Appendix H.1.10

High Precision Receivers - NAVAIR Anechoic Chamber Test Results

Anechoic Chamber Phase 0 Test (F5H)

Figure 1 displays the LTE F5H power levels of the turning point where the receiver's L1 tracking channel experienced a decrease of its C/N_0 measurement as compared to the reference receiver outside the chamber.

90%	Red arrow	Power when 90% of the receivers lose 1 dB in L1 C/N_0	-49 dBm
50%	Green arrow	Power when 50% of the receivers lose 1 dB in L1 C/N_0	-56 dBm
10%	Purple arrow	Power when 10% of the receivers lose 1 dB in L1 C/N_0	-82 dBm

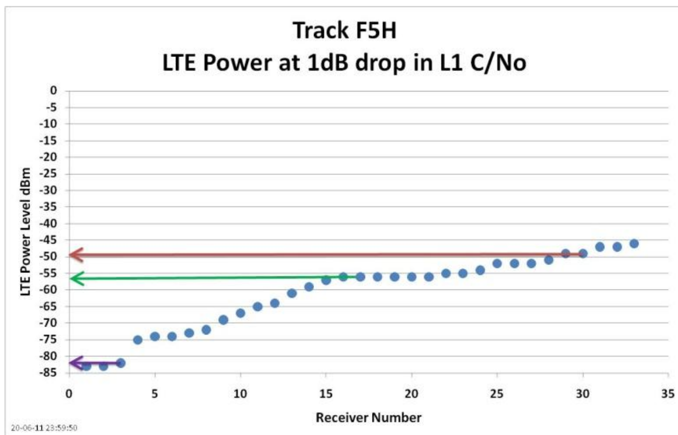


Figure 1 F5H Power at 1 dB Loss of L1 C/N_0

Figure 2 displays the F5H power levels of when the receivers lose lock on all satellites.

90%	Red arrow	Power when 90% of the receivers lose lock on all sats	-30 dBm
50%	Green arrow	Power when 50% of the receivers lose lock on all sats	-42 dBm
10%	Purple arrow	Power when 10% of the receivers lose lock on all sats	-61 dBm

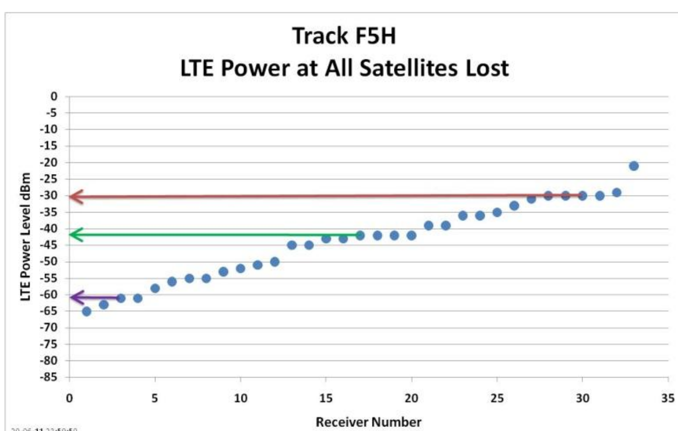


Figure 2 F5H Power at Loss of All Satellites

This class of high precision receivers uses proprietary semi-codeless tracking techniques. These tracking techniques require some signal components and aiding from the GPS L1 signal. If there are any interfering signals on either the GPS L1 or GPS L2 signal, then the measured value of the GPS L2 tracking channel will be also be affected. Figure 3 displays the F5H power levels of the turning point where the receiver's L2 tracking channel experiences a decrease of its C/N_0 measurement as compared to the reference receiver outside the chamber.

90%	Red arrow	Power when 90% of the receivers lose 1 dB in L2 C/N_0	-45 dBm
50%	Green arrow	Power when 50% of the receivers lose 1 dB in L2 C/N_0	-56 dBm
10%	Purple arrow	Power when 10% of the receivers lose 1 dB in L2 C/N_0	-78 dBm

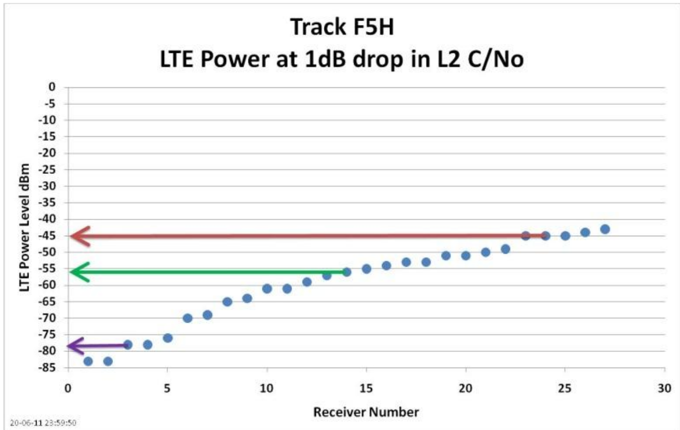


Figure 3 F5H Power at 1 dB Loss of L2 C/N0

Figure 4 displays the F5H power levels of when the receivers lose their ability to compute autonomous position.

90%	Red arrow	Power when 90% of the receivers lose position	-35 dBm
50%	Green arrow	Power when 50% of the receivers lose position	-45 dBm
10%	Purple arrow	Power when 10% of the receivers lose position	-68 dBm

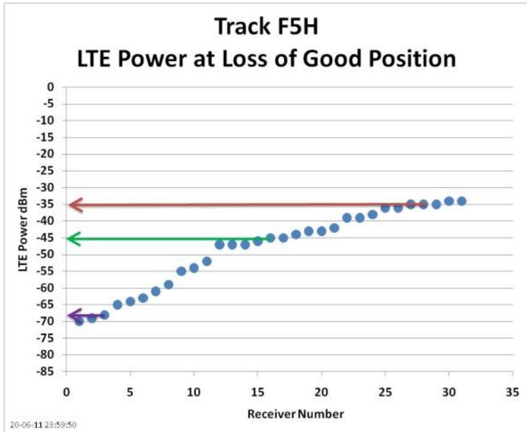


Figure 4 F5H Power at Loss of Good Position

Figure 5 displays the F5H power levels of when the receivers lose their ability to compute RTK positions.

90%	Red arrow	Power when 90% of the receivers lose RTK position	-38 dBm
50%	Green arrow	Power when 50% of the receivers lose RTK position	-47 dBm
10%	Purple arrow	Power when 10% of the receivers lose RTK position	-69 dBm

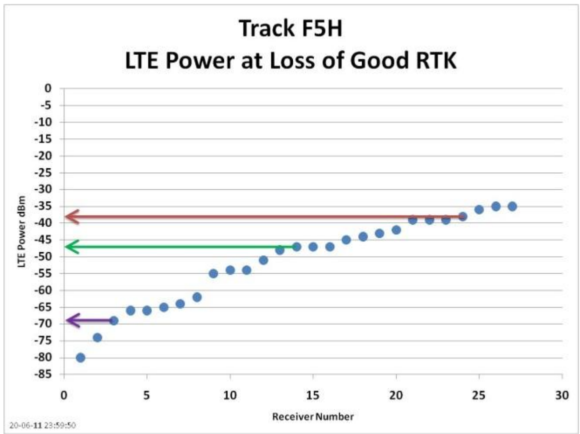


Figure 5 F5H Power at Loss of Good RTK

Figure 6 shows the F5H power level when the receivers experience more than 3dB loss in sensitivity.

90%	Red arrow	Power when 90% of the receivers lose 3 dB Sensitivity	-45 dBm
50%	Green arrow	Power when 50% of the receivers lose 3 dB Sensitivity	-60 dBm
10%	Purple arrow	Power when 10% of the receivers lose 3 dB Sensitivity	-70 dBm

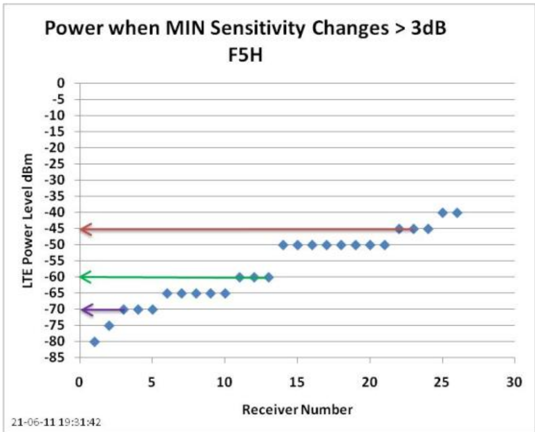


Figure 6 F5H Power at Change in Sensitivity

Figure 7 shows the LTE F5H power levels when the receiver's ability to reacquire signals from GPS satellites is affected.

90%	Red arrow	Power when 90% of the receivers can't reacquire sats	-35 dBm
50%	Green arrow	Power when 50% of the receivers can't reacquire sats	-45 dBm
10%	Purple arrow	Power when 10% of the receivers can't reacquire sats	-55 dBm

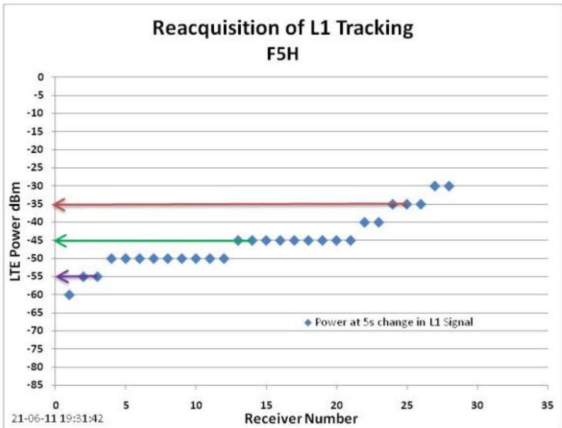


Figure 7 F5H Power for Reacquisition

Figure 8 shows the LTE F5H power levels when the receiver's ability to acquire signals from GPS satellites is affected.

90%	Red arrow	Power when 90% of the receivers can't acquire sats	-45 dBm
50%	Green arrow	Power when 50% of the receivers can't acquire sats	-55 dBm
10%	Purple arrow	Power when 10% of the receivers can't acquire sats	-75 dBm

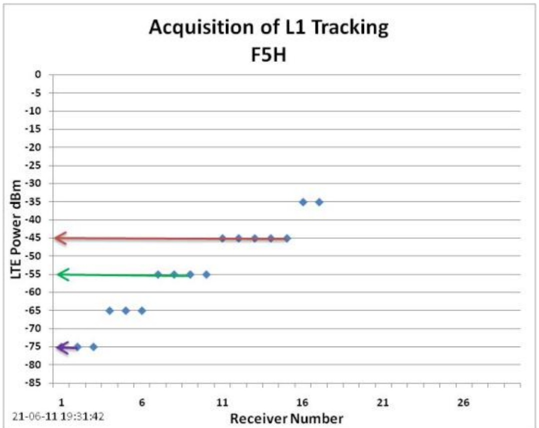


Figure 8 F5H Power for Acquisition

Anechoic Chamber Phase 1 Test (F5L + F5H)

Figure 9 displays the LTE F5L+F5H power levels at the turning point where the receiver's L1 tracking channel experiences a decrease of its C/N_0 measurement as compared to the reference receiver outside the chamber.

90%	Red arrow	Power when 90% of the receivers lose 1 dB in L1 C/N_0	-57 dBm
50%	Green arrow	Power when 50% of the receivers lose 1 dB in L1 C/N_0	-66 dBm
10%	Purple arrow	Power when 10% of the receivers lose 1 dB in L1 C/N_0	-82 dBm

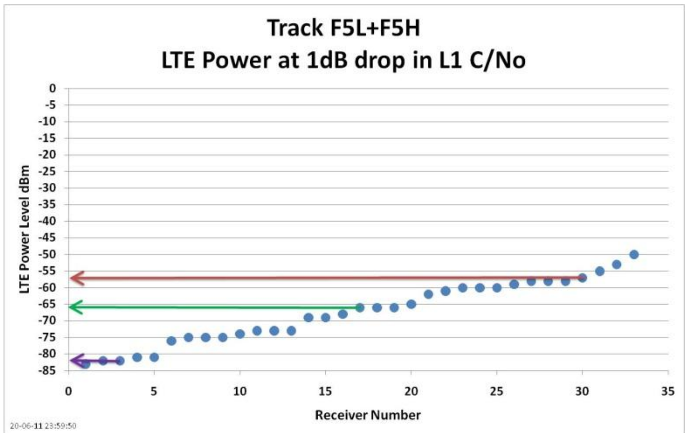


Figure 9 F5L+F5H Power at 1 dB Loss of L1 C/No

Figure 10 displays the LTE F5L+F5H power levels of when the receivers lose lock on all satellites.

90%	Red arrow	Power when 90% of the receivers lose lock on all sats	-44 dBm
50%	Green arrow	Power when 50% of the receivers lose lock on all sats	-54 dBm
10%	Purple arrow	Power when 10% of the receivers lose lock on all sats	-65 dBm

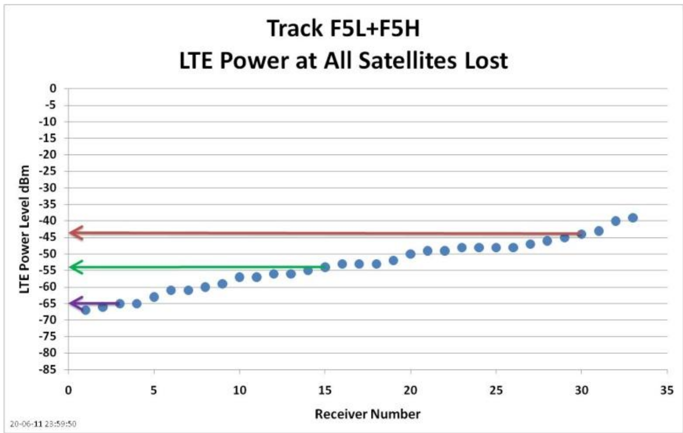


Figure 10 F5L+F5H Power at Loss of Satellites

This class of high precision receivers uses proprietary semi-codeless tracking techniques. These tracking techniques require some signal components and aiding from the GPS L1 signal. If there are any interfering signals on either the GPS L1 or GPS L2 signal, then the measured value of the GPS L2 tracking channel will be also be affected. Figure 11 displays the LTE F5L+F5H power levels at the turning point where the receiver's L2 tracking channel experiences a decrease of its C/N_0 measurement as compared to the reference receiver outside the chamber.

90%	Red arrow	Power when 90% of the receivers lose 1 dB in L2 C/N_0	-55 dBm
50%	Green arrow	Power when 50% of the receivers lose 1 dB in L2 C/N_0	-63 dBm
10%	Purple arrow	Power when 10% of the receivers lose 1 dB in L2 C/N_0	-83 dBm

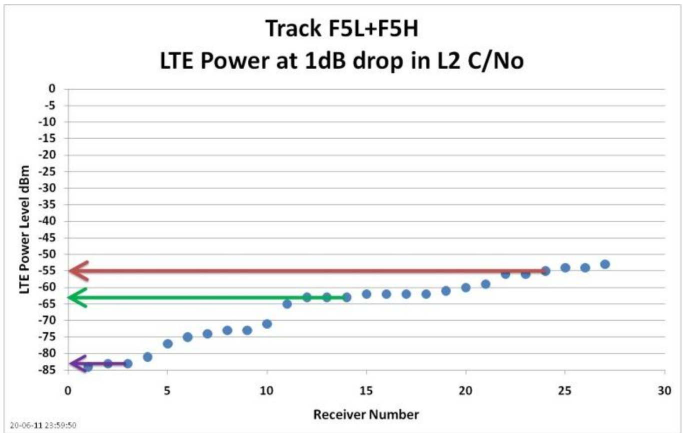


Figure 11 F5L+F5H Power at 1 dB Loss of L2 C/N0

Figure 12 displays the LTE F5L+F5H power levels at which the receivers lose their ability to compute autonomous position.

90%	Red arrow	Power when 90% of the receivers lose position	-49 dBm
50%	Green arrow	Power when 50% of the receivers lose position	-58 dBm
10%	Purple arrow	Power when 10% of the receivers lose position	-70 dBm

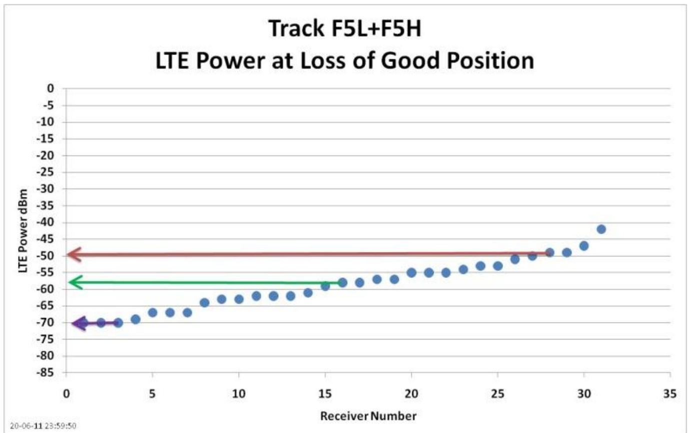


Figure 12 F5L+F5H Power at Loss of Good Position

Figure 13 displays the LTE F5L+F5H power levels at which the receivers lose their ability to compute RTK positions.

90%	Red arrow	Power when 90% of the receivers lose RTK position	-50 dBm
50%	Green arrow	Power when 50% of the receivers lose RTK position	-58 dBm
10%	Purple arrow	Power when 10% of the receivers lose RTK position	-70 dBm

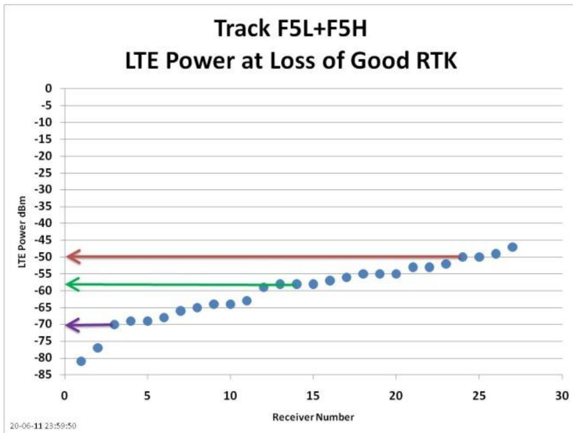


Figure 13 F5L+F5H Power at Loss of Good RTK

Figure 14 shows the F5L+F5H power level where the receivers experience more than 3dB loss in sensitivity.

90%	Red arrow	Power when 90% of the receivers lose 3 dB Sensitivity	-50 dBm
50%	Green arrow	Power when 50% of the receivers lose 3 dB Sensitivity	-60 dBm
10%	Purple arrow	Power when 10% of the receivers lose 3 dB Sensitivity	-75 dBm

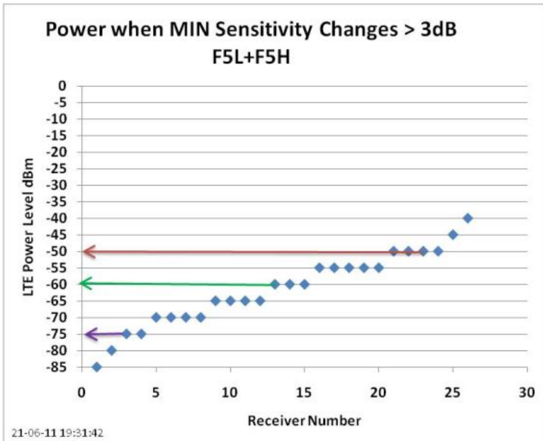


Figure 14 F5L+F5H Power at Change in Sensitivity

Figure 15 shows the LTE F5L+F5H power levels where the receiver's ability to reacquire signals from GPS satellites was impaired.

90%	Red arrow	Power when 90% of the receivers can't reacquire sats	-45 dBm
50%	Green arrow	Power when 50% of the receivers can't reacquire sats	-55 dBm
10%	Purple arrow	Power when 10% of the receivers can't reacquire sats	-75 dBm

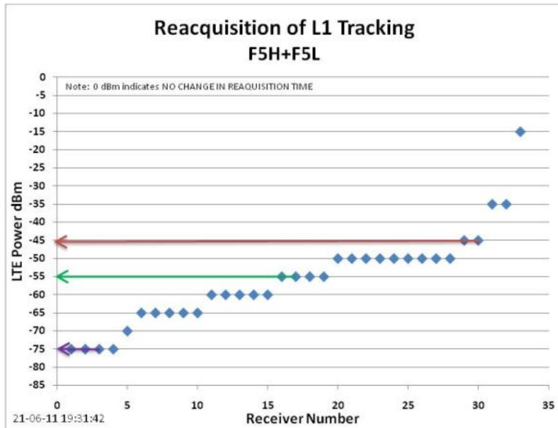


Figure 15 F5L+F5H Power for Reacquisition

Figure 16 shows the LTE F5L+F5H power levels where the receiver's ability to acquire signals from GPS satellites was impaired.

90%	Red arrow	Power when 90% of the receivers can't acquire sats	-45 dBm
50%	Green arrow	Power when 50% of the receivers can't acquire sats	-55 dBm
10%	Purple arrow	Power when 10% of the receivers can't acquire sats	-75 dBm

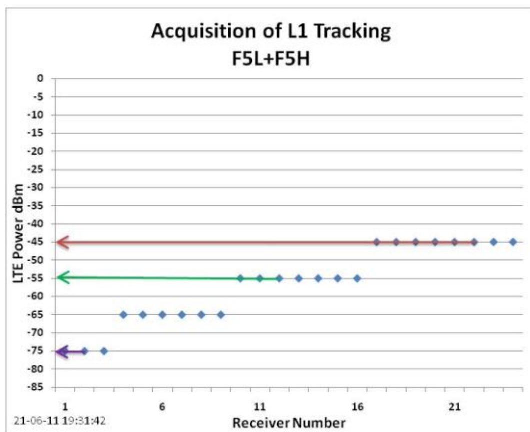


Figure 16 F5L+F5H Power for Acquisition

Anechoic Chamber Phase 2 Test (F10L + F10H)

Figure 17 displays the F10L+F10H power levels of the turning point where the receiver's tracking channel experiences a decrease of its L1 C/N_0 measurement as compared to the reference receiver outside the chamber.

90%	Red arrow	Power when 90% of the receivers lose 1 dB in L1 C/N_0	-55 dBm
50%	Green arrow	Power when 50% of the receivers lose 1 dB in L1 C/N_0	-72 dBm
10%	Purple arrow	Power when 10% of the receivers lose 1 dB in L1 C/N_0	-83 dBm

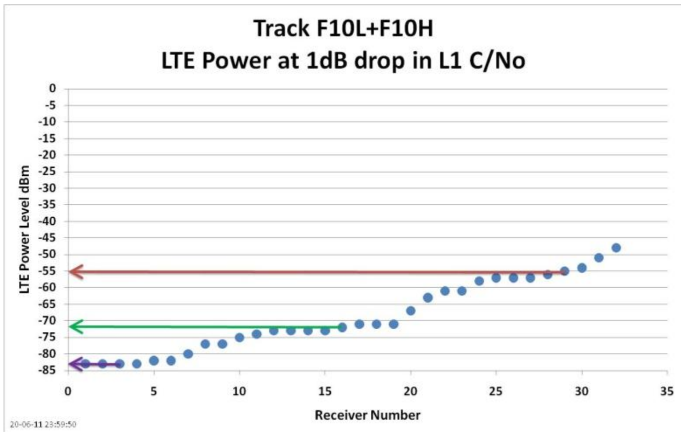


Figure 17 F10L+F10H Power at 1 dB Loss of L1 C/N0

Figure 18 displays the LTE F10L+F10H power levels at which the receivers lose lock on all satellites.

90%	Red arrow	Power when 90% of the receivers lose lock on all sats	-43 dBm
50%	Green arrow	Power when 50% of the receivers lose lock on all sats	-50 dBm
10%	Purple arrow	Power when 10% of the receivers lose lock on all sats	-63 dBm

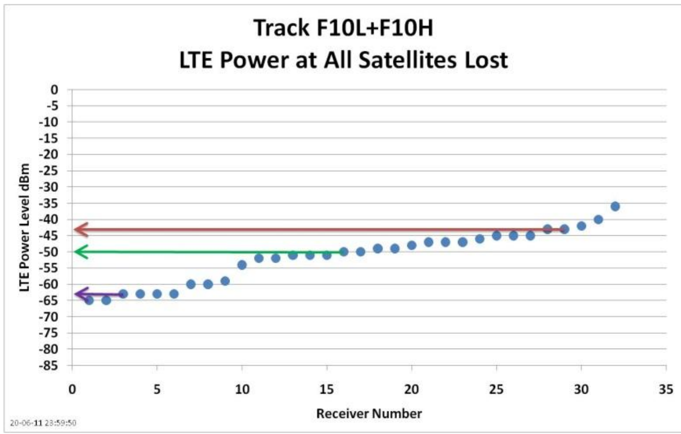


Figure 18 F10L+F10H Power at Loss of Satellites

This class of high precision receivers uses proprietary semi-codeless tracking techniques. These tracking techniques require some signal components and aiding from the GPS L1 signal. If there are any interfering signals on either the GPS L1 or GPS L2 signal, then the measured value of the GPS L2 tracking channel will be also be affected. Figure 19 displays the LTE F10L+F10H power levels of the turning point where the receiver's L2 tracking channel experiences a decrease of its C/N_0 measurement as compared to the reference receiver outside the chamber.

90%	Red arrow	Power when 90% of the receivers lose 1 dB in L2 C/N_0	-53 dBm
50%	Green arrow	Power when 50% of the receivers lose 1 dB in L2 C/N_0	-61 dBm
10%	Purple arrow	Power when 10% of the receivers lose 1 dB in L2 C/N_0	-77 dBm

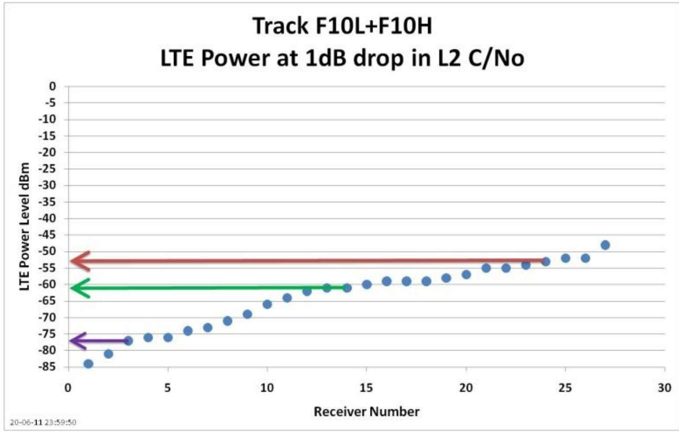


Figure 19 F10L+F10H Power at 1 dB Loss of L2 C/No

Figure 20 displays the LTE F10L+F10H power levels where the receivers lose their ability to compute autonomous position.

90%	Red arrow	Power when 90% of the receivers lose position	-47 dBm
50%	Green arrow	Power when 50% of the receivers lose position	-53 dBm
10%	Purple arrow	Power when 10% of the receivers lose position	-67 dBm

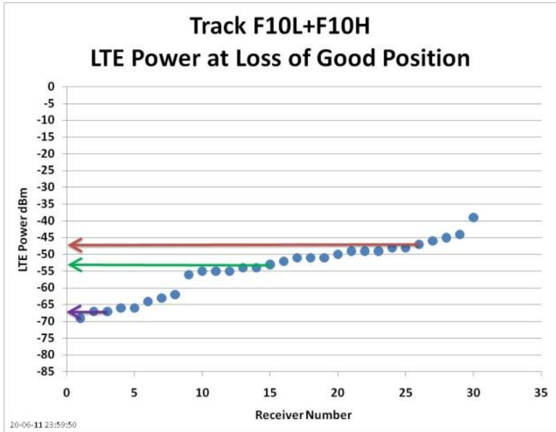


Figure 20 F10L+F10H Power at Loss of Good Position

Figure 21 displays the LTE F10L+F10H power levels where the receivers lose their ability to compute RTK positions.

90%	Red arrow	Power when 90% of the receivers lose RTK position	-47 dBm
50%	Green arrow	Power when 50% of the receivers lose RTK position	-55 dBm
10%	Purple arrow	Power when 10% of the receivers lose RTK position	-69 dBm

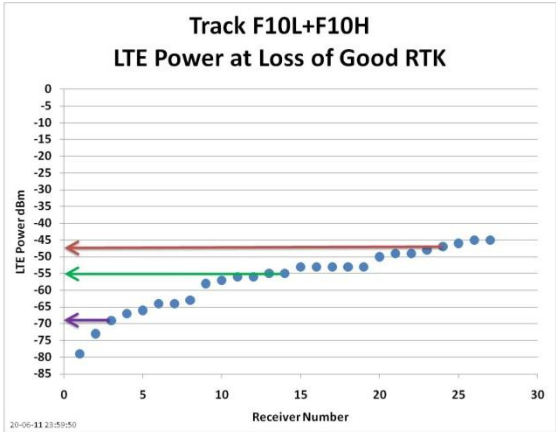


Figure 21 F10L+F10H Power at Loss of Good RTK

Figure 22 shows the LTE F10L+F10H power level where the receivers experience more than 3 dB loss in sensitivity.

90%	Red arrow	Power when 90% of the receivers lose 3 dB Sensitivity	-50 dBm
50%	Green arrow	Power when 50% of the receivers lose 3 dB Sensitivity	-65 dBm
10%	Purple arrow	Power when 10% of the receivers lose 3 dB Sensitivity	-70 dBm

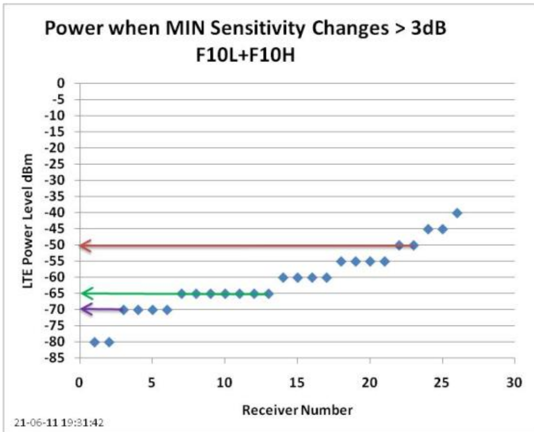


Figure 22 F10L+F10H Power at Change in Sensitivity

Figure 23 shows the LTE F10L+F10H power levels where the receiver’s ability to reacquire signals from GPS satellites was impaired.

90%	Red arrow	Power when 90% of the receivers can’t reacquire sats	-40 dBm
50%	Green arrow	Power when 50% of the receivers can’t reacquire sats	-55 dBm
10%	Purple arrow	Power when 10% of the receivers can’t reacquire sats	-70 dBm

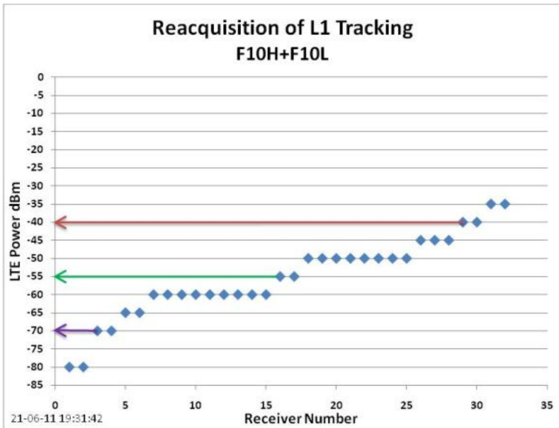


Figure 23 F10L+F10H Power for Reacquisition

Figure 24 shows the LTE F10L+F10H power levels where the receiver's ability to acquire signals from GPS satellites was impaired.

90%	Red arrow	Power when 90% of the receivers can't acquire sats	-45 dBm
50%	Green arrow	Power when 50% of the receivers can't acquire sats	-65 dBm
10%	Purple arrow	Power when 10% of the receivers can't acquire sats	-75 dBm

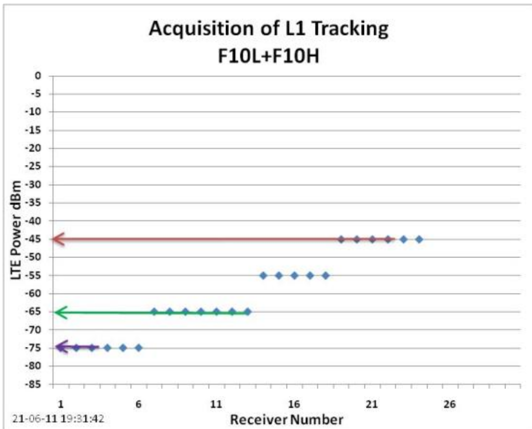


Figure 24 F10L+F10H Power for Acquisition

Anechoic Chamber Test (Handset)

Figure 25 displays the Handset power levels of the turning point where the receiver's tracking channel experiences a decrease of its L1 C/N_0 measurement as compared to the reference receiver outside the chamber.

90%	Red arrow	Power when 90% of the receivers lose 1 dB in L1 C/N_0	Not Observed
50%	Green arrow	Power when 50% of the receivers lose 1 dB in L1 C/N_0	-41 dBm
10%	Purple arrow	Power when 10% of the receivers lose 1 dB in L1 C/N_0	-77 dBm

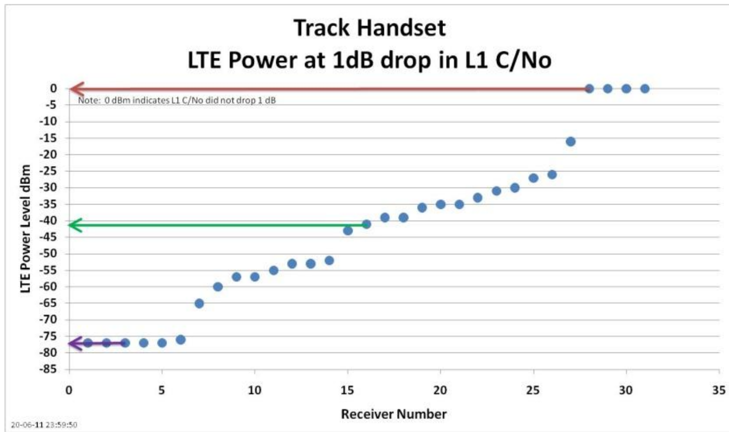


Figure 25 Handset Power at 1 dB Loss of L1 C/N0

Figure 26 displays the Handset power levels where the receivers lose lock on all satellites.

90%	Red arrow	Power when 90% of the receivers lose lock on all sats	Not Observed
50%	Green arrow	Power when 50% of the receivers lose lock on all sats	-22 dBm
10%	Purple arrow	Power when 10% of the receivers lose lock on all sats	-39 dBm

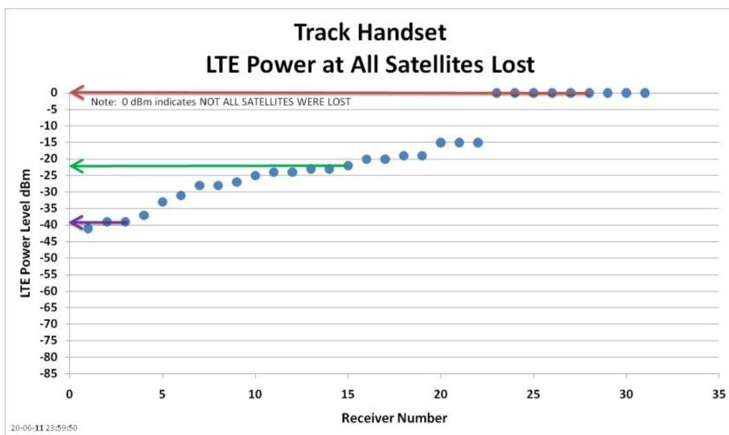


Figure 26 Handset Power at Loss of Satellites

This class of high precision receivers uses proprietary semi-codeless tracking techniques. These tracking techniques require some signal components and aiding from the GPS L1 signal. If there are any interfering signals on either the GPS L1 or GPS L2 signal, then the measured value of the GPS L2 tracking channel will be also be affected. Figure 27 displays the Handset power levels of the turning point where the receiver's L2 tracking channel experiences a 1 dB decrease of its C/N_0 measurement as compared to the reference receiver outside the chamber.

90%	Red arrow	Power when 90% of the receivers lose 1 dB in L2 C/N_0	-29 dBm
50%	Green arrow	Power when 50% of the receivers lose 1 dB in L2 C/N_0	-41 dBm
10%	Purple arrow	Power when 10% of the receivers lose 1 dB in L2 C/N_0	-63 dBm

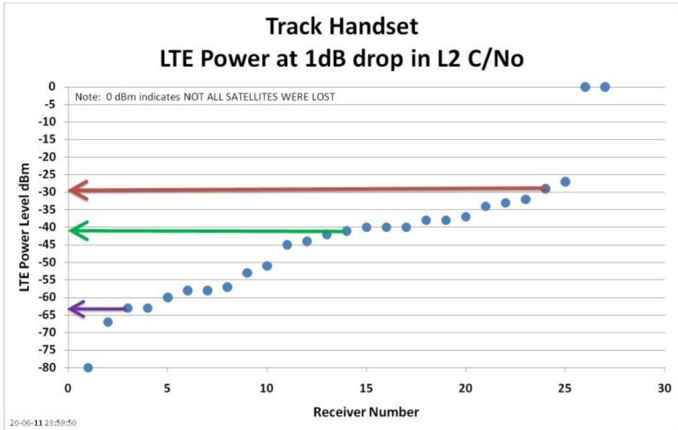


Figure 27 Handset Power at 1 dB Loss of L2 C/N0

Figure 28 displays the Handset power levels where the receivers lose their ability to compute autonomous position.

90%	Red arrow	Power when 90% of the receivers lose position	Not Observed
50%	Green arrow	Power when 50% of the receivers lose position	-26 dBm
10%	Purple arrow	Power when 10% of the receivers lose position	-43 dBm

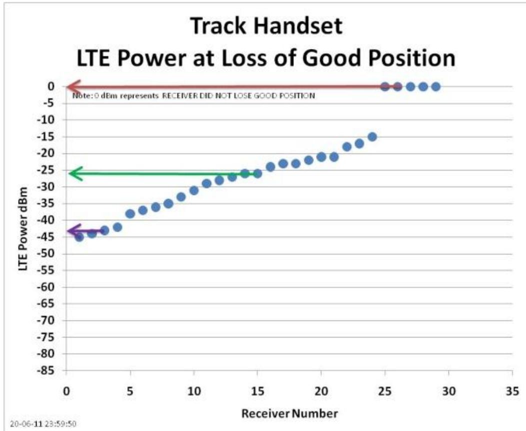


Figure 28 Handset Power at Loss of Good Position

Figure 29 displays the Handset power levels where the receivers lose their ability to compute RTK positions.

90%	Red arrow	Power when 90% of the receivers lose RTK position	-15 dBm
50%	Green arrow	Power when 50% of the receivers lose RTK position	-27 dBm
10%	Purple arrow	Power when 10% of the receivers lose RTK position	-46 dBm

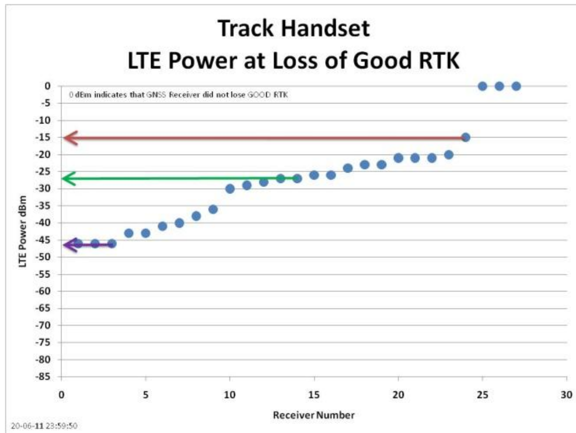


Figure 29 Handset Power at Loss of Good RTK

Anechoic Chamber Test (F10L)

Figure 30 displays the LTE F10L power levels of the turning point where the receiver's tracking channel experiences a decrease of its L1 C/N_0 measurement as compared to the reference receiver outside the chamber.

90%	Red arrow	Power when 90% of the receivers lose 1 dB in L1 C/N_0	-25 dBm
50%	Green arrow	Power when 50% of the receivers lose 1 dB in L1 C/N_0	-43 dBm
10%	Purple arrow	Power when 10% of the receivers lose 1 dB in L1 C/N_0	-67 dBm

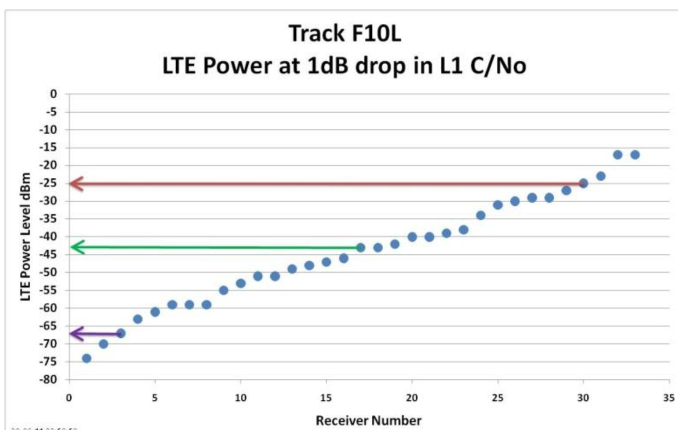


Figure 30 F10L Power at 1 dB Loss of L1 C/N0

Figure 31 displays the LTE F10L power levels where the receivers lose lock on all satellites.

90%	Red arrow	Power when 90% of the receivers lose lock on all sats	Not Observed
50%	Green arrow	Power when 50% of the receivers lose lock on all sats	-28 dBm
10%	Purple arrow	Power when 10% of the receivers lose lock on all sats	-54 dBm

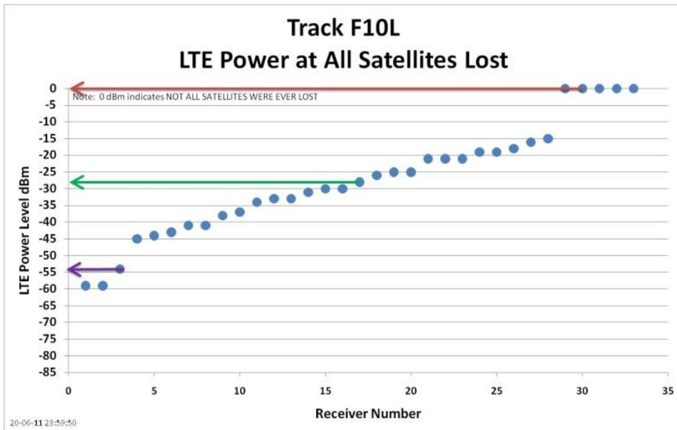


Figure 31 F10L Power at Loss of Satellites

This class of high precision receivers uses proprietary semi-codeless tracking techniques. These tracking techniques require some signal components and aiding from the GPS L1 signal. If there are any interfering signals on either the GPS L1 or GPS L2 signal, then the measured value of the GPS L2 tracking channel will be also be affected. Figure 32 displays the LTE F10L power levels of the turning point where the receiver's L2 tracking channel experiences a decrease of 1 dB in its C/N_0 measurement as compared to the reference receiver outside the chamber.

90%	Red arrow	Power when 90% of the receivers lose 1 dB in L2 C/N_0	-24 dBm
50%	Green arrow	Power when 50% of the receivers lose 1 dB in L2 C/N_0	-43 dBm
10%	Purple arrow	Power when 10% of the receivers lose 1 dB in L2 C/N_0	-73 dBm

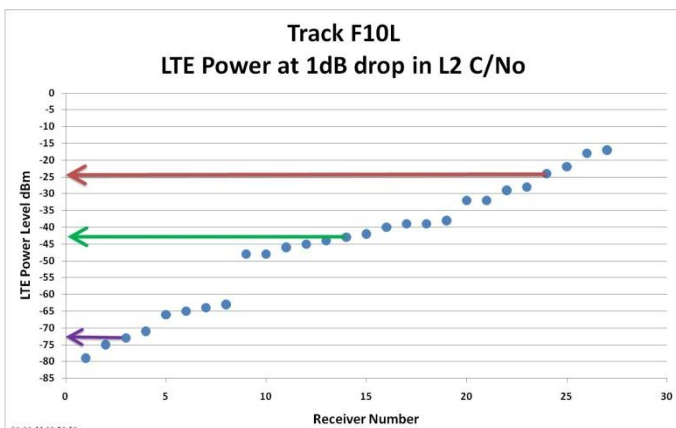


Figure 32 F10L Power at 1 dB Loss of L2 C/N0

Figure 33 displays the LTE F10L power levels where the receivers lose their ability to compute autonomous position.

90%	Red arrow	Power when 90% of the receivers lose position	Not Observed
50%	Green arrow	Power when 50% of the receivers lose position	-30 dBm
10%	Purple arrow	Power when 10% of the receivers lose position	-48 dBm

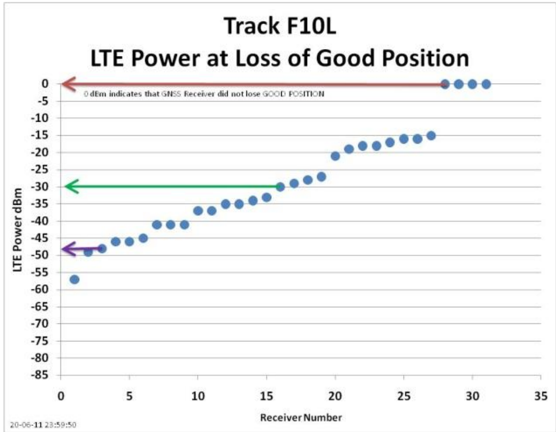


Figure 33 F10L Power at Loss of Good Position

Figure 34 displays the LTE F10L power levels where the receivers lose their ability to compute RTK positions.

90%	Red arrow	Power when 90% of the receivers lose RTK position	-16 dBm
50%	Green arrow	Power when 50% of the receivers lose RTK position	-35 dBm
10%	Purple arrow	Power when 10% of the receivers lose RTK position	-46 dBm

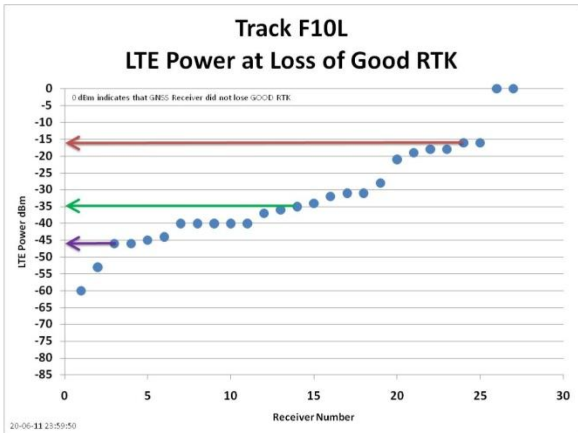


Figure 34 F10L Power at Loss of Good RTK

Figure 35 shows the F10L power level where the receivers experience more than 3 dB loss in sensitivity.

90%	Red arrow	Power when 90% of the receivers lose 3 dB Sensitivity	-15 dBm
50%	Green arrow	Power when 50% of the receivers lose 3 dB Sensitivity	-35 dBm
10%	Purple arrow	Power when 10% of the receivers lose 3 dB Sensitivity	-60 dBm

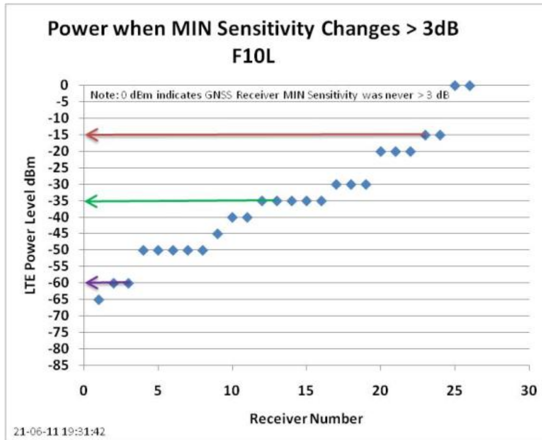


Figure 35 F10L Power at Change in Sensitivity

Figure 36 shows the LTE F10L power levels where the receiver's ability to reacquire signals from GPS satellites was affected.

