Public Safety Communications White Paper

A Case Study of Interference Between Public Safety Long Term Evolution (LTE) And Public Safety 700 MHz Land Mobile Radio

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A CASE STUDY OF INTERFERENCE BETWEEN PUBLIC SAFETY LTE AND PUBLIC SAFETY 700 MHZ LAND MOBILE RADIO

Newly developed broadband wireless technology to benefit the consumer market, known as "4G" (fourth generation) or Long Term Evolution (LTE), has been adapted to operate on frequencies to be exclusively used by public safety, and is to be deployed nationwide as the First Responder Network Authority (FirstNet). Public safety LTE occupies two blocks of spectrum at 758-768 MHz, which is paired with duplex spectrum that is offset +30 MHz, at 788-798 MHz. These frequency bands are adjacent to public safety narrowband spectrum for land mobile radio (LMR), which occupies 769-775 MHz that is similarly paired with duplex spectrum +30 MHz offset at 799-805 MHz. This technical white paper reports on the observations by Public Safety Communications Research (PSCR) personnel of one case study on the interference potential between these two services.

Introduction

This technical white paper discusses measurements of Project 25 (P25) LMR receivers' performance when subjected to adjacent service interference from public safety LTE, and interference to LTE base stations from P25. There were three areas of interest in these measurements: (1) eNb[1] and UE[2] interference onto mobile LMR, (2) eNb and UE interference onto LMR repeater, and (3) P25 mobile and P25 repeater interference onto eNb.

For the mobile LMR case, PSCR personnel used a Motorola XTL-5000/0-5 and XTL-5000/0-3 radio. For both the mobile LMR case and the eNb case, PSCR personnel used Rohde & Schwarz signal generators to create the appropriate P25 and LTE test signals.

For the LMR repeater measurement, receiver performance was measured *in situ* at a public safety LMR trunk site. The type of LMR repeater deployed at this site was a Motorola GTR-8000 repeater.

Many public safety radio networks specify a minimum performance level of 2 percent bit error ratio (BER). 0ur measurements of adjacent service interference rejection, likewise, used 2 percent BER as a performance parameter.

Measured data: LTE interference to mobile LMR receiver

Table 1 shows our measured adjacent service rejection of an LTE eNb signal by a P25 mobile radio. Table 2 shows our measured adjacent service rejection of an LTE UE signal by a P25 mobile radio. Figure 1 depicts the adjacent service rejection scenario.

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[1] eNb is the fixed base station LTE transceiver cell site equipment.

[2] UE is the mobile user equipment transceiver.

Table 1. Simulated LTE eNb interference onto P25 mobile/portable

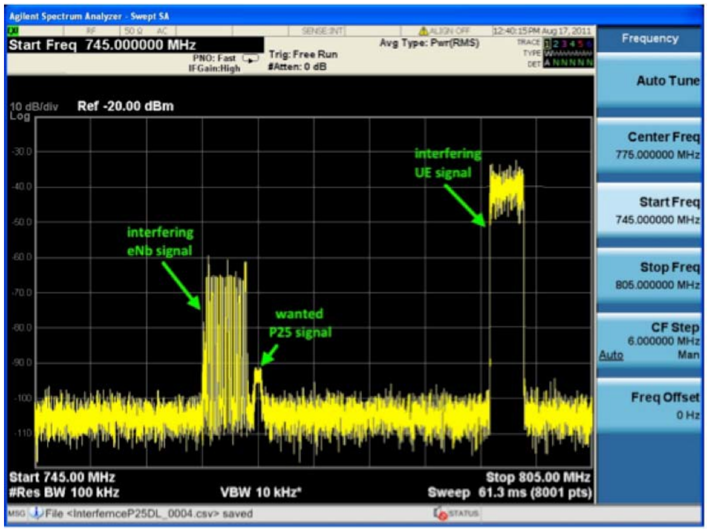
Simulated 10 MHz LTE eNb inter/erence onto P25 mobile radio				
Measurement date and time	01-Aug-12			
P25 signal generator make and model	Rohde & Schwarz SMIQ-06B			
Serial number	SG42080115			
Tuned frequency (MHz)	769.0125			
LTE signal generator make and model	Rohde & Schwarz SMU-200			
Serial number	102546			
Tuned frequency (MHz)	763			
Modulation	Test Mode 1.1			
Spectrum analyzer/power meter make and model	Tektronix RSA-3408			
Serial number	J300240			
Measurement channel bandwidth	*P25*		*LTE*	
	25 kHz		10 MHz	
Radio make and model	Motorola XTL-5000		Motorola XTL-5000	
Serial number	500CGK2168		500CFE0301	
Tuned frequency (MHz)	769.0125			
P25 Signal Generator Power (dBm)	*2% static BER*	*2% 60mph faded BER*	*2% static BER*	*2% 60mph faded BER*
	-91.4	-82.4	-90.9	-81.9
Measured P25 cable losses (dB)	27.9			
P25 reference sensitivity (dBm)	-119.3	-110.3	-118.8	-109.8
LTE sig gen interference power (dBm) @ $P_{refSensP25+3dB}$	-54.5		-54.3	
Measured LTE cable losses (dB)	7.9			
Delivered interference power (dBm) @ $P_{P25refSens+3dB}$	-62.4		-62.2	
LTE eNb rejection ratio (dB) @ 2% P25 BER	**56.9**	**47.9**	**56.6**	**47.6**

