-3 dBi average UE antenna gain)
UE Maximum OOBE PSD (select)	-95	dBW/MHz	ATC Order minimum requirement after 5 years
Uplink power control factor	9.5	dB	95% point of CSMAC CDF
Rx Antenna Coupling loss	10	dB	-10 dBi gain of GPS antenna
Tx/Rx Distance	3	Meters	Minimum plausible distance for use case
Path loss to GPS antenna	46.2	dB	Free Space
OOBE received by GPS antenna	-223.7	dBW/Hz	Assumes dB-for-dB reduction of OOBE PSD with fundamental tx power
MOPS OOBE limit	-206.5	dBW/Hz	RTCA DO-229D
OOBE Margin	17.2	dB	
Adjacent band power received	-45.7	dBm	
Overload limit	-16.7	dBm	RTCA DO-229D
Overload margin	29.0	dB	

2.2 Multiple users inside airport near plane parked at gate

The scenario assumptions and link calculations are given below.

2.2.1 Maximum UE Power

The maximum operational UE power was assumed to be 20 dBm. This corresponds to the CSMAC assumption [2], which is based on 23 dBm as the maximum rated PA power (as per 3GPP LTE specifications) and an assumed, average UE antenna gain of – 3dBi. It is noteworthy that the value is similar to the -4dBi average UE antenna gain allowed by the FCC in the 2003 ATC Order and the 5 dB coupling loss assumed by the TWG cellular subgroup for GPS antennas in handsets.

2.2.2 Uplink power control

The 95% point of the CDF curve for suburban environments is 10.5 dBm. This corresponds to a 9.5 dB power control backoff relative to the maximum operational UE power of 20 dBm. In reality, the uplink power control factor will be reduced by the airport's building penetration loss (for a base station external to the airport, as is typical at smaller airports) resulting in an increase of UE power. However, the shielding by the building will cause a similar reduction of the power radiated from the UE before it reaches the GPS antenna. As these two effects will largely cancel, the building penetration loss is ignored.

2.2.3 Antenna coupling loss

A net antenna coupling loss of 3 dB relative to isotropic transmit and receive antennas is booked. The rationale is provided below in Sections 2.2.3.1 and 2.2.3.2.

2.2.3.1 UE antenna gain towards GPS antenna

A device antenna coupling loss of 3 dB, relative to an isotropic radiator, is built into the CSMAC UE power distribution, so is not counted again.

2.2.3.2 GPS antenna gain towards UE

Using the pattern of an aviation GPS antenna provided in RTCA DO-235B, Fig. G-13, an antenna gain of -3 dBi is booked conservatively for elevation angles lower than 45^0 relative to the horizon.

2.2.4 Number of simultaneously transmitting devices

It is assumed that thirty LightSquared users are transmitting simultaneously at constant power (as detailed above) at varying distances from an aircraft parked at the gate and that their powers add at the GPS receiver. Specifically, five users are operating units on the jetway at a distance of 4-10 meters from the GPS antenna;

10 users are facing the aircraft at the front glass of the terminal building at a distance of 10 meters from the GPS antenna and an additional 15 users are further within the terminal at a distance of 11-25 meters from the GPS antenna. These are extremely conservative assumptions, both in terms of the number of active users within the separation distances and in terms of the likelihood of power addition at the GPS receiver. The latter likelihood is low because the TDMA component of the LTE protocol will, with very high probability, assign non-overlapping transmit-time epochs to the users. Indeed the CSMAC working groups assumed six simultaneous users per cell sector for its modeling assumptions. LightSquared chose to use a much higher number of users in this instance to demonstrate the substantial margin that exists overall for this type of use case. It should be noted that the pathloss for distances beyond 10 meters is such that users operating in that realm would not contribute significantly to the interference power at the GPS antenna. This follows from the fact that the pathloss varies as the square of the distance but received power (even in the case where the received power is assumed to be cumulative) varies linearly with the number of users.

2.2.5 Separation distance from UE to GPS receiver

As noted above, the separation distances vary from 4-25 meters.

2.2.6 OOBE PSD from UE

The example in Table 2 assumes -95 dBW/MHz.

2.2.7 OOBE threshold at the GPS receiver

The OOBE threshold used is -206.5 dBW/Hz, as per RTCA DO-229D.

2.2.8 Overload threshold at the GPS receiver

The overload threshold used is -16.7 dBm, as per RTCA DO-229D for a CW signal at 1626.5 MHz.

2.2.9 Link Calculations

Table 2 shows the link calculations for the multiple users case.