90% Red arrow	Power when 90% of the receivers can't reacquire sats	Not Observed
50% Green arrow	Power when 50% of the receivers can't reacquire sats	-35 dBm
10% Purple arrow	Power when 10% of the receivers can't reacquire sats	-55 dBm

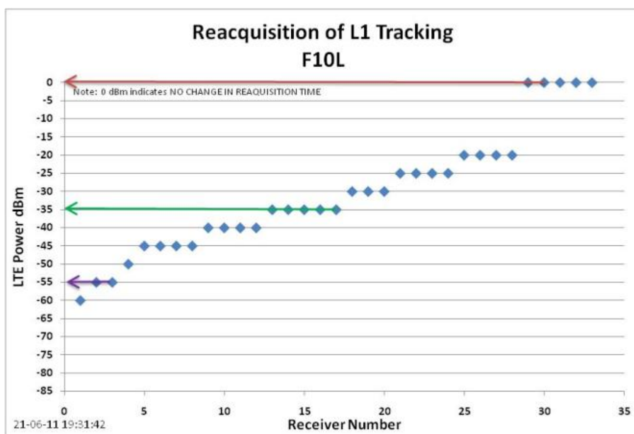


Figure 36 F10L Power for Reacquisition

Figure 37 shows the LTE F10L power levels where the receiver's ability to acquire signals from GPS satellites was affected.

90% Red arrow	Power when 90% of the receivers can't acquire sats	-15 dBm
50% Green arrow	Power when 50% of the receivers can't acquire sats	-35 dBm
10% Purple arrow	Power when 10% of the receivers can't acquire sats	-75 dBm

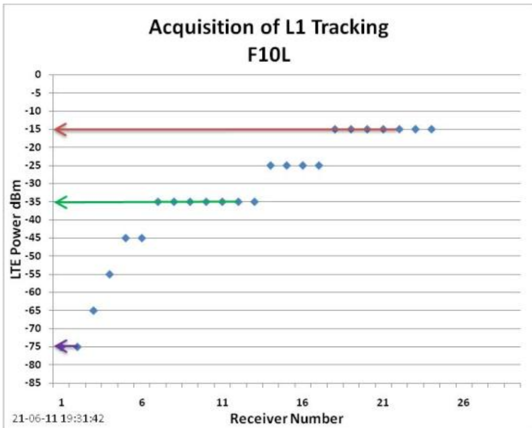


Figure 37 F10L Power for Acquisition

Anechoic Chamber Test (F5L)

Figure 38 displays the LTE F5L power levels of the turning point where the receiver's tracking channel experienced a 1 dB decrease in its L1 C/N_0 measurement as compared to the reference receiver outside the chamber.

90%	Red arrow	Power when 90% of the receivers lose 1 dB in L1 C/N_0	-25 dBm
50%	Green arrow	Power when 50% of the receivers lose 1 dB in L1 C/N_0	-43 dBm
10%	Purple arrow	Power when 10% of the receivers lose 1 dB in L1 C/N_0	-61 dBm

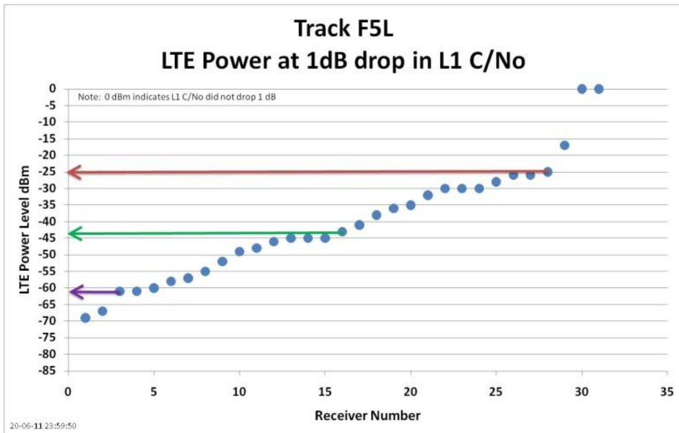


Figure 38 F5L Power at 1 dB Loss of L1 C/N0

Figure 39 displays the LTE F5L power levels where the receivers lose lock on all satellites.

90%	Red arrow	Power when 90% of the receivers lose lock on all sats	Not Observed
50%	Green arrow	Power when 50% of the receivers lose lock on all sats	Not Observed
10%	Purple arrow	Power when 10% of the receivers lose lock on all sats	-34 dBm

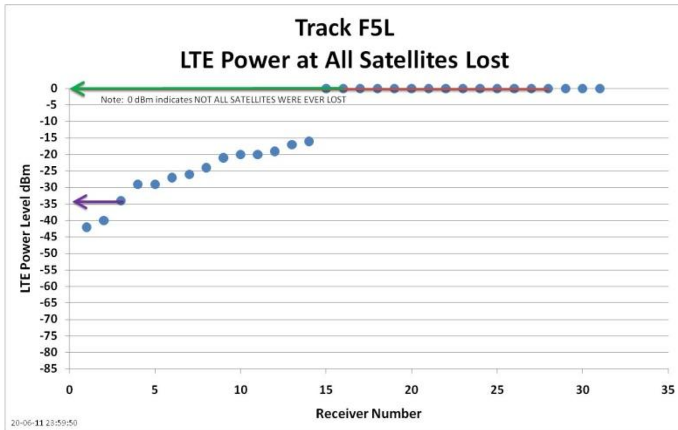


Figure 39 F5L Power at Loss of Satellites

This class of high precision receivers uses proprietary semi-codeless tracking techniques. These tracking techniques require some signal components and aiding from the GPS L1 signal. If there are any interfering signals on either the GPS L1 or GPS L2 signal, then the measured value of the GPS L2 tracking channel will be also be affected. Figure 40 displays the LTE F5L power levels of the turning point where the receiver's L2 tracking channel experiences a 1 dB decrease in its C/N_0 measurement as compared to the reference receiver outside the chamber.

90%	Red arrow	Power when 90% of the receivers lose 1 dB in L2 C/N_0	-20 dBm
50%	Green arrow	Power when 50% of the receivers lose 1 dB in L2 C/N_0	-42 dBm
10%	Purple arrow	Power when 10% of the receivers lose 1 dB in L2 C/N_0	-62 dBm

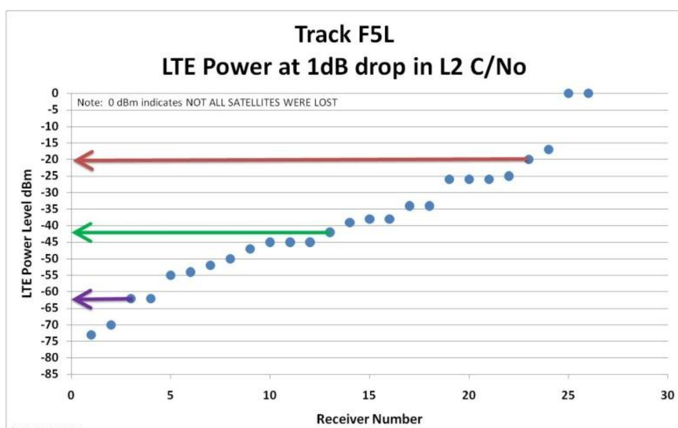


Figure 40 F5L Power at 1 dB Loss of L2 C/N0

Figure 41 displays the LTE F5L power levels of when the receivers lose their ability to compute autonomous position.

90%	Red arrow	Power when 90% of the receivers lose position	Not Observed
50%	Green arrow	Power when 50% of the receivers lose position	-18 dBm
10%	Purple arrow	Power when 10% of the receivers lose position	-38 dBm

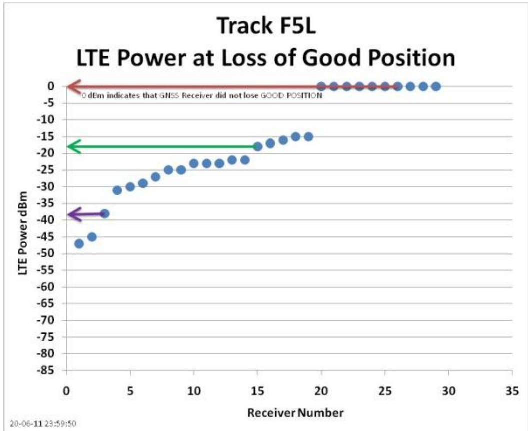


Figure 41 F5L Power at Loss of Good Position

Figure 42 displays the LTE F5L power levels of when the receivers lose their ability to compute RTK positions.

90%	Red arrow	Power when 90% of the receivers lose RTK position	Not Observed
50%	Green arrow	Power when 50% of the receivers lose RTK position	-21 dBm
10%	Purple arrow	Power when 10% of the receivers lose RTK position	-43 dBm

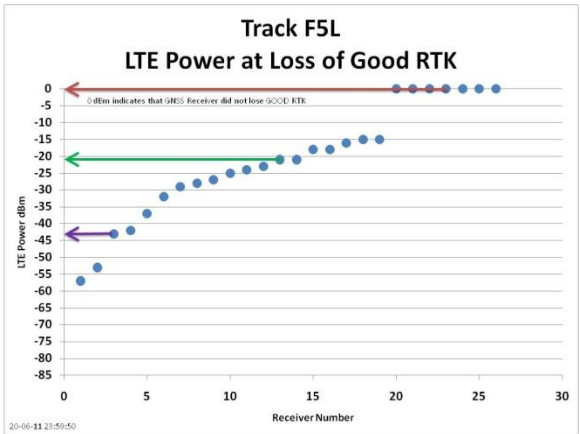


Figure 42 F5L Power at Loss of Good RTK

Anechoic Chamber Test (F10H)

Figure 43 displays the LTE F10H power levels of the turning point where the receiver's tracking channel experienced a 1 dB decrease in its L1 C/N_0 measurement as compared to the reference receiver outside the chamber.

90%	Red arrow	Power when 90% of the receivers lose 1 dB in L1 C/N_0	-47 dBm
50%	Green arrow	Power when 50% of the receivers lose 1 dB in L1 C/N_0	-56 dBm
10%	Purple arrow	Power when 10% of the receivers lose 1 dB in L1 C/N_0	-81 dBm

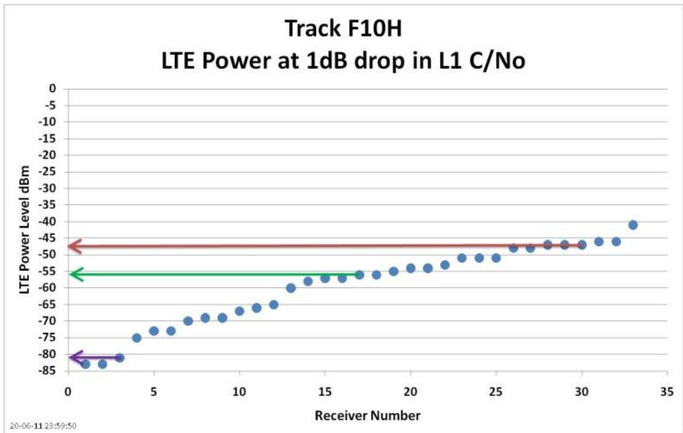


Figure 43 F10H Power at 1 dB Loss of L1 C/N0

Figure 44 displays the LTE F10H power levels where the receivers lose lock on all satellites.

90%	Red arrow	Power when 90% of the receivers lose lock on all sats	-38 dBm
50%	Green arrow	Power when 50% of the receivers lose lock on all sats	-43 dBm
10%	Purple arrow	Power when 10% of the receivers lose lock on all sats	-61 dBm

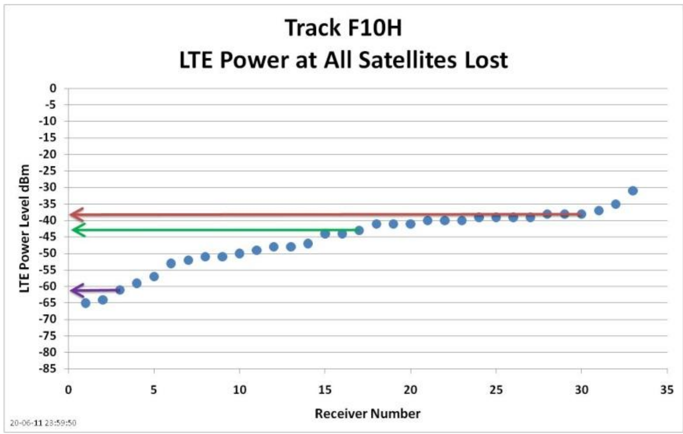


Figure 44 F10H Power at Loss of Satellites

This class of high precision receivers uses proprietary semi-codeless tracking techniques. These tracking techniques require some signal components and aiding from the GPS L1 signal. If there are any interfering signals on either the GPS L1 or GPS L2 signal, then the measured value of the GPS L2 tracking channel will be also be affected. Figure 45 displays the LTE F10H power levels of the turning point where the receiver's L2 tracking channel experiences a 1 dB decrease in its C/N_0 measurement as compared to the reference receiver outside the chamber.

90%	Red arrow	Power when 90% of the receivers lose 1 dB in L2 C/N_0	-47 dBm
50%	Green arrow	Power when 50% of the receivers lose 1 dB in L2 C/N_0	-57 dBm
10%	Purple arrow	Power when 10% of the receivers lose 1 dB in L2 C/N_0	-75 dBm

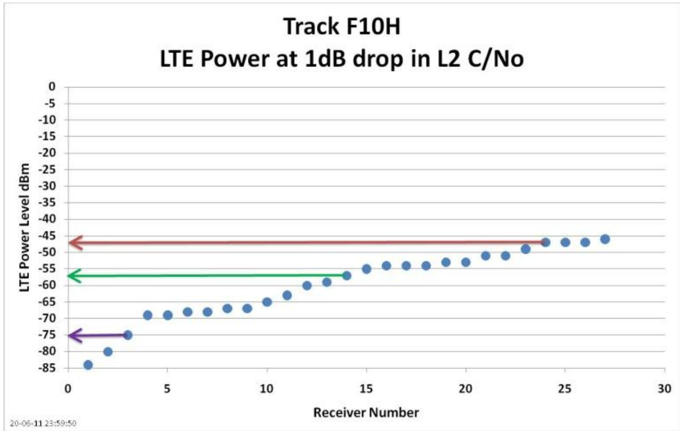


Figure 45 F10H Power at 1 dB Loss of L2 C/N0

Figure 46 displays the LTE F10H power levels of when the receivers lose their ability to compute autonomous position.

90%	Red arrow	Power when 90% of the receivers lose position	-40 dBm
50%	Green arrow	Power when 50% of the receivers lose position	-47 dBm
10%	Purple arrow	Power when 10% of the receivers lose position	-62 dBm

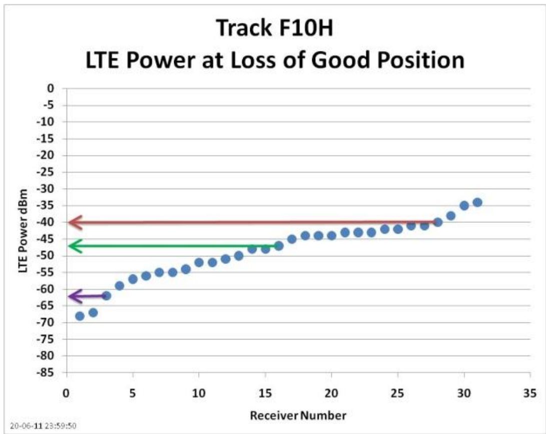


Figure 46 F10H Power at Loss of Good Position

Figure 47 displays the LTE F10H power levels of when the receivers lose their ability to compute RTK positions.

90%	Red arrow	Power when 90% of the receivers lose RTK position	-42 dBm
50%	Green arrow	Power when 50% of the receivers lose RTK position	-47 dBm
10%	Purple arrow	Power when 10% of the receivers lose RTK position	-63 dBm

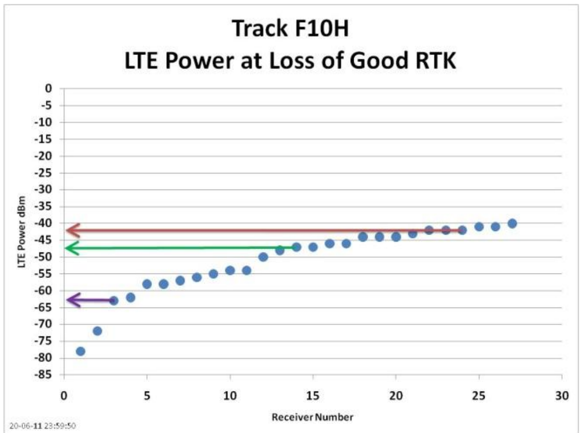


Figure 47 F10H Power at Loss of Good RTK

Appendix H.1.11

Timing Receivers - NAVAIR Anechoic Chamber Test Results

Anechoic Chamber Phase 0 Test (F5H) Timing

Figure 48 displays the LTE F5H power levels of the turning point where the receiver's L1 tracking channel experienced a decrease of its C/N_0 measurement as compared to the reference receiver outside the chamber.

90%	Red arrow	Power when 90% of the receivers lose 1 dB in L1 C/N_0:	-22 dBm
50%	Green arrow	Power when 50% of the receivers lose 1 dB in L1 C/N_0:	-36 dBm
10%	Purple arrow	Power when 10% of the receivers lose 1 dB in L1 C/N_0:	-74 dBm

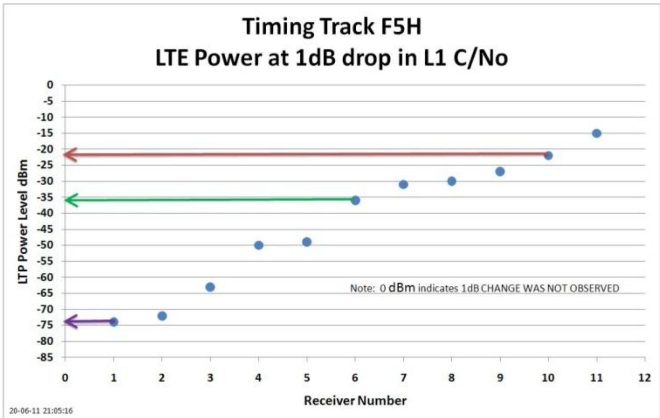


Figure 48 F5H Power at 1 dB Loss of L1 C/N_0

Figure 49 displays the F5H power levels of when the receivers lose lock on all satellites.

90%	Red arrow	Power when 90% of the receivers lose lock on all sats:	Not Observed
50%	Green arrow	Power when 50% of the receivers lose lock on all sats:	-23 dBm
10%	Purple arrow	Power when 10% of the receivers lose lock on all sats:	-63 dBm

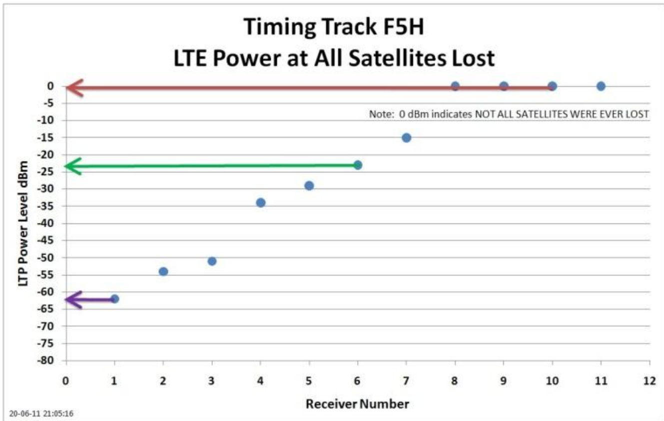


Figure 49 F5H Power at Loss of All Satellites

An important Key Performance Indicator for Timing receivers is their ability to keep their oscillators in "GPS-Lock" mode. Once a GPS receiver loses GPS-Lock, it can no longer keep its oscillator synchronized with GPS system time. Figure 50 shows the points at which the receivers lost the ability to steer their oscillators with F5H signals.

90%	Red arrow	Power when 90% of the receivers lose GPS Lock:	Not Observed
50%	Green arrow	Power when 50% of the receivers lose GPS Lock:	-17 dBm
10%	Purple arrow	Power when 10% of the receivers lose GPS Lock:	-64 dBm

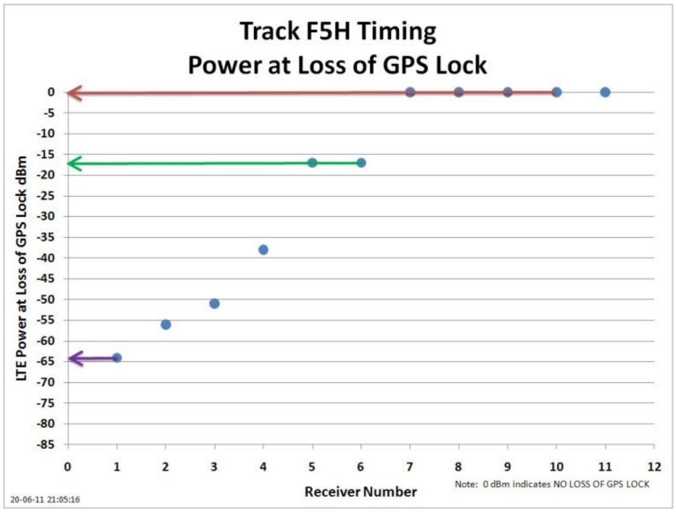


Figure 50 F5H Power at Loss of GPS Lock

Figure 51 shows the F5H power level when the receivers experience more than 3dB loss in Sensitivity.

90%	Red arrow	Power when 90% of the receivers lose 3 dB Sensitivity:	-25 dBm
50%	Green arrow	Power when 50% of the receivers lose 3 dB Sensitivity:	-40 dBm
10%	Purple arrow	Power when 10% of the receivers lose 3 dB Sensitivity:	-70 dBm

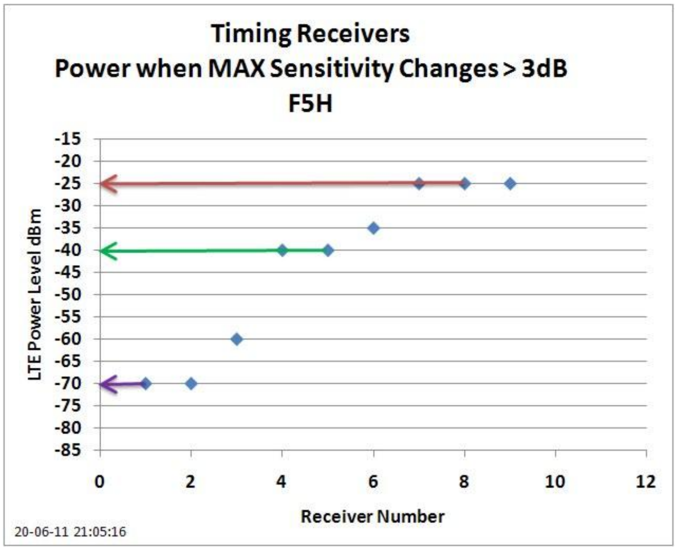


Figure 51 F5H Power at Change in Sensitivity

Figure 52 shows the LTE power levels when the receiver's ability to acquire L1 signals from GPS satellites is affected.

90%	Red arrow	Power when 90% of the receivers can't acquire sats:	Not Observed
50%	Green arrow	Power when 50% of the receivers can't acquire sats:	-25 dBm
10%	Purple arrow	Power when 10% of the receivers can't acquire sats:	-40 dBm

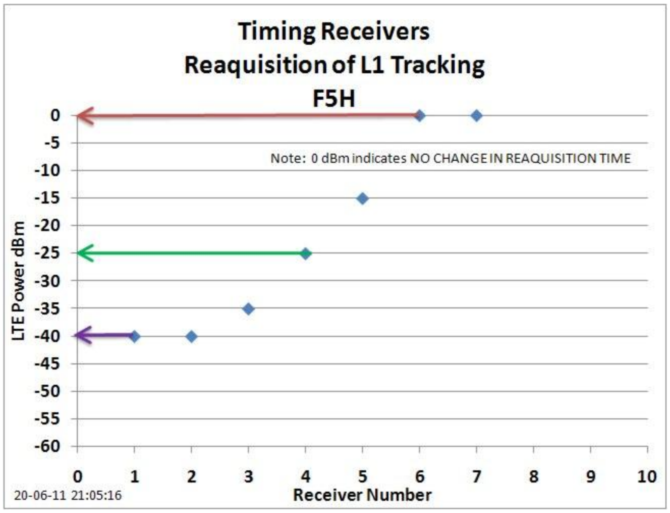


Figure 52 F5H Power for Reacquisition L1

Figure 53 shows the LTE power levels when the receiver's ability to acquire enough signals and enter into GPS-Lock mode.

90%	Red arrow	Power when 90% of the receivers can't GPS-Lock:	Not Observed
50%	Green arrow	Power when 50% of the receivers can't GPS-Lock:	-30 dBm
10%	Purple arrow	Power when 10% of the receivers can't GPS-Lock:	-60 dBm

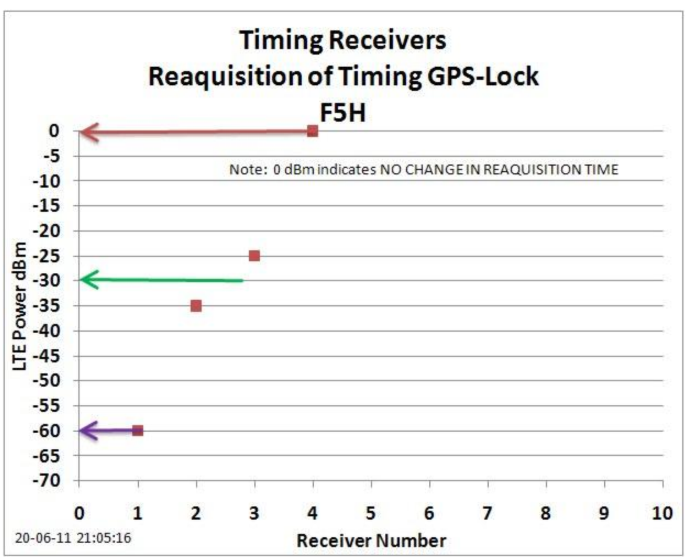


Figure 53 F5H Power for Reacquisition of GPS-Lock

Anechoic Chamber Phase 1 Test (F5L + F5H) Timing

Figure 54 displays the LTE F5L+F5H power levels at the turning point where the receiver's L1 tracking channel experiences a decrease of its C/N_0 measurement as compared to the reference receiver outside the chamber.

90% Red arrow	Power when 90% of the receivers lose 1 dB in L1 C/N_0:	-39 dBm
50% Green arrow	Power when 50% of the receivers lose 1 dB in L1 C/N_0:	-48 dBm
10% Purple arrow	Power when 10% of the receivers lose 1 dB in L1 C/N_0:	-77 dBm

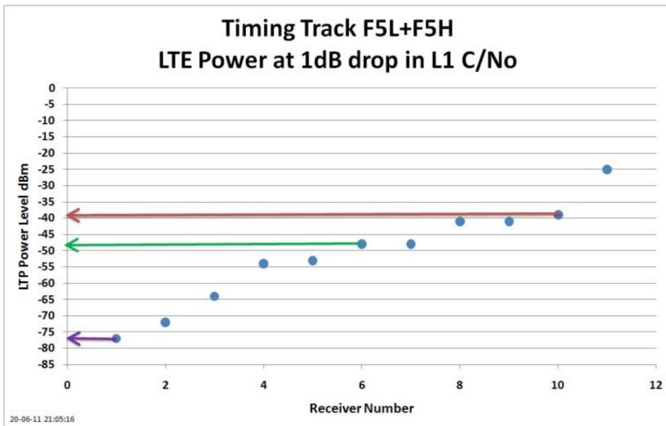


Figure 54 F5L+F5H Power at 1 dB Loss of L1 C/No

Figure 55 displays the LTE F5L+F5H power levels of when the receivers lose lock on all satellites.

90% Red arrow	Power when 90% of the receivers lose lock on all sats:	-19 dBm
50% Green arrow	Power when 50% of the receivers lose lock on all sats:	-34 dBm
10% Purple arrow	Power when 10% of the receivers lose lock on all sats:	-63 dBm

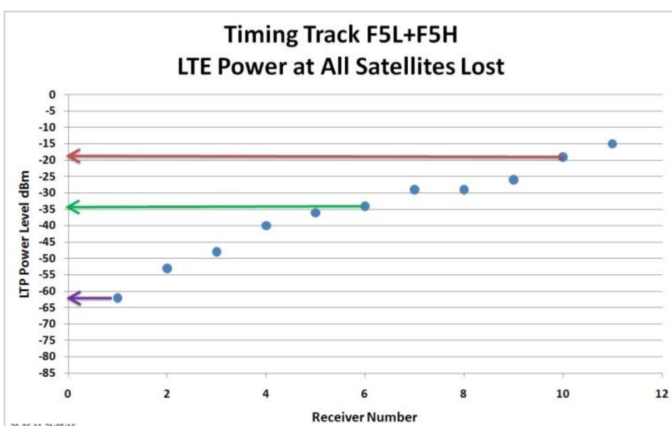


Figure 55 F5L+F5H Power at Loss of Satellites

An important Key Performance Indicator for Timing receivers is their ability to keep their oscillators in "GPS-Lock" mode. Once a GPS receiver loses GPS-Lock, it can no longer keep its oscillator synchronized with GPS system time. Figure 56 shows the LTE F5L+F5H power levels at which the receivers lost the ability to steer their oscillators.

90%	Red arrow	Power when 90% of the receivers lose GPS Lock:	-22 dBm
50%	Green arrow	Power when 50% of the receivers lose GPS Lock:	-39 dBm
10%	Purple arrow	Power when 10% of the receivers lose GPS Lock:	-63 dBm

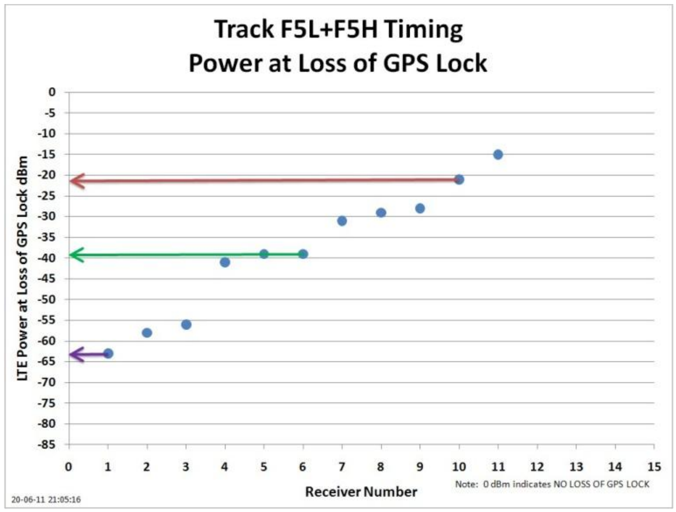


Figure 56 F5L+F5H Power at Loss of GPS Lock

Figure 57 shows the F5L+F5H power level where the receivers experience more than 3dB loss in sensitivity.

90%	Red arrow	Power when 90% of the receivers lose 3 dB Sensitivity:	-40 dBm
50%	Green arrow	Power when 50% of the receivers lose 3 dB Sensitivity:	-50 dBm
10%	Purple arrow	Power when 10% of the receivers lose 3 dB Sensitivity:	-70 dBm

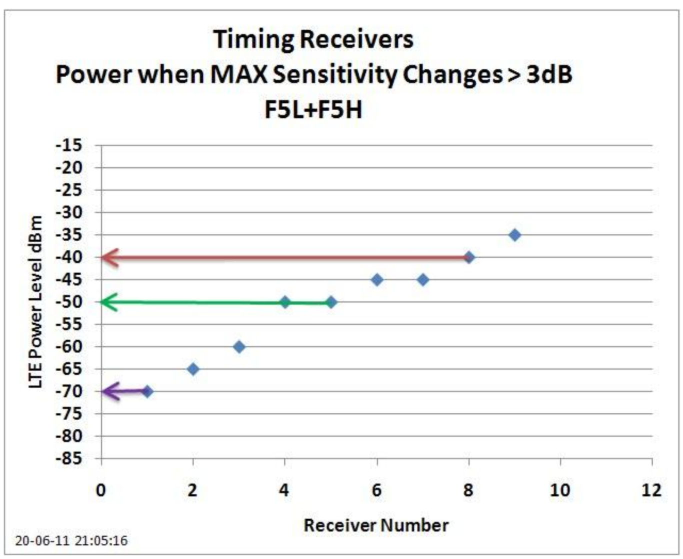


Figure 57 F5L+F5H Power at Change in Sensitivity

Figure 58 shows the LTE F5L+F5H power levels where the receiver's ability to acquire signals from GPS satellites was impaired.

90%	Red arrow	Power when 90% of the receivers can't acquire sats:	-25 dBm
50%	Green arrow	Power when 50% of the receivers can't acquire sats:	-45 dBm
10%	Purple arrow	Power when 10% of the receivers can't acquire sats:	-75 dBm

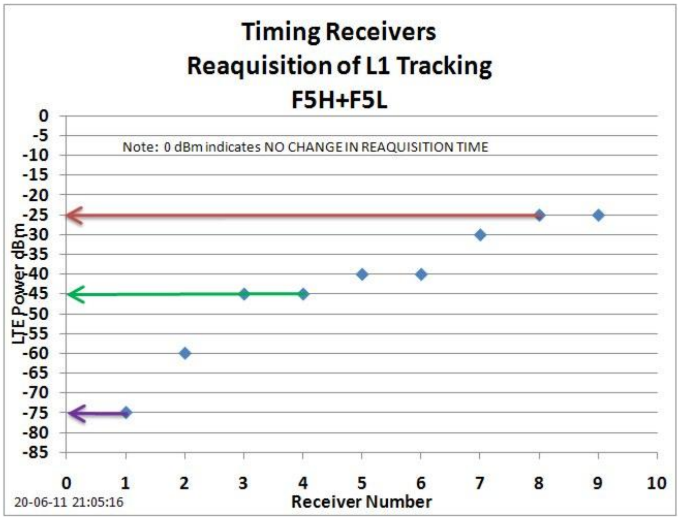


Figure 58 F5L+F5H Power for Reacquisition

Figure 59 shows the LTE F5L+F5H power levels where the receiver's ability to acquire satellites and enter into GPS-Lock mode was impaired.

90%	Red arrow	Power when 90% of the receivers can't GPS-Lock:	-35 dBm
50%	Green arrow	Power when 50% of the receivers can't GPS-Lock:	-45 dBm
10%	Purple arrow	Power when 10% of the receivers can't GPS-Lock:	-60 dBm

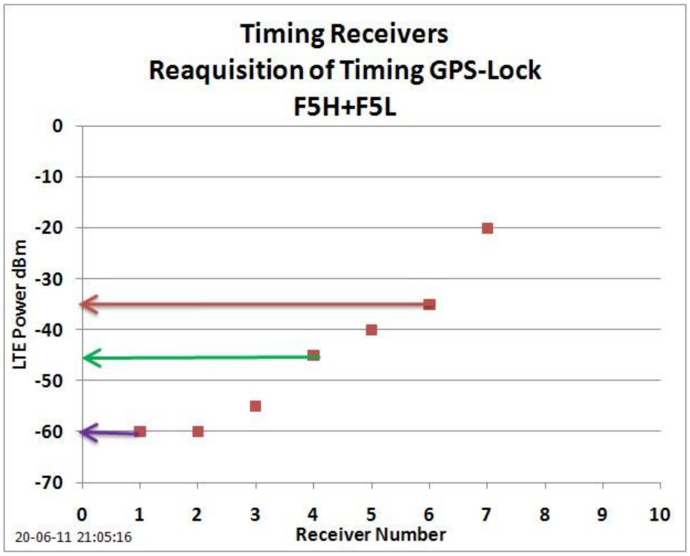


Figure 59 F5L+F5H Power for Reacquisition of GPS-Lock

Anechoic Chamber Phase 2 Test (F10L + F10H) Timing

Figure 60 displays the F10L+F10H power levels of the turning point where the receiver's tracking channel experiences a decrease of its L1 C/N_0 measurement as compared to the reference receiver outside the chamber.

90%	Red arrow	Power when 90% of the receivers lose 1 dB in L1 C/N_0;	-35 dBm
50%	Green arrow	Power when 50% of the receivers lose 1 dB in L1 C/N_0:	-45 dBm
10%	Purple arrow	Power when 10% of the receivers lose 1 dB in L1 C/N_0:	-72 dBm

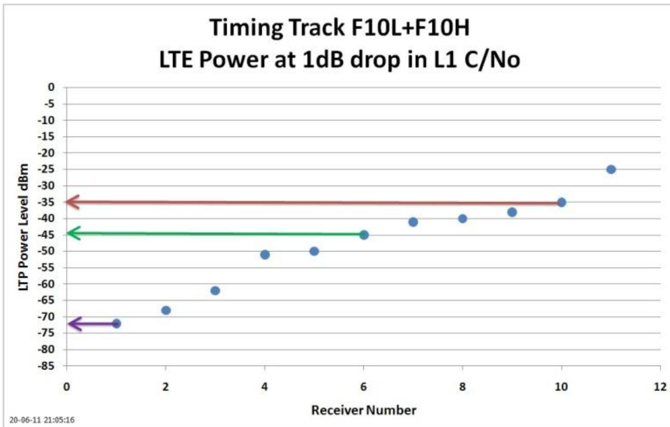


Figure 60 F10L+F10H Power at 1 dB Loss of L1 C/N0

Figure 61 displays the LTE F10L+F10H power levels at which the receivers lose lock on all satellites.

90%	Red arrow	Power when 90% of the receivers lose lock on all sats:	-17 dBm
50%	Green arrow	Power when 50% of the receivers lose lock on all sats:	-31 dBm
10%	Purple arrow	Power when 10% of the receivers lose lock on all sats:	-58 dBm

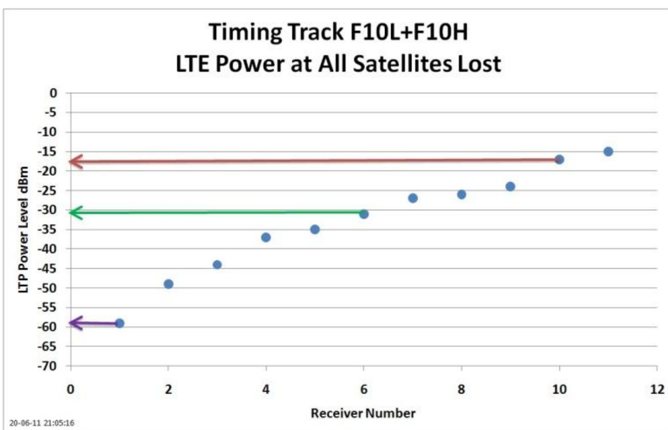


Figure 61 F10L+F10H Power at Loss of Satellites

An important Key Performance Indicator for Timing receivers is their ability to keep their oscillators in "GPS-Lock" mode. Once a GPS receiver loses GPS-Lock, it can no longer keep its oscillator synchronized with GPS system time. Figure 62 shows the LTE F10L+F10H point at which the receivers lose the ability to steer their oscillators.

90%	Red arrow	Power when 90% of the receivers lose GPS Lock:	-25 dBm
50%	Green arrow	Power when 50% of the receivers lose GPS Lock:	-34 dBm
10%	Purple arrow	Power when 10% of the receivers lose GPS Lock:	-60 dBm

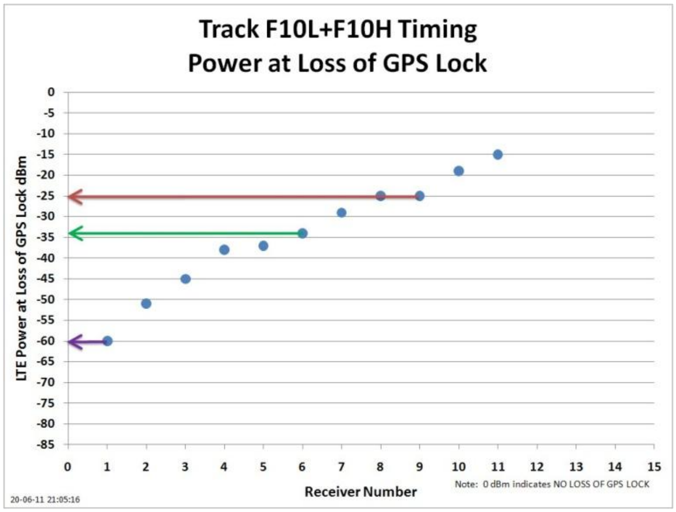


Figure 62 F10L+F10H Power at Loss of GPS-Lock

Figure 63 shows the LTE F10L+F10H power level where the receivers experience more than 3 dB loss in Sensitivity.

90%	Red arrow	Power when 90% of the receivers lose 3 dB Sensitivity	-35 dBm
50%	Green arrow	Power when 50% of the receivers lose 3 dB Sensitivity	-45 dBm
10%	Purple arrow	Power when 10% of the receivers lose 3 dB Sensitivity	-70 dBm

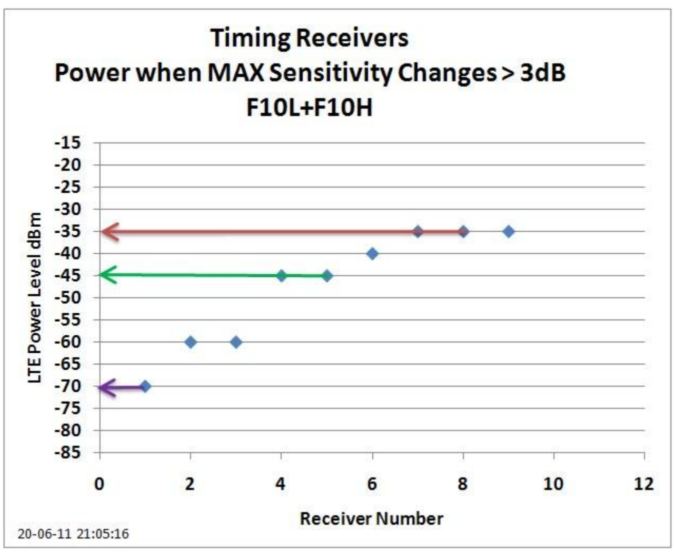


Figure 63 F10L+F10H Power at Change in Sensitivity

Figure 64 shows the LTE F10L+F10H power levels where the receiver's ability to acquire signals from GPS satellites was impaired.

90%	Red arrow	Power when 90% of the receivers can't acquire sats:	-30 dBm
50%	Green arrow	Power when 50% of the receivers can't acquire sats:	-40 dBm
10%	Purple arrow	Power when 10% of the receivers can't acquire sats:	-65 dBm

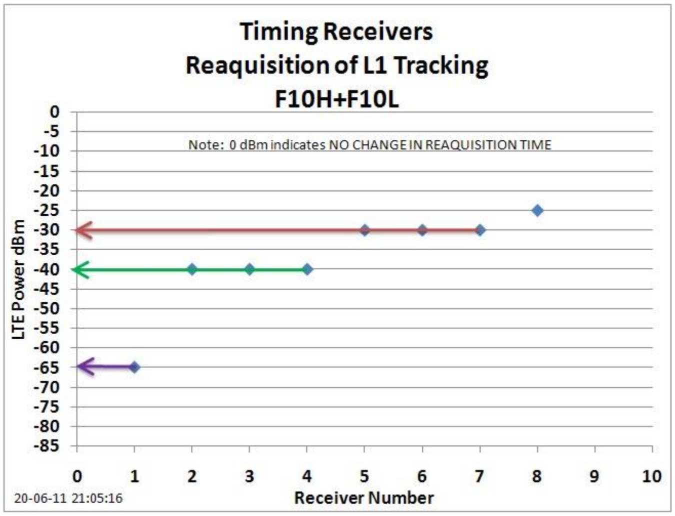


Figure 64 F10L+F10H Power for Reacquisition

Figure 65 shows the LTE F10L+F10H power levels where the receiver's ability to acquire signals from GPS satellites and enter GPS-Lock mode was impaired.

90%	Red arrow	Power when 90% of the receivers can't GPS-Lock:	-25 dBm
50%	Green arrow	Power when 50% of the receivers can't GPS-Lock:	-40 dBm
10%	Purple arrow	Power when 10% of the receivers can't GPS-Lock:	-60 dBm

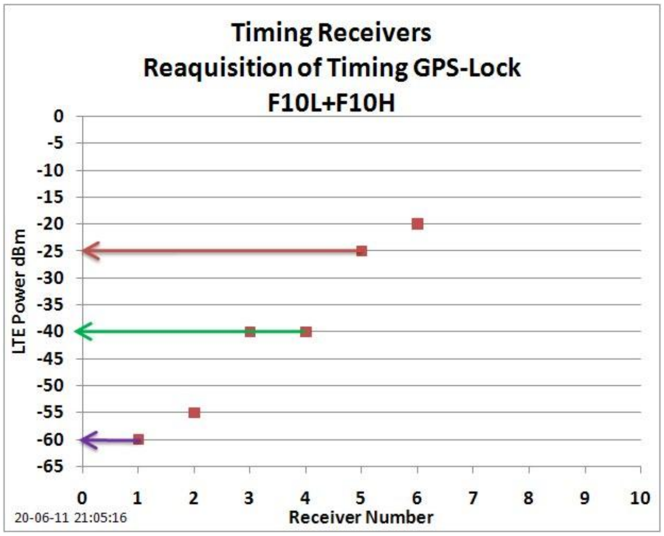


Figure 65 F10L+F10H Power for Reacquisition of GPS-Lock

Anechoic Chamber Test (Handset) Timing

Figure 66 displays the Handset power levels of the turning point where the receiver's tracking channel experiences a decrease of its L1 C/N_0 measurement as compared to the reference receiver outside the chamber.

90%	Red arrow	Power when 90% of the receivers lose 1 dB in L1 C/N_0: Not Observed
50%	Green arrow	Power when 50% of the receivers lose 1 dB in L1 C/N_0: Not Observed
10%	Purple arrow	Power when 10% of the receivers lose 1 dB in L1 C/N_0: -19 dBm

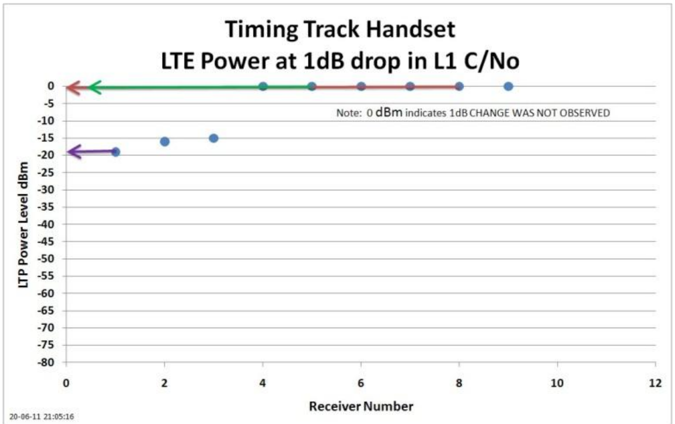


Figure 66 Handset Power at 1 dB Loss of L1 C/N0

Figure 67 displays the Handset power levels where the receivers lose lock on all satellites.

90%	Red arrow	Power when 90% of the receivers lose lock on all sats: Not Observed
50%	Green arrow	Power when 50% of the receivers lose lock on all sats: Not Observed
10%	Purple arrow	Power when 10% of the receivers lose lock on all sats: Not Observed

Note: a power value of 0 dBm indicates that this condition was not reached in this test.