Table 2. Simulated LTE UE interference onto P25 mobile/portable

Simulated 10 MHz LTE UE inter/erence onto P25 mobile radio				
Measurement date/time	01-Aug-12			
P25 signal generator make and model	Rohde & Schwarz SMIQ-06B			
Serial number	SG42080115			
Tuned frequency (MHz)	774.9875			
LTE signal generator make and model	Rohde & Schwarz SMU-200			
Serial number	102546			
Tuned frequency (MHz)	793			
LTE Bandwidth (MHz)	±5			
Total number of SC-FDMA subcarriers	50 resource blocks x 12 subcarriers per resource block = 600 subcarriers			
Modulation	QPSK SC-FDMA			
Spectrum analyzer/power meter make and model	Tektronix RSA-3408			
Serial number	J300240			
Measurement channel bandwidth	*P25*		*LTE*	
	25 kHz		10 MHz	
Radio make/model	Motorola XTL-5000		Motorola XTL-5000	
Serial number	500CGK2168		500CFE0301	
Tuned frequency (MHz)	774.9875			
P25 Signal Generator Power (dBm)	*2% static BER*	*2% 60mph faded BER*	*2% static BER*	*2% 60mph faded BER*
	-91.7	-82.7	-90.5	-81.5
Measured P25 cable losses (dB)	27.9			
P25 reference sensitivity (dBm)	-119.6	-110.6	-118.4	-109.4
LTE sig gen interference power (dBm) @ $P_{P25refSens+3dB}$	-18		-17	
Measured LTE cable losses (dB)	7.9			
Delivered interference power (dBm) @ $P_{P25refSens+3dB}$	-25.9		-24.9	
LTE UE rejection ratio (dB) @ 2% P25 BER	**93.7**	**84.7**	**93.5**	**84.5**

Figure 1 measures ratio of LTE and P25 signal powers to where spurious LTE spectra falling within P25 receiver bandwidth adversely affects P25 receiver performance.

Figure 1. Adjacent service rejection of LTE by P25



Discussion: LTE interference to mobile LMR receiver

Our measurements show that a P25 mobile/portable radio, receiving a wanted signal at 2 percent BER, can be subject to some degradation in BER performance when in the presence of a much stronger LTE signal. PSCR personnel applied a Rayleigh-faded[3] P25 signal 3 dB stronger than the mobile radio's 2 percent BER sensitivity point (yielding reduced BER}, and then combined a non-faded LTE eNb base station signal at a level roughly 47 dB stronger. The addition of this much stronger interfering LTE signal degraded P25 receiver performance back to 2 percent BER. This is equivalent to restoring the same signal-to-noise (S/N} by addition of the LTE signal into the P25 receiver passband increasing on-channel noise by 3 dB.

Similarly, the P25 mobile was resistant to an interfering UE [4] transmission roughly 84 dB stronger. The principal reason for the difference in these numbers arises from the fact that the UE signal at 788-798 MHz is roughly 20 MHz offset from the tuned frequency of the P25 mobile receiver (769.0125 MHz}, while there is only a 1 MHz guard band between the eNb signal at 758-768 MHz and the tuned frequency of the P25 mobile receiver.

