Appendix A

(Case Study)

Introduction

During an emergency exercise, radio tests were conducted by the fire departments of North York, East York and Scarborough to determine what effects cellular radiotelephone operations may have on their portable radiocommunication, in the 800 MHZ Public Safety band. Radiocommunication problems to portable radio operations experienced in the past led fire officials to believe that cellular communications may be part of the cause. The extent of the test was to initiate cellular telephone calls, in close proximity to the fire department's portable radio operations and listen for any affects on the received audio quality of their radiocommunication. While conducting the tests , they noticed a significant increase in received background noise and parts of communications dropped after several simultaneous phone calls were initiated. The North York Fire Department advised the Toronto District Office of the results of their testing and requested our assistance and comments regarding the cause and possible resolution of the interference they were experiencing from cellular communications. To determine if the operations of a cellular radiotelephone system or Advanced Mobile Phone Service (AMPS) has any detrimental effects on the portable radio operations of North York Fire, in the 821-824/866-869 MHZ Public Safety band. If cellular radiotelephone transmissions do have an effect, the next objective will be to identify the causes and quantify the technical and physical parameters that permit the interference. Third, to recommend a course of action to eliminate or reduce the occurrence of interference to North York Fire's portable operation This study contains the analysis performed by the Toronto District Office and the results of that analysis..

Background

North York Fire is authorized to use five duplex channels in the 821-824/866-869 MHz Public Safety Band (see Table 1), to provide radiocommunication in their daily activities. Frequencies are used in a conventional repeater mode.

Frequencies assigned to North York Fire in the Public Safety Band:

Table 1: Fixed Repeater Station Frequencies
(Mobiles and Access Bases are assigned the reverse pair)

Channel	TX (MHz)	RX (MHz)
1	866.2625	821.2625
2	866.7625	821.7625
3	867.2625	822.2625
4	867.7625	822.7625
5	867.9875	822.9875

Note: Portable-to-portable radiocommunication is accomplished via one of five repeater channels (duplex) or using one of five repeater TX frequencies in a simplex mode (talk-around).

Since the commencement of the North York Fire radiocommunication system, in the Public Safety band, users of the system have noted hearing intermittent background noise, voice modulation that sounded like phone conversations and parts of their radiocommunication dropped. Suspicion of interference from cellular radiotelephone operation prompted Fire officials to conduct their own testing into the cause.

North York Fire Testing Procedure

Testing was conducted at North York Fire Training Facility at 200 Bermondsey Rd. in North York, on December 21, 1996. Portable communications were established between members of the testing team located within the training grounds on channel 5 (TX-822.9875/RX-867.9875 MHz), via repeater VBE507 located at 740 Don Mills Rd. Channel 5 was selected for testing because it was noted as receiving problems in the past. Fire officials coordinating the exercise initiated phone calls with cellular telephones. Members of the testing team noted experiencing interference in the form of background noise and parts of conversations dropped after five simultaneous cellular phone calls had been established. A total of eight cellular phone calls were initiated with no change in the interference noted. When the cellular phones were deactivated, the background noise ceased. After the tests, a portion of the radio conversations were reviewed by listening to the logger tapes made from the received audio at the repeater to ensure that the signal was free of interference. The quality of the conversations were subjectively graded as being audible and intelligible, therefore, the interference experienced must have been localized to the testing location. The testing has given more weight to the Fire Department's suspicions about cellular communication causing interference which raises a concern, since increased use of cell phones is expected at the scene of most fires. Media covering the event, spectators, potential victims, even safety personnel themselves are anticipated to use cell phones in the proximity of the fire department's portable radios.

Analysis and Observations

Based on the frequency relationship between the 821-824/866-869 MHz Public Safety band and the 824-849/869-894 MHz Cellular band and given normal system operation (no defective transmitter equipment operation), the study focussed on the characteristics related to spurious response and intermodulation spurious response of the portables used by North York Fire to signals in the cellular band and the signal levels experienced in their operating environment from systems operating in the cellular band.

To determine the affects of cellular communications the following subjects will be reviewed, measured and analysed:

1) - the geographic relationship between the North York Fire system existing cellular systems, to clarify operational environments or operational separation.