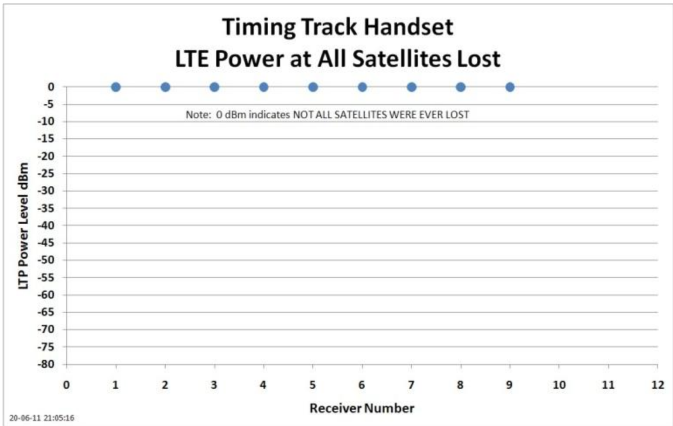


Figure 67 Handset Power at Loss of Satellites

An important Key Performance Indicator for Timing receivers is their ability to keep their oscillators in "GPS-Lock" mode. Once a GPS receiver loses GPS-Lock, it can no longer keep its oscillator synchronized with GPS system time. Figure 68 shows the Handset point at which the receivers lose the ability to steer their oscillators.

90%	Red arrow	Power when 90% of the receivers lose GPS Lock:	Not Observed
50%	Green arrow	Power when 50% of the receivers lose GPS Lock:	Not Observed
10%	Purple arrow	Power when 10% of the receivers lose GPS Lock:	Not Observed

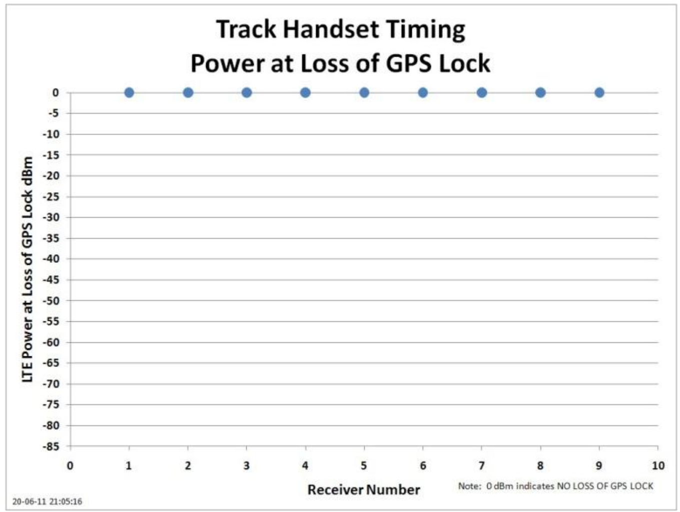


Figure 68 Handset Power at Loss of GPS Lock

Anechoic Chamber Test (F10L)

Figure 69 displays the LTE F10L power levels of the turning point where the receiver's tracking channel experiences a decrease of its L1 C/N_0 measurement as compared to the reference receiver outside the chamber.

90%	Red arrow	Power when 90% of the receivers lose 1 dB in L1 C/N_0:	Not Observed
50%	Green arrow	Power when 50% of the receivers lose 1 dB in L1 C/N_0:	-15 dBm
10%	Purple arrow	Power when 10% of the receivers lose 1 dB in L1 C/N_0:	-39 dBm

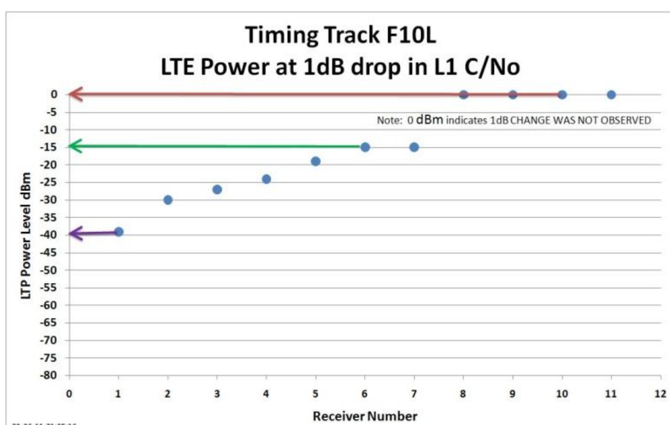


Figure 69 F10L Power at 1 dB Loss of L1 C/N0

Figure 70 displays the LTE F10L power levels where the receivers lose lock on all satellites.

90%	Red arrow	Power when 90% of the receivers lose lock on all sats:	Not Observed
50%	Green arrow	Power when 50% of the receivers lose lock on all sats:	Not Observed

10%	Purple arrow	Power when 10% of the receivers lose lock on all sats:	-21 dBm

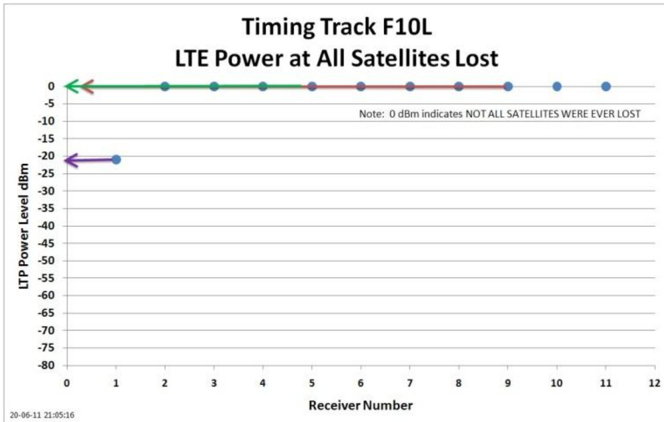


Figure 70 F10L Power at Loss of Satellites

An important Key Performance Indicator for Timing receivers is their ability to keep their oscillators in "GPS-Lock" mode. Once a GPS receiver loses GPS-Lock, it can no longer keep its oscillator synchronized with GPS system time. Figure 71 shows the LTE F10L point at which the receivers lose the ability to steer their oscillators.

90%	Red arrow	Power when 90% of the receivers lose GPS Lock:	Not Observed
50%	Green arrow	Power when 50% of the receivers lose GPS Lock:	Not Observed
10%	Purple arrow	Power when 10% of the receivers lose GPS Lock:	-24 dBm

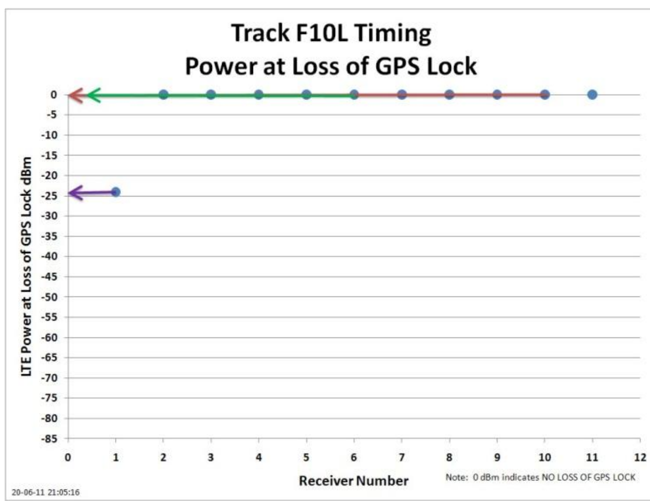


Figure 71 F10L Power at Loss of GPS Lock

Figure 72 shows the F10L power level where the receivers experience more than 3 dB loss in sensitivity.

90%	Red arrow	Power when 90% of the receivers lose 3 dB Sensitivity:	Not Observed
50%	Green arrow	Power when 50% of the receivers lose 3 dB Sensitivity:	-15 dBm
10%	Purple arrow	Power when 10% of the receivers lose 3 dB Sensitivity:	-35 dBm

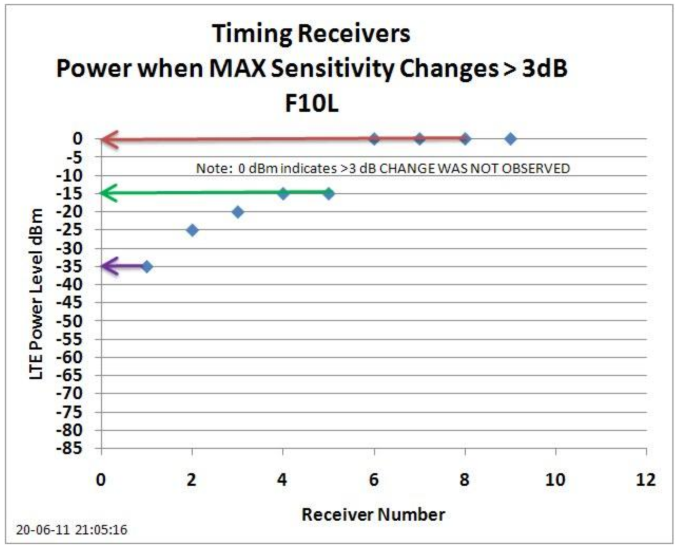


Figure 72 F10L Power at Change in Sensitivity

Figure 73 shows the LTE F10L power levels where the receiver's ability to acquire signals from GPS satellites was affected.

90%	Red arrow	Power when 90% of the receivers can't acquire sats:	Not Observed
50%	Green arrow	Power when 50% of the receivers can't acquire sats:	Not Observed
10%	Purple arrow	Power when 10% of the receivers can't acquire sats:	-60 dBm

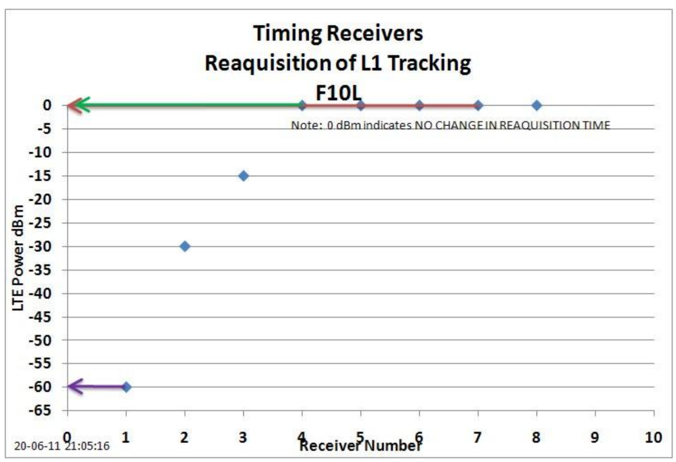


Figure 73 F10L Power for Reacquisition

Figure 74 shows the LTE F10L power levels where the receiver's ability to acquire signals from GPS satellites and enter GPS-Lock mode was affected.

90%	Red arrow	Power when 90% of the receivers can't GPS-Lock:	Not Observed
50%	Green arrow	Power when 50% of the receivers can't GPS-Lock:	Not Observed
10%	Purple arrow	Power when 10% of the receivers can't GPS-Lock:	-25 dBm

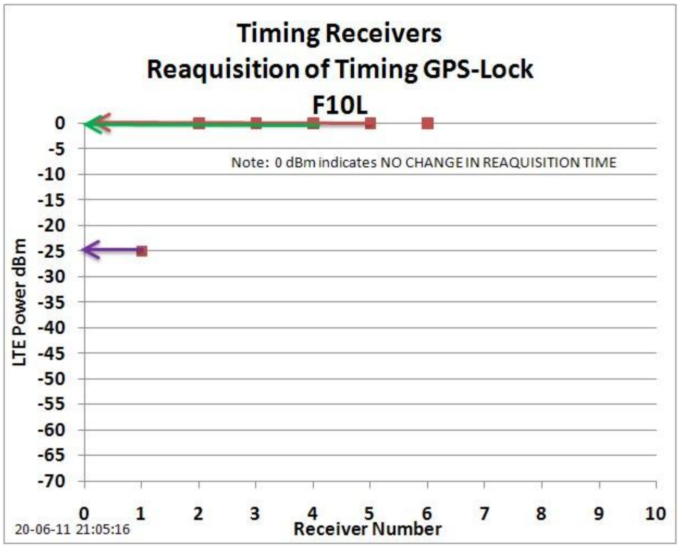


Figure 74 F10L Power for Reacquisition of GPS-Lock

Anechoic Chamber Test (F5L) Timing

Figure 75 displays the LTE F5L power levels of the turning point where the receiver's tracking channel experienced a 1 dB decrease in its L1 C/N_0 measurement as compared to the reference receiver outside the chamber.

90%	Red arrow	Power when 90% of the receivers lose 1 dB in L1 C/N_0:	Not Observed
50%	Green arrow	Power when 50% of the receivers lose 1 dB in L1 C/N_0:	-19 dBm
10%	Purple arrow	Power when 10% of the receivers lose 1 dB in L1 C/N_0:	-33 dBm

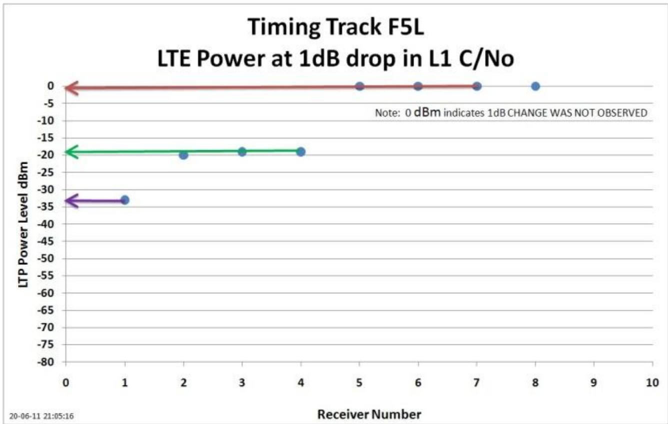


Figure 75 F5L Power at 1 dB Loss of L1 C/N0

Figure 76 displays the LTE F5L power levels where the receivers lose lock on all satellites.

90%	Red arrow	Power when 90% of the receivers lose lock on all sats:	Not Observed
50%	Green arrow	Power when 50% of the receivers lose lock on all sats:	Not Observed
10%	Purple arrow	Power when 10% of the receivers lose lock on all sats:	-18 dBm

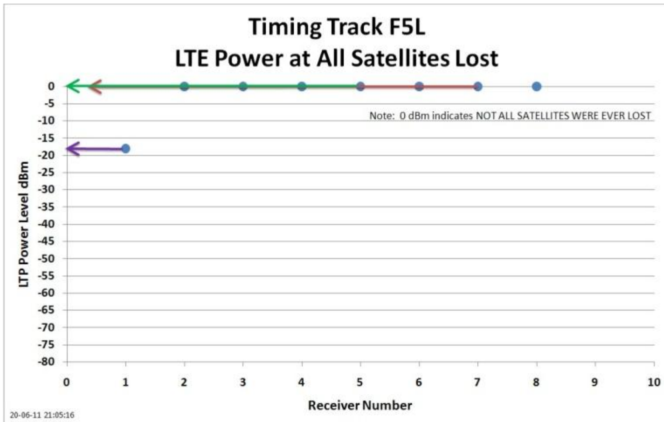


Figure 76 F5L Power at Loss of Satellites

An important Key Performance Indicator for Timing receivers is their ability to keep their oscillators in "GPS-Lock" mode. Once a GPS receiver loses GPS-Lock, it can no longer keep its oscillator synchronized with GPS system time. Figure 77 shows the point at which the receivers lose the ability to steer their oscillators with F5L signals.

90%	Red arrow	Power when 90% of the receivers lose GPS Lock:	Not Observed
50%	Green arrow	Power when 50% of the receivers lose GPS Lock:	Not Observed
10%	Purple arrow	Power when 10% of the receivers lose GPS Lock:	-23 dBm

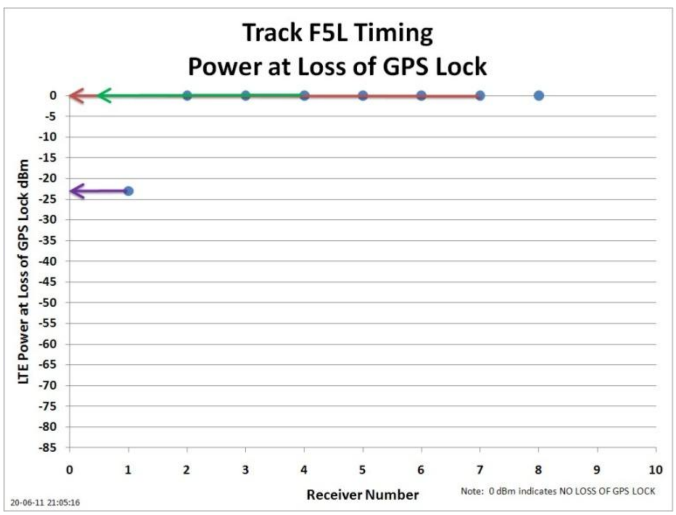


Figure 77 F5L Power at Loss of GPS Lock

Anechoic Chamber Test (F10H) Timing

Figure 78 displays the LTE F10H power levels of the turning point where the receiver's tracking channel experienced a 1 dB decrease in its L1 C/N_0 measurement as compared to the reference receiver outside the chamber.

90%	Red arrow	Power when 90% of the receivers lose 1 dB in L1 C/N_0:	-23 dBm
50%	Green arrow	Power when 50% of the receivers lose 1 dB in L1 C/N_0:	-37 dBm

10%	Purple arrow	Power when 10% of the receivers lose 1 dB in L1 C/N_0:	-72 dBm

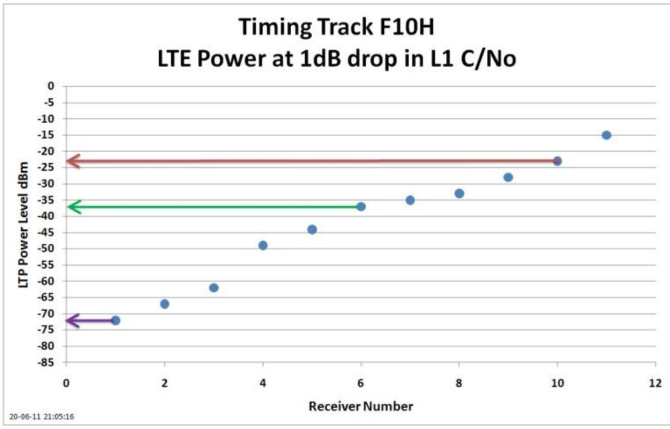


Figure 78 F10L Power at 1 dB Loss of L1 C/N0

Figure 79 displays the LTE F10H power levels where the receivers lose lock on all satellites.

90%	Red arrow	Power when 90% of the receivers lose lock on all sats:	Not Observed
50%	Green arrow	Power when 50% of the receivers lose lock on all sats:	-25 dBm
10%	Purple arrow	Power when 10% of the receivers lose lock on all sats:	-59 dBm

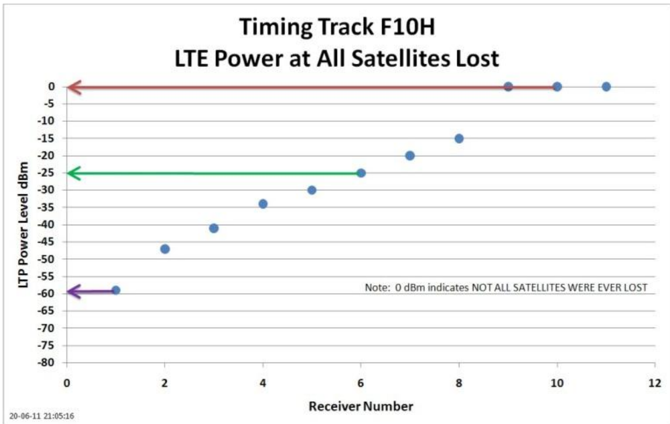


Figure 79 F10H Power at Loss of Satellites

An important Key Performance Indicator for Timing receivers is their ability to keep their oscillators in "GPS-Lock" mode. Once a GPS receiver loses GPS-Lock, it can no longer keep its oscillator synchronized with GPS system time. Figure 80 shows the point at which the receivers lose the ability to steer their oscillators with F10H signals.

90%	Red arrow	Power when 90% of the receivers lose GPS Lock:	Not Observed
50%	Green arrow	Power when 50% of the receivers lose GPS Lock:	-24 dBm
10%	Purple arrow	Power when 10% of the receivers lose GPS Lock:	-59 dBm

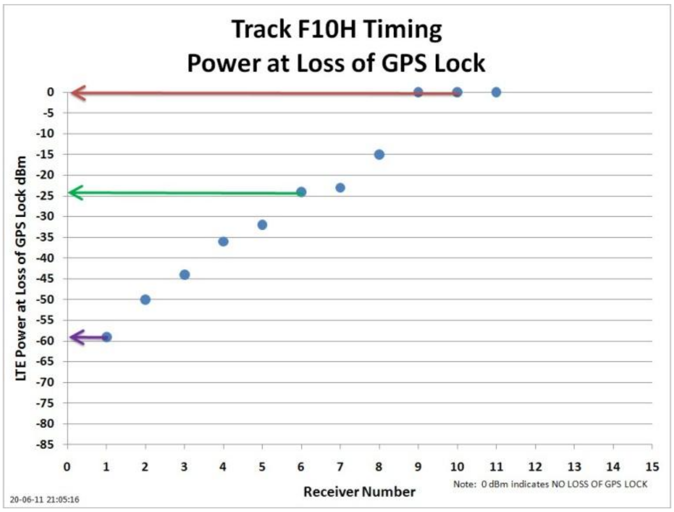


Figure 80 F10H Power at Loss of GPS Lock

Appendix H.1.12

PCTEL Antenna - NAVAIR Anechoic Chamber Test Results

There were two narrow band GPS L1 receivers configured with narrow band L1 Antennas (PCTEL) in the NAVAIR test campaign. The anonymous codes for these two units were T92202 and T44136. The results of their Key Performance Indicators are shown in Figure 81 below.

The C/N_0 levels of both receivers did not respond to F10L LTE emissions as can be seen in the L1 C/N_0 Differences plot. Both curves are flat across the full F10L test.

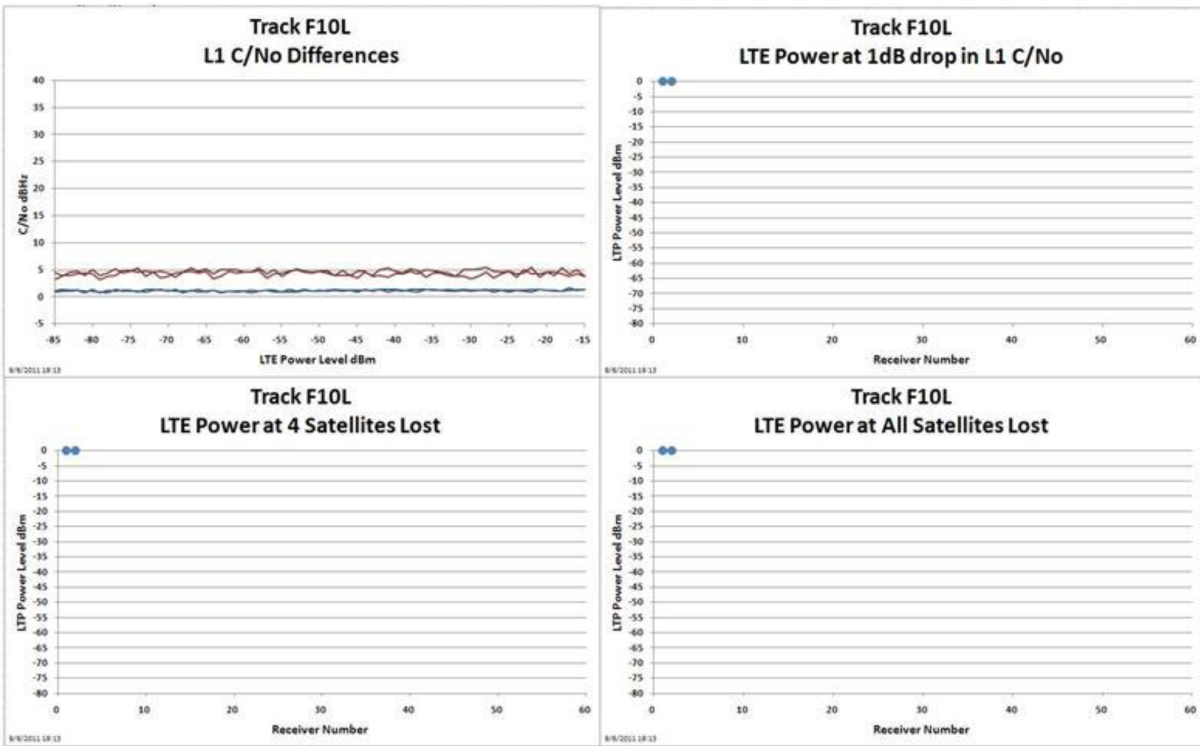


Figure 81 PCTEL F10L

There was some response to the C/N_0 levels to the F10H signal. The C/N_0 of one of the units shows a few dB increase at levels > -20 dBm. In Figure 82 a rise in the blue curve towards the end of the graph can be seen (highlighted circles). A 1dB drop occurs on one of the receivers at -20 dBm.

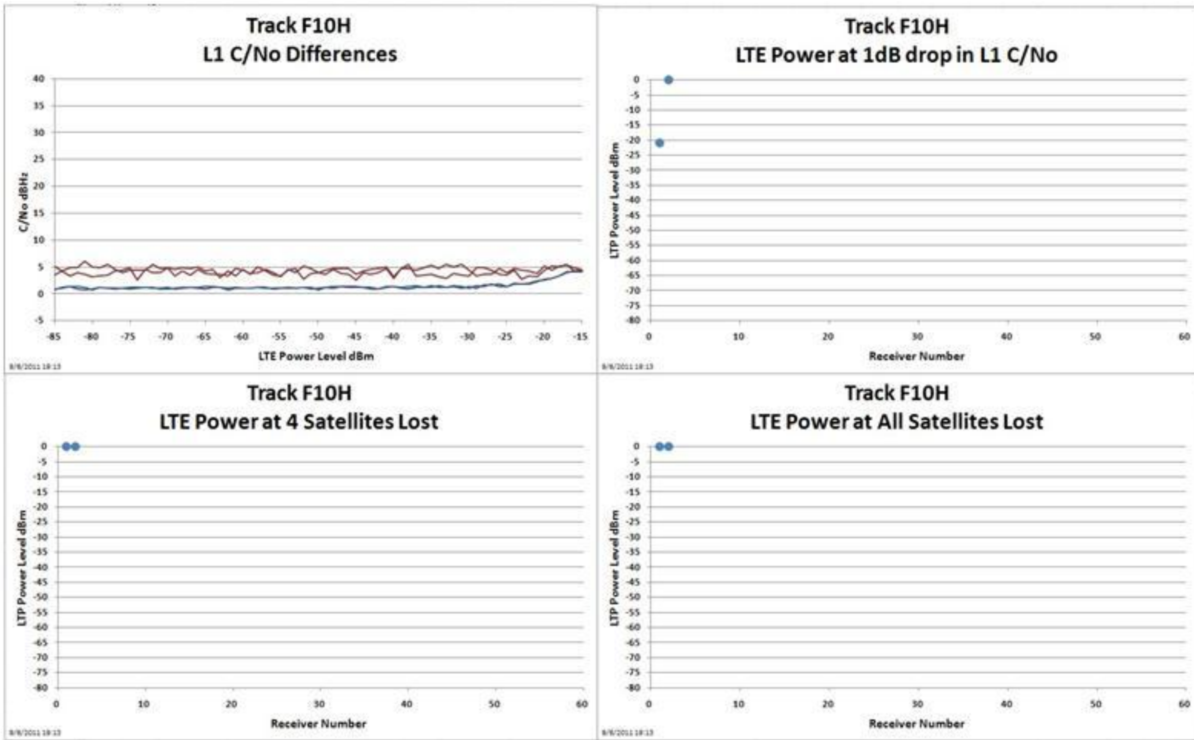


Figure 82 PCTEL F10H

There was a very large response in the C/N_0 levels to the F10L+F10H signal. A 1dB change in C/N_0 occurs on each receiver at the -40 dBm and -45 dBm levels respectively (Figure 83). Note also that one of the receivers losses lock on more than 4 satellites at the -42 dB point That receiver also loses lock on all satellites when the input LTE signal reaches -24 dBm

The Sub-Teams take the following position:

> This large response from the combined F10L+F10H is assumed to be caused by the third order harmonics of the two combined signals.

LightSquared takes the following position:

> The PCTEL antenna functioned normally (no alarms were triggered) in the Las Vegas field trials, as observed by several CMRS operators, including Sprint and Verizon. LightSquared also notes that intermod is not an issue with regard to the Lower 10 MHz channel operation on a stand-alone basis

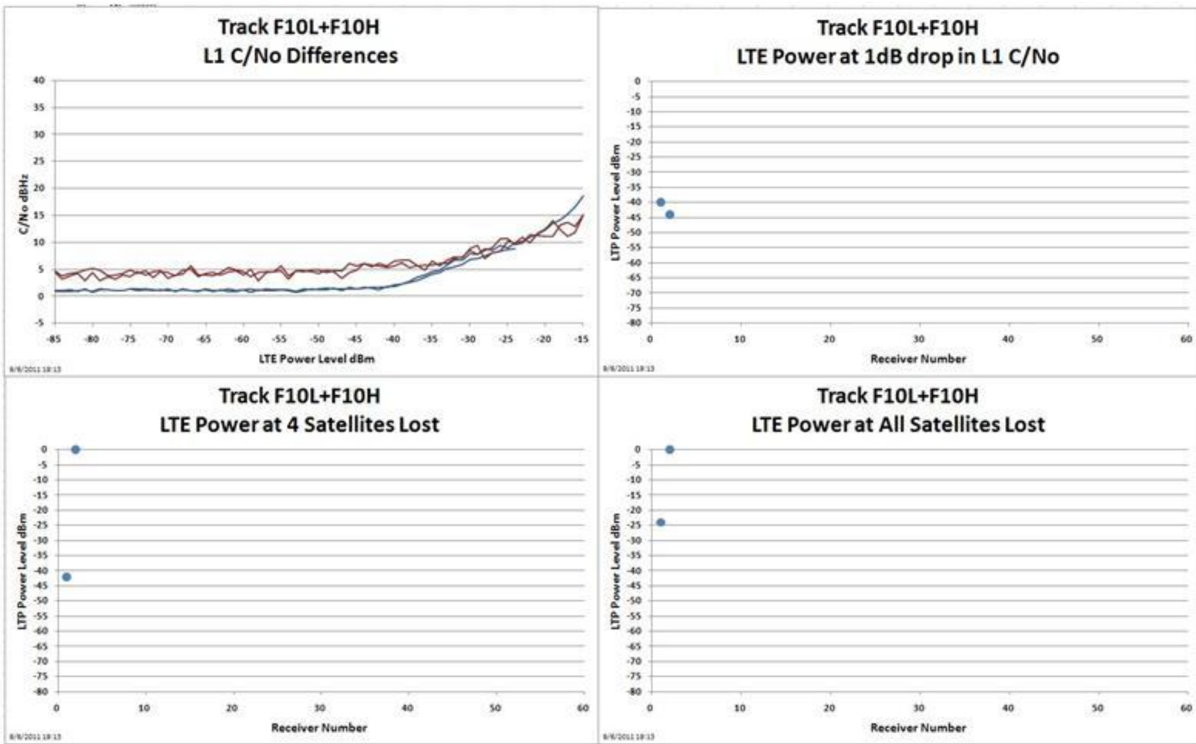


Figure 83 PCTEL F10L+F10H

Only one of these receivers collected data during the Handset emissions test. This receiver showed no response in its C/N_0 curve to this signal (Figure 84).

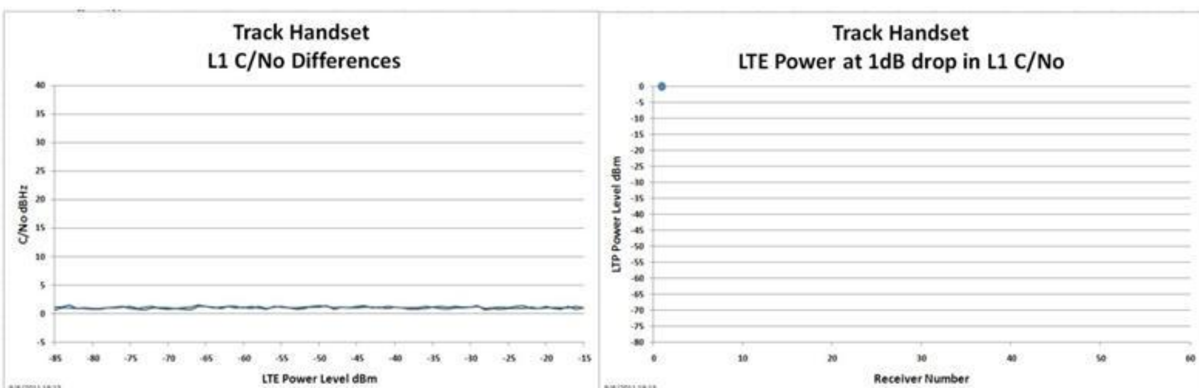


Figure 84 PCTEL Handset

There was no noticeable change in the C/N_0 levels of either receiver from the F5L signal (Figure 85).

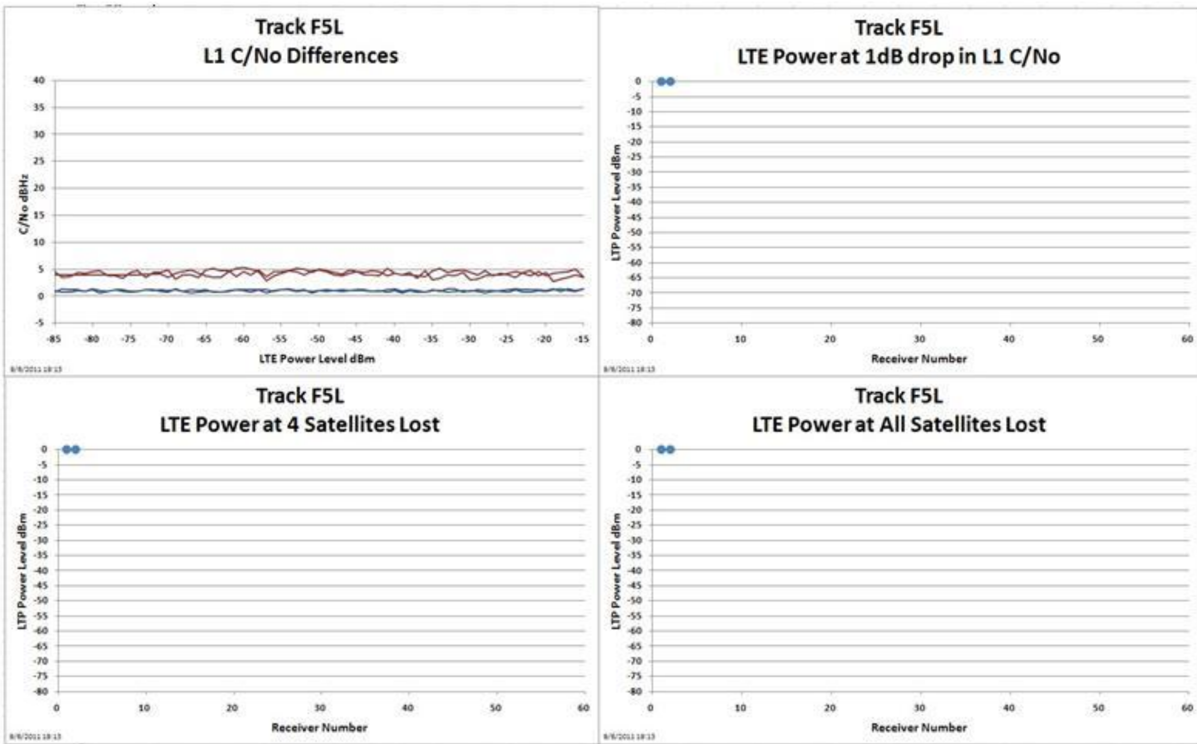


Figure 85 PCTEL F5L

There was some response in the C/N_0 levels to the F5H signal as seen in the blue curve of Figure 86. However the level of change of the C/N_0 was less than 1 dB. Note also that one of the receivers dropped more than four satellites when the power level reached -21 dBm.

The Sub-Teams take the following position:

> This loss of satellites is alarming giving the modest effect (<1dB) on the measured C/N_0 values. One possible explanation of this could be due to spectral content in the emissions interacting with the C/A codes and specific channel tracking frequencies. This alarming observation requires further research and investigation.

LightSquared takes the following position:

> The Sub-Teams believe this observation is alarming requires further research and investigation.

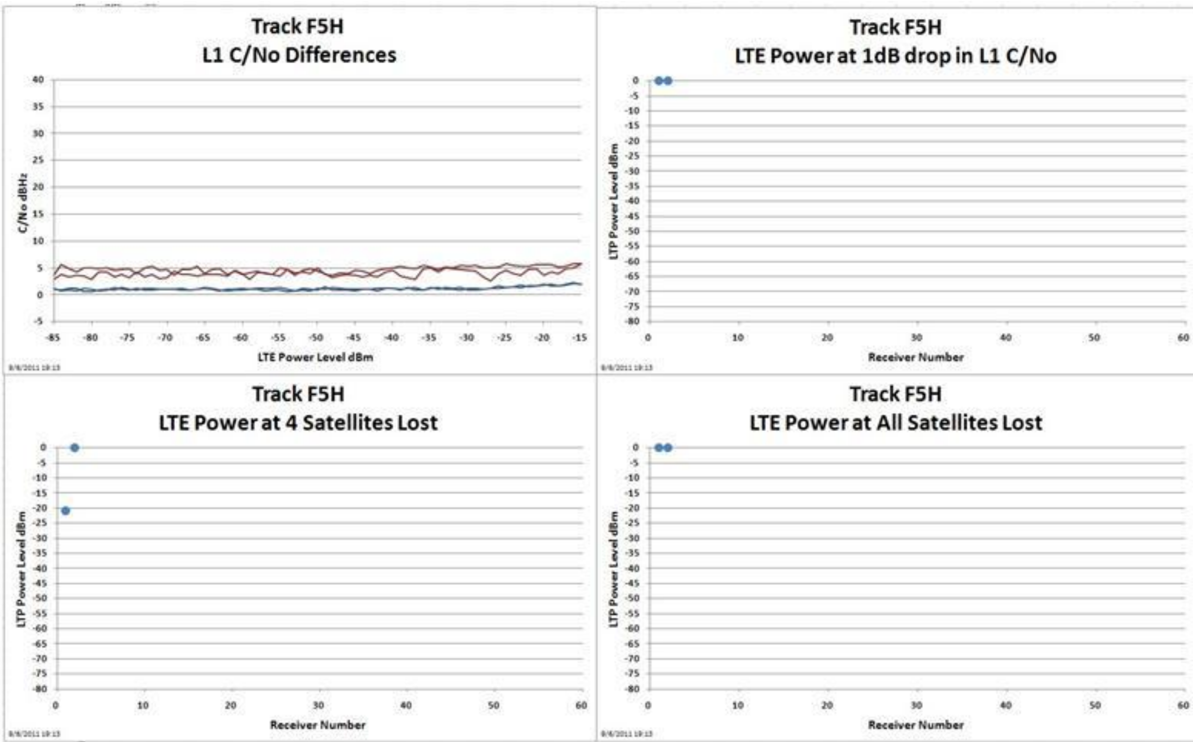


Figure 86 PCTEL F5H

There was a very large response in the C/N_0 levels to the F5L+F5H signal (Figure 87). The 1dB change in C/N_0 occurs on each receiver at the -42 and -49 dBm levels respectively (Figure 87). Note also that both of the receivers lose lock on more than four satellites at the -16 dBm and -42 dBm levels respectively. One of the receivers loses lock on all satellites when the input LTE signal reaches -34 dBm.

The Sub-Teams take the following position:

> This large response from the combined F5L+F5H is assumed to be caused by the third order harmonic of the two combined signals.

LightSquared takes the following position:

> LightSquared notes that the PCTEL antenna functioned well in the Las Vegas field tests, even in the presence of dual carriers. It further notes that intermodulation is not an issue with the lower 10 MHz channel on a stand-alone basis.

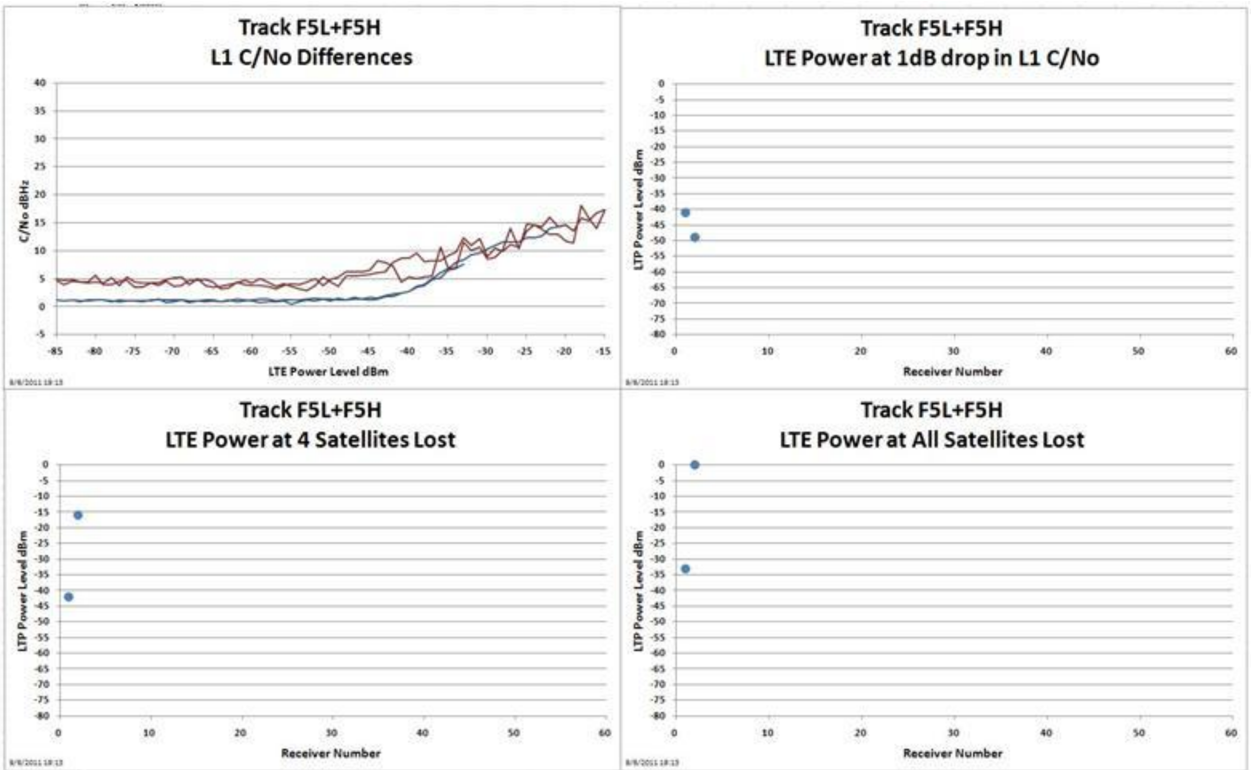


Figure 87 PCTEL F5L+F5H

There was no noticeable change in the sensitivity of these receivers to the F5H signal (Figure 88).

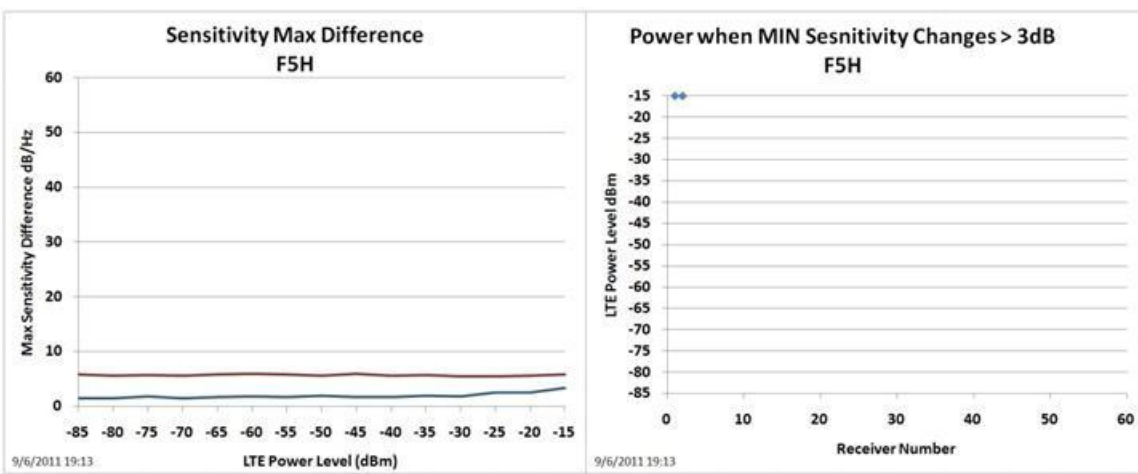


Figure 88 F5H Sensitivity

There was a significant change in the both receiver’s sensitivity to the F5L+F5H signal as shown in Figure 89.   The receivers sensitivity was impacted when the input signal was greater than -35 dBm and -40 dBm respectively.

The Sub-Teams take the following position:

> This significant impact from these signals is likely due to the third order harmonic of the two combined signals.

LightSquared takes the following position:

> LightSquared notes that the PCTEL antenna functioned well in the Las Vegas field tests, even in the presence of dual carriers. It further notes that intermodulation is not an issue with the lower 10 MHz channel on a stand-alone basis.

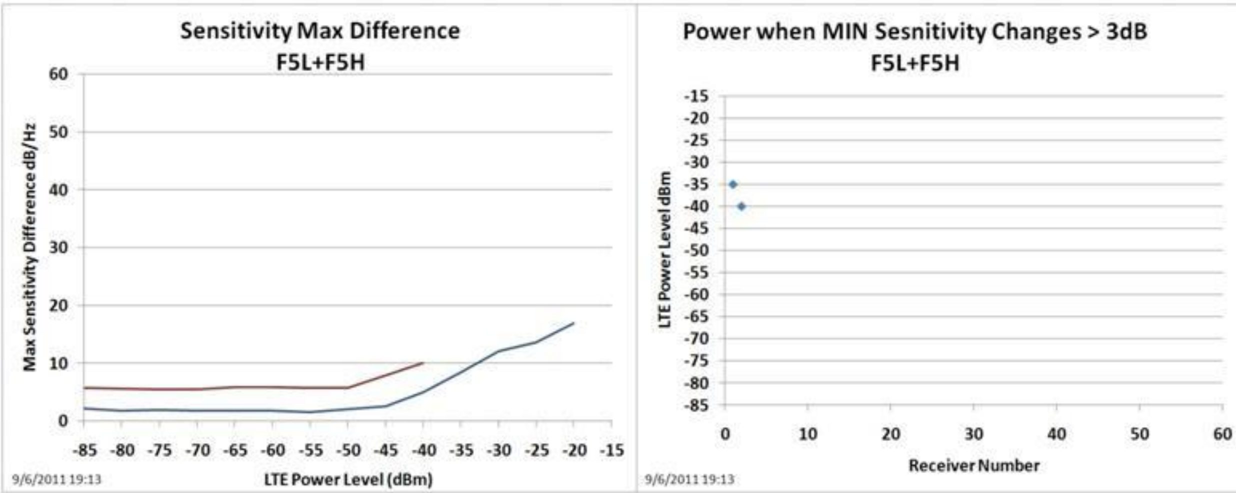


Figure 89 F5L+F5H Sensitivity

The receivers sensitivity was not affected by the F10L emission (Figure 90).