Table 2 Link calculations: Multiple users inside airport near plane parked at gate (illustrated in Fig. 2)

Parameter	Value	Unit	Note
Max UE Tx EIRP	20	dBm	Maximum as per CSMAC simulation (-3 dBi average UE antenna gain)
UE OOBE (select)	-95	dBW/MHz	ATC Order minimum requirement after 5 years
Uplink power control factor	9.5	dB	95% point of CSMAC CDF
Jetway User # 1 Path loss	48.8	dB	(1) Power addition for multiple users is extremely unlikely owing to strong TDMA component in LTE uplink (2) Assumes dB-for-dB reduction of OOBE PSD with fundamental Tx power
Jetway User # 1 Rx ant Coupling loss	6.17	dB	
OOBE received by GPS antenna	-222.4	dBW/Hz	
Adjacent band power received	-44.4	dBm	
Jetway User # 2 Path loss	51.5	dB	
Jetway User # 2 Rx ant Coupling loss	5.83	dB	
OOBE received by GPS antenna	-224.8	dBW/Hz	
Adjacent band power received	-46.8	dBm	
Jetway User # 3 Path loss	53.6	dB	
Jetway User # 3 Rx ant Coupling loss	5.67	dB	
OOBE received by GPS antenna	-226.8	dBW/Hz	
Adjacent band power received	-48.8	dBm	
Jetway User # 4 Path loss	55.3	dB	
Jetway User # 4 Rx ant Coupling loss	5.5	dB	
OOBE received by GPS antenna	-228.3	dBW/Hz	
Adjacent band power received	-50.3	dBm	
Jetway User # 5 Path loss	56.7	dB	
Jetway User # 5 Rx ant Coupling loss	5.5	dB	
OOBE received by GPS antenna	-229.7	dBW/Hz	
Adjacent band power received	-51.7	dBm	
OOBE received by GPS antenna from all Jet way UEs (5)	-218.6	dBW/Hz	
Adjacent band power received from all Jet way UEs (5)	-40.6	dBm	
Number of UE transmitting simultaneously in terminal, all spaced at 10 meters from GPS antenna	10	#	Power addition for multiple users is extremely unlikely owing to strong TDMA component in LTE uplink
Mean Path loss to GPS antenna	56.7	dB	Free Space propagation
Rx antenna Coupling loss	3.0	dB	
OOBE received by GPS antenna from all Terminal UEs (5)	-217.2	dBW/Hz	Assumes dB-for-dB reduction of OOBE PSD with fundamental tx power
Adjacent band power received from all Terminal UEs (5)	-39.2	dBm	
Number of UE transmitting simultaneously in terminal, evenly spaced 10 - 25 meters from GPS antenna	15	#	Power addition for multiple users is extremely unlikely owing to strong TDMA component in LTE uplink
Mean Path loss to GPS antenna	62.0	dB	Free Space propagation
Rx antenna Coupling loss	3.0	dB	
OOBE received by GPS antenna from all Terminal UEs (15)	-220.7	dBW/Hz	Assumes dB-for-dB reduction of OOBE PSD with fundamental tx power
Adjacent band power received from all Terminal UEs (15)	-42.7	dBm	
Total OOBE received by GPS antenna	-213.8	dBW/Hz	
Total Adjacent band power received	-35.8	dBm	
MOPS OOBE limit	-206.5	dBW/Hz	RTCA DO-229D
OOBE Margin	7.3	dB	
Overload limit	-16.7	dBm	RTCA DO-229D
Overload margin	19.1	dB	

3.0 Conclusions

The risk of interference is low for both scenarios, as significant margins exist for both OOBE and overload interference mechanisms.

This analysis ignored many real world factors, which would substantially increase the margin further. Some examples are provided below.

- Duty cycle. The present analysis assumes 100% duty cycle. Except for the case of data users uploading large files or uploading streaming media in lightly loaded sectors, the duty cycle will be well below 100%. As LTE transmit time epochs are small compared to the response time of GPS receivers, the latter will be sensitive to the average, not peak, power of the uplink transmissions. This means that a 50% duty cycle will result in a 3 dB reduction of average power.
- Practical limits on simultaneous users at full power. It is widely recognized that communications networks are not able to support large number users operating simultaneously at full power on the same sector. The present analysis assumes 30 simultaneous users whereas CSMAC has chosen to use six as the typical number. Reductions in the number of simultaneous users will reduce the aggregate interference power level at the GPS antenna.
- User body loss was not considered in the CSMAC simulations and is not counted here either. It is generally recognized that 3 dB of body loss is typical [3].

References

[1] RTCA DO-235B, Appendix E, Section E.6.3.

[2] Commerce Spectrum Management Advisory Committee Final Report, Working Group 1 – 1695-1710 MHz Meteorological-Satellite, January 22, 2013.

[3] FCC 03-15, 2003 ATC Order, Appendix C2, Section 1.2.1, p. 182.