In order to try to put these numbers into some sort of meaningful context, PSCR personnel modeled propagation coverage of a hypothetical transmitter site using 2 percent BER power contour and "2 percent BER plus 3 dB" power contour values in Figure 2. The yellow coverage regions show where 2 percent BER or better performance coverage, in the absence of the interfering LTE signal, would degrade to worse than 2 percent in the presence of an eNb signal that is about 47-dB stronger than the wanted P25 signal. Lime green-colored coverage areas are +3 dB or more over 2 percent BER sensitivity in the absence of an LTE signal, hence, when in the presence of that same interfering LTE signal, yields 2 percent BER or better (lower}. In other

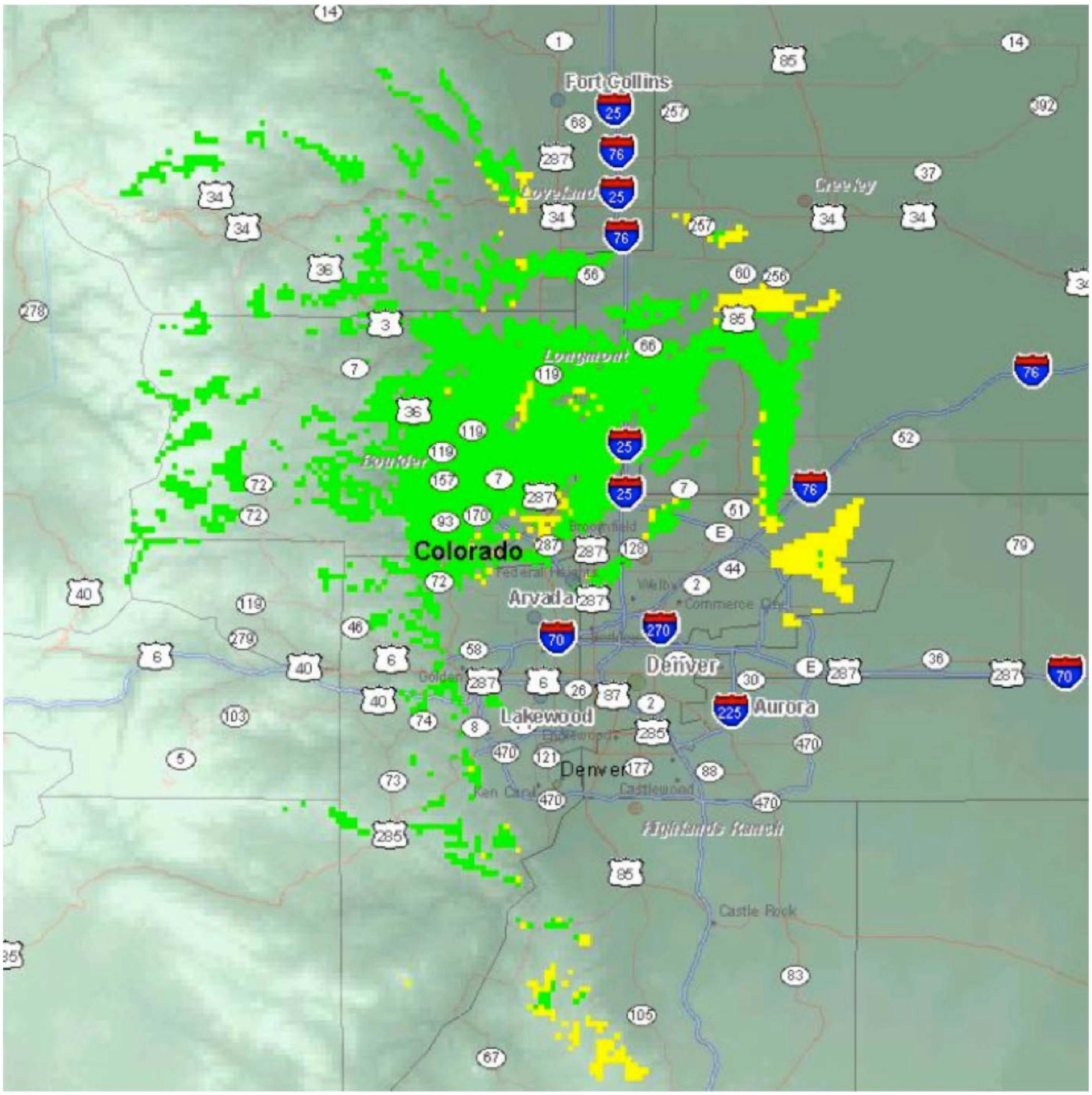
[3] Our laboratory-created faded signal simulated a single-path 60-mph fade.