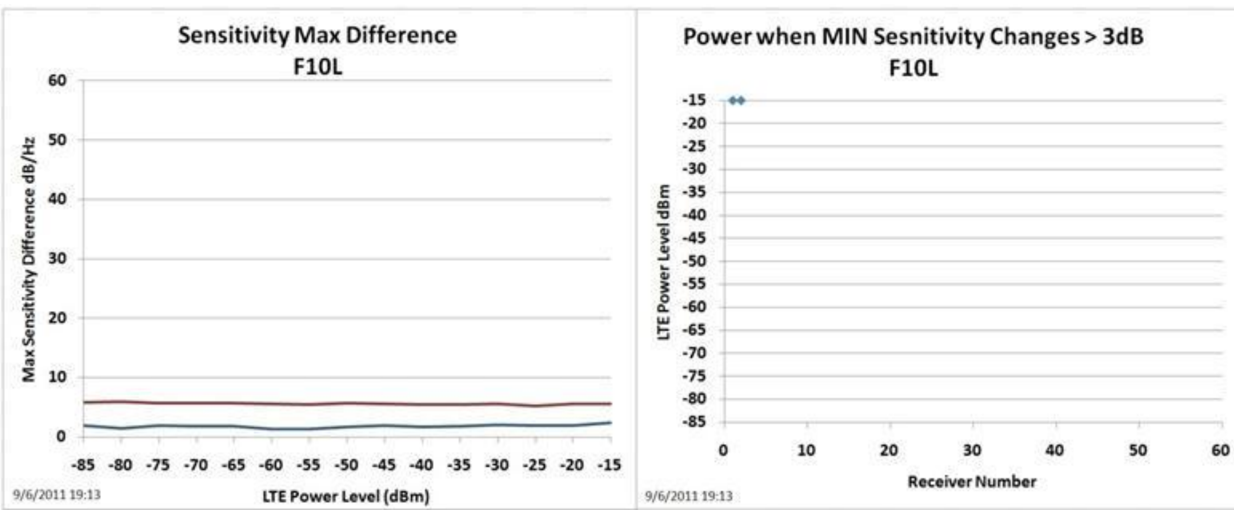


Figure 90 PCTEL F10L Sensitivity

There was a significant change in the both receivers sensitivity to the F10L+F10H signal (Figure 91) The receivers sensitivity was impacted when the input signal was greater than -35 dBm.

The Sub-Teams take the following position:

> This significant impact from these signals is likely due to the third order harmonic of the two combined signals.

LightSquared takes the following position:

LightSquared notes that the PCTEL antenna functioned well in the Las Vegas field tests, even in the presence of dual carriers. It further notes that intermodulation is not an issue with the lower 10 MHz channel on a stand-alone basis.

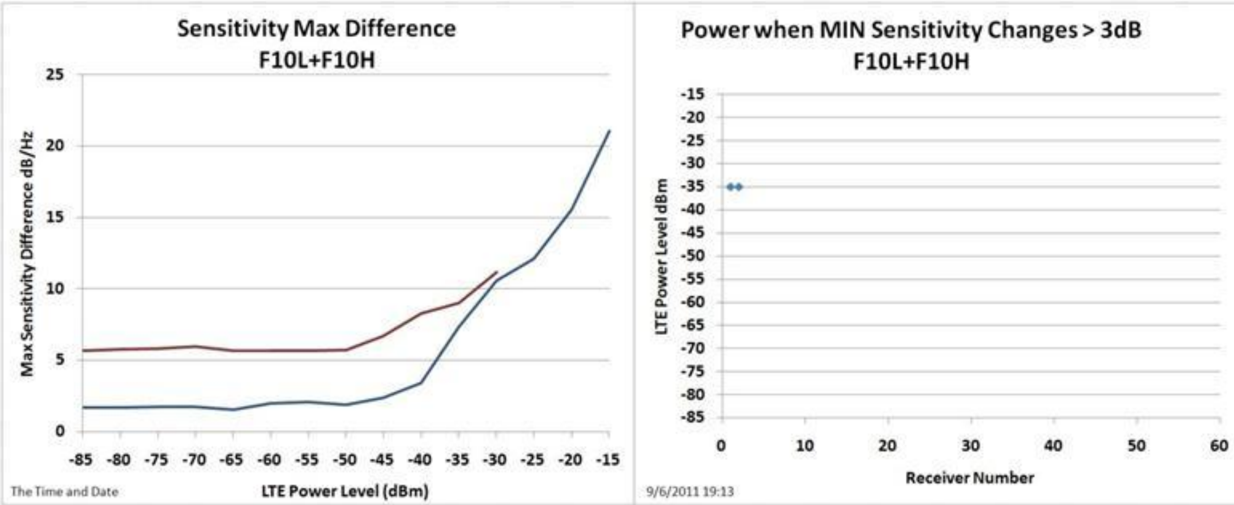


Figure 91 F10L+F10H Sensitivity

Reacquisition of the satellite signals was not affected by the F5H emission (Figure 92).

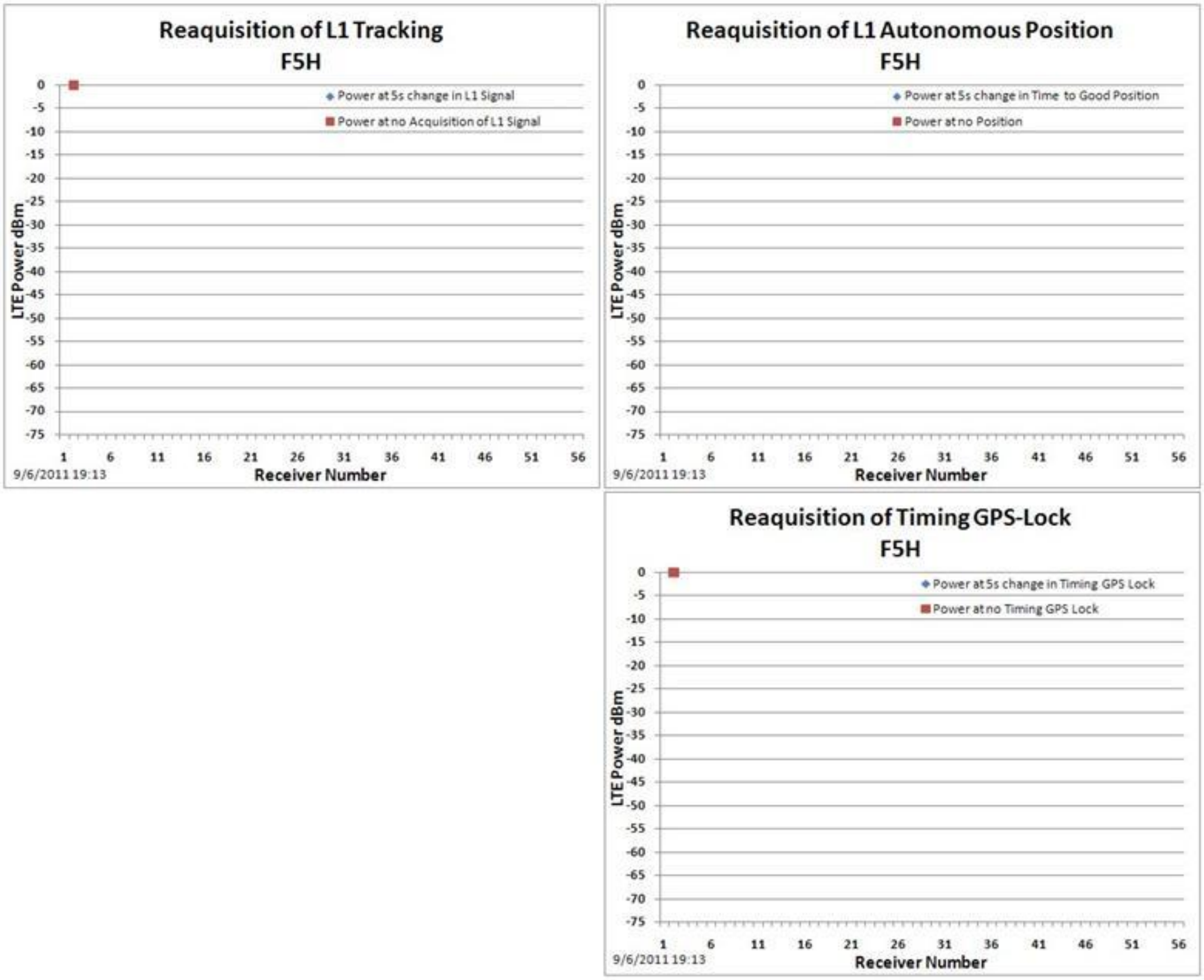


Figure 92 F5H Reacquisition

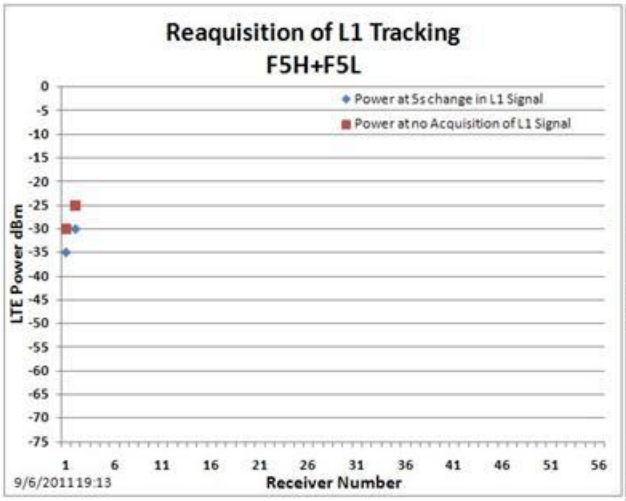
The was a significant impact on satellite acquisition by the F5H+F5L signal. The receivers were unable to acquire the satellite signal when the LTE input signal was above -25 dBm and -30 dBm respectively (Figure 93). These Timing receivers required an additional 5 seconds more than normal when the input signal level was greater than -40 dBm. They were also unable to re establish GPS Lock at all when the signal levels were above -30 dBm.

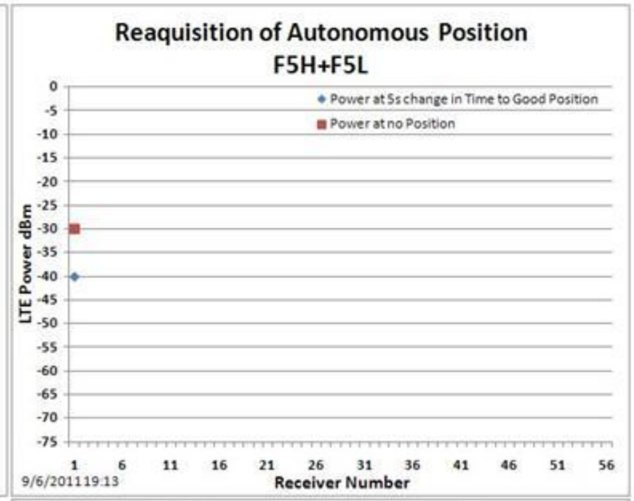
The Sub-Teams take the following position:

> It is expected that this degradation was caused by the third order harmonic of the two combined signals.

LightSquared takes the following position:

> LightSquared notes that the PCTEL antenna functioned well in the Las Vegas field tests, even in the presence of dual carriers. It further notes that intermodulation is not an issue with the lower 10 MHz channel on a stand-alone basis.





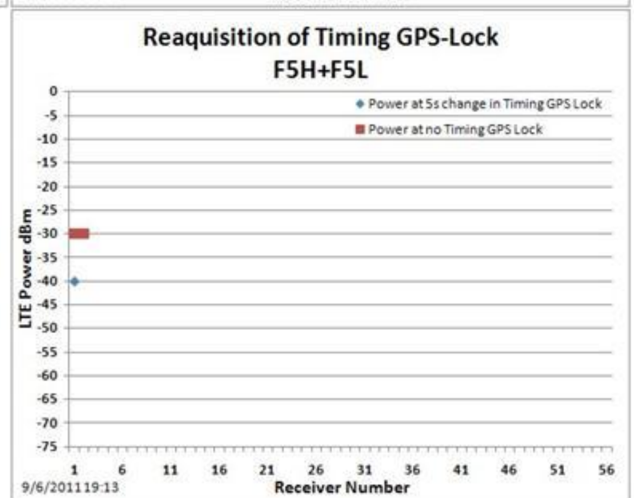


Figure 93 PCTEL F5H+F5L Reacquisition

The Reacquisition property of both receivers was not affected by the F10L signal (Figure 94)

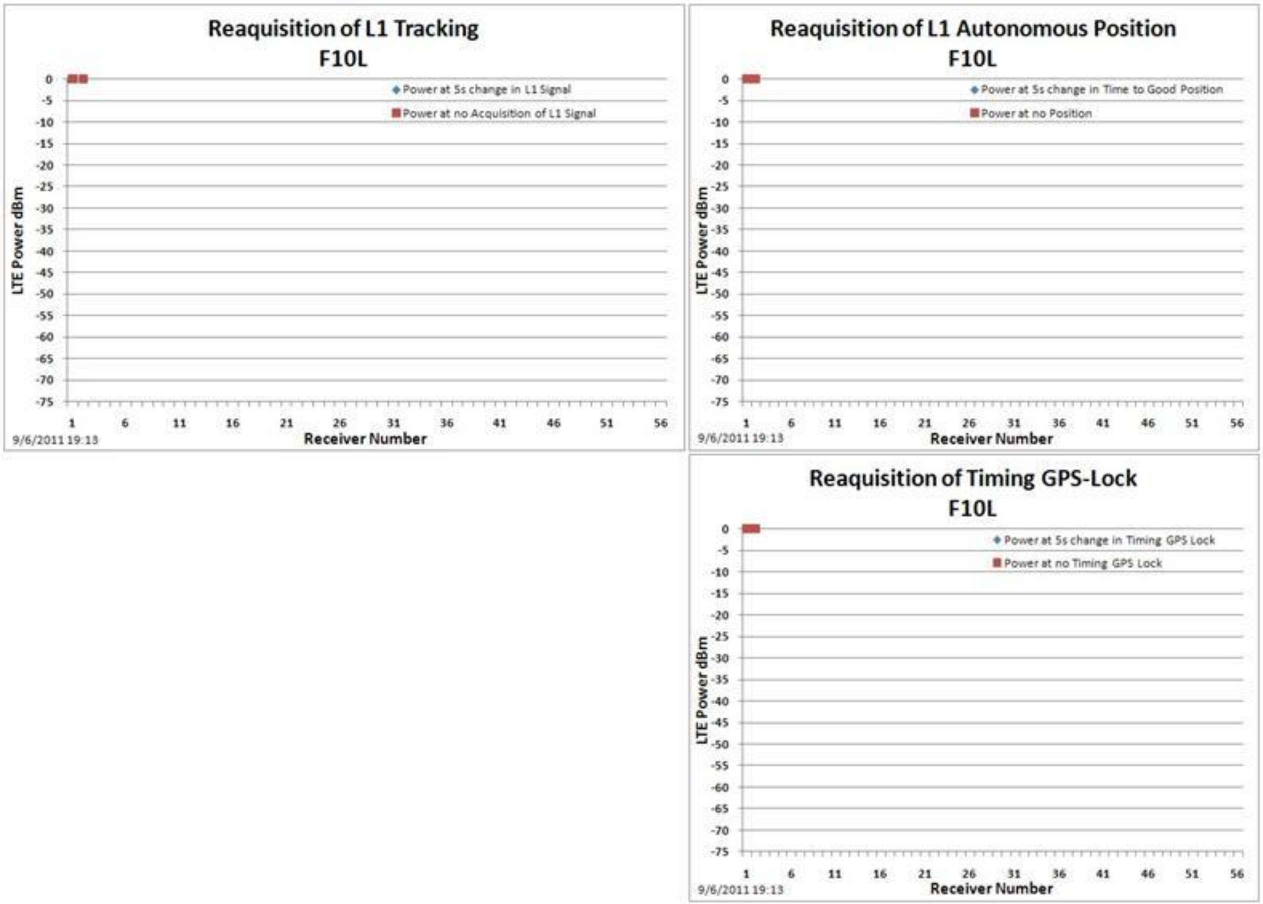


Figure 94 PCTEL F10L Reacquisition

There was a significant impact on satellite acquisition by the F10H+F10L signal. The receivers were unable to acquire the satellite signal when the LTE input signal was above -20 dBm and -25 dBm respectively (Figure 95). These Timing receivers were unable to re establish GPS Lock when the signal levels were above -25 dBm and -30 dBm respectively.

The Sub-Teams take the following position:

> It is assumed that this degradation was caused by the third order harmonic of the two combined signals.

LightSquared takes the following position:

> LightSquared notes that the PCTEL antenna functioned well in the Las Vegas field tests, even in the presence of dual carriers. It further notes that intermodulation is not an issue with the lower 10 MHz channel on a stand-alone basis.

Figure 95 PCTEL F10H+F10L Reacquisition

Appendix H.1.13

StarFire/OmniSTAR – NAVAIR Anechoic Chamber Test Results

OmniSTAR and StarFire types of L-Band augmentation signals were broadcast within the NAVAIR chamber. Each signal was broadcast on its own frequency.

Four receivers tracked one of the augmentation test signals during the Tracking tests at NAVAIR. The anonymous codes of the participating receivers were: H14892, H25314 H76180, and H91393.

The following charts illustrate the Energy/Bit ratio measured in dB for each tracking test scenario. This is an equivalent metric to C/N_0 used for the GPS tracking channels.

Figure 96 illustrates the L-Band tracking behavior during the F5H emissions. The receivers become degraded (-1dB point) between -75 dBm and -55 dBm depending on the receiver. All L-Band tracking is lost when LTE power is above -51 dBm.

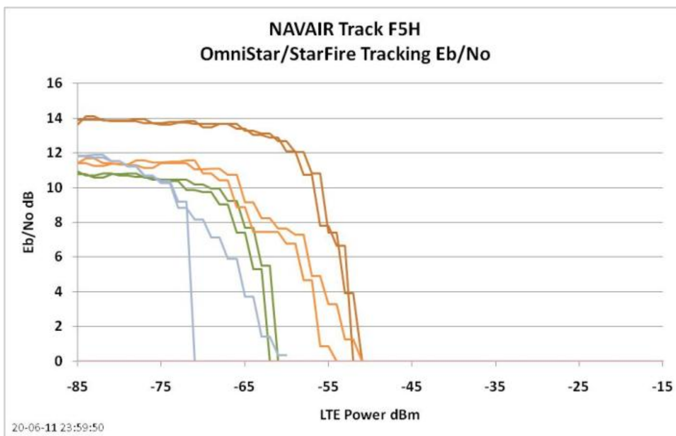


Figure 96 L-Band F5H

Figure 97 illustrates the L-Band tracking behavior during the F5L+F5H emissions. The receivers become degraded (-1dB point) between -82 dBm and -57 dBm depending on receiver. All L-Band tracking is lost when LTE power is above -53 dBm.

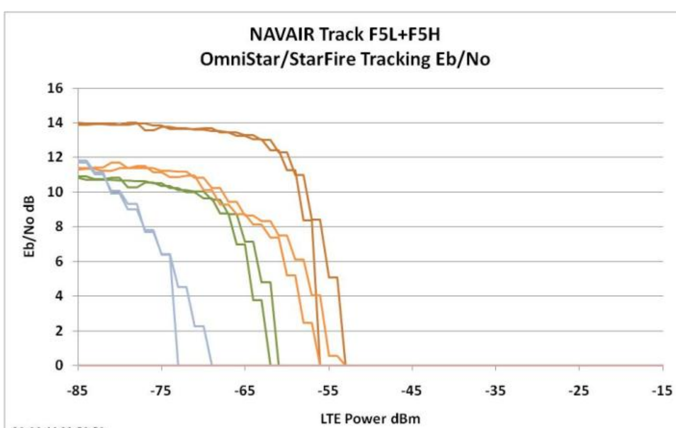


Figure 97 L-Band F5L+F5H

Figure 98 illustrates the L-Band tracking behavior during the F10L emissions. The receivers become degraded (-1dB point) between -83 dBm and -64 dBm depending on the receiver. All L-Band tracking is lost when LTE power is above -59 dBm.

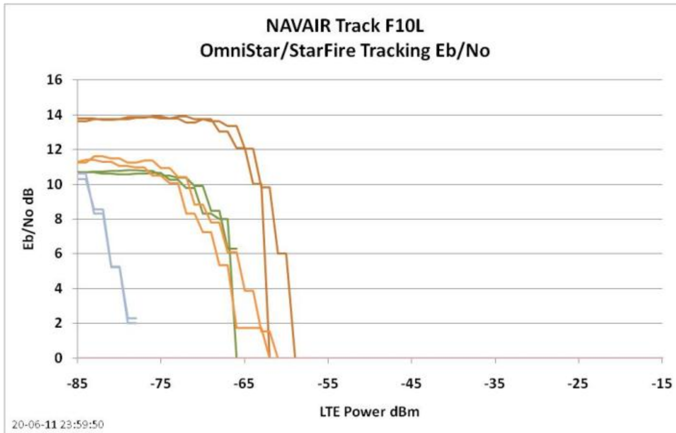


Figure 98 L-Band F10L

Figure 99 illustrates the L-Band tracking behavior during the F10H emissions. The receivers become degraded (-1dB point) between -83 dBm and -67 dBm depending on the receiver. All L-Band tracking is lost on the receivers if the LTE power is above -63 dBm.

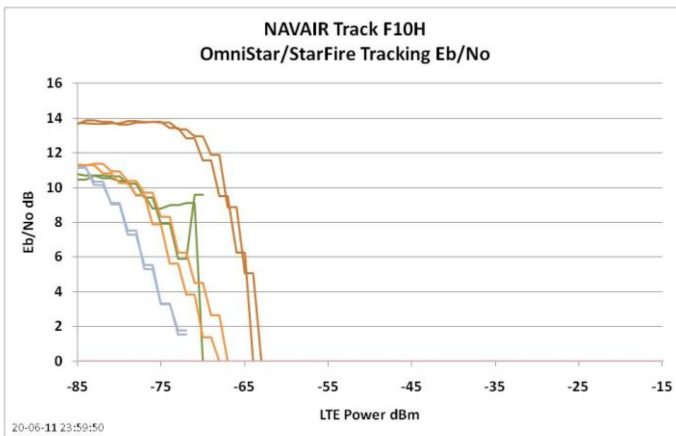


Figure 99 L-Band F10H

Figure 100 illustrates the L-Band tracking behavior during the F10L+F10H emissions. The receivers become degraded (-1dB point) between -83 dBm and -69 dBm depending on the receiver. All L-Band tracking is lost if the LTE power is above -65 dBm.

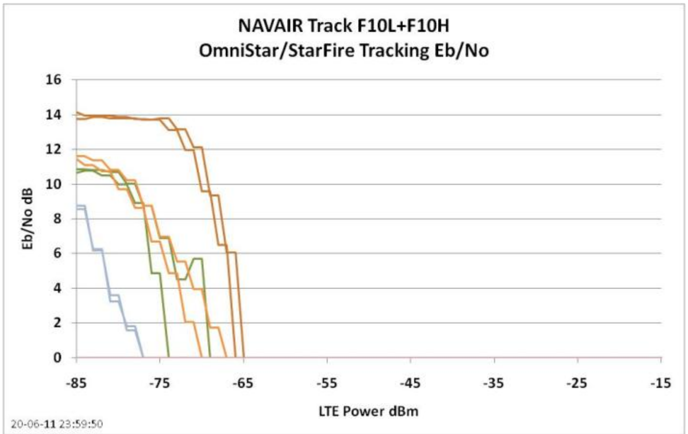


Figure 100 L-Band F10L+F10H

Figure 101 illustrates the L-Band tracking behavior during the Handset emissions. The receivers become degraded (-1dB point) between -57 dBm and -20 dBm depending on the receiver. All L-Band tracking is lost if the LTE power is above -19 dBm.

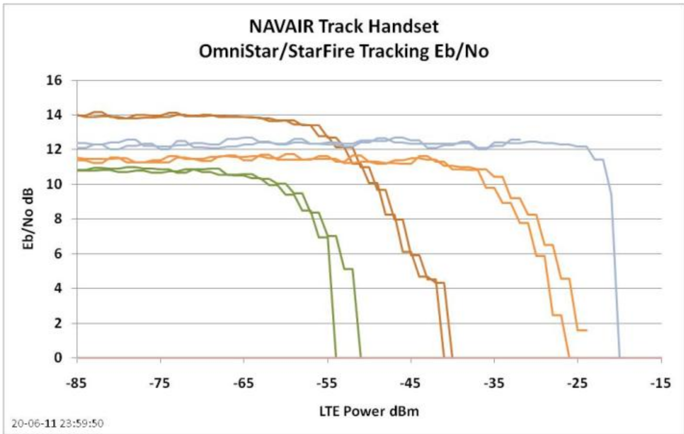


Figure 101 L-Band Handset

Appendix N.1

NPSTC Discussion and Concerns Regarding Interference to GPS Services Due to Terrestrial LTE Operations on Adjacent L-Band Allocations

Overview

It has been shown that strong RF emissions located in frequency bands near the radiolocation allocation of 1559 – 1610MHz; with the US GPS system centered at 1575.42MHz, can impact the availability, acquisition and accuracy of GPS services. While such interruptions may affect multiple services, Public Safety and associated supporting services have unique needs that are critical to the public welfare.

GPS is utilized within the Public Safety services in a number of ways. The list includes, but is not limited to:

1. Location of police officers via embedded GPS systems in portable “Handie-Talkie” radios, automatically reported to a dispatch center allowing:
    a. Rapid response to an officer in need; “man down” signaling. This can be critical to the health and safety of an officer including ultimately saving an officers life;
    b. Efficient and rapid dispatch of the closest officer to a situation;
    c. Tracking of officers movements and timing for introduction as evidentiary information.
2. Mobile data / computing and location of police and official vehicles for Automatic Vehicle Locations (AVL) services as well as location and time-stamping of documentary video evidence; Location Reporting is a key factor in Computer Aided Dispatch (CAD) systems:
    a. AVL allows rapid and efficient dispatch of police and fire equipment in response to calls, including E911 emergencies, from the public;
    b. Location and Time-stamped video can play a critical role as introduced evidence in the prosecution of crimes and cases. It can also play a role in resolution of disputes after traffic accidents and incidents.
    c. AVL, coupled with navigation, allows officers and officials to quickly respond to remote and difficult to locate locations.
3. GPS is utilized by thousands of systems to maintain accurate timing:
    a. Microsecond timing is utilized to maintain single frequency networks in simulcast systems.
        i. Such systems provide higher reliability coverage and service areas,
        ii. Fill in “dead zones” that would otherwise exist due to RF shadowing and building penetration losses; particularly in dense, urban environments,

   iii. Utilize scarce and valuable spectrum in a more efficient manner.

   b. Sub-millisecond timing is utilized to synchronize digitized voice and data in Public Safety and associated services such as Project 25. This will become more critical as Phase 2 is deployed.

   c. Millisecond timing is also derived from GPS for IP network timing consistent with IEEE 1588 PTP (Precision Timing Protocol) standards, allowing voted use of multiple receive sites in non-simulcast systems; thereby enhancing the overall readability of signals – particularly from handheld devices.

4. GPS timing is also prevalent in system timing critical to total infrastructure solutions:

   a. GPS timing and synchronization of microwave backhaul; minimizes possible audio distortion and reliability concerns of connectivity in P25 systems

   b. GPS timing provides time and date stamping at dispatch centers.

   c. GPS timing is used to provide Network time synchronization to multiple systems used by E911.

      i. Synchronized timing is provided to:

         1. CAD systems
         2. Radio systems
         3. Logging recorders
         4. Mobile Computer Terminals

   d. Synchronized timing is necessary to accurately create call incidents to be used for investigations.

5. Embedded GPS receivers in cell phones and cellular terminals play a role in E911 dispatch.

   a. Phase 2 E911 deployments, now available in many urban areas of the country and underway across much of the country, locates the caller within 30 – 50 meters in many cases.

   b. Many E911 calls now originate from cell phones; in certain locations, the percentage of E911 calls from cell phones exceeds 70% of all E911 calls.

Disruption of GPS service affects each of the above-listed use-cases in unique ways. A considerable investment of public funds has been made at the Federal, State, and Local levels to build out communications networks for the safety of our EMS, fire/rescue, and law enforcement responders, numerous public works agencies leading to the ultimate protection of human life of the civilian population as well as the responding officers and officials. The summarized list, above, states generalized use-cases of GPS within this service; specific impediments follow:

Infrastructure / Network Timing Issues

In Simulcast systems GPS is utilized to maintain critical network timing of RF frequency, data synchronization, and timing offset thereby allowing multiple transmitters to occupy the same channel, in overlapping service contours, in a constructive fashion. Such timing must be maintained with microsecond-level accuracy. To that end, GPS is utilized to train crystal, oven-stabilized crystal, and rubidium oscillators. Should GPS signaling be lost, the system will ultimately fail. Generally when tracking of at least 4 satellites in the GPS constellation is lost, an immediate alarm is sent to the dispatch or control center. Depending upon the reference clock system in use, timing may be lost in as little as 20 minutes; however, most systems will free-run with sufficient accuracy to maintain the network for a minimum of 4 hours. Certainly, within 24 hours the frequency reference system will fail and either the system will generate self-interference or the affected site(s) will shutdown as not to interfere with other sites within the network; this is dependant upon the version and type of simulcast system deployed. In the latter case, increasing coverage loss, depending upon the version of simulcast deployed, could take place.

Mitigation of infrastructure issues is possible and would require replacement of roof and tower-mounted antennas (which contain integrated antenna, low noise amplifier, and filtering) with new design antennas that contain multiple narrowband SAW filters, thus protecting the GPS receiver. In some cases where the GPS receiver is located within the antenna; replacement of the complete device would be necessary. Laboratory and Live-Air testing has tentatively proven that replacement of the external antenna with a new High Rejection antenna will mitigate future problems associated with blocking issues caused by strong L-band emissions. LightSquared has publicly stated that they will fund the replacement program for Public Safety infrastructure systems. Replacement of antennas must be complete prior to deployment of the terrestrial L-band system on a market by market basis.

Mobile Data / Computing and AVL

Mobile PC-based and stand-alone devices have been deployed into the Public Safety space for several years. Laboratory testing (Q1/2011), as well as Live-Air testing (Q2/2011), has suggested that these devices have the highest sensitivity to blocking of GPS due to L-band terrestrial transmissions. Lab testing has suggested that affected ranges may exceed 1 km; Live-Air testing confirmed blocking ranges in excess of 600 meters when a single L-band transmitter was in operation at 1552 MHz with an EIRP of +59dBm. Final deployment will involve 2 transmitters (at ~1552 MHz and ~1530 MHz), each at +62dBm. The latter case can also produce a 3rd order IM product (when the 5 or 10 MHz bandwidth of the LTE emission is considered) that falls directly upon the GPS allocation. It is estimated that the combined outage radius under this condition will exceed 850 meters and may extend to 1300 meters. Considering the proposed typical terrestrial LTE deployment separation distance of ~2 km, vast service outages are predicted.

Mitigation means are possible long term. The denial of service radius can be reduced to an acceptable distance of 15 meters or less through the use of replacement antennas on the vehicle. Replacement High Rejection antennas are being introduced and are becoming available as of Q2 / 2011. High Rejection GPS antennas have higher cost associated with the additional filtering and gain stages necessary to protect the target receivers. Communications systems utilized for Public Safety exhibit long lifetimes; similar to those utilized in the aviation industry. It is not uncommon for radio equipment to be utilized in service for a decade or longer. Vehicles; however, are replaced at more frequent intervals. As vehicles are replaced, High Rejection antennas can be affixed during the transfer process. An active program of replacement is, of course, possible; however, such replacement has not been budgeted by most jurisdictions nor has LightSquared suggested that a replacement program, such as that offered for Public Safety infrastructure equipment, is forthcoming. It would be reasonable to consider that, given a 3 – 5 year time frame, affected antennas might be replaced to an acceptable level although the time frame required may exceed this amount.

Portable Handset (Handie-Talkies) Devices

Just as in the mobile environment, the portable environment is represented by long-lived equipment. Unlike mobile devices that have external antennas, portable devices utilize unified designs in which much of the filtering and LNA stages is part of the handset device. Simple replacement of the antenna will not alleviate the problem. While it is possible to improve the performance and protection of the GPS receiver through re-design of its antenna to incorporate additional filtering and gain stages, upgrading, replacing or retrofitting units already in the field is impractical and costly. Even if such antennas were designed, portable devices are power drain-sensitive. Any improved antenna design will consume more power from the portable device yielding a shorter battery life. Laboratory testing has suggested denial of service radii up to 400 meters (about a quarter of a mile) are possible for some devices; Live-Air testing verified denial of service radii of up to 140 meters for single frequency (~1552 MHz) LTE operation. This is expected to increase to ~200 meters in the vicinity of dual frequency L-band LTE base station operations. Denial-of-GPS-Service to portable devices represents perhaps the largest concern to the Public Safety market. Officers rely on “Man-Down” signaling for immediate response under life and death situations. In certain circumstances, an officer may be unable to voice their location; GPS tracking is the only backup they may have for rescue or aid.

Cellular Location Service Performance / E911 Calls

The performance of Cellular-based devices does not directly impact the performance of a Public Safety system; however, it does affect the ability of EMS, fire/rescue, and law enforcement personnel to respond to an incident. As mentioned in the summary, E911 calls made from cellular telephones and terminals are rapidly overtaking conventional POTS calls to the dispatch center. In some locations, cellular-based E911 calls now exceed 70% of all calls received and that number is expected to continue to increase. Interference to GPS services; particularly location reporting, directly impacts the ability of Public Safety services to respond in a timely manner to received calls. We are therefore, concerned with the impact of L-band-based LTE signals on cellular E911 services.

Expected Performance of GPS Systems

Performance of Public Safety Location services are generally more stringent than those mandated for consumer devices / E911 performance. Contractual obligations to equipment manufacturers often place accuracy requirements of 15 meters for delivered equipment; 15 meters is considered to be the maximum acceptable inaccuracy of positioning data for Public Safety systems today. E911 consumer devices such as those incorporated in cell phones are subject to Federal E911 location accuracy performance requirements. Title 47 of the Code of Federal Regulations (CFR 20.18) states that for handset-based technologies, such as GPS or assisted GPS, the location accuracy of E911 calls placed from cell phones to public safety answering points (PSAP's) will have an accuracy of 50 meters for 67 percent of calls and 150 meters for 95 percent of calls.

Any long term use of L-band terrestrial systems that pose a threat to GPS performance must be able to show that 15 meter accuracy is maintained at any location where GPS service is available.

Extent of Testing to Date; Concern Over Limited Levels of Testing

To date, interference testing has taken 3 forms:

1. Individual equipment manufacturer testing of their own devices under laboratory conditions, conducted and radiated, beginning in Q4 / 2010;
2. Working Group radiated testing of GPS equipment under laboratory conditions, utilizing calibrated anechoic chambers in three phases:
    a. Precision Timing and Aviation devices (including equipment representative of Public Safety infrastructure equipment),
    b. General Location and Navigation devices (including Public Safety subscriber units);
    c. Cellular industry handset devices.
3. Live Sky testing:
    a. Holloman AFB; testing was not generally open to manufacturers, and,
    b. Las Vegas multi-site testing during a 2 week period in May, 2011.

Testing listed in Item 1, above, was undertaken by a limited number of manufacturers to determine the potential affects of LightSquared L-band LTE signals upon manufactured GPS-enabled devices. Some of these tests are a matter of public record with the FCC.

Testing listed in Item 2 represent the majority of all testing done to date. To its advantage, the repeatability of testing inherent in controlled laboratory conditions allows direct comparison of performance from a cross-section of devices. To its deficit, such testing does not, by design, represent the peak interference levels that may be present in real-world deployment. In an anechoic chamber, reflections are eliminated to the best extent possible. The device under test is illuminated only with the main, incident ray from the emitting antenna. Contrast this to real world conditions where a cellular-based system may illuminate a device with multiple direct and reflected rays as well as from direct and reflected energy from adjacent cells. In addition, time constraints forced limitations upon the total number of devices tested as well as the specific tests that could be performed. Public Safety was allowed to test approximately 50% of the devices originally submitted for evaluation. Similar limitations generally occurred within all product groups submitted to the General Location and Navigation sub-group.

Item 3, Live Sky testing, represents the closest approximation to date of a real-world deployment. Results from Live Sky testing indicate that multiple reflections were present in the received interference levels. At least one manufacturer of Public Safety equipment observed denial of service radii of just over 600 meters (about 0.4 miles) for one class of GPS-enabled mobile computing device and 140 meters for one type of portable radio devices. Contrasted to laboratory measurements where the device was only illuminated with a single, direct ray, the denial of service radii were approximately 350 and 90 meters respectively. The additional contribution of interference energy comes form several sources: The L-band LTE sector bore sight to the device under test provides a direct and, at times, at least one reflected ray. Since the deployed antenna height above ground level of the L-band LTE base station was under 20 meters at one test site, several close-in buildings provided strong reflections that created constructively to the total received power. Furthermore, additional reflections from the adjacent cells from nearby objects, buildings and other contributing structures also added to the total received interference power. At times and at certain locations, peak interference power levels exceeded 3dB above the expected free space path loss for a line of sight signal at 1550 MHz. For this reason, the denial of service radius observed during Live Sky testing at times exceeded that of the laboratory measurements.

In addition, Live Sky testing did not fully exercise the interference environment as would have been the case in a wider scale deployment. Under varying conditions of terrain, multiple sites could simultaneously contribute to the total interference power at the input of the victim device. Testing in the City of Las Vegas was performed over relatively uniform ground level heights for subscriber devices. While a single, high site system was deployed on the Las Vegas Strip, when considered with other deployed sites, of which only one other site was simultaneously active during any given test period, separation distances between sites were not typical of a true deployment scenario. Therefore, total interference power at the victim receiver was not fully representative of an actual deployment although interference potential of a full deployment can be inferred.

One factor to which a communications system is generally designed is the average signal power level delivered to the target receiver. To calculate the link budget of a communications system, several loss factors are taken into account. These include shadow margin, propagation path loss exponent, and a host of other factors. Due to these factors, an additional link margin factor is usually built into the system. When one considers interference to an existing system, however, one must assume the peak power delivered to the victim device; it is the peak interference level that will limit the robustness of the deployed, adjacent service – in this case, GPS. To that end, a cautious approach to deployment of L-band terrestrial LTE is warranted. Deployment, if approved, should take place in stages. While listed in the Mitigation Means section of this submission text, prudent deployment would dictate use of 5 MHz, followed by 10 MHz downlinks at ~1529 MHz. During these first phases of deployment, further controlled testing of potential interference due to LTE emissions at 1552 MHz should be performed if eventual operation at that allocation is contemplated. These tests must include further Live Sky testing under controlled conditions.

Mitigation Means

Mitigation of interference to GPS services from L-band emissions can take several forms; a balanced approach may satisfy the needs of current users as well as expansion of 4G services nationwide. These steps include:

From the equipment manufacturer and GPS equipment professional / Public Safety user:

1. Replacement of infrastructure antennas with High Rejection types;
2. Replacement of mobile antennas, also with High Rejection variants once available, although this can be cost-prohibitive in the moderate term;
3. Long term potential replacement of removable antennas for vehicles (2 --- 5 years) when possible and long term replacement of portable devices (>>5 years in some cases).

From the L-band Terrestrial Service Provider side:

1. Initial operation at 1528 MHz; 5 MHz followed by 10 MHz LTE. Initial tests have suggested that operation at power levels up to +62dBm utilizing either bandwidth profile (5 or 10 MHz) at ~1530 MHz do not negatively impact current Public Safety GPS devices although Working Group test have only been performed at 5 MHz bandwidth to date.
2. Long term (3 – 5 years) it may be possible to deploy base station equipment at ~1550 MHz. This is dependant upon replacement of currently-deployed Public Safety GPS receive equipment (as well as consumer and other commercial antennas and devices also currently deployed to receive GPS).
3. Sensitivity of Public Safety devices to +23dBm emissions near 1630 MHz (uplink/subscriber devices) must be fully understood. This impact must be addressed.
4. It may also be worth considering use of alternative, staggered downlink allocations in lieu of ~1550 MHz:
   a. LightSquared may have access to 5 MHz of spectrum at 1670 – 1675 MHZ on a Nationwide basis; limited by certain Federal exclusionary zones.
   b. Likewise, operation of downlink systems above ~1630 MHz should exhibit similar levels of insensitivity to interference as that of ~1530 MHz.
   c. A double-pass duplexer for the LTE L-band subscriber device could be utilized to receive downlink signals above 1630 and below 1538 MHz. The subscriber devices may be able to utilize ~1550 and ~1630 MHz as uplink channels at power levels of +23dBm. While slightly more difficult to produce than a standard duplexer, it nonetheless should alleviate concerns over interference predicted from the current proposed band plan.

5. It has also been noted that Harbinger, the parent of LightSquared, has bid on S-band spectrum located in the 2 GHz range. If the 40 MHz sought in that band were to be acquired, it could be paired with L-band MSS spectrum; the former utilized for downlink purposes leaving up to 40 MHz of spectrum at L-band for uplink-only purposes. A time-staggered ramp up of frequency use at L-band for uplink channels could insure that much of the current equipment now susceptible to interference would be replaced or retired. Furthermore, since the proposed uplink power is 40dB lower than that of the downlink proposal, any denial of service zones should be minimal although this is yet to be verified.

Conclusions

Theoretical analysis, organized, industry-wide and individual company laboratory testing, and fielded, Live Sky testing has indicated that terrestrial use of L-band allocations near accepted and utilized Satellite Navigation allocations (1559 – 1610MHz), including GPS, does diminish location accuracy and / or preclude, under certain circumstances, GPS service entirely. Each impacted device will exhibit a denial of service radius. To that end, the critical needs of Public Safety can be addressed by the following statements:

1. With respect to the maximum acceptable Denial of Service distance from a transmitter that Public Safety and associated services would accept:

   Ideally the maxim acceptable denial of GPS service area from any transmitting source should be zero for applications that are in the best interest of the public's safety. After giving careful consideration to the various location dependent applications that exist, denial of service distances greater than 10 meters (or approximately 33 feet) may create occlusion regions where persons wearing court ordered electronic monitoring devices would be undetected. In a dense urban environment where cell site density may be potentially high to meet subscriber capacity, the likelihood of cell site coverage overlap is also high; leading to excessively large regions where public safety GPS applications may be degraded. This nominal distance is representative of the distance between a single transmitting antenna to ground level if the antenna is mounted on a three-story building in an urban area.

2. The maximum acceptable Time to First Fix (acquisition) Time that Public Safety can accept is best answered by Federal E911 requirements and concerns over the best interest of the public at large:

   Phase II E-911 systems are designed to automatically display a cell phone subscriber's location and call back number to the call taker or dispatcher answering an E911 call at a PSAP (Public Safety Answering Point). If a caller is unable to speak or the call is being made from a weak signal area such that the call taker has difficulty in understanding the caller, every second delayed in determining the caller's location may be the difference between life and death. The same applies to EMS, fire/rescue and Law Enforcement vehicles and police when they are en route to a scene or transporting patients to the closest available hospitals. Other than delays associated with an initial cold start of a GPS, the time to first fix for public safety applications should be zero.

Appendix O.1

1. THE LIGHTSQUARED BROADBAND TERRESTRIAL NETWORK
TECHNICAL CHARACTERISTICS

Table
1.1.1 Frequency offset (f_{offset}) from the FCC authorized bandwidth (B)
1.1.2 Plan of record to the TWG
1.1.3 Base Station Single-City Tower Concentration Pattern
1.2.1 Spectrum Deployment Phases

Consistent with Item 1 of the Work Plan, LightSquared provided information to the WG on its LTE network base station and mobile station/user equipment (UE) technical characteristics.

LightSquared Downlink Operating Parameters

LightSquared's present deployment plans call for approximately 36,000 transmit sites to be built that transmit a maximum of 62 dBm (32 dBW) EIRP per channel. LightSquared plans to deploy up to two channels per sector. The EIRP per sector will be up to 65 dBm (35 dBW).

The FCC authorization allows a maximum transmit power of 72 dBm (42 dBW) EIRP per sector.

The out-of-channel emission (OOCE)[1] power spectral density (PSD) limits at the transmit antenna output (including the antenna gain) are as follows:

- At 1 MHz offset from edge of ATCt channel: - 32.4 dBW/MHz
- At 2 MHz offset from edge of ATCt channel: - 39.4 dBW/MHz

The out-of-band emission (OOBE) PSD limits are as follows:

- In the RNSS band (1559 – 1610 MHz) band: -100 dBW/MHz (1 MHz measurement bandwidth)
- In the AMT band (1435 – 1525 MHz) the limits are per 47 CFR 25.202(f)[2]:

[1] The term, "OOCE" is used to refer to adjacent channel emissions that are contained within the MSS L-band. When these emission fall outside the MSS L-band, they are referred to as OOBE.
2 The requirements for the AMT band are for measurements performed at the antenna connector.

Frequency offset (f_{offset}) from the FCC authorized bandwidth (B)	Attenuation (dB) below the mean output power in watts (P) of the transmitter	Measurement bandwidth
B/2 =< f_{offset} < B	25	4 kHz
B =< f_{offset} < 5B/2	35	4 kHz
5B/2 =< f_{offset}	43 + 10log(P)	4 kHz

Table 0.1

At the commencement of the working group process LightSquared presented the following plan of record to the TWG:

Phase	Spectrum
0	One 5 MHz channel: 1550.2 MHz - 1555.2 MHz, 62 dBm EIRP per 5 MHz channel.
1	Two 5 MHz channel: 1526.3 MHz -1531.3 MHz & 1550.2 MHz - 1555.2 MHz, 62 dBm EIRP per 5 MHz channel.
2	Two 10 MHz channel: 1526 MHz -1536 MHz & 1545.2 MHz - 1555.2 MHz, 62 dBm EIRP per 10 MHz channel.

Table 0.2

In addition to the deployment phases identified above, the sub-teams also assessed one or more potential alternate deployment scenarios, including a standalone 5 MHz channel centered on 1528.8 MHz and a standalone 10 MHz channel centered on 1531.0 MHz.

The channel modulation is 3GPP LTE (OFDM).

Network loading effect: 2.2 dB reduction from maximum aggregate transmit EIRP

This 2.2 dB reduction was considered only by the Aviation sub-team for the purpose of evaluating aggregate RFI effects from a large number of base stations; see Section 4.4.2. The analysis for space-based receivers assumed 100% loading. This element did not apply to any other sub teams.

*Note: In a 4G LTE network not all the sites will be transmitting on all subcarriers simultaneously, with networks typically designed with 60% load during busy hour. When a large number of base stations are considered, the average Tx EIRP per base station would be 2.2 dB (10 * LOG_{10}(0.6)) lower than the maximum EIRP of 32 dBW. In non-busy hour the network loading will be even smaller.*

Base Station Antenna Pattern and Siting Parameters

The typical base station sector antenna characteristics are listed in the table below.

• Parameter	• Value
Horizontal plane beamwidth (-3dB)	66.32 degrees
Vertical plane beamwidth (-3dB)	7.95 degrees
Gain	16.5 dBi
Front-to-back ratio	35.03 dB
Electrical downtilt	2 degrees (elevation)
Polarization	+45 and -45 linear, cross-polarized

Table 0.3 Base Station Single-City Tower Concentration Pattern

The distance between transmitters depends on type of morphology around each site and other capacity and coverage considerations. We expect that it would typically be:

- Dense urban environment = 0.4-0.8 km
- Urban environment = 1-2 km
- Suburban environment = 2-4 km
- Rural environment 5-8 km3

User Equipment (Uplink) Technical Characteristics

LightSquared's deployment plans call for a maximum EIRP of +23 dBm (-7 dBW) from its UE device (consistent with 3GPP Band 24 specifications). LightSquared's FCC authorization allows for a maximum EIRP of 30 dBm (0 dBW). LightSquared's current deployment plans conform to the 3GPP specifications. When communicating with LightSquared towers, LightSquared UEs will transmit in the MSS uplink L-band (1626.5 MHz -1660.5 MHz).

In use case analyses, it may be appropriate to consider the aggregate effects of multiple UEs.