2) - theoretical calculation of intermodulation products falling within the passband of North York Fire's, channel 5 (Channel 5 has been specifically documented[1] as problematic, although verbal reports of similar interference problems have been received by North York Fire officials. The scope of this investigation will be limited to channel 5 with the theory that our findings will also hold true for the entire complement of channels licenced to North York Fire)

3) - signal levels experienced at certain distances from an AMPS fixed station and a class III mobile subscriber station operating in the cellular mobile band within the operational environments.

4) - intermodulation spurious response characteristics of a North York Fire portable radio.

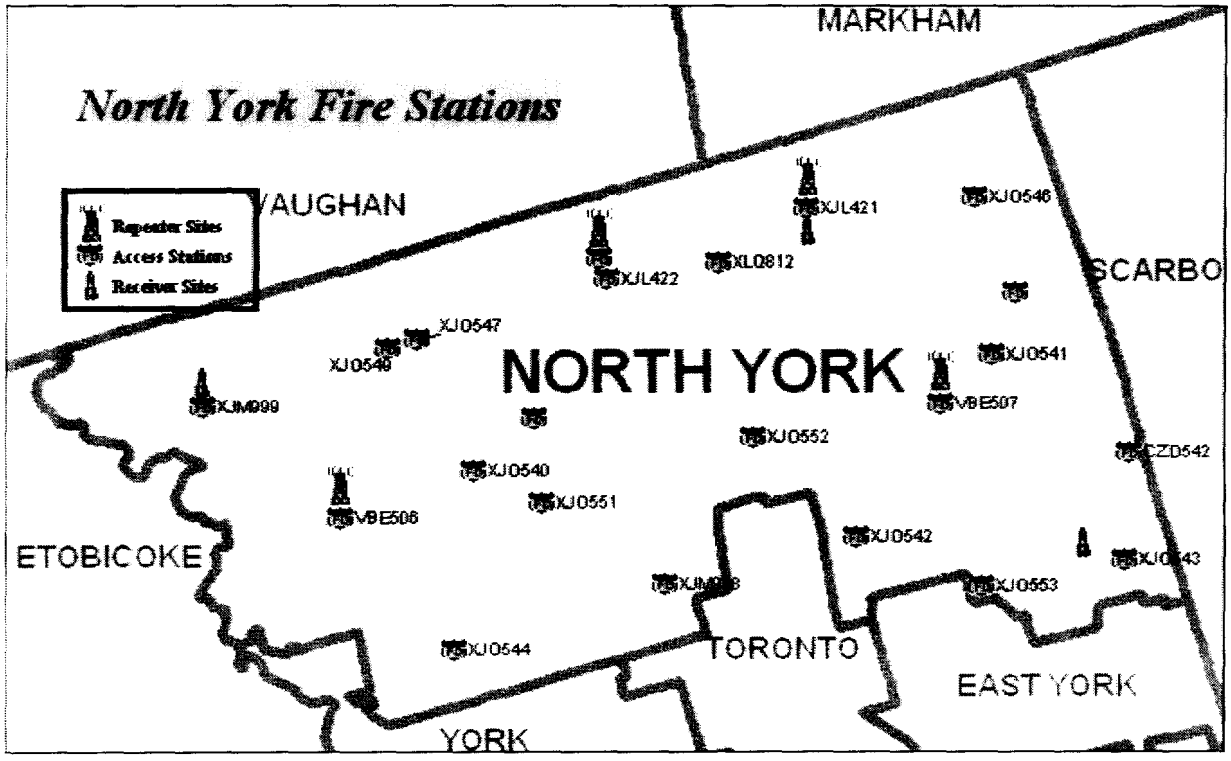
---

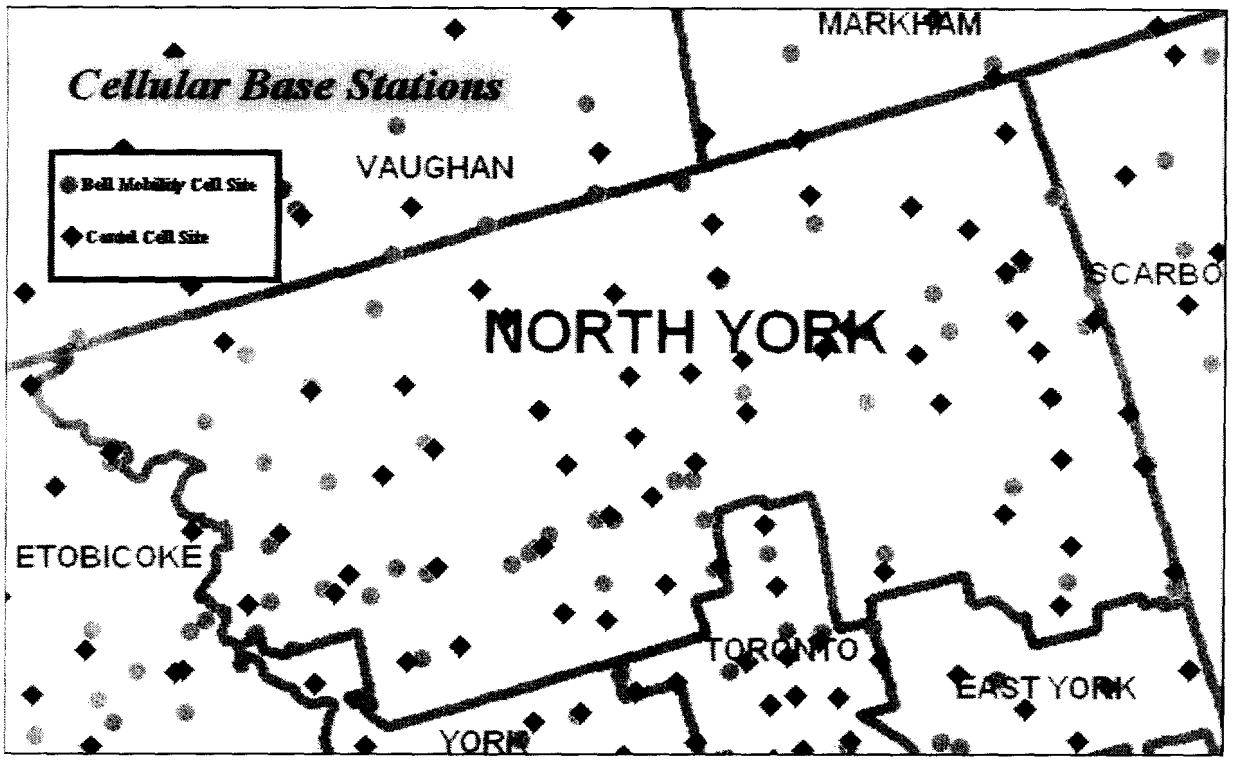
[1] Problems to the reception of channel 5 by portable radios were experienced and documented by North York Fire, during firefighting activities at 2 Forest Laneway, North York on January 6,1995 and again during training exercises at 200 Bermondsey Rd., North York on December 21.

5) - spurious response characteristics of a North York Fire portable radio.

Geographical Relationship between the North York Fire System and Cellular Systems

Figure's 1 and 2 are provided to illustrate the geographical relationship between the licenced fixed stations associated with the North York Fire Department system and the licenced fixed stations associated with Cellular systems. Figure 1 shows the locations of fixed stations that North York Fire portables are required to communicate within the Municipality of North York. Figure 2 shows the locations of cellular base stations (cell sites) that cellular subscriber stations (cellular phones) communicate within the Municipality of North York. We found that North York Fire portable operations may, at times, be required to operate in close proximity to cellular fixed stations and cellular phones. It is the intention of this report to determine what the signal levels are from cellular base stations and cellular phones, at what distance you receive these levels and what impact these levels have on North York Fire's portables.





Theoretical Calculation of Intermodulation Products and Analysis

The cellular band was evaluated for two frequency, third order and three frequency, third order intermodulation interference possibilities. Tables 3, 4 and 5 provide the algebraic formulas that confirm intermodulation products on North York Fire's channel 5 (867.9875 MHz), can be produced by combinations of cellular base station and cellular phone frequencies.