[4] UE is the mobile user equipment transceiver.

words in Figure 2, the lime green-color shows where the signal is not degraded and the yellow coverage regions show were coverage is degraded.

This same Figure can be used to show radio frequency (RF) coverage degradation when a mobile UE transmitter, collocated with the mobile P25 receiver, transmits a signal that is about 84 dB stronger at the mobile/portable P25 antenna.

Figure 2. Hypothetical RF coverage plots



Measured data: LTE eNb interference to trunked site LMR repeater

A transportable eNb was deployed at a public safety LMR site and positioned approximately 125 ft. from the LMR antenna tower. Referring to Figure 3, a utilities demarcation box and small building structure is apparent in the northwest corner of the site. The transportable eNb was positioned just east of the utilities demarcation box. The LMR antenna tower is visible at the northeast corner of the site.

Figure 3. Transportable eNb deployment location

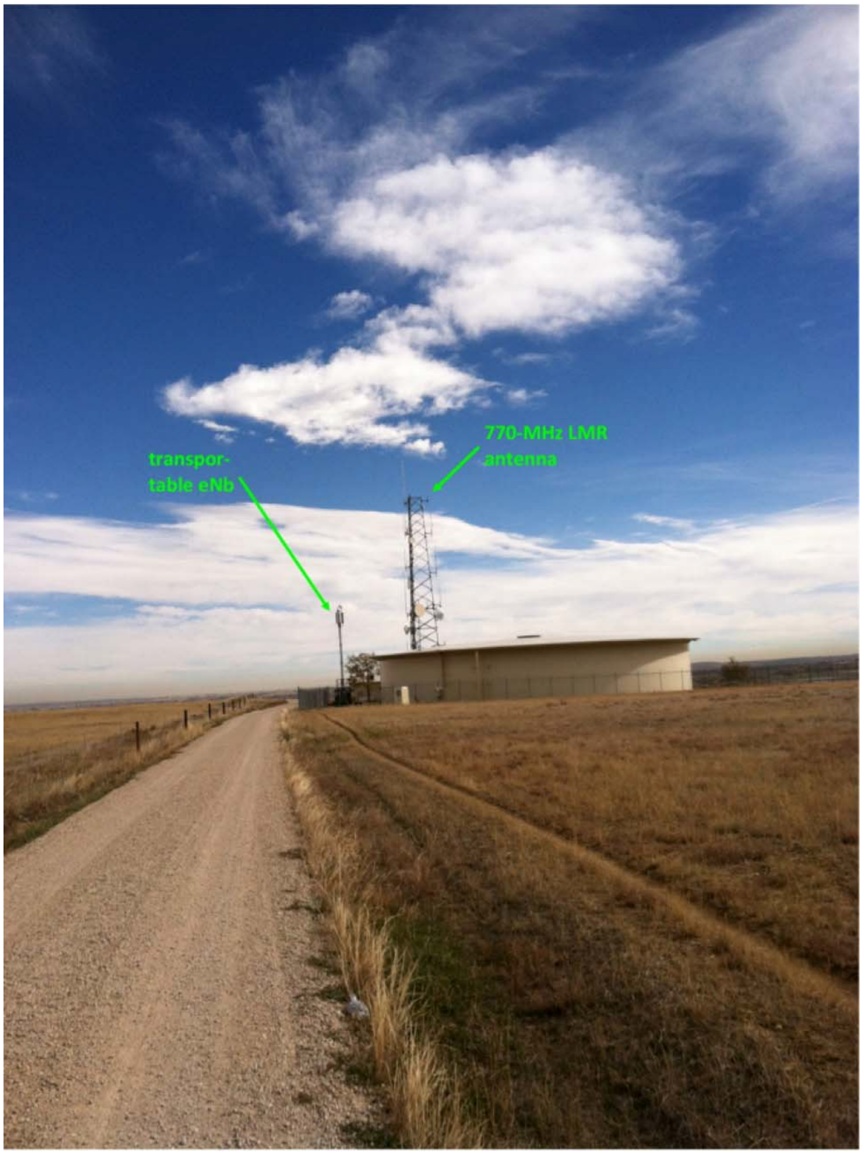
The top of the water tank is estimated to be 20-25 ft. in height and the height of the perimeter chain link fence is an estimated 8 ft. (see Figure 4). Antennas for the 700 MHz LMR system were 80 ft. AHAGL[5] on the tower. The eNb antennas were 35 ft. AHAGL. The eNb antennas are comprised of three antenna panels, each directional in azimuth covering approximately 120°. One of the panels was aligned to point directly toward the antenna tower.