The spectrum deployment phases for UE match those of the downlink portion of the network, with a positive frequency offset of 101.5 MHz:

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3 LS responses to NTIA Questions Document

Phase	Spectrum
Phase 0	One 5 MHz channel: 1651.7 MHz - 1656.7 MHz with smallest bandwidth a user can transmit is 180 kHz
Phase 1	Two 5 MHz channels: 1627.8 MHz - 1632.8 MHz & 1651.7 MHz - 1656.7 MHz with smallest bandwidth a user can transmit is 180 kHz
Phase 2	Two 10 MHz channels: 1627.5 MHz - 1637.5 MHz & 1646.7 MHz - 1656.7 MHz with smallest bandwidth a user can transmit is 180 kHz

Table 0.1

The out-of-channel emission (OOCE) limit is -58dBW/4kHz at 1 MHz offset beyond the edges of assigned spectrum bands.

The out-of-band emission (OOBE) limit into the adjacent RNSS band (1559–1610 MHz) is -90 dBW/MHz wideband (1 MHz bandwidth) initially, increasing to -95 dBW/MHz after 5 years of start of service. Narrowband OOBE limits are -100 and -105 dBW, respectively, in a 1 kHz bandwidth.

LTE systems employ UE uplink power control. This power control is used for intra-network interference management and to make the most efficient use of UE power, while maintaining the link quality and averages approximately 10 dB. However, for the purposes of the testing and analysis conducted by the TWG, no reductions in UE transmit power were made.

Appendix S.1

Space Based Receiver Test Report

A preliminary report on the effects of CONDUCTED LightSquared emissions on four high-precision GPS receivers

CONTENTS

1. Introduction, Scope, Motivation

This report describes conducted interference measurements of the effects of a simulation of the LightSquared Phase 1A signal on four high precision receivers. All these receivers track at least the GPS CA code, and use semi-codeless tracking of P(Y)1 and P(Y)2. Two of these receivers are NASA science receivers which are used on board satellites, and two are typical of those used in NASA's high accuracy ground network, which is part of the International GNSS Service (IGS).

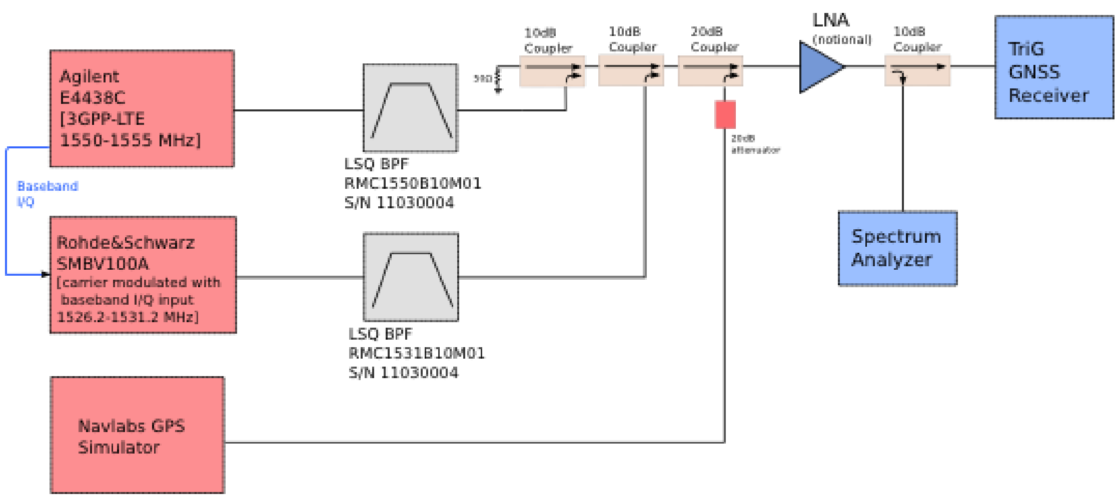
These measurements were made at an RF lab at the Jet Propulsion Laboratory (JPL) on 22 March 2011. The tests were conducted by Stephan Esterhuizen, Dave Stowers, Dmitry Turbiner, and Larry Young from JPL, and Steve Holley from LightSquared.

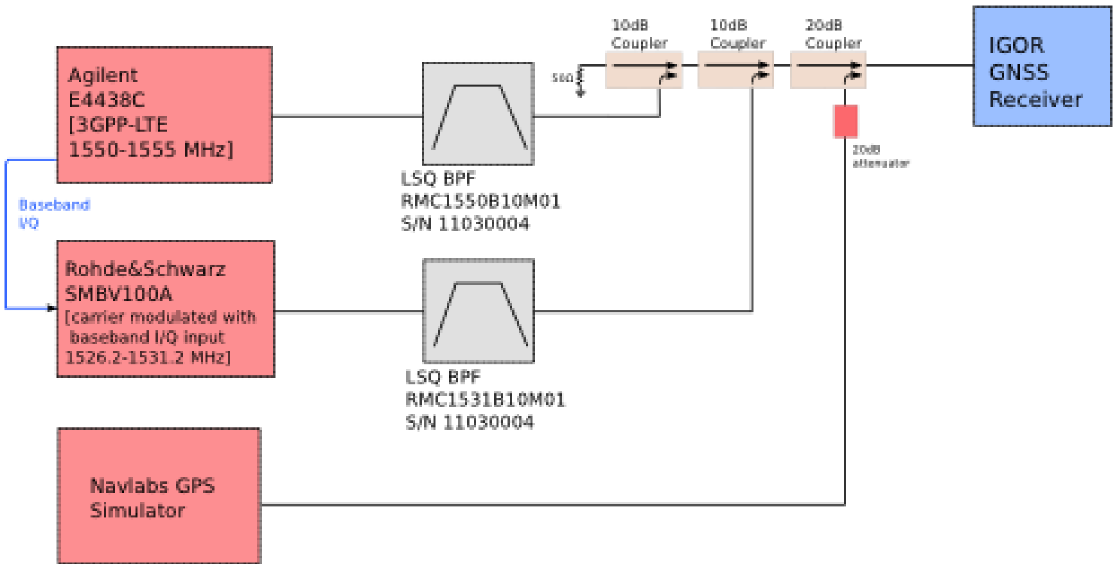
We chose to perform a conducted test in order to achieve the best accuracy. The conducted tests use carefully calibrated levels of signal, noise, and interference. Our primary observable is the change of C/No due to interference, and so the most important parameters for us to determine accurately are the noise and interference power levels. We set the signal high enough to provide a conveniently high level of C/No to start from. Since the space receivers were developed by the JPL group doing this test, we understand the algorithm used for those receivers' generation of C/No.

Although C/No degradation is what this report covers, we collected time tagged C/No, pseudorange, and carrier phase observables from each signal. In addition, we logged the onboard position solutions. In the case of the TriG and IGOR space receivers, these included 4 D position and its time derivatives, the formal errors, and the Chi-squared statistics for the solutions.

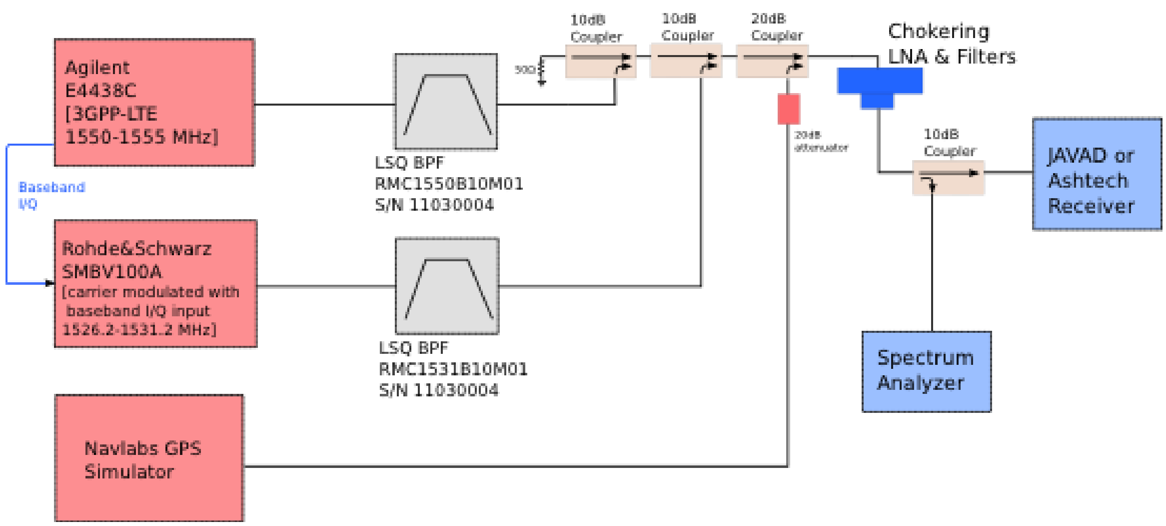
2. Block Diagram of Test Setups

The test setups for the TriG, IGOR, JAVAD Delta G3T, and Ashtech Z12 receivers are shown below. The signal to the Javad and Ashtech was amplified using a standard Ashtech choke ring preamplifier and filter set, part no. 701945-02 REV:E.





Agilent E4438C [3GPP-LTE 1550-1555 MHz]
Baseband I/Q
Rohde&Schwarz SMBV100A [carrier modulated with baseband I/Q input 1526.2-1531.2 MHz]
Navlabs GPS Simulator
LSQ BPF RMC1550B10M01 S/N 11030004
LSQ BPF RMC1531B10M01 S/N 11030004
50Ω
10dB Coupler
10dB Coupler
20dB Coupler
20dB attenuator
IGOR GNSS Receiver



Agilent E4438C [3GPP-LTE 1550-1555 MHz]
Baseband I/Q
Rohde&Schwarz SMBV100A [carrier modulated with baseband I/Q input 1526.2-1531.2 MHz]
Navlabs GPS Simulator
LSQ BPF RMC1550B10M01 S/N 11030004
LSQ BPF RMC1531B10M01 S/N 11030004
50Ω
10dB Coupler
10dB Coupler
20dB Coupler
20dB attenuator
Chokering LNA & Filters
10dB Coupler
JAVAD or Ashtech Receiver
Spectrum Analyzer

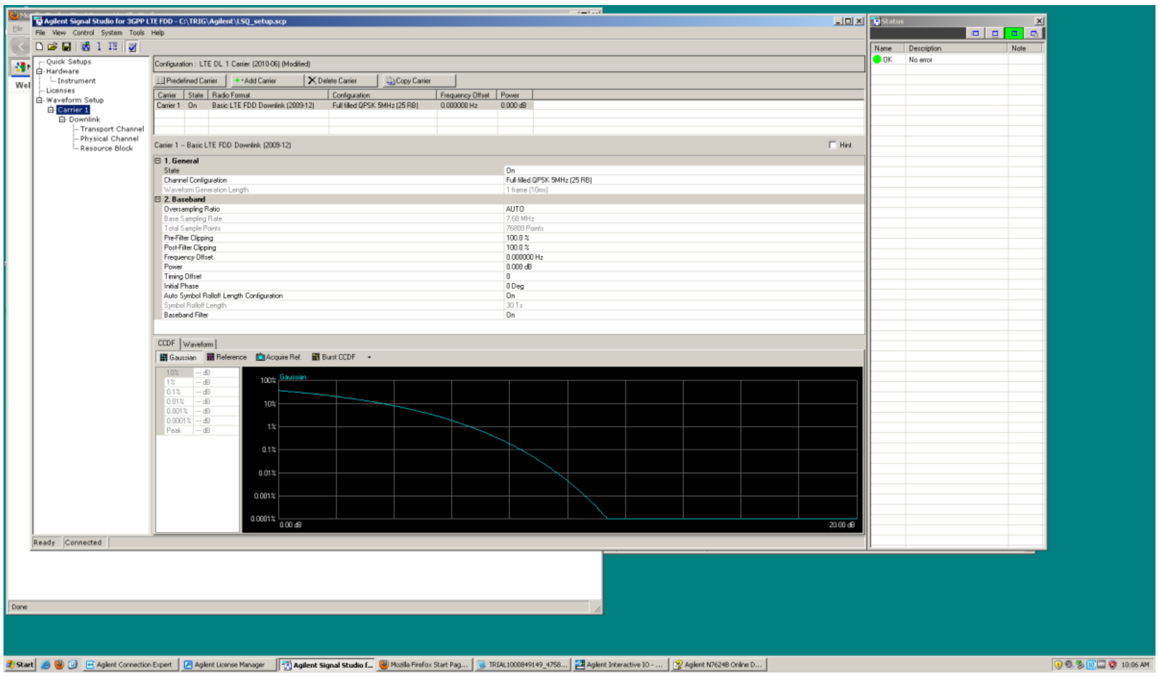
3. Antenna Output Simulator

LightSquared Signal Generation and Band-Pass Filters.

We are generating a Phase 1A LightSquared downstream signal configuration:

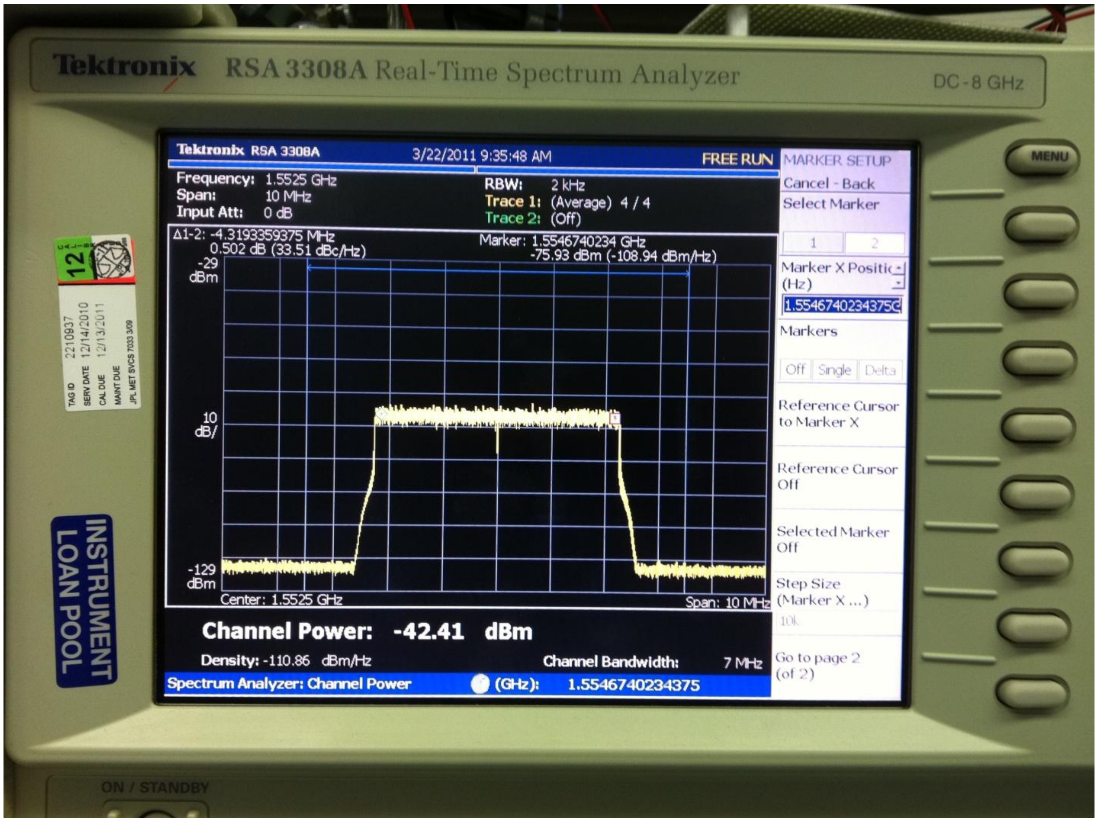
CHANNEL 1:

Agilent Signal Studio for 3GPP LTE FDD is used to generate a Full filled QPSK 5MHz (25RB) Basic LTE FDD Downlink (v. 2009-12)



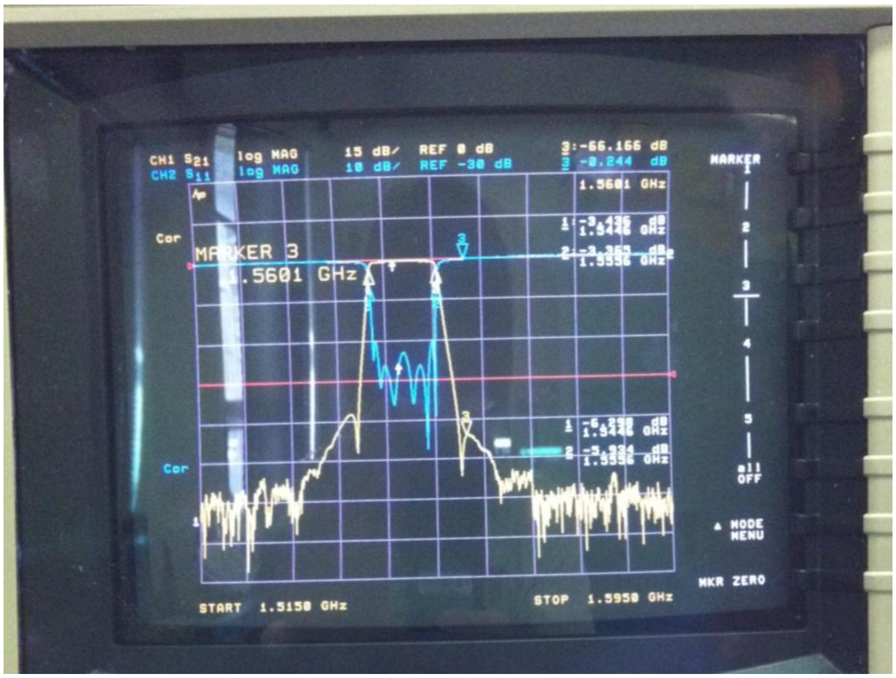
This LTE Base-Band signal is then loaded onto an Agilent E4438C Vector Signal Generator which modulates it onto a 1552.5 MHz carrier.

The E4438C is configured to simultaneously output this same LTE Base-Band waveform onto its External I/Q Outputs.



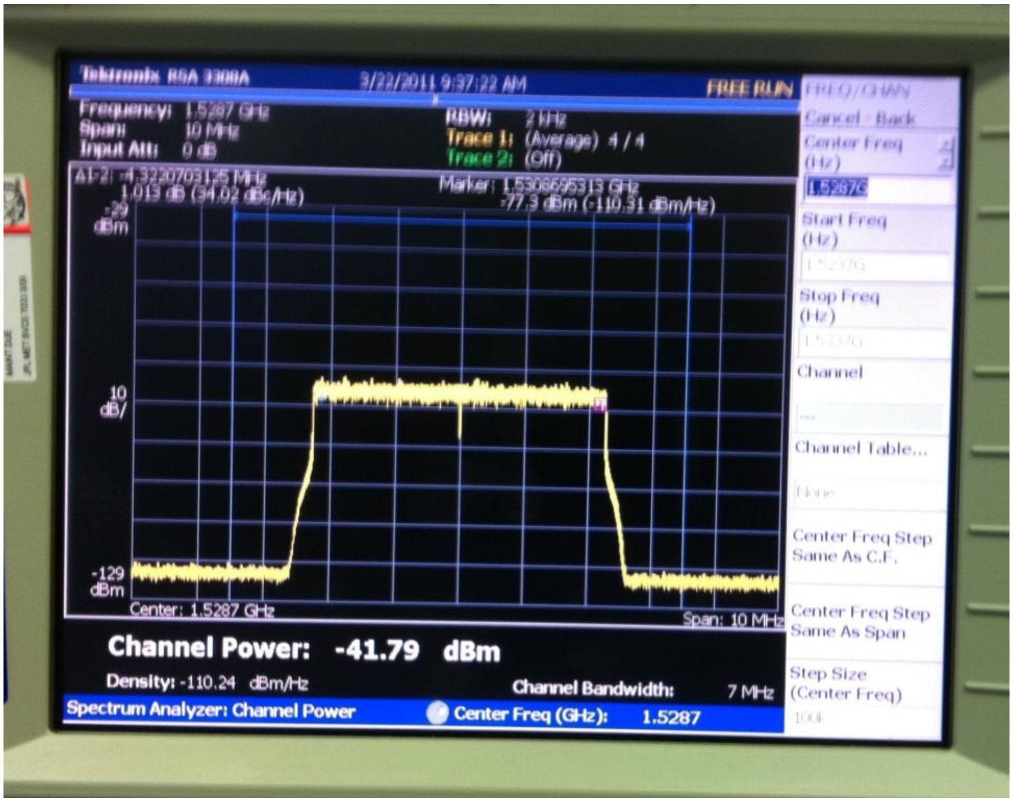
The E4438C RF output is connected to a Band-Pass Filter supplied by LightSquared:

Model:	RMC1550B10M01
S/N:	11030004
S21 -3dB pts:	1446.1 MHz -- 1555.61 MHz
Attenuation:	At least 66dB above 1560 MHz



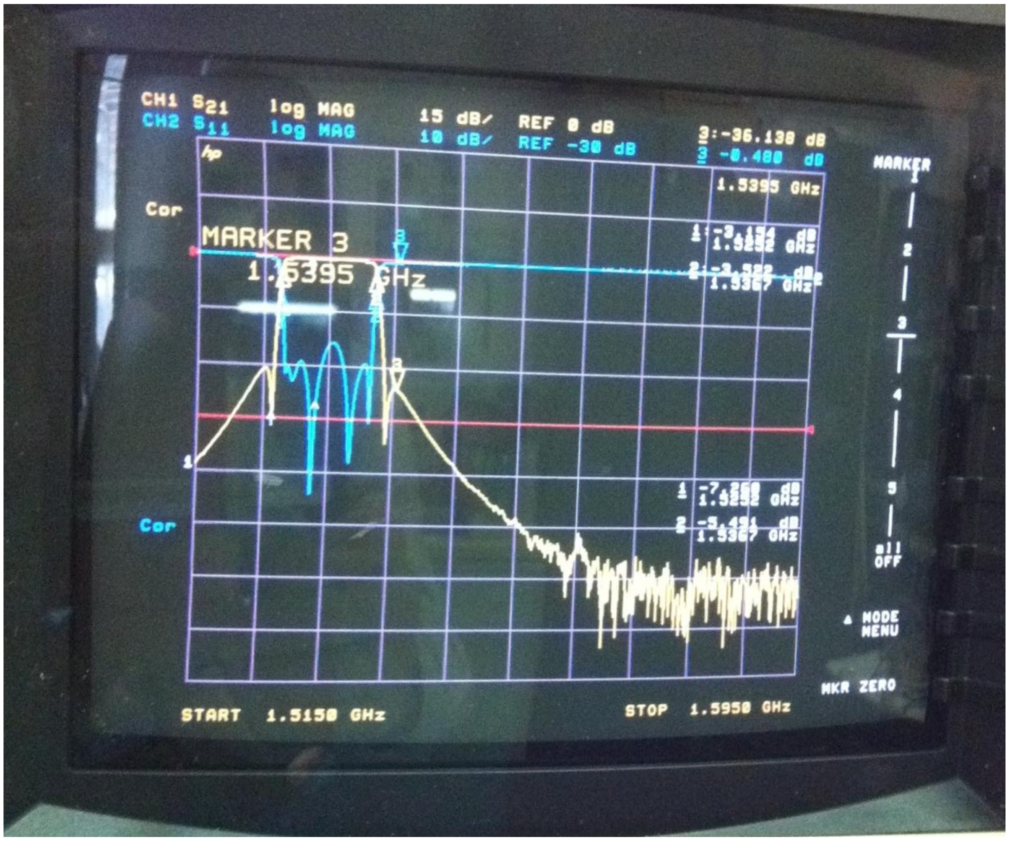
CHANNEL 2:

The External I/Q Outputs of the E4438C are connected to the **I/Q modulator** inputs of a **RHODE&SCHWARZ SMBV100A** Vector Signal Generator set to a **1528.7 MHz carrier**.



The SMBV100A RF output is connected to a Band-Pass Filter supplied by LightSquared:

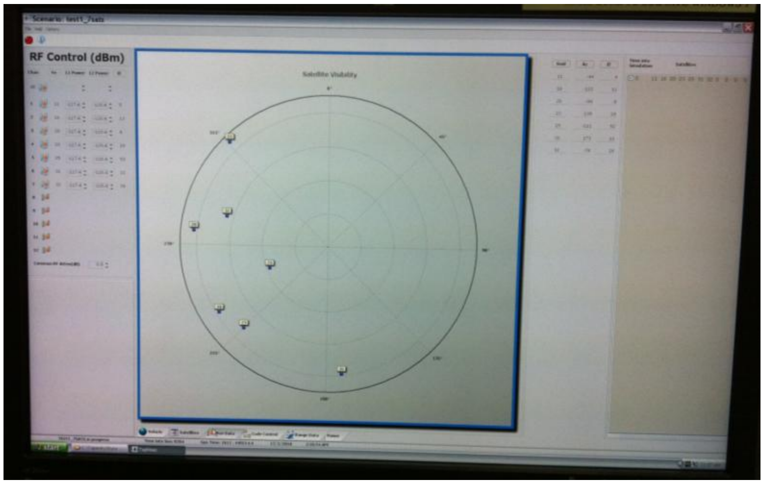
Model	RMC1531B10M01
S/N	11030004
S21 -3dB pts	1525.2 MHz – 1536.7 MHz
Attenuation	At least 36dB at 1539.5 MHz

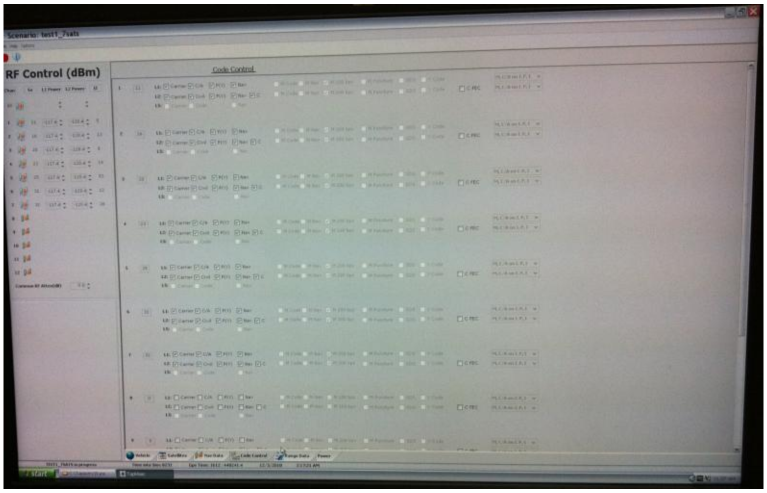


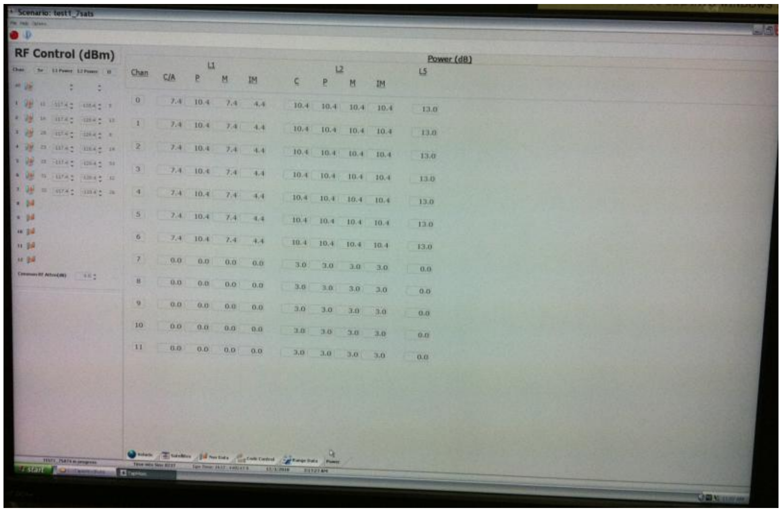
GPS Signal Generation

We are using a **NAVLABS** GPS Simulator configured as:

- 7 satellites
- **Constant Power** throughout the scenario (ie: no Antenna Gain Pattern effects, Atmospheric Attenuation, etc) in order to make the interference effects more apparent
- L1 C/A power set 3dB above P1 and P2 powers







Combining Signals into an *Antenna Simulator*: Measured Resulting Signal Power, Noise Spectrum and Power, and Distortion-Free Dynamic Range

We would like our ”Antenna Output Simulator” be as close as possible to reproducing real signals picked up by an antenna:

An important goal for our strategy for combining the three Signal Sources was to produce a **constant low power density broadband noise floor,** representative of normal operation.

Of particular importance is maintaining **a constant noise power in the GPS L1 pass-band, independent of varying interfering LightSquared signal powers.**

Our strategy for combining the three Signal Sources was chosen for the following reasons:

1. The “Antenna Output Simulator” ” mainline is terminated with a **50 Ohm broadband shunt**.
   - This presents a broadband 50 Ohm source impedance to the GPS receiver LNA.
   - This shunt acts as a noise generator producing a constant noise density of approx -174 dBm/Hz or equivalent to 300K (room temperature) across a wide frequency range.
2. The two LightSquared Signals are coupled onto the ”Antenna Output Simulator” mainline using **-10dB Directional Couplers**
   - This isolates the GPS receiver LNA from the uneven output impedance of the LightSquared band-pass filters.
   - Only a 10th of the broadband noise from the VSG’s and band-pass filters is coupled into the Antenna Simulator Mainline, or approx 30K.
3. The signal from the GPS Simulator is first attenuated by a **-20dB pad** and then coupled onto the ”Antenna Output Simulator” mainline using a **-20dB Directional Coupler**
   - With this attenuation, the simulator power sets a realistic C/No of approx 48 dB-Hz. Note: Because of its lower noise floor, the TriG receiver used a simulator signal power setting 2 dB below the other three receivers.
   - Only a 100th of the broadband noise from the -20dB pad is coupled into the Antenna Simulator Mainline, or approx 3K.
   - The -20dB pad effectively isolates the Antenna Simulator mainline from the broadband noise generated by the GPS simulator which may be shaped and higher than 300K.

LightSquared Signal Power and Spectrum Measurement:

The *Antenna Output Simulator* port was connected to a calibrated **Tektronix RSA3308A** Spectrum Analyzer.

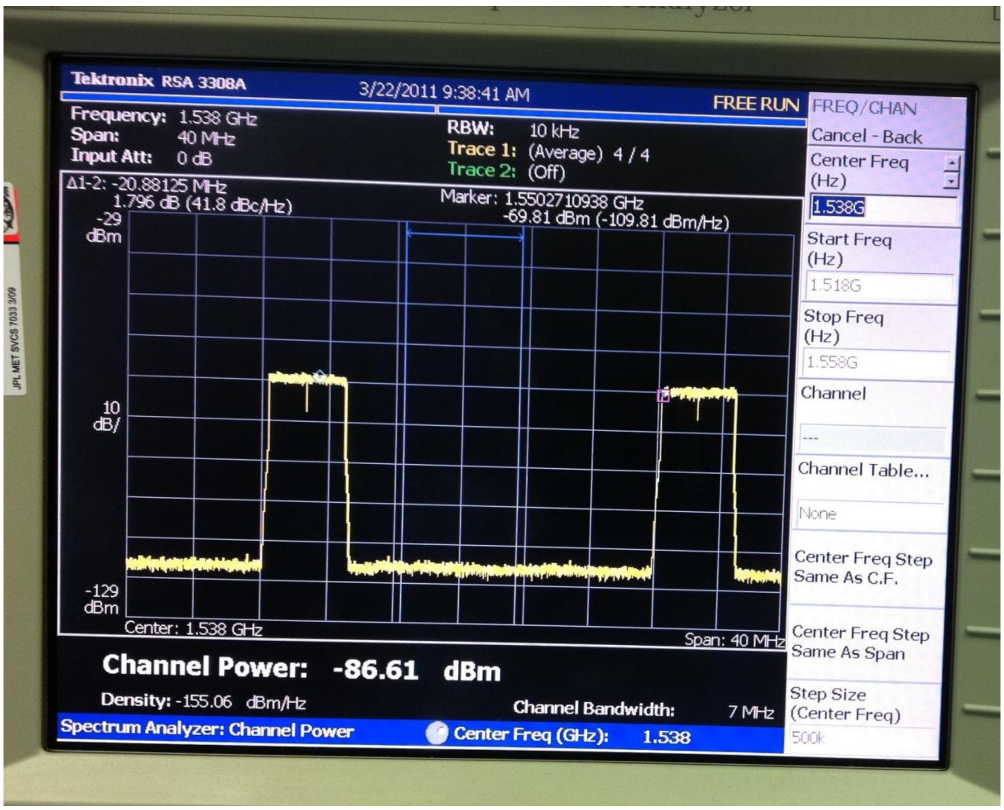
The function: **Measure -- Channel Power** was used with a channel BW set to **7 MHz** and a **Rectangular** integration Filter Shape.

In order to compensate for total losses due to **directional couplers, cables, filters, I/Q modulator sensitivity,** on each Signal Generator, the **Amplitude Offset** was adjusted until the measured powers for each LightSquared channel match the Amplitude read-off on the Signal Generators.

The final Amplitude offset values ended up being:

- Channel 1 – 1552.5 MHz – E4438C**:** **-12.02 dB**
- Channel 2 – 1528.7 MHz – SMBV100A: **-19.7 dB**

A picture of the final spectrum when both Channels are set to the same level:



Noise Power and Spectrum Measurement:

In a Space environment, an antenna pointed partially towards the Earth would pick-up 150K of Thermal Noise from the antenna, cable losses, wideband pre-select filter and LNA Noise Figure contribute another 150K giving a **Total System Noise Temperature of about 300K.**

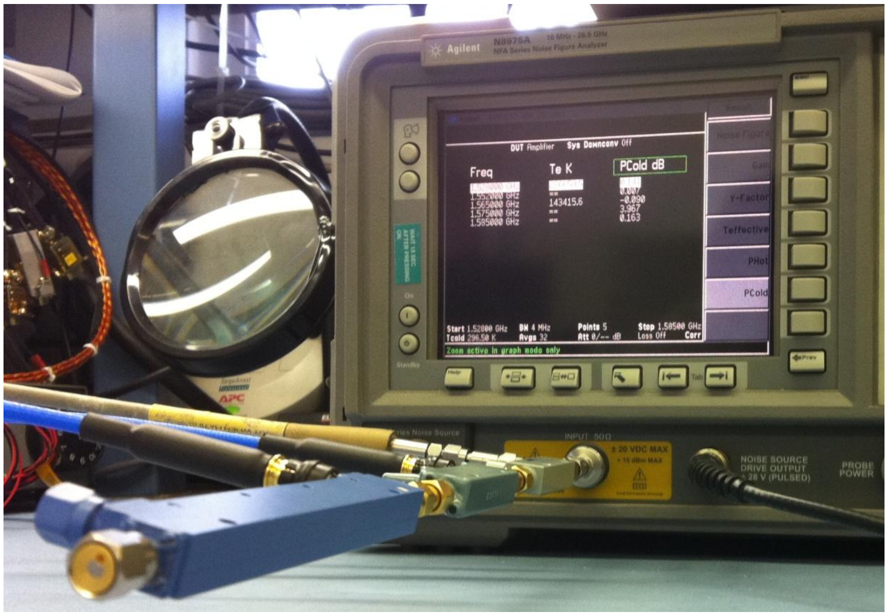
Therefore, in order for our ”Antenna Output Simulator” to output realistic power levels, the Total Equivalent Noise System Temperature has to be in the neighborhood of 300K or equivalent to a Noise Density of about -174 dBm/Hz.

In order to measure the Total Noise Temperature of our ”Antenna Output Simulator”, an **Agilent N8975A Noise Figure Analyzer (NFA)** is used together with an **HP 346A Noise Source** for calibration.

The NFA Cold Noise Power measurement result is used. The Cold Noise Power Pcold reading is in units of dB referenced to the Noise Power generated by a resistor at a temperature of 296.5K. After calibration, connecting the HP 346A to the NFA yields a Pcold of 0.0dB as expected (In Pcold mode, the HP 346A is turned OFF and is acting as a perfect 50 Ohm resistor).

When we connect our ”Antenna Output Simulator” output port, we measure a Noise Power that is very close to 0.1dB, at all measured frequencies except at 1575 MHz (@4 MHz BW) where we measure close to +4dB. The reason for the higher power at 1575 MHz is because of the main C/A lobe being above the noise floor.

We conclude that the Noise Power coming out of our Antenna Simulator output port is very close to 303K or -173.8 dBm/Hz.



In order to verify the spectrum of our broadband noise floor for flatness, we use a combination of an LNA and a Tektronix RSA3308A Spectrum Analyzer.

The LNA is first characterized on an **Agilent N8975A** Noise Figure Meter

Brand:	Richardson Electronics (RELL)
Model:	1216A
S/N:	070+0011

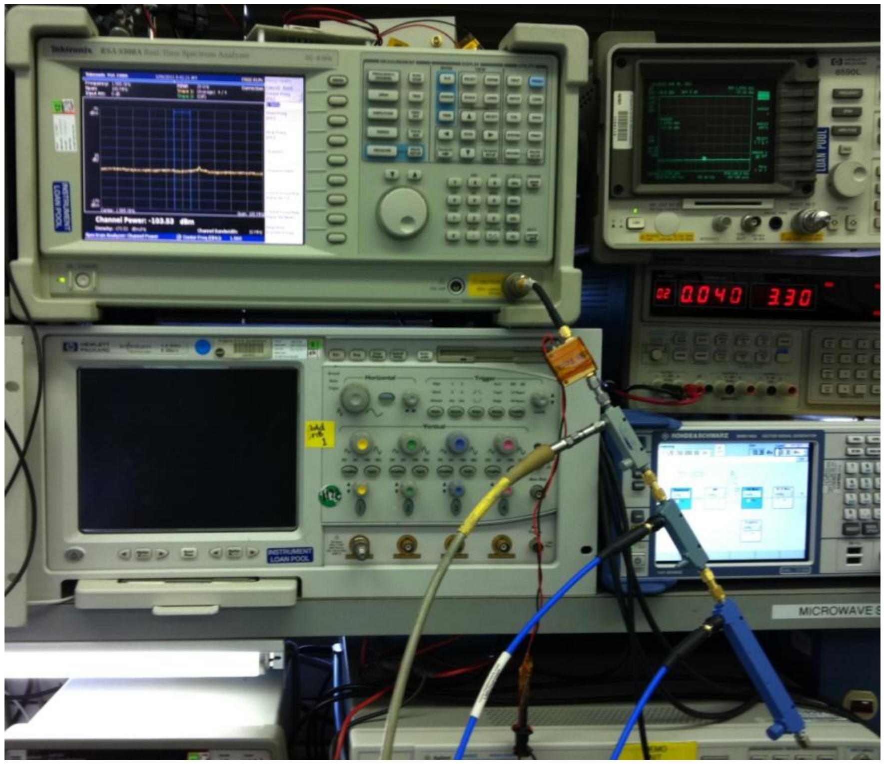
At **1565 MHz:**

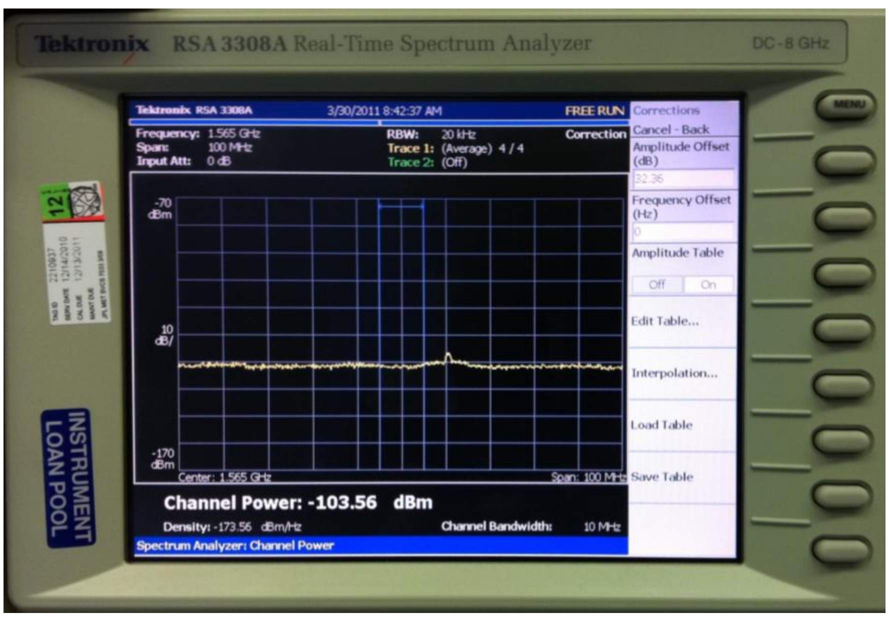
Gain = 32.36dB NF = 0.54dB Te = 38.47K Pcold = 32.99 dB

We can now set-up an **Amplitude Correction** of **32.36dB** in the Spectrum Analyzer to compensate for the LNA gain**.**

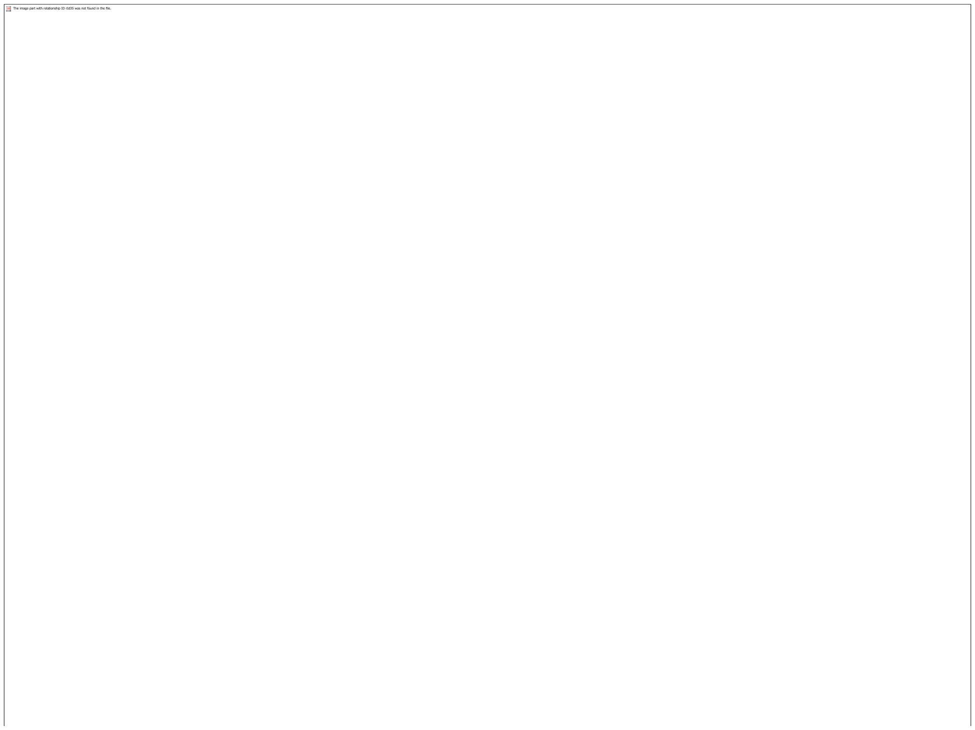
Check 1: Upon connecting our "Antenna Output Simulator" output to the input of this LNA, we shoul of 303K + 38.47K = 341K or **-173.3 dBr** . We measured a Noise Floor Power Densit We also remark that the

noise floor is flat in





Check 2: We can also verify the power accuracy of weak LightSquared signals: Below is shown the output of the E4438C LightSquared Signal Generator output when set to -100 dBm.



GPS Signal Power Measurement:

- Power of total GPS signal out of Simulator at GPS L1 (7 satellites): -66.1dBm (in 20MHz integration BW)
- Measured loss due to -20dB directional coupler: -19.1dB
- Measured loss due to -20dB pad: -20.0dB
- Power of GPS signal coupled onto Antenna Simulator mainline (7 satellites): -105.2 dBm (in 20MHz BW)
- Power of GPS signal coupled onto Antenna Simulator mainline (per satellite): **-113.7 dBm** (in 20MHz BW)

NOTE: This was the GPS simulator power used for tests of the IGOR, Ashtech, and JAVAD receivers. The simulator output power for each signal was reduced by 2 dB for tests involving the TriG receiver. Because of its lower noise figure, less signal power was required to reach a C/No of 48 dB-Hz.

Intermodulation and Distortion-Free Dynamic Range:

In order to make meaningful susceptibility measurements of GPS receivers to LightSquared emissions, we need to make sure that as we raise the power of LightSquared signals coming out of our Antenna Output Simulator, we are not raising the power in the GPS L1 pass-band.

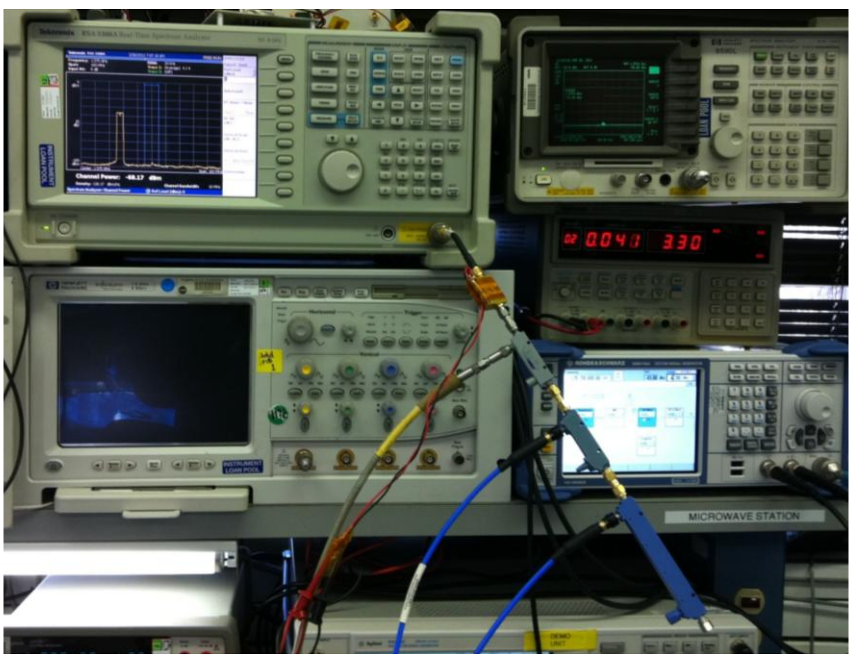
The dominant effect by which the Noise Power in the GPS L1 pass-band gets raised is 3rd order Intermodulation Distortion between the two LightSquared Channels:

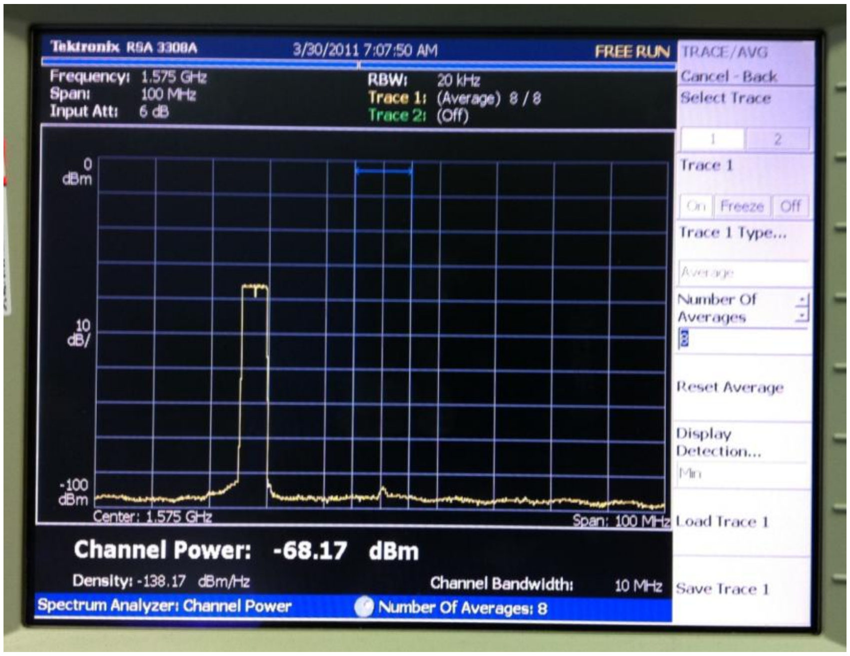
When the two LightSquared signals centered at 1552.5 MHz and 1528.7 MHz pass through an odd-order non-linearity, one set of Intermodulation Products is produced in the GPS L1 pass-band:

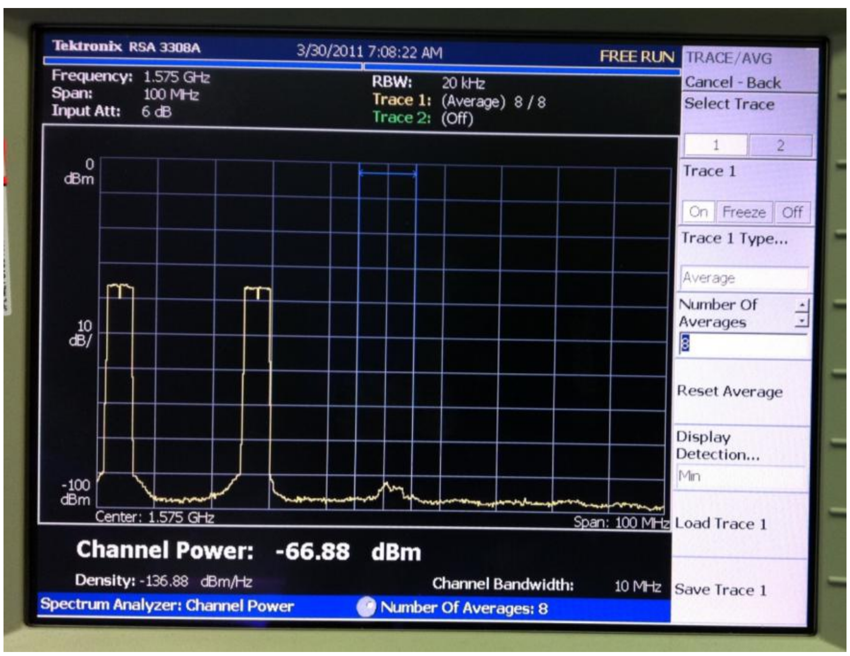
2 x 1552.7 MHz - 1528.8 MHz == 1576.6 MHz

In order to observe this IMD effect:

We connect our ”Antenna Output Simulator” output to an LNA (Richardson Electronics Model 1216A, measured above) and monitor its output on a spectrum analyzer. With only one LightSquared signal turned ON at -45dBm, we do not observe any added power in the GPS L1 pass-band. With both LightSquared signals turned ON at -45dBm each we observe an Intermodulation Product appear in the GPS L1 pass-band. This is also shown to affect the receiver C/No in the GS receiver result section below.