Table 2: Two Frequency, Third Order Intermodulation Products From a Cellular Base Station		
Sub-band/ Channel Numbers	Intermodulation Product (M, N are channel numbers, ***frequencies*** are in MHz) **2 * F1 - F2 = Frx**	Examples _ = Difference to Ch.5 RX frequency
A = Rogers Cantel / 1 - 333, 667 - 716, 991 - 1023	$2(870+0.03[M-1023]) - (870+0.03N) = 867.9875 \pm .0125$ $\Rightarrow 2M = N + 1979$ where $991 \leq M \leq 1023 \cap 3 \leq N \leq 67$ $\cup$ $2(870+0.03M) - (870+0.03N) = 867.9875 \pm .0125$ $\Rightarrow 2M + 67 = N$ where $(1 \leq M \leq 133 \cap 69 \leq N \leq 333) \cup (300 \leq M \leq 324 \cap 667 \leq N \leq 715)$	M = 991, N = 3 _ = 2.5 kHz $\cup$ M = 324, N = 715 _ = 2.5 kHz
B= Bell Mobility/ 334 - 666, 717 - 799	$2(870+0.03M) - (870+0.03N) = 867.9875 \pm .0125$ $\Rightarrow 2M + 67 = N$ where $334 \leq M \leq 366 \cap 735 \leq N \leq 799$	M = 366, N = 799 _ = 2.5 kHz
NOTE : $\cap$ = AND; $\cup$ = OR		

Table 3: Three Frequency, Third Order Intermodulation Products

From a Cellular Base Station		
Sub-band / Channel Numbers	Intermodulation Product (M, N, P are channel numbers, ***frequencies*** are in MHz) **F1 + F2 - F3 = Frx**	Examples _ = Difference to Ch.5 RX frequency
A = Rogers Cantel / 1 - 333, 667 - 716, 991 - 1023	(***870***+0.03[M-1023]) + (***870***+0.03N) - (***870***+0.03P) = ***867.9875*** ± .0125 ⇒ M + N - 956 = P where1≤ N ≤ 266∩ 991≤ M ≤ 1023 ∩ 36 ≤ P≤ 333 ∪ (***870***+0.03M) + (***870***+0.03N) - (***870***+0.03P) = ***867.9875*** ± .0125 ⇒ M + N + 67 = P where 267≤ M≤ 333 ∩ 267≤ N ≤ 333 ∩ 667≤ P ≤ 716	M = 1023, N = 266, P = 333 _ = 2.5 kHz ∪ M = 267, N = 333, P = 667 _ = 2.5 kHz
B= Bell Mobility / 334 - 666, 717 - 799	(***870***+0.03M) + (***870***+0.03N) -(***870***+0.03P) = ***867.9875*** ± .0125 ⇒ M + N + 67 = P where 334 ≤ M ≤398 ∩ 334 ≤ N ≤ 398 ∩ 735 ≤ P ≤ 799	M = 398, N = 334, P = 799 _ = 2.5 kHz
NOTE : ∩ = AND; ∪ = OR		

Table 4: Two Frequency, Third Order Intermodulation Products From Cellular Phones		
Channel Numbers	Intermodulation Product (M, N are channel numbers, ***frequencies*** are in MHz) **2 * F1 - F2 = Frx**	Examples _ = Difference to Ch.5 RX frequency
1 - 1023	2(***825***+0.03M) - (***825***+0.03[N-1023]) = ***867.9875*** ± .0125 ⇒ 2M - 410 = N where 701≤M≤716 ∩ 992≤N≤1022 ∪ 2(***825***+0.03 M) - (***825***+0.03N) = ***867.9875*** ± .0125 ⇒ 2 M - 1433 = N where 717≤M≤799 ∩ 1≤N≤165	M = 710, N = 1010 _ = ***2.5*** kHz ∪ M = 750, N = 67 _ = ***2.5*** kHz
NOTE : ∩ = AND; ∪ = OR		