PSCR personnel conducted an *in situ* measurement of interference potential from the transportable eNb onto the P25 LMR base. A similar methodology as that performed with the mobile radio was employed. Specifically, the 2 percent BER sensitivity level of the repeater was determined *in situ* by injecting a P25 test signal into a test port built into the LMR system hardware as the vendor had delivered it; then, the transportable eNb was powered on and the LMR repeater sensitivity monitored for any degradation to BER.

[5] Antenna Height Above Ground Level

2 percent BER sensitivity, with environmental noise floor, was measured by the repeater maintenance software application to be about -117 dBm at the LMR channel's receiver frequency of 799.29375 MHz, with no eNb signal. When the eNb transmitter began co-radiating on the site at 20 watts transmitter power, no discernible degradation in repeater receiver BER was observed by state and federal personnel on site.

Figure 4. Transportable eNb deployed at northwest corner of site



Discussion: LTE eNb interference to trunked site LMR repeater

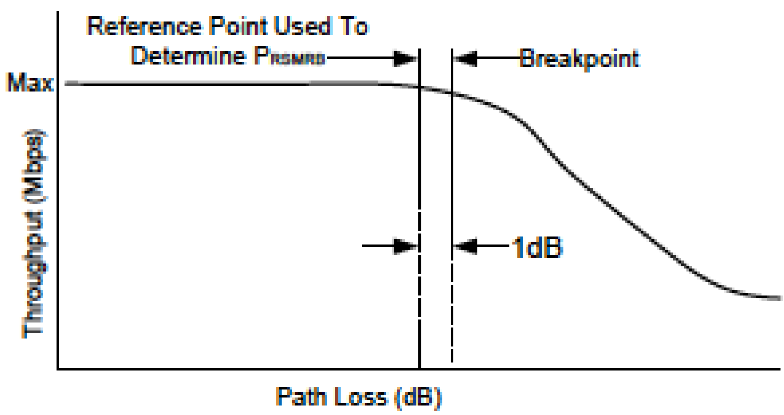
The lack of any observable degradation to P25 repeater receiver performance suggests that collocating an eNb cell at a 700 MHz P25 LMR site will not reduce the operational range or effectiveness of the LMR system. Even after a few months of eNb operation, there are no reports of interference raised by incumbent users at the site. While care should be taken *not* to infer that observations at this one site, with its unique LMR channel assignments and RF hardware topology, will apply ubiquitously at any other site, it is clear that any interference issues that might arise can be overcome with existing technology.

Measured data: P25 interference to LTE eNb receiver

Adjacent-service rejection was measured in accordance with the PSCR's LTE Demonstration Network Test Plan, Phase 1, basic functionality tests (http://www.pscr.gov/projects/broadband/700mhz_demo_net/testing/Phase1_small_cell_basic_functionality_tests_v1.0_03112013.pdf). As a pre-requisite, the adjacent-service rejection test first requires the eNb receiver sensitivity reference point be characterized.

The eNb's receiver sensitivity reference point is the minimum received power (from a real or simulated UE) that facilitates the maximum allocation of eNb transmitter resource blocks[6]. Further decreases in received power (or equivalently, increases in path loss) result in the eNb responding to the UE with a reduced number of resource blocks, i.e., reduced bandwidth and throughput, as depicted in Figure 5.