We use the following method to measure the Distortion-Free Dynamic Range of our ”Antenna Output Simulator” and to verify that no new power is being added to the GPS L1 pass-band **before** the output of our ”Antenna Output Simulator”, ie: that any Intermodulation products that we observe on a spectrum analyzer are being created **after** the ”Antenna Output Simulator” output port:

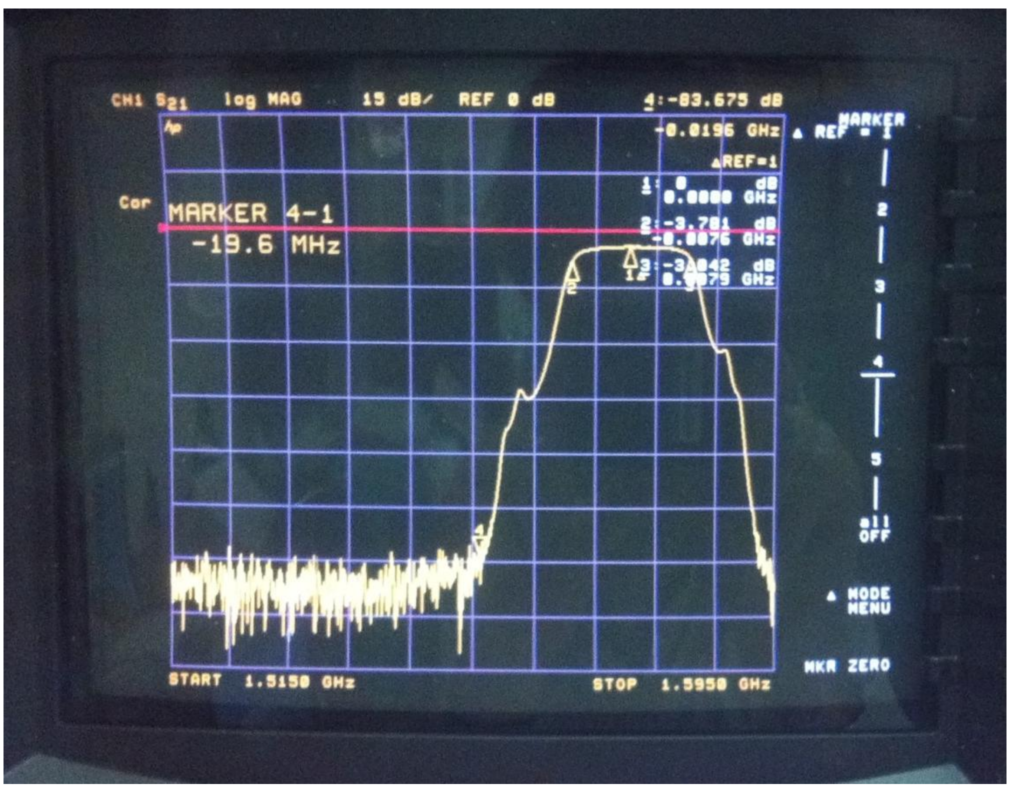
We insert a GPS L1 band-pass filter with a steep cutoff between the output of our Antenna Simulator and an LNA. We monitor the output of the LNA on a spectrum analyzer as we alternate turning ON and OFF the LightSquared signals. We increase the power of both signals until we start noticing an increase in power in the GPS L1 pass-band.

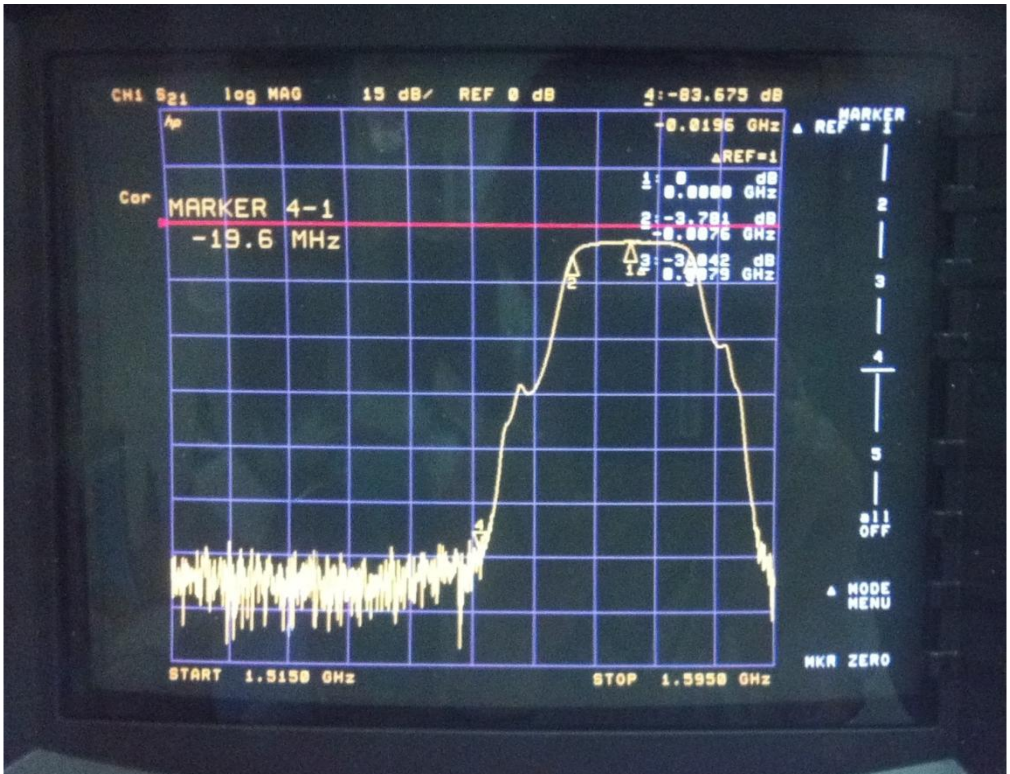
We make such a filter by connecting in succession **three microwave cavity filters**. Measuring this filter on a **HP 8722C** Network Analyzer we get:

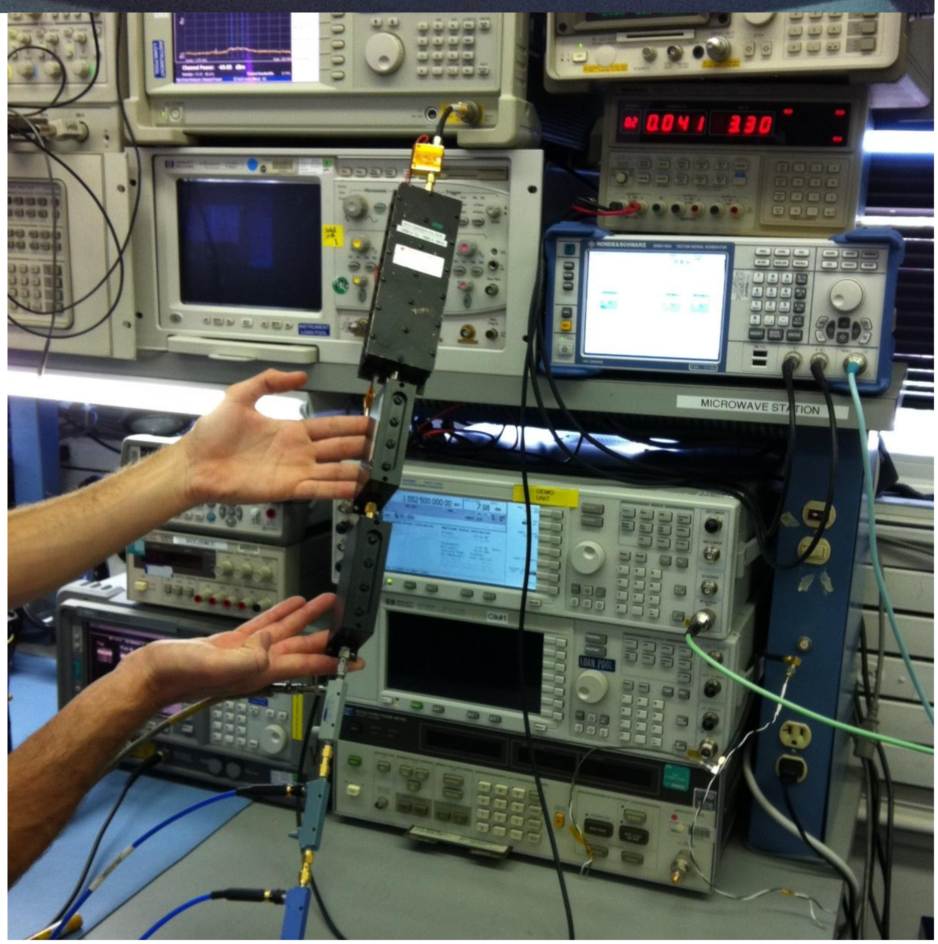
- S21 at 1575 MHz = -4.3 dB
- S21 at 1555 MHz = -83 dB

We notice no added power in GPS L1 pass-band even when both VSG are set to maximum output (+10.3dBm and +7.98dBm for 1528.7 and 1552.5 signals respectively).

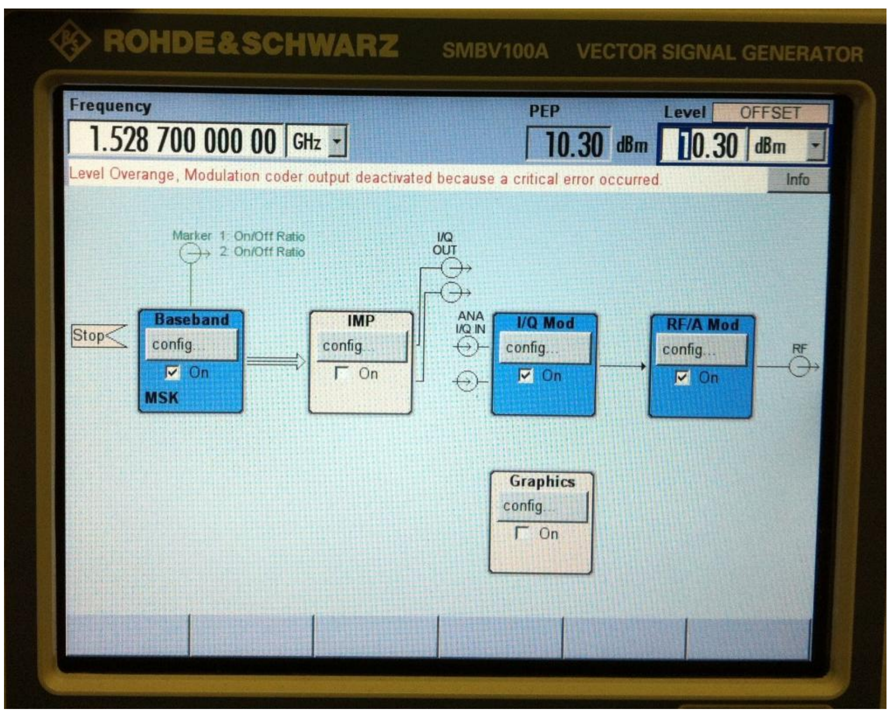
From this experiment we conclude that there are no IMD products coming out of our ”Antenna Output Simulator” output port, and that our Distortion-Free Dynamic Range is at least as wide as the output power ranges of our Signal Generators.

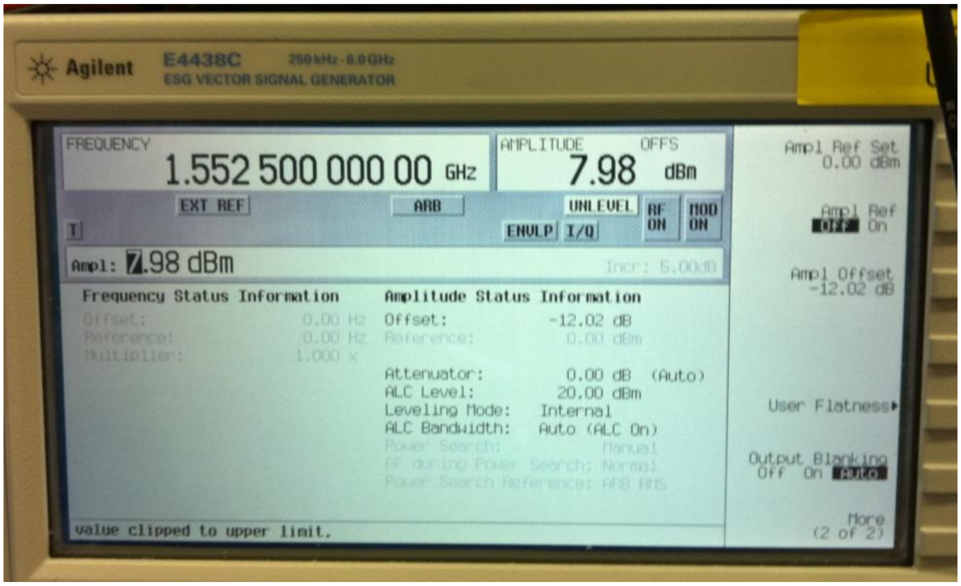



CH1 S21 log MAG 15 dB/ REF 0 dB 4:-83.675 dB
-0.0196 GHz
ΔREF=1
Cor
MARKER 4-1
-19.6 MHz
MARKER
Δ REF = 1
all
OFF
Δ MODE
MENU
MKR ZERO
START 1.5150 GHz
STOP 1.5950 GHz




Tektronix RSA 3308A
3/30/2011 7:20:17 AM
FREE RUN
AMPLITUDE
Cancel - Back
Frequency: 1.575 GHz
Span: 100 MHz
Input Att: 6 dB
RBW: 20 kHz
Trace 1: (Average) 4 / 4
Trace 2: (Off)
Ref Level (dBm)
-10
Auto Level
RF Atten / Mixer
Auto RFAtt Mixer
RF Att (dB)
6
Vertical Scale (dB/div)
10
Vertical Units
dBm dBμV V μV W
Corrections...
-10 dBm
10 dB/
-110 dBm
Center: 1.575 GHz
Span: 100 MHz
Channel Power: -69.85 dBm
Density: -139.85 dBm/Hz
Channel Bandwidth: 10 MHz
Spectrum Analyzer: Channel Power
Ref Level (dBm): -10


ROHDE&SCHWARZ
SMBV100A VECTOR SIGNAL GENERATOR
Frequency
1.528 700 000 00 GHz
PEP
10.30 dBm
Level
OFFSET
10.30 dBm
Level Overange, Modulation coder output deactivated because a critical error occurred.
Info
Marker 1: On/Off Ratio
2: On/Off Ratio
I/Q OUT
Stop
Baseband
config...
On
MSK
IMP
config...
On
ANA I/Q IN
I/Q Mod
config...
On
RF/A Mod
config...
On
RF
Graphics
config...
On


Agilent
E4438C
250 kHz - 6.0 GHz
ESG VECTOR SIGNAL GENERATOR
FREQUENCY
1.552 500 000 00 GHz
AMPLITUDE
OFFS
7.98 dBm
EXT REF
ARB
UNLEVEL
RF ON
MOD ON
ENVLP
I/Q
Ampl: 7.98 dBm
Incr: 5.00dB
Frequency Status Information
Offset: 0.00 Hz
Reference: 0.00 Hz
Multiplier: 1.000 x
Amplitude Status Information
Offset: -12.02 dB
Reference: 0.00 dBm
Attenuator: 0.00 dB (Auto)
ALC Level: 20.00 dBm
Leveling Mode: Internal
ALC Bandwidth: Auto (ALC On)
Power Search: Manual
RF during Power Search: Normal
Power Search Reference: ARB RMS
value clipped to upper limit.
Ampl Ref Set 0.00 dBm
Ampl Ref Off On
Ampl Offset -12.02 dB
User Flatness
Output Blanking Off On Auto
More (2 of 2)

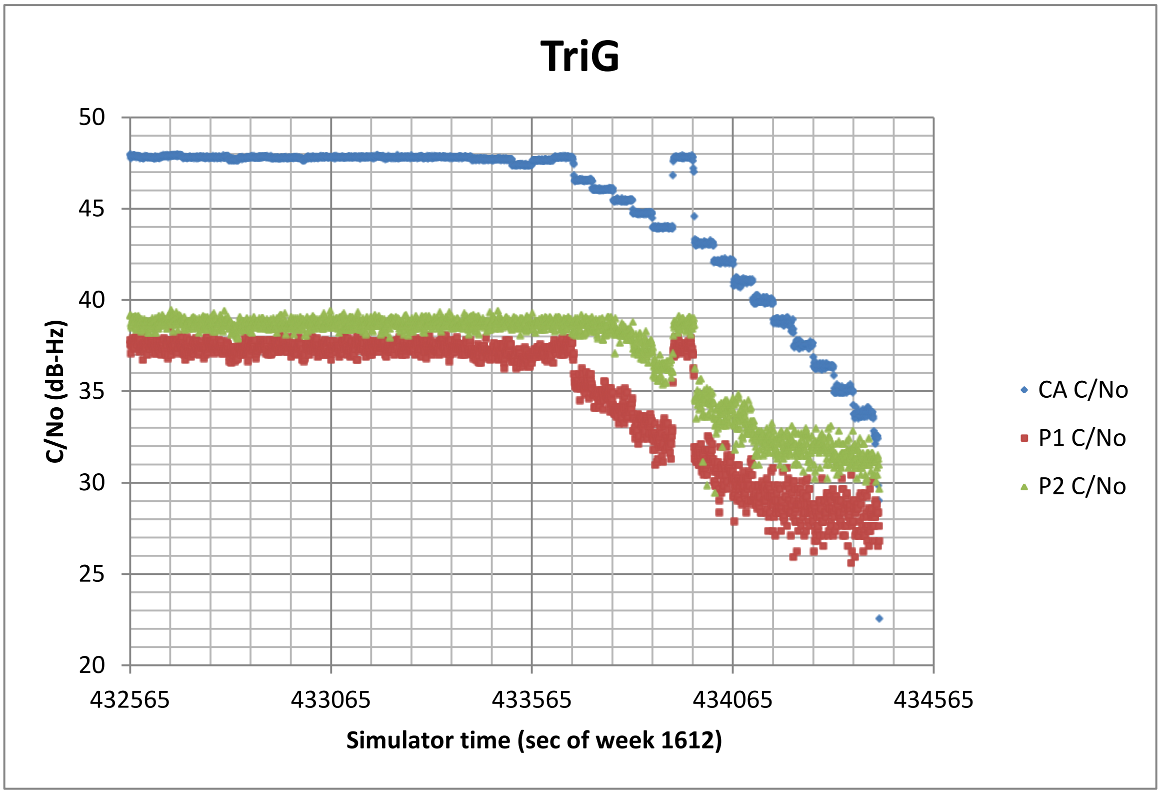
4. GPS Receiver Results: C/No vs LightSquared power

TriG Receiver:

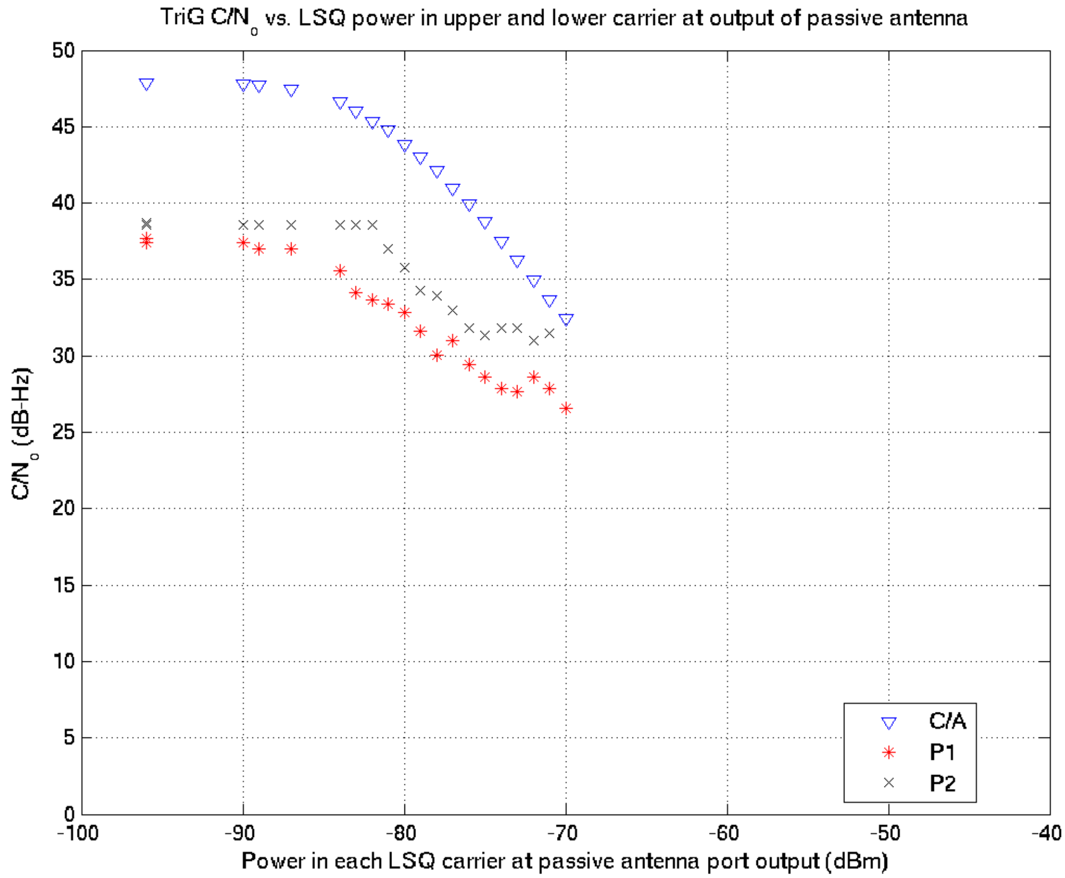
Caltech's Jet Propulsion Laboratory (JPL) is developing the TriG receiver to fill NASA's needs for the next generation advanced flight GNSS receiver. All four of the receivers tested track civil codes, and use semi-codeless tracking to track Y1 and Y2 signals. The TriG has the special feature that it can be reprogrammed to track new signals at different frequencies after launch. It can track four frequencies simultaneously. One likely scenario is that at launch it would be set to track GPS L1 and L2, and GLONASS L1 and L2 signals. After the Galileo constellation has grown to a sufficient level, the four frequencies would switch to GPS L1+ Galileo E1, GPS L2, GPS L5 + Galileo E5, and GLONASS L1. After the GPS L5 capable satellites have reached a sufficient number the four RF channels would be switched to GPS L1+ Galileo E1, GPS L5 + Galileo E5, GLONASS L1, and GLONASS L2.

This flexibility in choice of frequency requires a front end that is covered by a very wide band filter, so that any of the signal bands above are available. The plot below shows the measured C/No from the TriG versus time for the C/A, P(Y)1, and P(Y)2 signals. Table 1 shows the levels of the simulated LightSquared signal in each of the two frequency bands versus time. To equate a given interferer power level to the GPS performance measurements you must review the table below the charts. First identify the interferer power level you are interested in analyzing. Then take the time stamp value in the table and transpose it to the chart. Then relate the time to the GPS C/No performance measurements. The plot following Table 1 displays values of C/No logged during the test graphed directly vs interference power level.

TABLE 1: Lost lock at -70 dBm

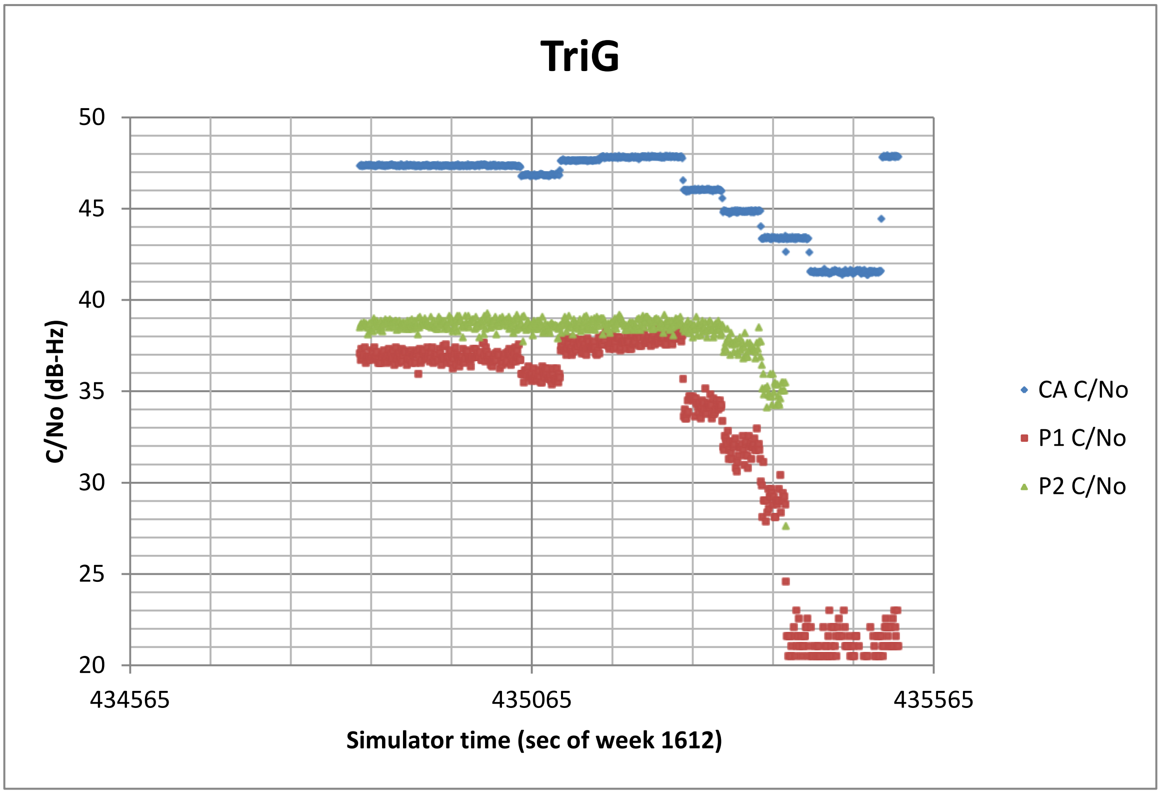


time	433415	433515	433565	433615	433665	433715	433765	433815	433865	433915
dBm	-90	-87	-89	-96	-84	-83	-82	-81	-80	-96
time	433965	434015	434065	434115	434165	434215	434265	434315	434365	434415
dBm	-79	-78	-77	-76	-75	-74	-73	-72	-71	-70



Since we knew intermodulation products were produced that coincided with the L1 GPS band, we decided to investigate the importance of that effect compared to the leakage of LightSquared interference from the 1550.2 to 1555.2 MHz band. By producing only this band in the LightSquared simulation, the third order intermodulation products at L1 were squelched. The plot below shows the measured C/No from the TriG versus time for the C/A, P(Y)1, and P(Y)2 signals. Table 2 shows the levels of the simulated LightSquared signal in versus time. Note the big difference from the results with both bands present. In particular, if we compare the LightSquared power required to produce about – 3 dB degradation to the CA C/No, it takes about -74 dBm with just the upper band, and only -82 dBm with both bands present, a difference of 8 dB.

TABLE 2

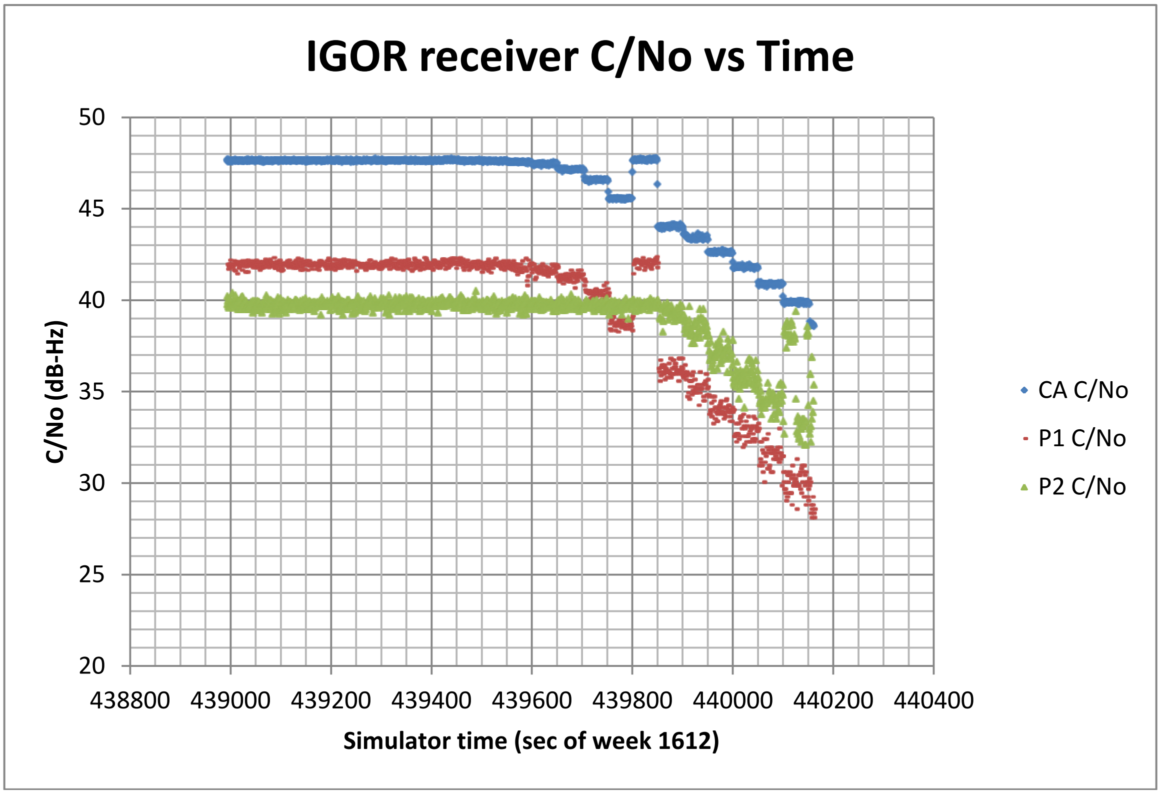


time	434700	435050	435100	435150	435200	435250	435300	435350	435410	435500
dBm	-80	-77	-83	-90	-100	-74	-71	-68	-65	OFF

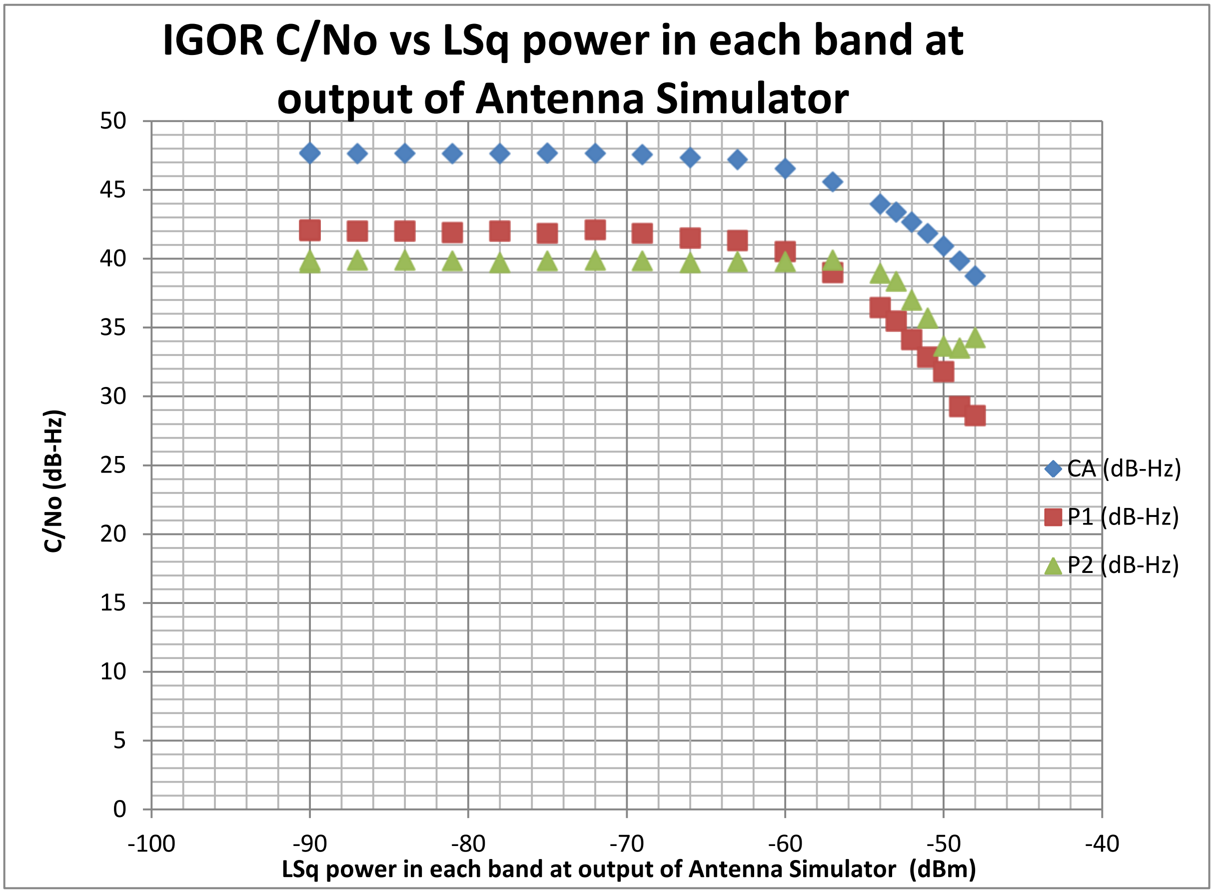
IGOR Receiver

The plot below shows the measured C/No from the IGOR versus time for the C/A, P(Y)1, and P(Y)2 signals. Table 3 shows the levels of the simulated LightSquared signal in each of the two frequency bands versus time. To equate a given interferer power level to the GPS performance measurements you must review the table below the charts. First identify the interferer power level you are interested in analyzing. Then take the time stamp value in the table and transpose it to the chart. Then relate the time to the GPS C/No performance measurements. The plot following Table 3 displays values of C/No logged during the test graphed directly vs interference power level.

TABLE 3: Loss of lock occurred at -48 dBm

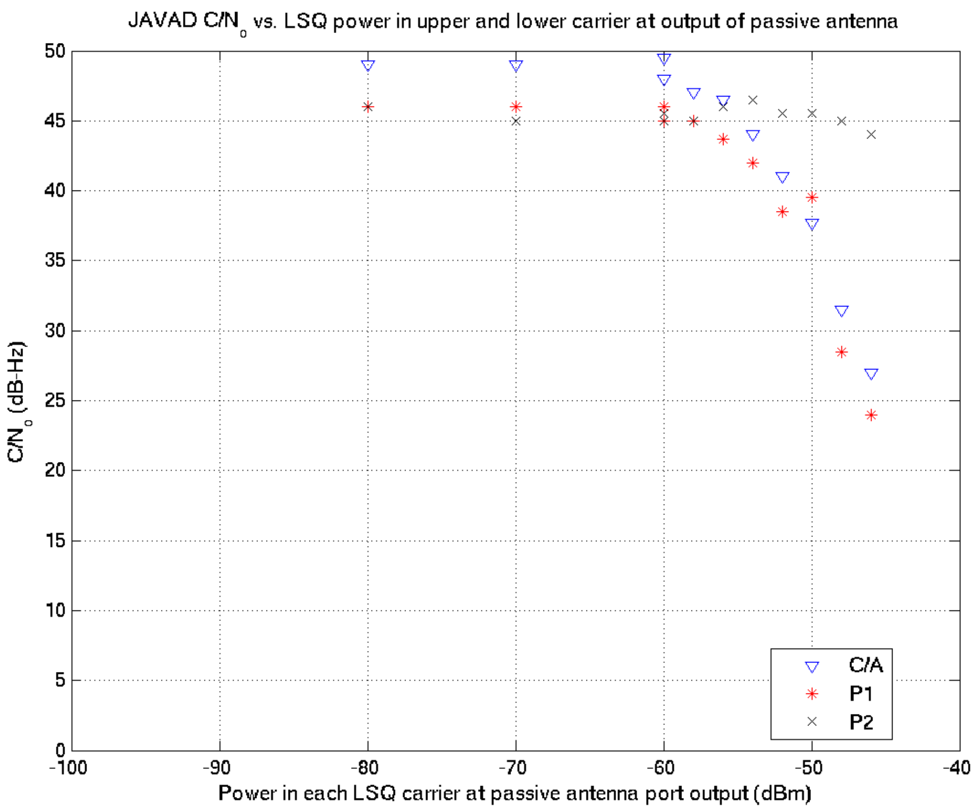


time	439100	439200	439250	439300	439350	439400	439450	439500	439550	439600
dBm	OFF	-90	-87	-84	-81	-78	-75	-72	-69	-66
time	439650	439700	439750	439800	439850	439900	439950	440000	440050	440100
dBm	-63	-60	-57	-90	-54	-53	-52	-51	-50	-49
time	440150									
dBm	-48									


IGOR C/No vs LSq power in each band at output of Antenna Simulator
C/No (dB-Hz)
50
45
40
35
30
25
20
15
10
5
0
-100
-90
-80
-70
-60
-50
-40
LSq power in each band at output of Antenna Simulator (dBm)
CA (dB-Hz)
P1 (dB-Hz)
P2 (dB-Hz)

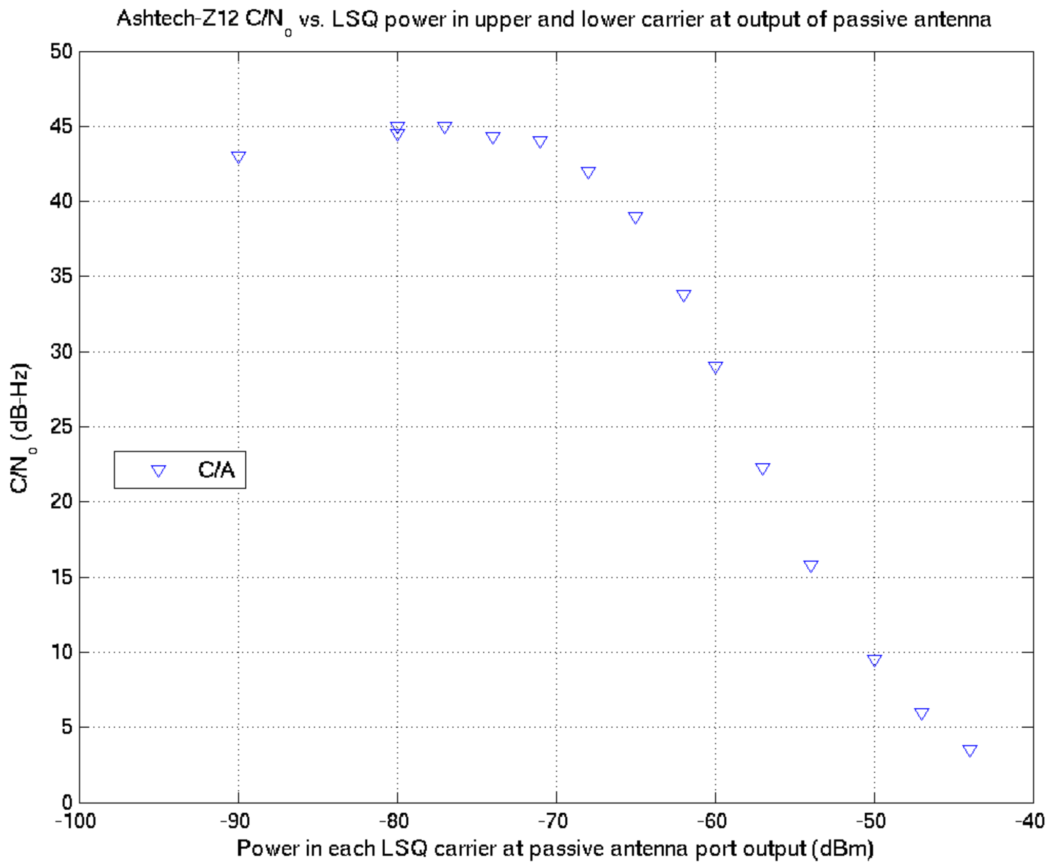
JAVAD Delta G3T receiver

The plot below shows the measured CA, P(Y)1, and P(Y)2 C/No from the JAVAD versus the LightSquared signal power in each of the two frequency bands. These data were read from the laptop used for logging data.



Ashtech Z-12 (Part NO. 700845-10) receiver

The plot below shows the measured CA code C/No from the Ashtech versus the LightSquared signal power in each of the two frequency bands. These data were read from the laptop used for logging data.



5. Conclusions

The conducted signal tests described above constitute a well calibrated test of the effects of interference from a realistic simulation of the LightSquared Phase 1A signal. The power per LightSquared band that caused a -1 dB degradation in C/No varied from about -84 dBm for the next generation flight receiver with a reconfigurable front end, to about -60 dBm for the JAVAD ground receiver.

The effect of adding the lower band caused an increase of about 8 dB in the sensitivity of the TriG receiver as evidenced by the interference power required to reduce its C/No by 3 dB. We consider this to be the result of third order intermodulation products formed from twice the upper band frequency minus the lower band.

Appendix S.2

Analysis of LightSquared Base Station Emissions

DRAFT

5/5/2011

ANALYSIS OF LIGHTSQUARED BASE STATION EMISSIONS ON NASA HIGH-PRECISION GPS RECEIVERS

1. Introduction

This report describes analysis of LightSquared base station interference to four high-precision GPS receivers used in NASA spaceborne and terrestrial applications. All four receivers are capable of processing the L1 C/A-code and L1/L2 P(Y) code GPS signals. The P(Y) code signals are processed using various semi-codeless techniques to obtain the L2 carrier phase. Interference assessment is based on estimating the interference levels expected in various spaceborne and terrestrial scenarios and comparing them against interference limits/thresholds obtained through conduction measurements on the four receivers by JPL. This testing was performed at JPL on March 22, 2011 using a simulated LightSquared Phase I signal (i.e. two 5 MHz channels centered at 1528.8 MHz and 1552.7 MHz) and is described in the TWG report, "A Preliminary Report on the Effects of Conducted LightSquared Emissions on Four High-Precision GPS Receivers." LightSquared provided filters for this conducted testing and a LightSquared representative participated in the testing. The spaceborne analysis includes both an atmospheric radio occultation (RO) application where the GPS receiver antenna is directed towards the Earth limb in order to measure properties of the atmosphere and the more typical navigation application where the GPS receiver antenna is pointed upwards to obtain spacecraft position, velocity, time and/or attitude. Two precision terrestrial receivers used in the IGS (International GNSS Service) and SCIGN (Southern California Integrated GPS Network) are also examined.

2. Analysis Assumptions

Table 1 shows the GPS characteristics and LightSquared base station characteristics used in the various analyses. Three types of analysis were performed: (1) aggregate base station interference into spaceborne GPS receiver; (2) interference from single base station into terrestrial receiver; and (3) aggregate base station interference into terrestrial receiver. For the space receiver analysis, 3 cases were considered: (a) radio occultation (RO) receiver onboard COSMIC-2 satellite in 800 km/72° inclined orbit (see Figure 1); (b) RO receiver onboard COSMIC-2 satellite in 520 km/24° inclined orbit; and (c) navigation receiver onboard typical LEO in 400 km altitude orbit.

2.1. GPS Receiver Characteristics

2.1.1. Spaceborne Receiver Analysis

For the spaceborne receiver analysis a MATLAB simulation program was developed to model the receiver onboard a satellite in various orbits and interference statistics calculated for a LightSquared base station deployment of approximately 34940 stations distributed among 139 major cities in the US. This city data was provided by LightSquared. Two types of space receiver applications were considered: (1) the RO application which involves pointing the GPS receiver antenna towards the earth limb in order to receive GPS signals traversing the atmosphere; and (2) the more typical navigation application in which the antenna is pointed in the zenith direction towards the GPS constellation. In both cases interference thresholds for the TRIG and IGOR space receivers (as determined by the JPL conduction testing) are considered.

The TRIG and IGOR receivers are designed for RO measurements but can also be used for navigation/Precision Orbit Determination (POD). In the RO technique a GPS receiver in LEO observes the propagation delay of GPS signals which travel through the atmosphere. Occultations occur as each GPS satellite rises or sets on the horizon as viewed by the space receiver. From the changing delay, the (altitude) variation in the atmosphere's index of refraction can be measured and altitude profiles of ionosphere electron density, atmospheric density, pressure, temperature, and water vapor can be derived. Consequently, the receiver antenna main-beam is directed towards the earth limb (and also, in this case, the main-beams of the interfering base stations). JPL is planning the next generation of RO measurements with receivers onboard the COSMIC-2 constellation, which will have initial launch in 2014 and consist of six satellites in a 520 km orbit at 24 degrees inclination and six more at 800 km orbit and 72 degrees inclination. Each satellite will have actively steered array antennas with approximately +15 dBic gain directed along the limb of the earth in the forward (for rising GPS sats) and aft (for setting GPS sats) directions. Figure 2 shows the gain pattern for the forward antenna with the main-beam directed 26.2° below the satellite velocity vector towards earth limb. The 12 elements of the array are on a 60 cm tall x 40 cm wide mounting plate and mounted on the front of the spacecraft so that the plate is vertical and the outward normal to the plate is parallel to the spacecraft's velocity vector (assuming circular orbit).