Table 5: Three Frequency, Third Order Intermodulation Products From a Cellular Phones		
Channel Numbers	Intermodulation Product (M, N, P are channel numbers, ***frequencies*** are in MHz) **F1 + F2 - F3 = Frx**	Examples _ = Difference to Ch.5 RX frequency
1 - 1023	(***825***+0.03M) + (***825***+0.03N) - (***825***+0.03[P-1023]) = ***867.9875*** ± .0125 $\Rightarrow$ M + N - 410 = P where 602$\leq$ M $\leq$ 732 $\cap$ 701$\leq$ N $\leq$ 799 $\cap$ 991 $\leq$ P$\leq$ 1023 $\cup$ (***825***+0.03M) + (***825***+0.03N) - (***825***+0.03P) = ***867.9875*** ± .0125 $\Rightarrow$ M + N - 1433 = P where 635$\leq$ M$\leq$ 716 $\cap$ 718$\leq$ N $\leq$ 799 $\cap$ 1$\leq$ P $\leq$ 82	M = 650, N = 760, P = 1000 _ = 2.5 kHz $\cup$ M = 643, N = 795, P = 5 _ = 2.5 kHz
NOTE : $\cap$ = AND; $\cup$ = OR		

Analysis:

Using Table 2 as an example, cellular base channels 991 and 3 can produce an intermodulation product that is slightly off (still within the passband) Channel 5's receive frequency (867.9875 MHz):

If M = 991, then N = 2(991) - 1979 = 3
Substitute M & N in formula : 2(***870***+0.03[M-1023]) - (***870***+0.03N) = ***867.9875*** ± .0125
Then: 2(***870***+0.03[991-1023]) - (***870***+0.03[3]) = ***867.9875*** ± .0125
Intermodulation Product= ***867.990*** MHz

There is the theoretical case that an intermodulation product exists. In fact, calculating all the possible products specified in the above tables resulted in over 58,000 different combinations. When you consider the intermodulation spurious response characteristic of the North York Fire portable as typically -72 dB and the 12 dB Sinad sensitivity level of -118 dBm (0.28uV), we can presume that intermodulation products with received signal levels above -46dBm may cause a problem. Further measurements, tests and analysis will determine how accurate this initial assessment is, if these levels are feasible and where you can experience them.

Field Measurements of Signal Levels and Observations

3) To determine the relative receive signal levels around a cellular base station, the following measuring equipment and cellular base station were used:

Measuring Equipment

Spectrum Analyser	- Hewlett Packard HP8594E (Cal. Internal self calibration done prior to performing measurements) - Resolution BW: 1 kHz - Amplitude: peak level
Antenna	- Larsen NMOQ 900B (865-965 MHz), Unity gain
Cable	- 3.7 metres, RG 58/U

Cellular base station

Location	- 310 Industrial Parkway, Aurora, Ontario
Sector X, ERP/Azimuth	- 15.0 dBW @ 40° TN
Sector Y, ERP/Azimuth	- 15.0 dBW @ 160° TN
Sector Z, ERP/Azimuth	- 18.1 dBW @ 280° TN

⇨ Parameters provided by cellular service provider. Typical cell site ERP parameters.

Note: Cable loss and antenna gain are factored into measured signal level.

Measurements were conducted close to the main azimuths of each sector at 0.1 km intervals and signal levels recorded in Table 6:

Table 6: Signal levels around Cellular base station

Distance (Km)	Signal Level along Sector X (dBm)	Signal Level along Sector Y (dBm)	Signal Level along Sector Z (dBm)
0.1	-37	-37	n/a
0.2	-33	-34	-31
0.3	-37	-36	-35
0.4	-39	-37	-37
0.5	-43	-35	-41
0.6	-48	-43	-39
0.7	-50	-59	-40
0.8	-55	-63	-42
0.9	-54	-48	-57
1	-55	-53	-59

Observations:

Our measurements found the received signal levels to be between -28dBm to -63dBm, from 0.1 to 1 km of a cellular base station. All measurements were taken at 2 metres AGL, some with line-of-site and some with an obstructed RF path.

Measurements were also conducted at the North York Fire Training Facility. The following Figure 4 and Table 7 show the physical distance and signal levels measured at points around the Facility.

Table 7: Cellular Signal Levels around North York Fire, Training Facility

Point	Signal Level (dBm)
A	-33
B	-53
C	-48
D	-48
E	-28
F	-52

Observations:

Our measurements found the received signal levels to be between -28dBm to -63dBm, from 0.1 to 1 km of a cellular base station. All measurements were taken at 2 metres AGL, some with line-of-site and some with an obstructed RF path.