Figure 5. Reference Point



Once the reference point is established, then the adjacent service rejection test operating point is set by reducing path loss (thereby increasing LTE UE signal power to the eNb) by 6 dB, enabling maximum eNb transmitter data throughput. The interfering adjacent-service P25 signal is then simultaneously injected into the eNb receiver and its power adjusted to a level to where the LTE throughput begins to decrease as it did in the sensitivity test. The interference rejection ratio is the ratio of the interfering (P25 LMR) signal to the wanted (LTE) signal. Figure 6 and Figure 7 on the next page, present spectrum analyzer traces that depict the LMR (P25) interference signals relative to the broadband eNb and UE signals. The Figures show that during testing, the interfering P25 signal is 50 dB stronger than the wanted UE signal, i.e., the adjacent-service rejection ratio is about 50 dB.

[6] A resource block consists of twelve 15-kHz OFDM subcarriers. There are 50 resource blocks in an LTE signal.

Figure 6. Adjacent-service rejection of eNb receiver to P25 mobile signal

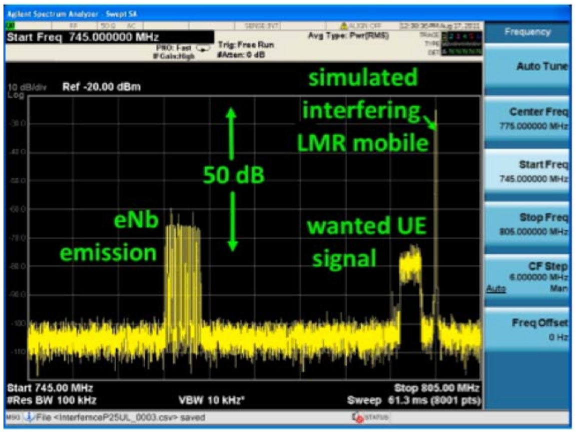
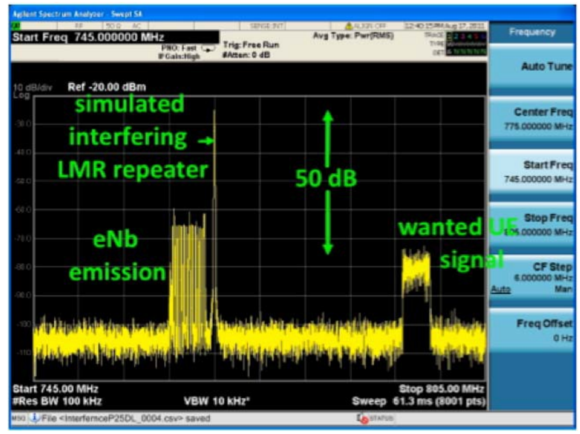


Figure 7. Adjacent-service rejection of eNb receiver to P25 repeater signal



Discussion: P25 interference to LTE eNb receiver

Because the eNb is simultaneously transmitting and receiving from a common antenna port, the adjacent-service rejection test required a specialized test jig. The specialized test jig is shown in Figure 2 of the PSCR LTE Demonstration Network Test Plan and is not discussed further here. However, its significance to this discussion is that the interfering signal, at maximum available power from the Rohde & Schwarz signal generator, underwent additional attenuation introduced by the test jig, prior to delivery to the eNb antenna port, to levels that were inadequate to force the eNb to begin reducing its data throughput rate. Hence, the reported rejection ratio, 50 dB, is worse than the actual performance that would be expected. The eNb should actually be able to reject an interfering P25 signal stronger than that reported here, but our test setup would not allow us to quantify by how much more than 50 dB.

Discussion: P25 interference to LTE UE receiver

PSCR personnel did not assess the adjacent-service rejection characteristics of UE receivers. The PCS Type Certification Review Board tests UE devices for compliance to the applicable standards.

Conclusions

These observations suggest that P25 LMR at 770/800 MHz and PSBB LTE at 760/790 MHz can coexist at LMR transmitter sites as well as on itinerant platforms, and that implementing prudent engineering design practices can solve any interference problems that may arise.

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