The TRIG is the next generation NASA/JPL RO receiver designed to work with new signals from GPS and other GNSS satellites. It can also be used for POD. It has a very wide RF pre-select filter (i.e. 3 dB bandwidth from 1100 MHz to 1660 MHz) to allow the receiver to be reprogrammed in flight to different frequencies over the full range of GNSS signals. The wide bandwidth also results in lower insertion loss, less variation of signal delay and phase with temperature, and allows newer processing techniques by using a signal bandwidth much greater than the conventional 20 MHz.

The IGOR is the current generation RO receiver manufactured by Broadreach Engineering and is based on the NASA/JPL Black Jack space receiver. IGOR receivers have been deployed as primary science payloads on the COSMIC mission, TerraSAR-X, Tandem-X, and TACSAT-2 missions. IGOR has a wideband pre-select filter and narrowband L1 and L2 filters. IGOR can also function as a POD GPS receiver.

For the usual space navigation application, the TRIG/IGOR receivers are assumed to use a zenith pointed choke ring antenna with 6.8 dBic gain with gain pattern shown in Figure 3. For this analysis a typical LEO altitude of 400 km is assumed and again a 72° inclination is considered which causes the satellite to pass over the entire CONUS numerous times.

The interference thresholds used in the analysis are shown in Table 2 and are based on the conduction testing by JPL last March. Although anechoic chamber testing and live-sky testing have also been performed with these receivers, the conduction testing offers the best accuracy since signal, noise, and interference levels can be carefully controlled and calibrated. In the conduction testing, the primary observable was the degradation in C/No due to simulated LightSquared Phase 1 signal interference (two 5 MHz channels) measured during steady state tracking. (It should be noted, however, that JPL also collected pseudorange, carrier phase, and position solution data. They also collected data for the TRIG using a Phase 0 simulated LightSquared signal.) Table 2 shows the interference levels (sum of interference powers in both 5 MHz channels) at the output of the GPS receiver antenna which results in 1 dB, 3 dB, and 5 dB C/No degradation for the four NASA receivers along with the interference level which causes loss of GPS signal tracking. It's apparent that the next-generation TRIG space receiver is the most sensitive of the four receivers.

2.1.2. Terrestrial Receiver Analysis (single base station)

This analysis considers the impact of interference from a single LightSquared base station on the four receivers assuming they are located at fixed positions on the ground. The TRIG/IGOR space receivers are tested on the ground prior to launch and during "burn-in" operations. The JAVAD/ASHTECH receivers are commonly used in surveying and high precision ground networks such as the IGS (Figure 7) and SCIGN (Figure 8 and Figure 9). The Ashtech Z-12 is a standard dual frequency (L1/L2) phase and pseudorange measuring instrument that can track up to 12 GPS satellites. The JAVAD Delta-G3T is a newer 36-channel receiver capable of tracking GPS L1/L2/L2C/L5 and GLONASS L1/L2. Since the closest base station will dominate the aggregate interference, it's useful to estimate the required separation distance between GPS receiver and base station in order that certain interference threshold levels are not exceeded. For this analysis the GPS receiver is assumed to be 1 meter above the ground (e.g. tripod mounted) with a zenith pointed choke ring antenna with gain pattern shown in Figure 3. This antenna is designed specifically to reduce multipath effects and consists of vertically aligned concentric rings centered about the antenna element (usually a crossed dipole) connected to a ground plane. The vertical rings shape the antenna pattern such that multipath signals incident on the antenna at the horizon and negative elevation angles are attenuated. The separation distance contours were calculated with MathCad software for different interference thresholds given in Table 2.

2.1.3. Terrestrial Receiver Analysis (multiple base stations)

This analysis considered aggregate interference from the LightSquared deployment in the Las Vegas area. LightSquared provided the lat/lon locations and height above ground for 215 base stations (645 sectors) that it is planning to deploy in Las Vegas – one of its initial market areas. The objective is to determine the interference impact to a high precision ground network GPS receiver (e.g.. JAVAD/ASHTECH) if it were to be located at different positions in the area (or a similar LightSquared market area). Again the receivers are assumed to use zenith pointed choke ring antennas at 1 meter above ground. For this analysis a MATLAB program was developed which sub-divides the Las Vegas geographic area into a large number of quadrangles or cells (i.e. 878,628 cells each approx 100 square meters in size) and the aggregate interference calculated at the centroid of each map cell from the base stations within radio LOS of the map cell location. The result is an interference matrix map that shows the aggregate interference over the geographic area. By applying different interference thresholds (Table 2) to the matrix map, the % area where interference exceeds the threshold can be determined.

2.2. LightSquared Base Station Characteristics

As shown in Table 1, for all three analysis types, base station sector main-beam EIRP levels and antenna patterns are the same and based on data provided by LightSquared. The main-beam EIRP per channel is 62 dBm (32 dBW) per (5 MHz) OFDM channel and assuming two 5 MHz channels per sector (i.e. Phase 1 spectrum) this is 65 dBm (35 dBW) per sector. It is assumed there are 3 sectors per base station – each covering 120° in azimuth – with the sector 1 antenna of each base station oriented North (0° AZ); the sector 2 antenna oriented Southeast (120° AZ); and the sector 3 antenna oriented Southwest (240° AZ). The gain pattern of the sector antenna is the Tongyu model pattern provided by LightSquared and shown in Figure 5. The main-beams of all sector antennas are assumed to have a 2° downtilt from horizontal.

2.2.1. Spaceborne Receiver Analysis

For the spaceborne receiver analysis the aggregate interference power at the output of the GPS receiver antenna is calculated at one second time steps in the satellite orbit from 34939 base stations distributed among 139 US cities as illustrated in Figure 4. LightSquared provided data listing the total number of base stations planned for each of 139 major US cities. Since specific lat/lon locations for the base stations in each city were not available and the GPS receiver in this case is onboard a satellite, it was assumed for the interference calculations that all base stations for a particular city are co-located at the city center. For example, two base stations separated by 10 km will have an angular separation of only 0.7° at 800 km satellite altitude so that the difference in receive antenna gain between the two will be very small. Sector antenna gain towards the satellite is calculated by first determining the appropriate AZ/EL angles from the base-station/satellite geometry; then summing the AZ plane discrimination with the EL plane discrimination (Figure 5); and then subtracting this total discrimination from the max sector gain of 16.5 dBi to get the net sector gain towards the satellite. In accordance with guidance from LightSquared, however, the max overhead sector antenna discrimination is assumed to be 20 dB (i.e. the min net overhead antenna gain is assumed to be 16.5-20 = -3.5 dBi) to account for ground multipath reflection. LightSquared found this to be true from experimental studies using the planned 2 degree antenna downtilt. Also note that the interference contributions from all 3 sectors per base station are included. The maximum interference from a base station will occur when it sees the satellite at low elevation angles. Free-space loss is assumed, but because of uncertainty in the path loss due to blockage and shadowing of base stations on the satellite horizon from terrain or man-made structures, analysis results were generated for two base station mask angles: (1) a 0° elevation mask on the base stations so that all base stations which see the satellite above 0° elevation angle are included in the aggregate interference calculation; and (2) a 5° mask angle so that only base stations which see the satellite above 5° elevation angle contribute to the aggregate interference. For the space receiver analysis, results were also generated for the case when the base station EIRP is increased from 32 dBW to 42 dBW, which is the maximum authorized power under the FCC rules. LightSquared, however, has stated that they plan to operate at a maximum EIRP level of 32 dBW per channel.

2.2.2. Terrestrial Receiver Analysis (single base station)

For this analysis of interference from single base station, a base station height of 18.3 meters (60 feet) above ground is assumed. This is the average height above ground computed from LightSquared base station data for the Las Vegas, Phoenix, and Denver areas. GPS receiver height is assumed to be 1 meter. Separation distance results were calculated for a number of different propagation models besides free-space loss (i.e. Hata, Extended Hata, Walfisch-Ikegami, NTIA/ITM). These models are based on extensive measurements of radio propagation losses and used in cellular systems planning. Figure 6 shows that there is a significant spread in path loss among these models. For example, for a 10 km distance path loss varies from 115 dB (free-space) to 180 dB (extended HATA in urban area). This leads to a significant difference in separation distances. The issue of which propagation model is appropriate in various terrestrial interference scenarios requires further discussion in the TWG.

2.2.3. Terrestrial Receiver Analysis (multiple base stations)

As noted previously, this analysis considers aggregate interference from 215 base stations (645 sectors) in the LightSquared Las Vegas deployment. It assumes the specific base station lat/lon/height data provided by LightSquared. Again results were generated for different propagation models shown in Figure 6.

3. Analysis Results

(*Editor's Note:* The results presented in the following sections are intended to draw no conclusions or make any recommendations as to what level of interference may be tolerated by the various GPS receivers based on the scenarios for those receivers.)

3.1.Spaceborne Receiver Analysis Results

Interference results for the RO GPS RX onboard a COSMIC-2 satellite (800 km/72° orbit) are shown in Table 3a and Table 3b. Table 3a assumes a 0 ° elevation mask on the base stations while Table 3b assumes a 5° elevation mask on the base stations. The entries in these tables are interpreted as follows. Consider, for example, Table 3a and an aggregate interference threshold of -82 dBm (2nd column). For this row in the table, the first column indicates that an interference power level of -82 dBm at the output of the GPS receiver antenna will cause a 1 dB drop in the C/No for the TRIG receiver (for both the L1 C/A-code and L1 P-code channels of the receiver). Column 3 indicates that over the 10-day simulation period, the aggregate interference (from the ~34900 base stations) at the GPS antenna output actually exceeds this level about 9% of the time (i.e. since 10 days = 240 hours, the interference exceeds -82 dBm for 0.09 x 240 = 21.6 hours total over the 10-day period). In other words, for 9% of the time, the receiver C/No degradation is *at least* 1 dB. In the table header, the peak interference level is shown to reach -55.1 dBm (enough for the TRIG to lose lock). Column 4 indicates that over the 10-day period, there are 268 interference events (i.e. 268 separate time intervals during which interference exceeds -82 dBm). Note that these time intervals may be very short or fairly long depending on how many interfering base stations the satellite sees on the particular orbit pass over the US. The sum duration of all 268 interference events is the 21.6 hours. Also, there can be multiple interference events for a single orbit pass as different numbers of base stations pass through the FOV of the receiver antenna. Column 5 indicates that the average duration of an interference event is about 4.9 minutes and the maximum duration from column 6 is 16.9 minutes. Table 3a also shows that for a threshold of -67 dBm (where TRIG loses lock), interference exceeds this level about 3% of the time with 152 interference events of average duration 2.9 min and max duration 10.6 min. It should be noted that the duration of an atmospheric occultation (as the signal path moves from skimming the Earth's surface to an altitude of about 100 km) is only one to two minutes. Table 3b with the 5° elevation mask ignores interference from the low elevation angle base stations, but still shows average interference event duration of 3.8 min at the -67 dBm TRIG loss of lock threshold. (Compared to Table 3a there are fewer events, 57 vs 152, but the average duration is longer.)

The impact to the IGOR space receiver is seen to be much less. Note, however, that these results are only for the forward looking RO antenna. There will also be an aft pointing RO antenna, so interference will occur both when the CONUS is coming into the forward looking antenna FOV and when it is leaving the aft looking antenna FOV. Further analysis is required to determine the interference statistics when both antennas are included.

For the case of RO receiver onboard COSMIC-2 satellite in the 520 km/24° inclined orbit, the peak interference was found to be -88.2 dBm. This is much lower than for the 800 km/72° inclined orbit since the satellite does not pass over the US, but only sees a few base stations on the southern border. This level of interference is expected to cause less than 1 dB of degradation to the TRIG receiver.

Interference results for the navigation mode GPS RX with zenith pointed antenna onboard a LEOSAT (400 km/72° orbit) are shown in Table 4a (0° base station elevation mask) and Table 4b (5° base station elevation mask). The majority of GPS receivers used in space are small, lightweight, low-power devices providing spacecraft 3-dimensional position and velocity as well as timing and possibly 3-axis attitude determination. Tables 4a and 4 b show that compared to the RO case, interference effects are much less due to the backlobes and sidelobes of the receiving antenna facing towards the earth (and interfering base stations). Note also that no satellite body masking is included in this case which will likely further reduce the interference.

Although LightSquared is planning to operate the base stations at a maximum EIRP of 32 dBW per channel, the current FCC rules allow them to operate up to 42 dBW EIRP. Tables 5a, 5b, 6a, and 6b show the interference results if the base stations were to operate at 42 dBW EIRP.

3.2.Terrestrial Receiver (single base station) Analysis Results

Separation distance contours for the four receivers are shown in Figures 10-13. In these polar plots, the base station is assumed to be at the center of the plot with the 3 sector antennas oriented in the 0°, 120°, and 240° azimuth directions. The radial rings show distance from the center (base station) in km. Contours are shown for several different propagation models. The least conservative models are shown on the left side and the most conservative on the right side. Note the different distance scales on the plots. In each case, the contours are associated with the receiver interference threshold that causes 1 dB C/No drop in the C/A-code channel. Referring to Table 2, these thresholds are -82 dBm (TRIG); -57 dBm (IGOR); -54 dBm (JAVAD); and -68 dBm (Ashtech). Base station height is 18.3 meters and GPS rx height is 1 meter. For these heights the radio LOS distance is 22 km so a receiver beyond 22 km is assumed not to receive interference. There is large variation in required separation distance depending on the assumed propagation model. Free-space loss yields the largest (most protective) separation distances: 22 km (TRIG); 4 km (IGOR); 3 km (JAVAD); and 14 km (Ashtech).

3.3.Terrestrial Receiver (multiple base station) Analysis Results

The results of this analysis are shown in Figures 14-18 and Table 7. Figure 14a shows the interference map for the LightSquared Las Vegas deployment of 215 base stations assuming the free-space propagation model. The colors correspond to different levels of aggregate interference (dBm) at the output of the GPS receiver antenna (assumed to be the choke ring antenna with gain pattern in

Figure 3). Figure 14b shows the interference map with a -56 dBm threshold applied to the map (again assuming free-space propagation loss). This is the threshold which causes a 1 dB C/No degradation in the JAVAD receiver (Table 2). The red area is where the interference exceeds the -56 dBm level. In this case a total of 2008 km^2. Figure 14c is a similar type map for the Ashtech receiver which has a -68 dBm (1 dB degradation) threshold. Because the threshold is lower, the area is now 3529 km^2. As noted earlier, the propagation model assumed in the calculations has a significant effect on the results. Figures 15-18 show interference maps using different propagation models. Table 7 shows the interference exclusion areas for the JAVAD/Ashtech threshold levels with other propagation models. Further work will need to be done in the TWG to determine what is the appropriate propagation model to be used in these scenarios.

Table 1. NASA GPS Receiver Analysis Assumptions

		SPACEBORNE RECEIVER ANALYSIS	**TERRESTRIAL RECEIVER ANALYSIS (SINGLE LSQ BASE STATION)**	**TERRESTRIAL RECEIVER ANALYSIS (MULTIPLE LSQ BASE STATIONS)**
GPS CHARACTERISTICS	COMPUTATION METHOD	MATLAB TIME SIMULATION TO COMPUTE AGG INTERFERENCE FROM CONUS BASE STATIONS INTO ORBITING GPS RX (10-DAY SIM PERIOD @ 1-SEC TIME STEP)	MATHCAD CALCULATION USED TO COMPUTE REQUIRED SEPARATION DISTANCE CONTOURS FROM SINGLE BASE STATION	MATLAB INTERFERENCE MATRIX MAP COMPUTATION TO DETERMINE AGG LEVEL OF INTERFERENCE FROM MULTIPLE BASE STATIONS IN LAS VEGAS DEPLOYMENT
	GPS RX TYPE (all dual-frequency semi-codeless)	TRIG (next-gen space/occulation rx); IGOR (current gen space/occulation rx)	TRIG; IGOR; JAVAD; ASHTECH	JAVAD; ASHTECH
	ORBIT	COSMIC 2 HI ALT (800 km/72°) **(FIG 1)** COSMIC 2 LO ALT (520 km/24°) GENERIC LEO (400 km/72°)	N/A	N/A
	GPS RX ANTENNA TYPE	OCCULT 12-ELEMENT ARRAY (15.2 dBic for COSMIC-2 ORBITS) **(FIG 2)**; CHOKE RING (6.8 dBic for GENERIC LEO) **(FIG 3)**	CHOKE RING (6.8 dBic) **(FIG 3)**	CHOKE RING (6.8 dBic) **(FIG 3)**
	GPS RX ANTENNA POINTING	TOWARDS EARTH LIMB (COSMIC-2 OCCULT ORBITS); ZENITH (GENERIC LEO)	ZENITH POINTED	ZENITH POINTED
	GPS RX ANTENNA PATTERN	OCCULT 12-ELEMENT ARRAY; CHOKE RING	CHOKE RING	CHOKE RING
	INTERFERENCE THRESHOLD	THRESHOLDS AS MEASURED DURING JPL CONDUCTED TESTING **(TABLE 2)**	THRESHOLDS AS MEASURED DURING JPL CONDUCTED TESTING **(TABLE 2)**	THRESHOLDS AS MEASURED DURING JPL CONDUCTED TESTING **(TABLE 2)**
	POLARIZATION LOSS	3 DB	3 DB	3 DB
LIGHTSQUARED BASE STATION CHARACTERISTICS	DEPLOYMENT	34939 BASE STATIONS ACROSS 139 CONUS CITIES **(FIG 4)**	SINGLE LSQ BASE STATION (18.3 meter/60 ft tall)	215 BASE STATIONS (645 SECTORS) IN LAS VEGAS DEPLOYMENT (LAT/LON/HEIGHT per LSQ PROVIDED DATA)
	SPECTRUM PHASE	PHASE 1: TWO (5 MHz) CHANNELS	PHASE 1: TWO (5 MHz) CHANNELS	PHASE 1: TWO (5 MHz) CHANNELS
	CHANNEL FREQS	1526.3 - 1531.3 MHz/ 1550.2 - 1555.2 MHz	1526.3 - 1531.3 MHz/ 1550.2 - 1555.2 MHz	1526.3 - 1531.3 MHz/ 1550.2 - 1555.2 MHz
	EIRP/CHANNEL STRUCTURE	62 dBm per (5 MHz) channel	62 dBm per (5 MHz) channel	62 dBm per (5 MHz) channel
	CHANNELS PER SECTOR	2 (PHASE 1)	2 (PHASE 1)	2 (PHASE 1)
	EIRP per SECTOR	65 dBm	65 dBm	65 dBm
	SECTORS per BASE STATION	3 (0° AZ; 120° AZ; 240° AZ)	3 (0° AZ; 120° AZ; 240° AZ)	3 (0° AZ; 120° AZ; 240° AZ)
	SECTOR ANTENNA PATTERN	Tongyu TDJ (16.5 dBi mainbeam gain; 66.87° x 8.08°; -45°/+45° LP; 2° downtilt) **(FIG 5)**	Tongyu TDJ (16.5 dBi mainbeam gain; 66.87° x 8.08°; -45°/+45° LP; 2° downtilt) **(FIG 5)**	Tongyu TDJ (16.5 dBi mainbeam gain; 66.87° x 8.08°; -45°/+45° LP; 2° downtilt) **(FIG 5)**
	PROPAGATION MODEL	FREE-SPACE; CASES FOR 0° and 5° ELEVATION MASK ON BASE STATIONS; MAX 20 DB SECTOR ANTENNA OVERHEAD DISCRIMINATION DUE TO GROUND REFLECTION	RESULTS GENERATED FOR VARIOUS PROP MODELS (FREE-SPACE, HATA, EXTENDED HATA, Walfisch-Ikegami, NTIA/ITM) **(FIG 6)**	RESULTS GENERATED FOR VARIOUS PROP MODELS (FREE-SPACE, HATA, EXTENDED HATA, Walfisch-Ikegami, NTIA/ITM) **(FIG 6)**

Table 2. Summary of JPL Conduction Testing Interference Thresholds

		NASA GPS RECEIVER SUSCEPTIBILITY TO LSQ INTERFERENCE (BASED ON JPL CONDUCTED TESTING)											
		NOTE: POWER LEVEL SHOWN IS TOTAL POWER AT OUTPUT OF GPS RX PASSIVE ANTENNA (dBm)											
LSQ Signal Spectrum	Interference Criterion	TRIG			IGOR			JAVAD Delta G3T			Ashtech Z-12		
		L1 C/A	L1 P	L2 P	L1 C/A	L1 P	L2 P	L1 C/A	L1 P	L2 P	L1 C/A	L1 P	L2 P
LSQ Phase 1 (two 5 MHz channels @ 1526.3-1531.3 and 1550.2-1555.2)	1 dB C/No degradation	C: -82	C: -82	C: -78	C: -57	C: -59	C: -51	C: -54	C: -56	C: -43	C:-68		
	3 dB C/No degradation	C: -78	C: -80	C: -77	C: -53	C: -54	C: -49	C: -51	C: -52	C: -43	C:-65		
	5 dB C/No degradation	C: -75	C: -73	C: -74	C: -49	C: -51	C: -48	C: -49	C: -50	C: -43	C:-62		
	Loss of Lock	C: -67	C:-67	C: -67	C: -45	C: -45	C: -45	C: -43	C: -43	C: -43	C: -38	C: -38	C: -38

Figure 1. Ground Track of COSMIC-2 Satellite in 800 km/72° Orbit Over 10-Day Sim Period

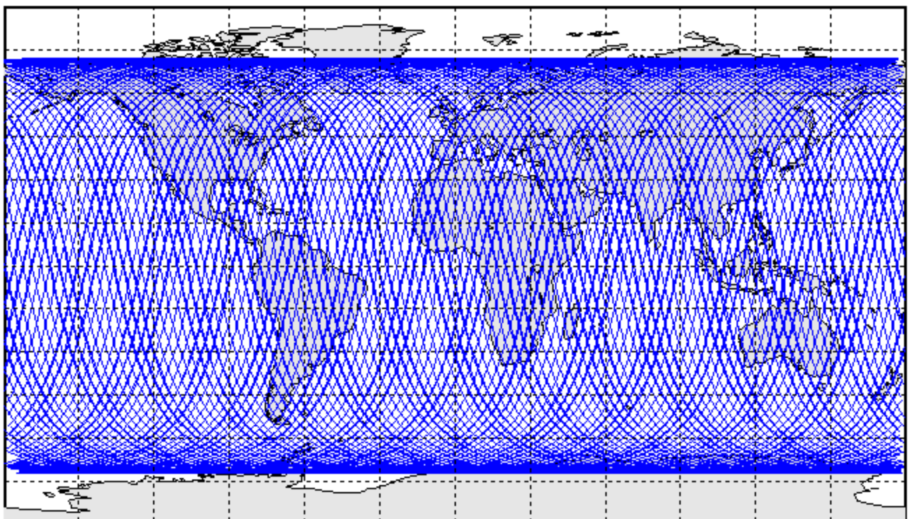


Figure 2. Gain Pattern of JPL GPS RX Occultation Antenna (12-element array with 15.2 dBic mainbeam pointed towards Earth limb)

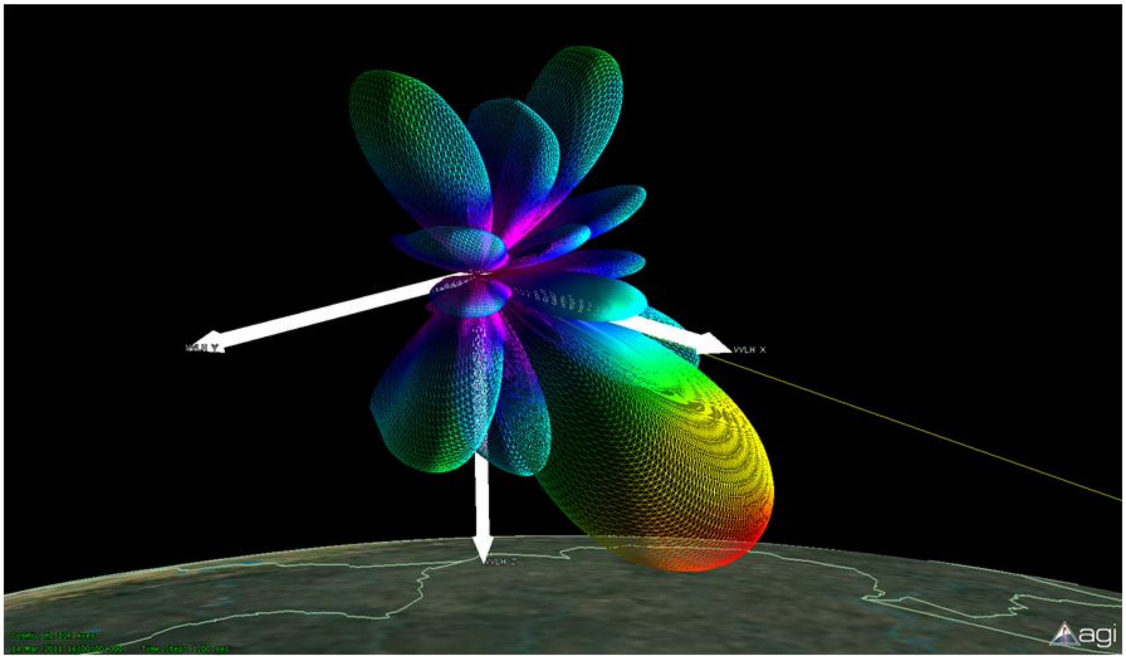
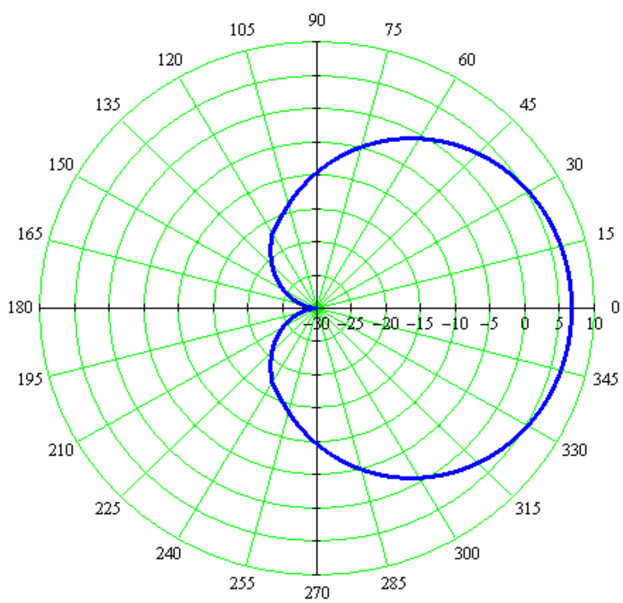


Figure 3. GPS Receiver Choke Ring Gain Pattern (6.75 dBic gain)



Off-boresight Angle (deg) θ =	Gain (dBic) Choke_Ring2(θ)
0	6.7537
5	6.7081
10	6.5967
15	6.4016
20	6.1077
25	5.7031
30	5.1787
35	4.5286
40	3.7497
45	2.8421
50	1.8087
55	0.6556
60	-0.6083
65	-1.9709
70	-3.4173
75	-4.9294
80	-6.4863
85	-8.0639
90	-9.6353

Figure 4a. Spaceborne GPS RX Interference Scenario – Aggregate Interference Computed from ~ 35,000 Base Stations Distributed Across 139 US Cities

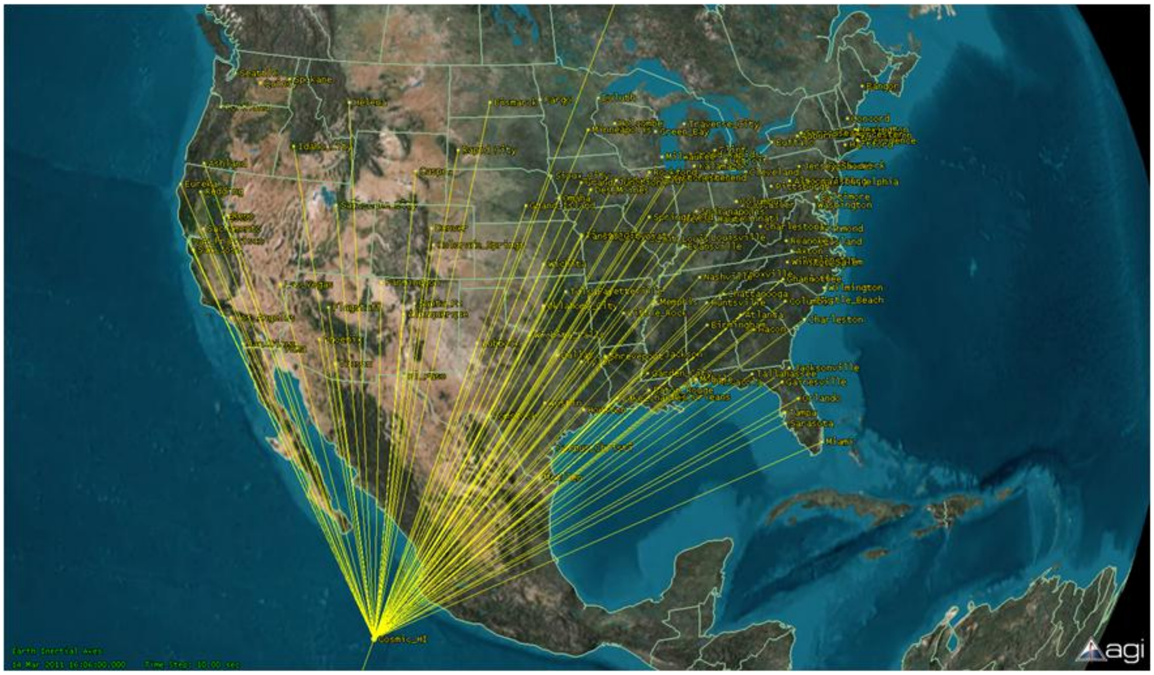


Figure 4b. Spaceborne GPS RX Occultation Scenario – Mainbeam of Array Antenna is Pointed 26.2° Below the Satellite Local Horizontal Towards the Earth Limb

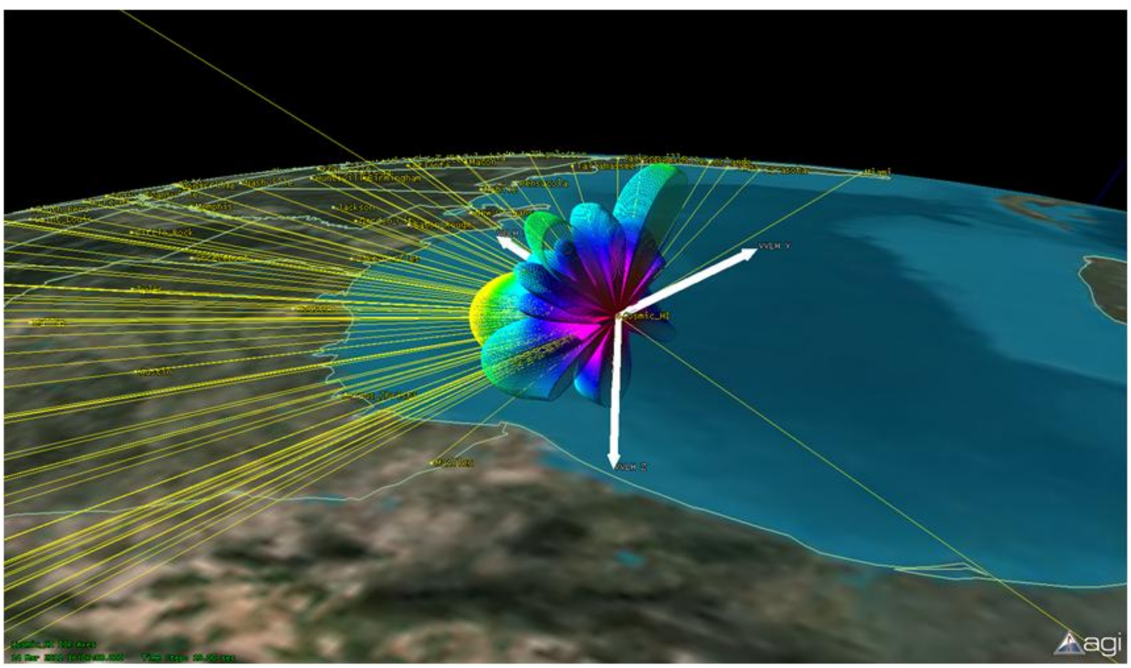


Figure 5. LightSquared Tongyu Model Base Station Sector Antenna Pattern (16.5 dBi max gain)

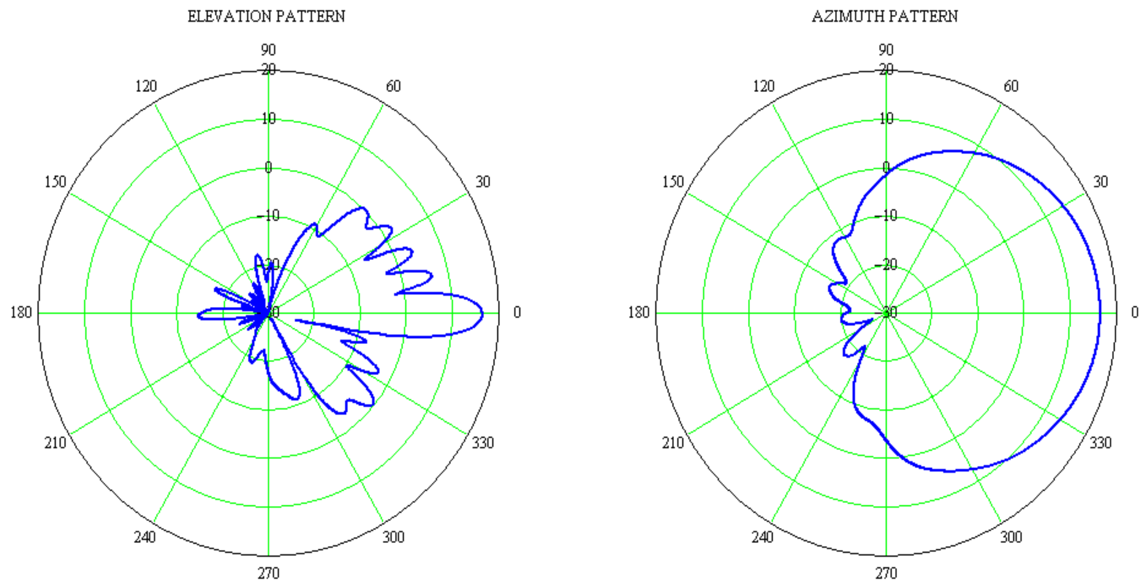


Figure 6. Comparison of Various Terrestrial Propagation Models

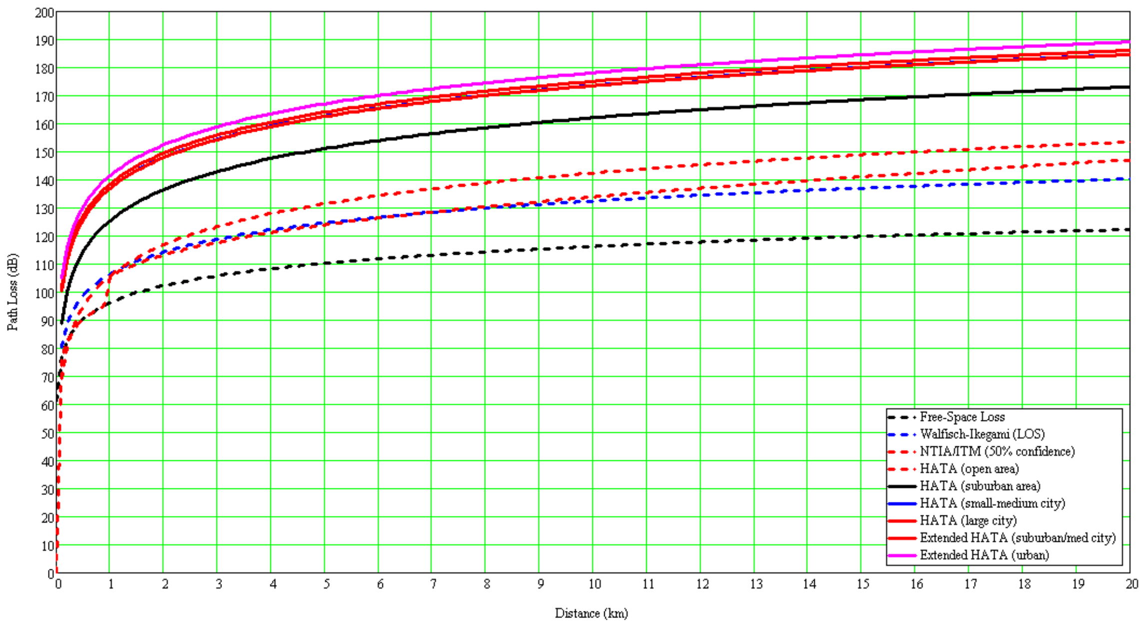


Figure 7. Locations of GPS Receivers of the International GNSS Service (IGS). There are 58 receivers in CONUS. The IGS collects, archives, and distributes GPS data for a wide range of applications and experiments (e.g. earth rotation, ionospheric maps, GPS/GLONASS ephemeris)

IGS Receivers in Southern California Area

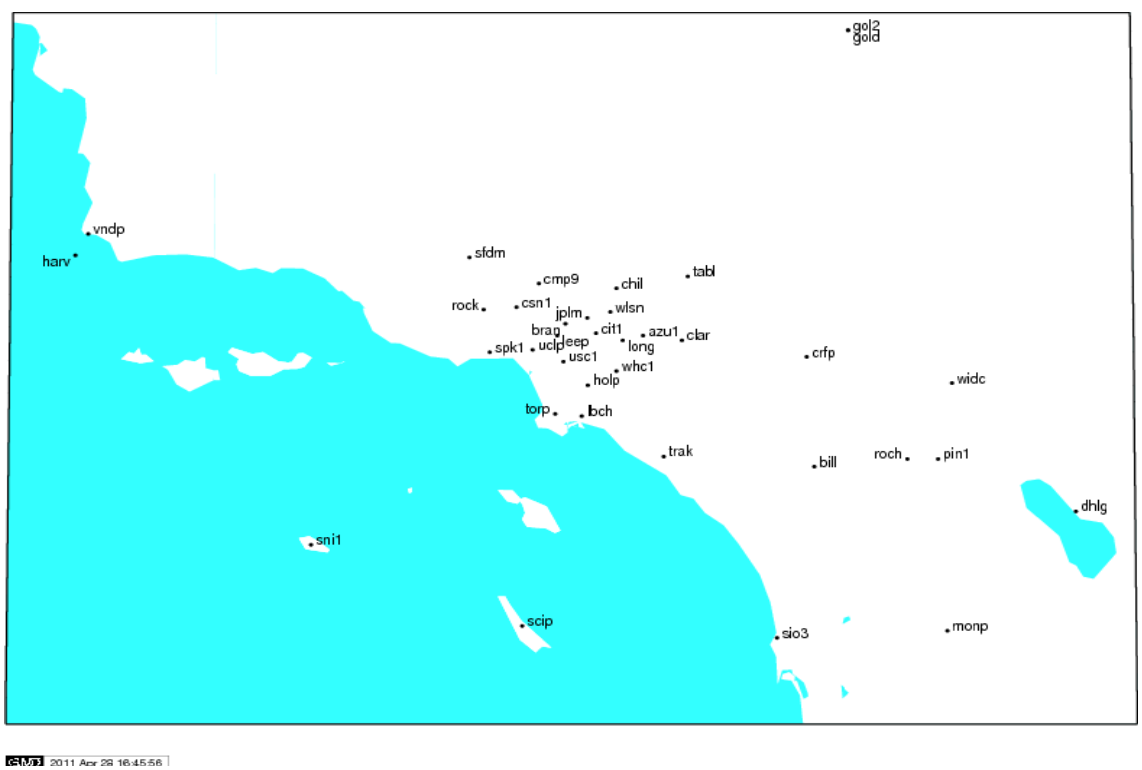


Figure 8. Locations of the 123 GPS Receivers of the SCIGN (Southern California Integrated GPS Network). The network continuously records mm-scale movements of the Earth's crust to estimate earthquake hazard.

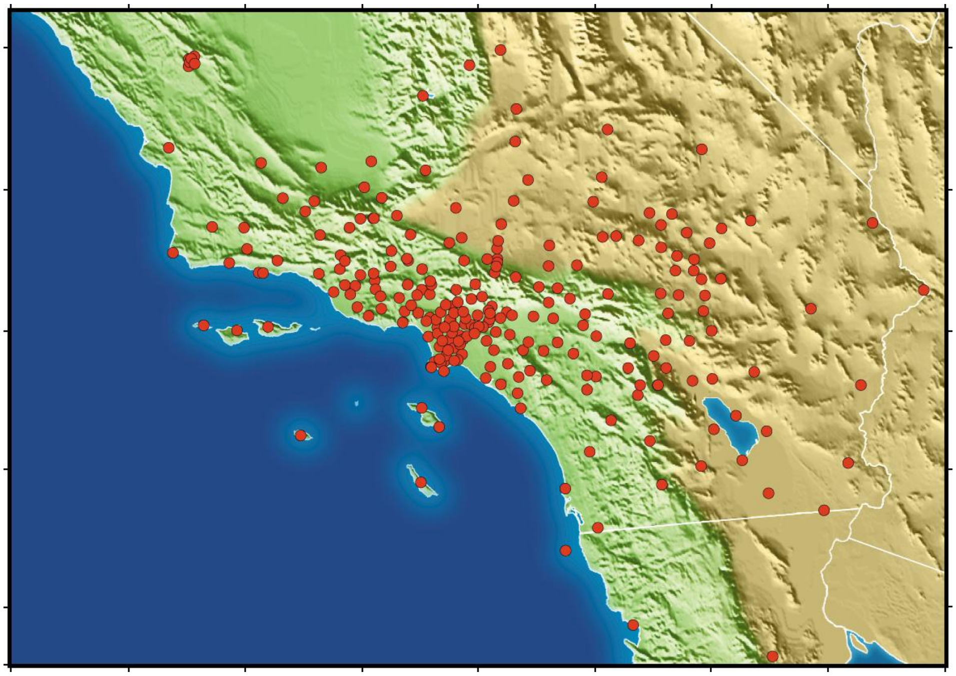


Figure 9. The Packard SCIGN Station (located in Elysian Park above downtown L.A.)

Table 3a. Interference Results for JPL Occultation GPS RX Onboard COSMIC-2 Satellite (800 km/72° orbit) With Earth Limb Pointed Array Antenna (0 ° elevation mask on base stations)

LSQ Interference Results for JPL Occultation GPS Receiver					
GPS RX Onboard COSMIC-2 Satellite in 800 km/72° Orbit					
Interference from 34939 LSQ Base Stations Located Across 139 US Cities					
Two LSQ channels per sector @ 32 dBW max EIRP per channel					
Tongyu sector antenna pattern (16.5 dBi max gain); 3 sectors per base station					
0° Elevation Mask on LSQ Base Stations					
Min overhead sector antenna gain of -3.5 dBi (16.5-20) due to signal ground reflection					
Peak Interference Level = -55.1 dBm					
RX C/No Degradation (based on JPL conduction testing)	Agg Interference Threshold **(dBm)** (int power at output of GPS RX antenna)	% Time (over 10-day period) that Interference Exceeds Threshold	# of Interference Events over 10-day sim period	Avg Duration of Interference Event (min)	Max Interference Event Duration (min)
	-56.000	0.009	11.000	0.112	0.367
IGOR (1 dB; C/A)	**-57.000**	0.074	59.000	0.180	0.800
	-58.000	0.217	80.000	0.390	2.167
IGOR (1 dB; P1)	**-59.000**	0.384	93.000	0.595	3.533
	-60.000	0.595	86.000	0.996	5.550
	-61.000	0.829	105.000	1.137	5.767
	-62.000	1.154	136.000	1.222	6.033
	-63.000	1.531	156.000	1.413	7.617
	-64.000	1.918	157.000	1.760	8.233
	-65.000	2.297	158.000	2.094	8.900
	-66.000	2.652	165.000	2.314	9.783
TRIG (Lost Lock; C/A & P1 & P2)	**-67.000**	3.033	152.000	2.873	10.600
	-68.000	3.414	157.000	3.131	10.750
	-69.000	3.787	185.000	2.948	11.483
	-70.000	4.150	153.000	3.906	11.683
	-71.000	4.477	139.000	4.638	12.017
	-72.000	4.800	145.000	4.767	12.433
TRIG (5 dB; P1)	**-73.000**	5.131	147.000	5.027	12.683
TRIG (5 dB; P2)	**-74.000**	5.452	163.000	4.817	13.350
TRIG (5 dB; C/A)	**-75.000**	5.851	193.000	4.366	13.700
	-76.000	6.262	205.000	4.399	13.917
TRIG (3 dB; P2)	**-77.000**	6.696	225.000	4.285	14.167
TRIG (3 dB; C/A) ; TRIG (1 dB; P2)	**-78.000**	7.135	240.000	4.281	15.167
	-79.000	7.601	257.000	4.259	16.117
TRIG (3 dB; P1)	**-80.000**	8.084	264.000	4.409	16.717
	-81.000	8.554	279.000	4.415	16.950
TRIG (1 dB; C/A & P1)	**-82.000**	9.059	268.000	4.867	16.983
	-83.000	9.491	258.000	5.297	17.083
	-84.000	9.878	254.000	5.600	17.150
	-85.000	10.252	266.000	5.550	17.283
	-300.000	15.749	175.000	12.960	25.300

Table 3b. Interference Results for JPL Occultation GPS RX Onboard COSMIC-2 Satellite (800 km/72° orbit) With Earth Limb Pointed Array Antenna (5 ° elevation mask on base stations)

LSQ Interference Results for JPL Occultation GPS Receiver					
GPS RX Onboard COSMIC Satellite in 800 km/72° Orbit					
Interference from 34939 LSQ Base Stations Located Across 139 US Cities					
Two LSQ channels per sector @ 32 dBW max EIRP per channel					
Tongyu sector antenna pattern (16.5 dBi max gain); 3 sectors per base station					
5° Elevation Mask on LSQ Base Stations					
Min overhead sector antenna gain of -3.5 dBi (16.5-20) due to signal ground reflection					
Peak Interference Level = -60.2 dBm					
RX C/No Degradation (based on JPL conduction testing)	Agg Interference Threshold **(dBm)** (int power at output of GPS RX antenna)	% Time (over 10-day period) that Interference Exceeds Threshold	# of Interference Events over 10-day sim period	Avg Duration of Interference Event (min)	Max Interference Event Duration (min)
	-56.000	0.000	0.000	0.000	0.000
IGOR (1 dB; C/A)	**-57.000**	0.000	0.000	0.000	0.000
	-58.000	0.000	0.000	0.000	0.000
IGOR (1 dB; P1)	**-59.000**	0.000	0.000	0.000	0.000
	-60.000	0.000	0.000	0.000	0.000
	-61.000	0.082	18.000	0.653	1.733
	-62.000	0.236	23.000	1.478	2.983
	-63.000	0.429	41.000	1.506	3.717
	-64.000	0.684	57.000	1.727	5.933
	-65.000	0.918	52.000	2.542	6.433
	-66.000	1.210	56.000	3.111	7.033
TRIG (Lost Lock; C/A & P1 & P2)	**-67.000**	1.502	57.000	3.795	7.983
	-68.000	1.817	81.000	3.230	8.150
	-69.000	2.069	76.000	3.921	8.433
	-70.000	2.355	79.000	4.292	8.917
	-71.000	2.655	75.000	5.097	9.583
	-72.000	2.994	94.000	4.586	9.850
TRIG (5 dB; P1)	**-73.000**	3.328	95.000	5.044	10.467
TRIG (5 dB; P2)	**-74.000**	3.578	94.000	5.481	11.067
TRIG (5 dB; C/A)	**-75.000**	3.844	110.000	5.032	11.450
	-76.000	4.113	111.000	5.335	11.533
TRIG (3 dB; P2)	**-77.000**	4.420	107.000	5.948	11.533
TRIG (3 dB; C/A) TRIG (1 dB; P2)	**-78.000**	4.697	121.000	5.589	11.750
	-79.000	4.982	127.000	5.649	12.750
TRIG (3 dB; P1)	**-80.000**	5.275	128.000	5.934	13.217
	-81.000	5.562	121.000	6.619	13.717
TRIG (1 dB; C/A & P1)	**-82.000**	5.853	134.000	6.290	14.083
	-83.000	6.116	132.000	6.672	14.350
	-84.000	6.410	143.000	6.455	14.350
	-85.000	6.703	165.000	5.850	14.433
	-300.000	12.180	189.000	9.280	21.683

Table 4a. Interference Results for JPL GPS RX Onboard LEOSAT (400 km/72° orbit) With Zenith Pointed Choke Ring Antenna (0 ° elevation mask on base stations)

LSQ Interference Results for JPL GPS Receiver with Zenith Pointed 7 dBic Choke Ring Antenna					
GPS RX Onboard LEO Satellite in 400 km/72° Orbit					
Interference from 34939 LSQ Base Stations Located Across 139 US Cities					
Two LSQ channels per sector @ 32 dBW max EIRP per channel					
Tongyu sector antenna pattern (16.5 dBi max gain); 3 sectors per base station					
Min overhead sector antenna gain of -3.5 dBi (16.5-20) due to signal ground reflection					
0° Elevation Mask on LSQ Base Stations					
Peak Interference Level = -78.1 dBm					
RX C/No Degradation (based on JPL conduction testing)	Agg Interference Threshold **(dBm)** (int power at output of GPS RX antenna)	% Time (over 10-day period) that Interference Exceeds Threshold	# of Interference Events over 10-day sim period	Avg Duration of Interference Event (min)	Max Interference Event Duration (min)
	-56.000	0.000	0.000	0.000	0.000
IGOR (1 dB; C/A)	**-57.000**	0.000	0.000	0.000	0.000
	-58.000	0.000	0.000	0.000	0.000
IGOR (1 dB; P1)	**-59.000**	0.000	0.000	0.000	0.000
	-60.000	0.000	0.000	0.000	0.000
	-61.000	0.000	0.000	0.000	0.000
	-62.000	0.000	0.000	0.000	0.000
	-63.000	0.000	0.000	0.000	0.000
	-64.000	0.000	0.000	0.000	0.000
	-65.000	0.000	0.000	0.000	0.000
	-66.000	0.000	0.000	0.000	0.000
TRIG (Lost Lock; C/A & P1 & P2)	**-67.000**	0.000	0.000	0.000	0.000
	-68.000	0.000	0.000	0.000	0.000
	-69.000	0.000	0.000	0.000	0.000
	-70.000	0.000	0.000	0.000	0.000
	-71.000	0.000	0.000	0.000	0.000
	-72.000	0.000	0.000	0.000	0.000
TRIG (5 dB; P1)	**-73.000**	0.000	0.000	0.000	0.000
TRIG (5 dB; P2)	**-74.000**	0.000	0.000	0.000	0.000
TRIG (5 dB; C/A)	**-75.000**	0.000	0.000	0.000	0.000
	-76.000	0.000	0.000	0.000	0.000
TRIG (3 dB; P2)	**-77.000**	0.000	0.000	0.000	0.000
TRIG (3 dB; C/A) TRIG (1 dB; P2)	**-78.000**	0.000	0.000	0.000	0.000
	-79.000	0.161	80.000	0.290	1.467
TRIG (3 dB; P1)	**-80.000**	0.601	183.000	0.473	4.717
	-81.000	1.517	364.000	0.600	8.300
TRIG (1 dB; C/A & P1)	**-82.000**	2.980	322.000	1.332	11.533
	-83.000	3.915	257.000	2.193	13.067
	-84.000	4.651	290.000	2.309	13.133
	-85.000	5.387	264.000	2.938	13.983
	-300.000	15.327	165.000	13.377	25.167

Table 4b. Interference Results for JPL GPS RX Onboard LEOSAT (400 km/72° orbit) With Zenith Pointed Choke Ring Antenna (5 ° elevation mask on base stations)

LSQ Interference Results for JPL GPS Receiver with Zenith Pointed 7 dBic Choke Ring Antenna
GPS RX Onboard LEO Satellite in 400 km/72° Orbit
Interference from 34939 LSQ Base Stations Located Across 139 US Cities
Two LSQ channels per sector @ 32 dBW max EIRP per channel
Tongyu sector antenna pattern (16.5 dBi max gain); 3 sectors per base station
Min overhead sector antenna gain of -3.5 dBi (16.5-20) due to signal ground reflection
5° Elevation Mask on LSQ Base Stations
Peak Interference Level = -81.3 dBm

RX C/No Degradation (based on JPL conduction testing)	Agg Interference Threshold **(dBm)** (int power at output of GPS RX antenna)	% Time (over 10-day period) that Interference Exceeds Threshold	# of Interference Events over 10-day sim period	Avg Duration of Interference Event (min)	Max Interference Event Duration (min)
	-56.000	0.000	0.000	0.000	0.000
IGOR (1 dB; C/A)	**-57.000**	0.000	0.000	0.000	0.000
	-58.000	0.000	0.000	0.000	0.000
IGOR (1 dB; P1)	**-59.000**	0.000	0.000	0.000	0.000
	-60.000	0.000	0.000	0.000	0.000
	-61.000	0.000	0.000	0.000	0.000
	-62.000	0.000	0.000	0.000	0.000
	-63.000	0.000	0.000	0.000	0.000
	-64.000	0.000	0.000	0.000	0.000
	-65.000	0.000	0.000	0.000	0.000
	-66.000	0.000	0.000	0.000	0.000
TRIG (Lost Lock; C/A & P1 & P2)	**-67.000**	0.000	0.000	0.000	0.000
	-68.000	0.000	0.000	0.000	0.000
	-69.000	0.000	0.000	0.000	0.000
	-70.000	0.000	0.000	0.000	0.000
	-71.000	0.000	0.000	0.000	0.000
	-72.000	0.000	0.000	0.000	0.000
TRIG (5 dB; P1)	**-73.000**	0.000	0.000	0.000	0.000
TRIG (5 dB; P2)	**-74.000**	0.000	0.000	0.000	0.000
TRIG (5 dB; C/A)	**-75.000**	0.000	0.000	0.000	0.000
	-76.000	0.000	0.000	0.000	0.000
TRIG (3 dB; P2)	**-77.000**	0.000	0.000	0.000	0.000
TRIG (3 dB; C/A) TRIG (1 dB; P2)	**-78.000**	0.000	0.000	0.000	0.000
	-79.000	0.000	0.000	0.000	0.000
TRIG (3 dB; P1)	**-80.000**	0.000	0.000	0.000	0.000
	-81.000	0.000	0.000	0.000	0.000
TRIG (1 dB; C/A & P1)	**-82.000**	0.147	15.000	1.407	2.383
	-83.000	0.493	60.000	1.184	3.867
	-84.000	1.107	55.000	2.899	7.283
	-85.000	1.793	103.000	2.507	8.083
	-300.000	11.515	167.000	9.929	21.450

Table 5a. Interference Results for RO GPS RX Onboard COSMIC-2 Satellite (800 km/72° orbit) With Earth Limb Pointed Array Antenna (0 ° elevation mask on base stations/42 dBW EIRP)

LSQ Interference Results for JPL Occultation GPS Receiver					
GPS RX Onboard COSMIC Satellite in 800 km/72° Orbit					
Interference from 34939 LSQ Base Stations Located Across 139 US Cities					
Two LSQ channels per sector @ 42 dBW max EIRP per channel					
Tongyu sector antenna pattern (16.5 dBi max gain); 3 sectors per base station					
0° Elevation Mask on LSQ Base Stations					
Min overhead sector antenna gain of -3.5 dBi (16.5-20) due to signal ground reflection					
Peak Interference Level = -45.1 dBm					
RX C/No Degradation (based on JPL conduction testing)	Agg Interference Threshold **(dBm)** (int power at output of GPS RX antenna)	% Time (over 10-day period) that Interference Exceeds Threshold	# of Interference Events over 10-day sim period	Avg Duration of Interferenc e Event (min)	Max Interference Event Duration (min)
IGOR (Lost Lock)	**-46.000**	0.009	11.000	0.112	0.367
	-47.000	0.074	59.000	0.180	0.800
IGOR (5dB;P2)	**-48.000**	0.217	80.000	0.390	2.167
IGOR (5 dB; C/A)	**-49.000**	0.384	93.000	0.595	3.533
	-50.000	0.595	86.000	0.996	5.550
IGOR (1 dB; P2) IGOR(5dB;P1)	**-51.000**	0.829	105.000	1.137	5.767
	-52.000	1.154	136.000	1.222	6.033
IGOR (3 dB; C/A)	**-53.000**	1.531	156.000	1.413	7.617
IGOR (3dB; P1)	**-54.000**	1.918	157.000	1.760	8.233
	-55.000	2.297	158.000	2.094	8.900
	-56.000	2.652	165.000	2.314	9.783
IGOR (1 dB; C/A)	**-57.000**	3.033	152.000	2.873	10.600
	-58.000	3.414	157.000	3.131	10.750
IGOR (1 dB; P1)	**-59.000**	3.787	185.000	2.948	11.483
	-60.000	4.150	153.000	3.906	11.683
	-61.000	4.477	139.000	4.638	12.017
	-62.000	4.800	145.000	4.767	12.433
	-63.000	5.131	147.000	5.027	12.683
	-64.000	5.452	163.000	4.817	13.350
	-65.000	5.851	193.000	4.366	13.700
	-66.000	6.262	205.000	4.399	13.917
TRIG (Lost Lock; C/A & P1 & P2)	**-67.000**	6.696	225.000	4.285	14.167
	-68.000	7.135	240.000	4.281	15.167
	-69.000	7.601	257.000	4.259	16.117
	-70.000	8.084	264.000	4.409	16.717
	-71.000	8.554	279.000	4.415	16.950
	-72.000	9.059	268.000	4.867	16.983
TRIG (5 dB; P1)	**-73.000**	9.491	258.000	5.297	17.083
TRIG (5 dB; P2)	**-74.000**	9.878	254.000	5.600	17.150
TRIG (5 dB; C/A)	**-75.000**	10.252	266.000	5.550	17.283
	-76.000	10.624	247.000	6.194	17.600
TRIG (3 dB; P2)	**-77.000**	10.978	243.000	6.506	17.733
TRIG (3 dB; C/A) TRIG (1 dB; P2)	**-78.000**	11.325	244.000	6.683	17.733
	-79.000	11.647	244.000	6.874	17.750
TRIG (3 dB; P1)	**-80.000**	11.912	239.000	7.177	17.783
	-81.000	12.170	258.000	6.793	17.983
TRIG (1 dB; C/A & P1)	**-82.000**	12.459	257.000	6.981	19.033
	-83.000	12.712	258.000	7.095	19.033
	-84.000	12.985	259.000	7.219	20.067
	-85.000	13.269	255.000	7.493	20.067
	-300.000	15.749	175.000	12.960	25.300

Table 5b. Interference Results for RO GPS RX Onboard COSMIC-2 Satellite (800 km/72° orbit) With Earth Limb Pointed Array Antenna (5 ° elevation mask on base stations/42 dBW EIRP)

LSQ Interference Results for JPL Occultation GPS Receiver					
GPS RX Onboard COSMIC Satellite in 800 km/72° Orbit					
Interference from 34939 LSQ Base Stations Located Across 139 US Cities					
Two LSQ channels per sector @ 42 dBW max EIRP per channel					
Tongyu sector antenna pattern (16.5 dBi max gain); 3 sectors per base station					
Min overhead sector antenna gain of -3.5 dBi (16.5-20) due to signal ground reflection					
5° Elevation Mask on LSQ Base Stations					
Peak Interference Level = -50.2 dBm					
RX C/No Degradation (based on JPL conduction testing)	Agg Interference Threshold **(dBm)** (int power at output of GPS RX antenna)	% Time (over 10-day period) that Interference Exceeds Threshold	# of Interference Events over 10-day sim period	Avg Duration of Interferenc e Event (min)	Max Interference Event Duration (min)
IGOR (Lost Lock)	**-46.000**	0.000	0.000	0.000	0.000
	-47.000	0.000	0.000	0.000	0.000
IGOR (5dB;P2)	**-48.000**	0.000	0.000	0.000	0.000
IGOR (5 dB; C/A)	**-49.000**	0.000	0.000	0.000	0.000
	-50.000	0.000	0.000	0.000	0.000
IGOR (1 dB; P2) IGOR(5dB;P1)	**-51.000**	0.082	18.000	0.653	1.733
	-52.000	0.236	23.000	1.478	2.983
IGOR (3 dB; C/A)	**-53.000**	0.429	41.000	1.506	3.717
IGOR (3dB; P1)	**-54.000**	0.684	57.000	1.727	5.933
	-55.000	0.918	52.000	2.542	6.433
	-56.000	1.210	56.000	3.111	7.033
IGOR (1 dB; C/A)	**-57.000**	1.502	57.000	3.795	7.983
	-58.000	1.817	81.000	3.230	8.150
IGOR (1 dB; P1)	**-59.000**	2.069	76.000	3.921	8.433
	-60.000	2.355	79.000	4.292	8.917
	-61.000	2.655	75.000	5.097	9.583
	-62.000	2.994	94.000	4.586	9.850
	-63.000	3.328	95.000	5.044	10.467
	-64.000	3.578	94.000	5.481	11.067
	-65.000	3.844	110.000	5.032	11.450
	-66.000	4.113	111.000	5.335	11.533
TRIG (Lost Lock; C/A & P1 & P2)	**-67.000**	4.420	107.000	5.948	11.533
	-68.000	4.697	121.000	5.589	11.750
	-69.000	4.982	127.000	5.649	12.750
	-70.000	5.275	128.000	5.934	13.217
	-71.000	5.562	121.000	6.619	13.717
	-72.000	5.853	134.000	6.290	14.083
TRIG (5 dB; P1)	**-73.000**	6.116	132.000	6.672	14.350
TRIG (5 dB; P2)	**-74.000**	6.410	143.000	6.455	14.350
TRIG (5 dB; C/A)	**-75.000**	6.703	165.000	5.850	14.433
	-76.000	7.024	174.000	5.813	14.733
TRIG (3 dB; P2)	**-77.000**	7.293	186.000	5.646	15.267
TRIG (3 dB; C/A) TRIG (1 dB; P2)	**-78.000**	7.615	208.000	5.272	15.267
	-79.000	7.936	192.000	5.952	15.267
TRIG (3 dB; P1)	**-80.000**	8.217	192.000	6.163	15.433
	-81.000	8.473	200.000	6.101	15.517
TRIG (1 dB; C/A & P1)	**-82.000**	8.743	205.000	6.141	15.583
	-83.000	8.984	211.000	6.131	15.583
	-84.000	9.212	212.000	6.257	15.583
	-85.000	9.474	218.000	6.258	15.600
	-300.000	12.180	189.000	9.280	21.683

Table 6a. Interference Results for GPS RX Onboard LEOSAT (400 km/72° orbit) With Zenith Pointed Choke Ring Antenna (0 ° elevation mask on base stations/42 dBW EIRP)

LSQ Interference Results for JPL GPS Receiver with Zenith Pointed 7 dBic Choke Ring Antenna					
GPS RX Onboard LEO Satellite in 400 km/72° Orbit					
Interference from 34939 LSQ Base Stations Located Across 139 US Cities					
Two LSQ channels per sector @ 42 dBW max EIRP per channel					
Tongyu sector antenna pattern (16.5 dBi max gain); 3 sectors per base station					
Min overhead sector antenna gain of -3.5 dBi (16.5-20) due to signal ground reflection					
0° Elevation Mask on LSQ Base Stations					
Peak Interference Level = -68.1 dBm					
RX C/No Degradation (based on JPL conduction testing)	Agg Interference Threshold **(dBm)** (int power at output of GPS RX antenna)	% Time (over 10-day period) that Interference Exceeds Threshold	# of Interference Events over 10-day sim period	Avg Duration of Interferenc e Event (min)	Max Interference Event Duration (min)
TRIG (Lost Lock; C/A & P1 & P2)	**-67.000**	0.000	0.000	0.000	0.000
	-68.000	0.000	0.000	0.000	0.000
	-69.000	0.161	80.000	0.290	1.467
	-70.000	0.601	183.000	0.473	4.717
	-71.000	1.517	364.000	0.600	8.300
	-72.000	2.980	322.000	1.332	11.533
TRIG (5 dB; P1)	**-73.000**	3.915	257.000	2.193	13.067
TRIG (5 dB; P2)	**-74.000**	4.651	290.000	2.309	13.133
TRIG (5 dB; C/A)	**-75.000**	5.387	264.000	2.938	13.983
	-76.000	6.160	297.000	2.986	14.083
TRIG (3 dB; P2)	**-77.000**	6.820	200.000	4.911	14.667
TRIG (3 dB; C/A) TRIG (1 dB; P2)	**-78.000**	7.177	211.000	4.898	14.750
	-79.000	7.551	225.000	4.832	14.967
TRIG (3 dB; P1)	**-80.000**	7.974	240.000	4.785	15.650
	-81.000	8.319	210.000	5.704	17.267
TRIG (1 dB; C/A & P1)	**-82.000**	8.620	179.000	6.935	17.733
	-83.000	8.896	197.000	6.503	17.933
	-84.000	9.103	151.000	8.681	18.083
	-85.000	9.186	122.000	10.842	18.083
	-300.000	15.327	165.000	13.377	25.167

Table 6b. Interference Results for GPS RX Onboard LEOSAT (400 km/72° orbit) With Zenith Pointed Choke Ring Antenna (5 ° elevation mask on base stations/42 dBW EIRP)

LSQ Interference Results for JPL GPS Receiver with Zenith Pointed 7 dBic Choke Ring Antenna					
GPS RX Onboard LEO Satellite in 400 km/72° Orbit					
Interference from 34939 LSQ Base Stations Located Across 139 US Cities					
Two LSQ channels per sector @ 42 dBW max EIRP per channel					
Tongyu sector antenna pattern (16.5 dBi max gain); 3 sectors per base station					
Min overhead sector antenna gain of -3.5 dBi (16.5-20) due to signal ground reflection					
5° Elevation Mask on LSQ Base Stations					
Peak Interference Level = -71.3 dBm					
RX C/No Degradation (based on JPL conduction testing)	Agg Interference Threshold **(dBm)** (int power at output of GPS RX antenna)	% Time (over 10-day period) that Interference Exceeds Threshold	# of Interference Events over 10-day sim period	Avg Duration of Interference Event (min)	Max Interference Event Duration (min)
TRIG (Lost Lock; C/A & P1 & P2)	**-67.000**	0.000	0.000	0.000	0.000
	-68.000	0.000	0.000	0.000	0.000
	-69.000	0.000	0.000	0.000	0.000
	-70.000	0.000	0.000	0.000	0.000
	-71.000	0.000	0.000	0.000	0.000
	-72.000	0.147	15.000	1.407	2.383
TRIG (5 dB; P1)	**-73.000**	0.493	60.000	1.184	3.867
TRIG (5 dB; P2)	**-74.000**	1.107	55.000	2.899	7.283
TRIG (5 dB; C/A)	**-75.000**	1.793	103.000	2.507	8.083
	-76.000	2.389	105.000	3.276	9.217
TRIG (3 dB; P2)	**-77.000**	3.050	122.000	3.600	9.617
TRIG (3 dB; C/A) TRIG (1 dB; P2)	**-78.000**	3.529	89.000	5.710	10.633
	-79.000	3.927	100.000	5.655	10.850
TRIG (3 dB; P1)	**-80.000**	4.247	94.000	6.506	11.100
	-81.000	4.539	96.000	6.809	11.367
TRIG (1 dB; C/A & P1)	**-82.000**	4.790	92.000	7.497	11.633
	-83.000	5.062	118.000	6.177	11.967
	-84.000	5.361	104.000	7.423	12.183
	-85.000	5.609	104.000	7.767	13.000
	-300.000	11.515	167.000	9.929	21.450

Figure 10. Separation Distance Contours for TRIG and Interference Threshold = -82 dBm (1 dB C/No degradation)

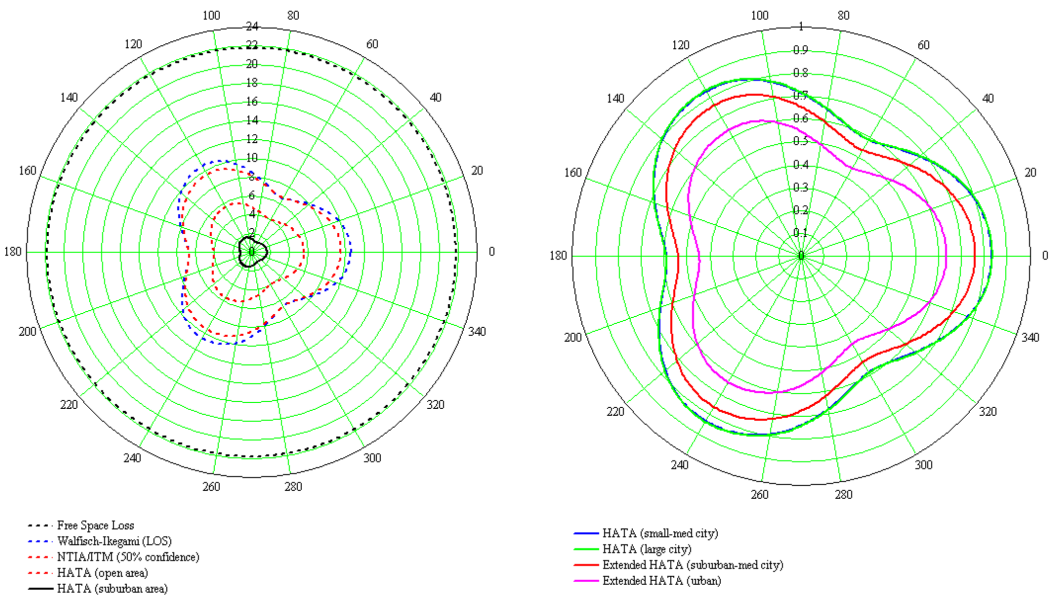


Figure 11. Separation Distance Contours for IGOR and Interference Threshold = -57 dBm (1 dB C/No degradation)

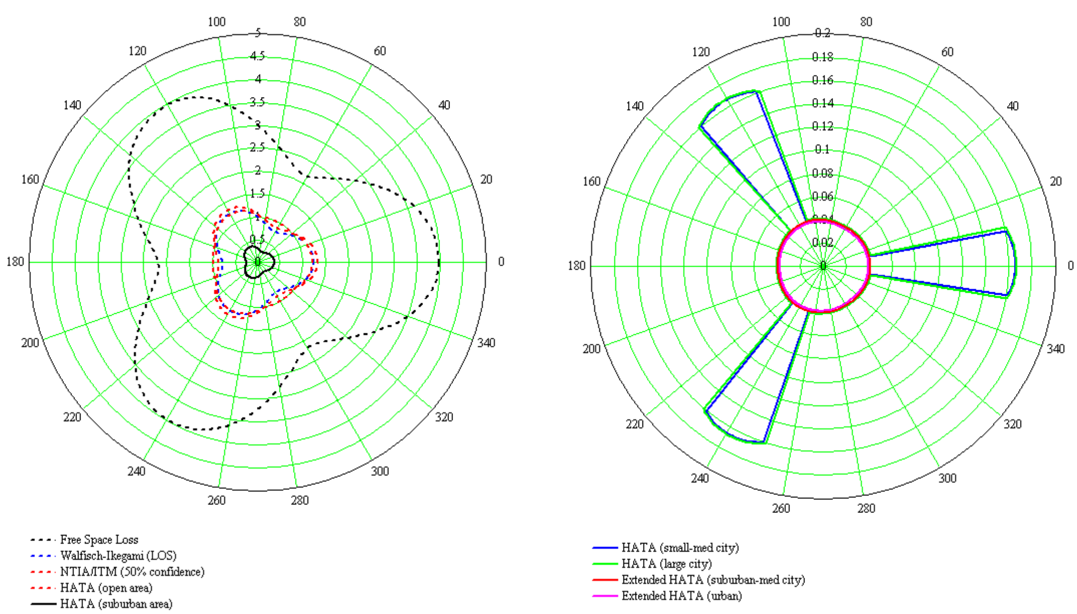


Figure 12. Separation Distance Contours for JAVAD and Interference Threshold = -54 dBm (1 dB C/No degradation)

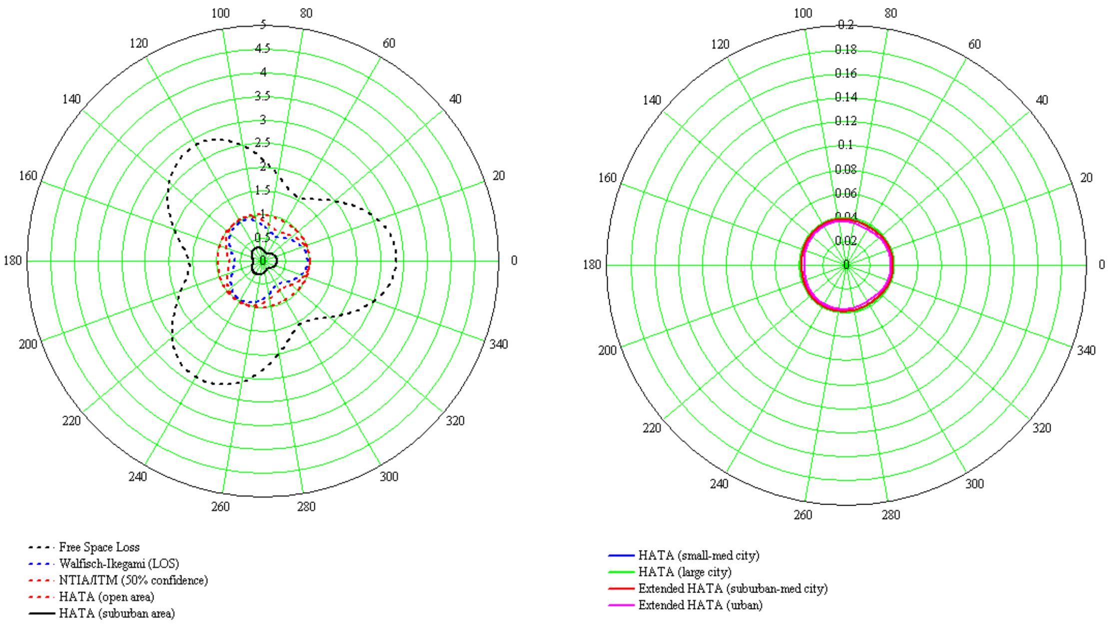


Figure 13. Separation Distance Contours for Ashtech and Interference Threshold = -68 dBm (1 dB C/No degradation)

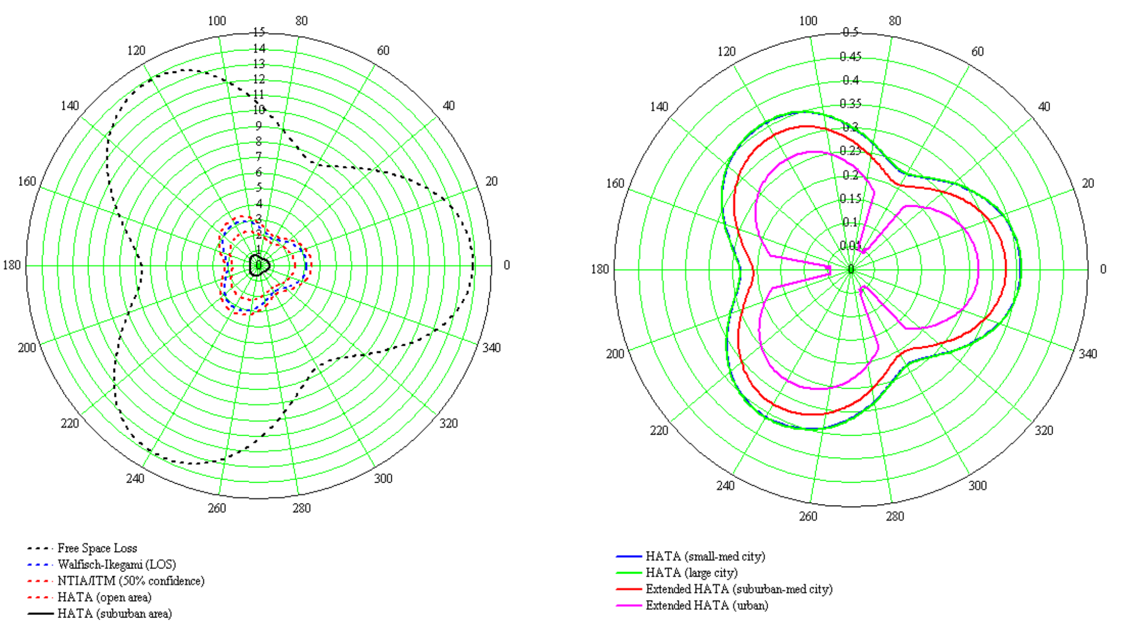


Figure 14a. Interference Map for LightSquared Las Vegas Deployment (215 Base Stations) (Free-Space Loss Propagation Model)

Note: Values are aggregate interference power at output of GPS rx choke-ring antenna (dBm)

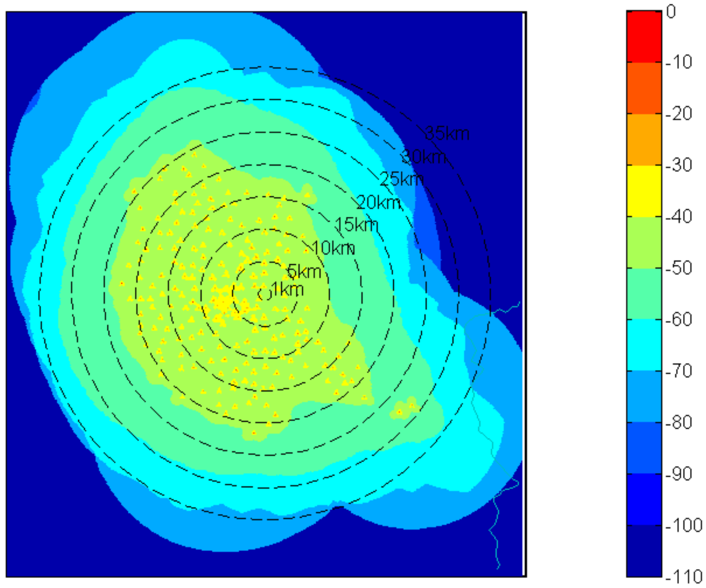


Figure 14b. Interference Exclusion Map for -56 dBm Interference Threshold (1 dB degradation for JAVAD receiver) (red area is where interference exceeds -56 dBm and is 2008 km^2) (Free-space propagation model)

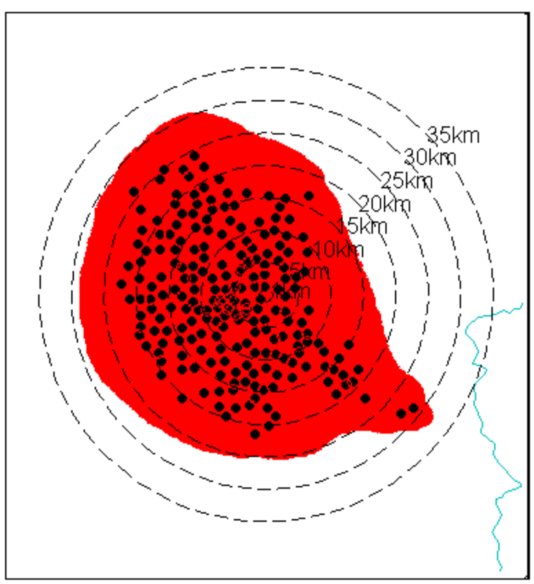


Figure 14c. Interference Exclusion Map for -68 dBm Interference Threshold (1 dB degradation for Ashtech receiver) (red area is where interference exceeds -68 dBm and is 3529 km^2) (Free-space propagation model)

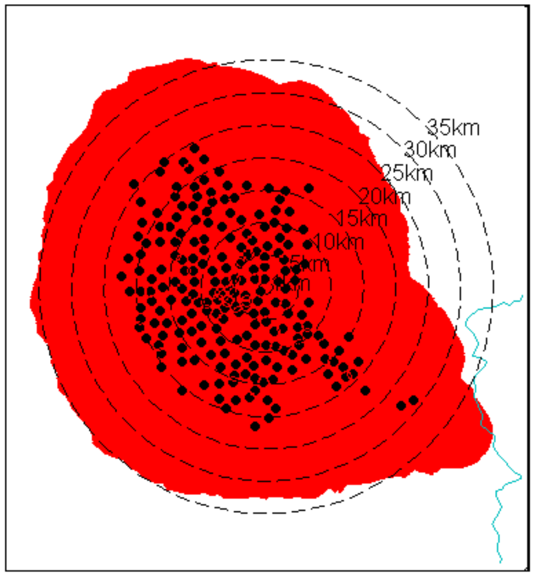


Figure 15. Interference Map for LightSquared Las Vegas Deployment (NTIA/ITM Model)

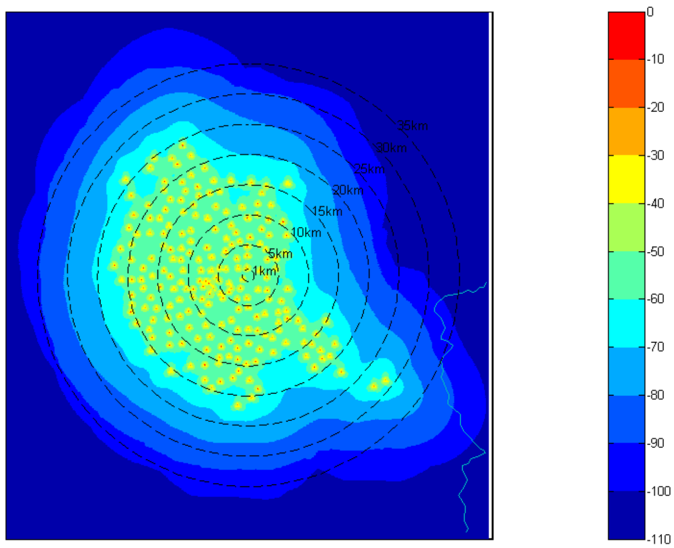


Figure 16. Interference Map for LightSquared Las Vegas Deployment (Hata-open area Model)

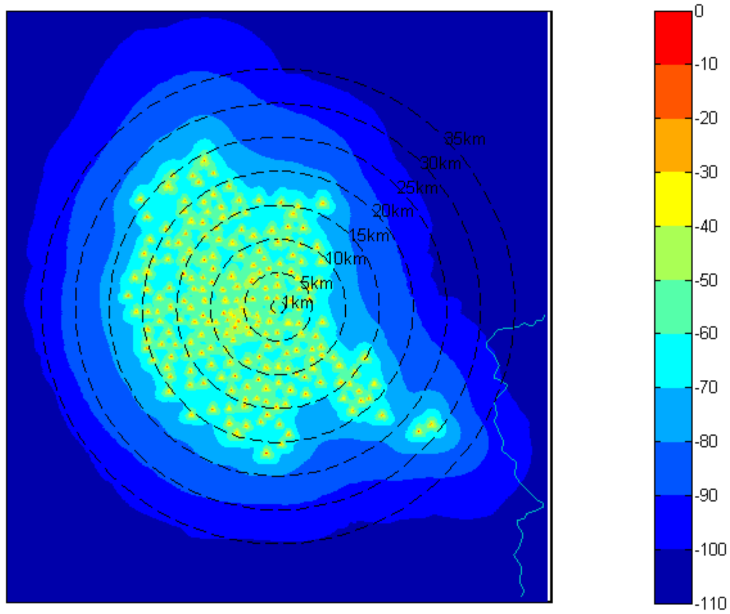


Figure 17. Interference Map for LightSquared Las Vegas Deployment (Hata-suburban Model)

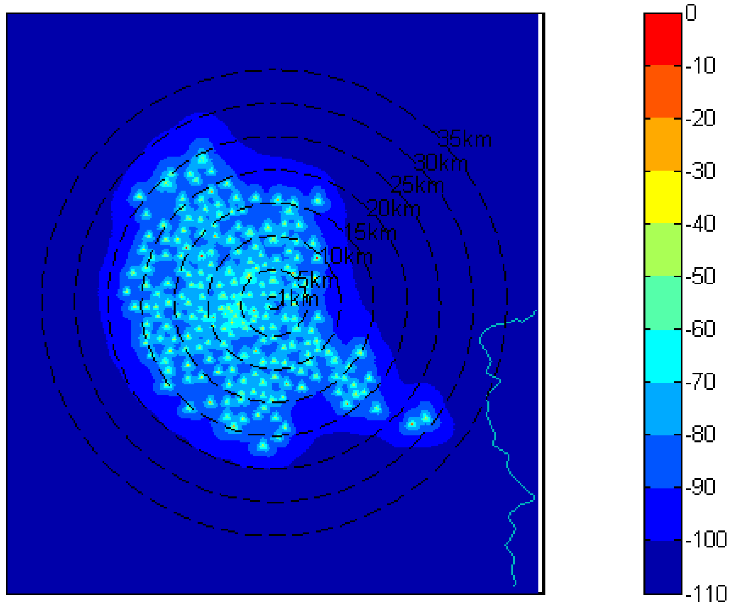


Figure 18. Interference Map for LightSquared Las Vegas Deployment (Hata-med city Model)

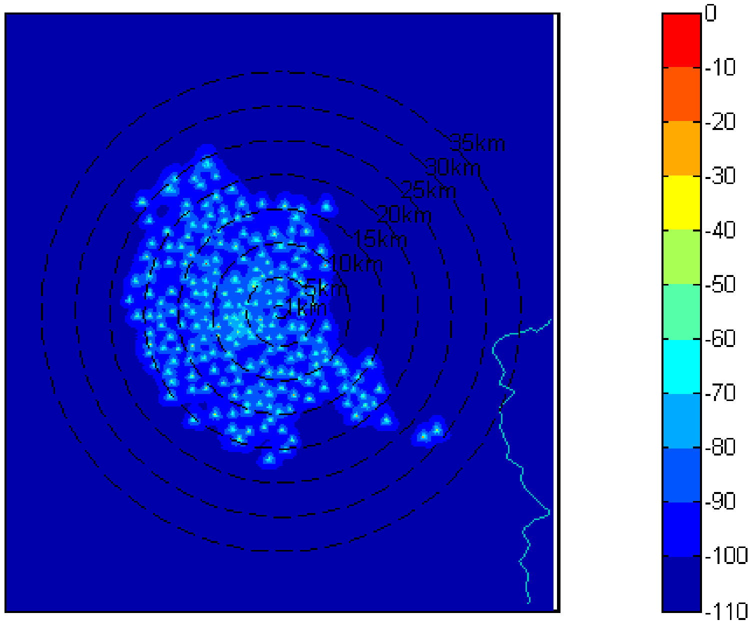


Table 7. Exclusion Areas for LightSquared Las Vegas Deployment for Different Propagation Models

Note: Values are total area in which interference exceeds the 1 dB C/No degradation thresholds (-56/-68 dBm) for JAVAD/Ashtech receivers

Propagation Model	JAVAD 1 dB C/No degradation threshold	Ashtech 1 dB C/No degradation threshold
	-56 dBm	-68 dBm
Free-Space Loss	2008 km^2	3529 km^2
Walfisch-Ikegami (LOS)	532.1 km^2	1478 km^2
NTIA/ITM (50% confidence)	632 km^2	1420 km^2
Hata (open area)	424 km^2	1123 km^2
Hata (suburban)	32.4 km^2	154.8 km^2
Hata (small-med city)	5.3 km^2	34.9 km^2
Hata (large city)	5.3 km^2	34 km^2
Extended Hata (suburban-med city)	4 km^2	28.1 km^2
Extended Hata (urban)	2.6 km^2	18.3 km^2

Appendix W.1

Working Group Roster

			SUB-TEAMS						
NAME	AFFILIATION	ROLE	Aviation	Cellular	General Location /Nav	High Precision	Networks	Space-Based	Timing
Maqbool Aliani	LightSquared	Advisor	X	X	X				
Ted Allwardt	Wabtec	Advisor				X			X
Dominic Arcuri	RCC	TWG Member							
Steve Baruch	USGIC	Observer							
Chaminda Basnayke	OnStar	Advisor			X				
Steve Berger	LightSquared	Advisor		X					
Knute Berstis	NCO/PNT	TWG Member				X			
John Betz	MITRE/USAF	TWG Member							
Mike Biggs	FAA	TWG Member	X						
Frederick Blume	UNAVCO	Advisor				X	X		X
Ron Borsato	Spirent	Advisor		X					
Pierre Bouniol	Thales	Advisor	X						
Joe Brabec	Topcon Positions Sys.	Advisor				X			
Cady Brooks	BI	Advisor			X				
Greg Buchwald	Motorola Solutions	Advisor			X				X
Jim Buck	BI	Advisor			X				
Scott Burgett	Garmin	TWG Member			X				
Joseph Burns	United	Advisor	X						
Kevin Butler	Sprint Nextel	Advisor		X					
Bob Calaff	T-Mobile	Advisor		X					
Jeffrey Carlisle	LightSquared	WG Co-Chair							
Mark Cato	Airline Pilots Assoc.	Advisor	X						
Brett Christian	Sprint Nextel	Advisor		X					X
Ann Ciganer	Trimble	Info. Facilitator	X	X	X	X	X	X	X
Frank Collin	Motorola Mobility	Advisor		X					
Cormac Conroy	Qualcomm	Advisor		X					
Shawn Coppel	American Electric Power	Advisor					X		X
Giselle Creeser	Lockheed Martin	TWG Member (Alternate)							
Charles Daniels	Overlook Systems Tech.	Advisor							

NAME	AFFILIATION	ROLE	SUB-TEAMS						
			Aviation	Cellular	General Location /Nav	High Precision	Networks	Space-Based	Timing
Wim De Wilde	Septentrio	Advisor				X			
Vinod Devan	LightSquared	Observer							
Santanu Dutta	LightSquared	TWG Member	X	X					
Rick Engelman	Sprint Nextel	TWG Member		X					X
Walter Feller	Hemisphere GPS	Advisor			X	X			
Pat Fenton	Novatel	TWG Member				X	X		Lead
John Foley	Garmin	TWG Member	X		X				
Hugo Fruehof	FEI-Zyfer	Advisor							X
Paul Galyean	Navcom	TWG Member				Lead	X		
Edward Gander	True Position	Advisor							X
Alex Gerdenitsch	Motorola Mobility	Advisor		X					
Henry Goldberg	LightSquared	Observer							
Capt. Anil Hariharan	USAF	TWG Member							
Martin Harriman	LightSquared	Info. Facilitator							
Scott Harris	Florida CORS Network	Advisor					X		
Chris Hegarty	MITRE/FAA	TWG Member	Lead						
Bronson Hokuf	Garmin	TWG Member			X				
Bruce Jacobs	LightSquared	Observer							
Jill Johnson	Leica Geosystems	Advisor				X			
Kevin Judge	Judge Software	TWG Member (Alternate)		X	X				
Sai Kalyanaraman	Rockwell Collins	TWG Member	X					X	
Rich Keegan	Navcom	Advisor				X			
Jerry Knight	Navcom	TWG Member							
Steve Koehne	Topcon	Advisor				X	X		
Galen Koepke	NIST	Advisor							X
Richard Kolacz	GSTS	Advisor							
Karl Kreb	Los Angeles County	Advisor							X
Karl Kreb	County of Los Angeles	Advisor							X
Sandeep Krishnamurthy	Motorola	Advisor		X					

			SUB-TEAMS						
NAME	AFFILIATION	ROLE	Aviation	Cellular	General Location /Nav	High Precision	Networks	Space-Based	Timing
Rob Kubik	Samsung	Advisor		X					
Eric Kunz	Furuno USA	Advisor			X				
Joe Kuran	WCCCA	Advisor			X				X
Chris Kurby	LightSquared	Advisor		X					
John Lacey	Lockheed Martin	TWG Member							
Farokh Latif	APCO	TWG Member							
Rich Lee	LightSquared	TWG Member		Lead		X	X		
Alfred Leick	Univ. of Maine	Advisor				X			
Sanjay Mani	Symmetricom	Advisor							X
Keith Mathers	Sprint Nextel	Advisor							X
Amy Mehlman	LightSquared	Observer							
Charlie Meyer	Alcatel-Lucent	Advisor		X					X
Fred Moorefield	USAF	TWG Member							
Capt. Mulholland	NPSTC	Advisor			X				
David Mullholland	NPS	Advisor			X				
Tim Murphy	Boeing	TWG Member	X						
Pierre Nemry	Septentrio	Advisor				X			
David Overdorf	AT&T	Advisor							X
Ajay Parikh	LightSquared	Advisor	X						X
Gary Pasicznyk	City and County of Denver	TWG Member							
Gil Passwaters	Furuno USA	Advisor			X				X
Bruce Peetz	Trimble	TWG Member			X	X	Lead		X
Brian Poindexter	Garmin	TWG Member			X				
Gary Poon	Los Angeles County	Advisor							X
Gary Poon	County of Los Angeles	Advisor							X
Tom Powell	Aerospace/USAF	TWG Member			X			X	
Scott Prather	AT&T	Advisor		X					
Olav Queseth	Ericsson	Advisor							X
Brian Ramsay	NASA	TWG Member						Liaison	

			SUB-TEAMS						
NAME	AFFILIATION	ROLE	Aviation	Cellular	General Location /Nav	High Precision	Networks	Space-Based	Timing
William Range	New Mexico E-911	Advisor		X					
Pat Reddan	Zeta/FAA	TWG Member	X						
Daniel Reigh	Lockheed Martin	TWG Member							
Mark Rentz	Navcom	TWG Member				X	X		
Stuart Riley	Trimble	TWG Member				X	X		
Raul Rodriguez	USGIC	Observer							
Narothum Saxena	USCellular	Advisor		X					
Karl Shallberg	ZETA	Advisor	X						
Sanyogita Shamsunder	Verizon Wireless	Advisor		X					
Michael Shaw	Lockheed Martin	TWG Member (Alternate)							
David Shively	AT&T	TWG Member		X					X
Patryk Siemion	LightSquared	Observer							
Mike Simmons	Garmin	TWG Member			Lead				
Joe Ben Slivka	Summit County, CO	Advisor			X				
Fraser Smith	Topcon Positions Sys.	Advisor				X			
Claudio Soddu	Inmarsat	Advisor				X			
Geoffrey Stearn	LightSquared	Info. Facilitator	X	X	X	X	X	X	X
Jim Sternberg	JS Engineering	Advisor							X
Bill Stone	Verizon Wireless	TWG Member		X					
Thomas Struzzieri	State of Virginia	Advisor			X				X
Mark Sturza	LightSquared	TWG Member	X						
Michael Swiek	USGIC	Info. Facilitator	X	X	X	X	X	X	X
Frank Takac	Leica Geosystems	Advisor					X		
Andreas Thiel	U-Blox	Advisor		X	X				
Lisa Thompson	Arlington County, VA	Advisor							X
Charles Trimble	USGIC	WG Co-Chair							
Michael Tseytlin	LightSquared	Advisor		X	X	X	X	X	
Greg Turetzky	CSR	TWG Member		X	X				
A.J. Van Dierendonck	USGIC	TWG Member	X		X	X			

NAME	AFFILIATION	ROLE	SUB-TEAMS						
			Aviation	Cellular	General Location /Nav	High Precision	Networks	Space-Based	Timing
Rick Walton	Lockheed Martin	TWG Member	X						
David Weinreich	Globalstar	Advisor		X	X	X	X		
Marc Weiss	NIST	Advisor							X
Vince Wolfe	TomTom	Advisor			X				
Arthur Woo	Furuno/eRide	Advisor			X				
Michael Woodmansee	Ericsson	Advisor							X
Larry Young	NASA	TWG Member				X		X	