4) To determine the relative receive signal levels from a cellular phone, the following measuring equipment and cellular phone were used:

Measuring Equipment

Spectrum Analyser	- Hewlett Packard HP8594E (Cal. Internal self calibration done prior to performing measurements) - Resolution BW: 30 kHz - Amplitude: peak level
Antenna	- Larsen NMOQ 900B (865-965 MHZ), Unity gain
Cable	- 3.7 metres, RG 58/U
Cellular Phone	- Motorola Micro-Tac Lite (Class III) - Cellular phone transmissions were made at 10 Km from a cell site to try and obtain a nominal ERP of 0.6 watts.

Note: Cable loss and antenna gain are factored into measured signal level

Table 8: Signal Levels from Cellular Phone	
Distance (metres)	Signal Level (dBm)
3	-16
6	-26
9	-27
12	-28
15	-38
18	-39
21	-40
24	-41
27	-42
30	-43
33	-48
36	-44
39	-45
42	-45
45	-52
48	-49
51	-53
54	-53

Observations:

Our measurements found the received signal levels to be between -16dBm to -53dBm, from 3.0 to 55 metres of a class 3, cellular phone. All measurements were taken at 2 metres AGL, with line-of-site.

Measured Intermodulation Response Characteristics of North York Fire Portables

North York Fire portables were tested to determine the signal level required to cause intermodulation interference to the reception of a desired signal. Signal levels chosen for the following tests were determined from the results of the measurements in section 3.4 and 3.5 and the receiver audio quality was subjectively evaluated. Because audio outputs were not obtainable on the portables tested, the results are not expressed in terms of degradation to 12 dB Sinad . DCS was not disabled during Test 1 and 2 to accurately reflect the normal operation and results.

Test 1

To determine the affects of two frequency, third order intermodulation interference, a desired signal was generated on 867.9875 MHZ, with a modulating tone of 3 kHz, deviation of 2.4 kHz and a DCS code of 306 deviated at 1 kHz. The desired signal was adjusted to squelch threshold (-113 dBm for portable A and -111 dBm for portable B). Two other signals were generated on frequencies (cellular base transmit frequencies) determined to produce an intermod within the passband of 867.9875 MHZ. They were modulated with 1 kHz and a deviation of 8 kHz (standard test modulation - RSS 118, section 5.8). The levels of these signals were increased to see the affects on the desired signal. The following tables are the results of those tests.

Table 9: Portable A - The affects of two frequency, third order intermodulation interference from cellular base frequencies

F1 level (-dBm) 869.070 MHZ	F2 Level (-dBm) 870.150 MHZ	Affects on Desired Audio Output
-60	-60	No affect
-50	-50	No affect
-45	-45	Intermittent squelch breaks
-40	-40	Increased intermittent squelch breaks
-38	-38	Increased intermittent squelch breaks
-37	-37	Increased intermittent squelch breaks
-35	-37	**No audio output**, receiver desensed Desired signal power, P (Desired) increased to -109 dBm to achieve audio; intermod interference heard in audio.
-30	-37	**No audio output**, receiver desensed Desired signal power, P (Desired) increased to -103 dBm to achieve audio; intermod interference heard in audio.
-25	-37	**No audio output**, receiver desensed Desired signal power, P (Desired) increased to -90 dBm to achieve audio; severe intermod interference heard in audio.
-23	-37	**No audio output**, receiver desensed Desired signal power, P (Desired) increased to -75 dBm to achieve audio; severe intermod interference heard in audio.

Table 10: Portable B - The affects of two frequency, third order intermodulation interference from cellular base frequencies		
F1 level (-dBm) 869.070 MHz	F2 Level (-dBm) 870.150 MHz	Affects on Desired Audio Output
-60	-60	No affect
-50	-50	No affect
-40	-40	No affect
-37	-37	Intermittent squelch breaks
-34	-37	Increased intermittent squelch breaks
-32	-37	**No audio output**, receiver desensed Desired signal power, P (Desired) increased to -107 dBm to achieve audio; intermod interference heard in audio.
-30	-37	**No audio output**, receiver desensed Desired signal power, P (Desired) increased to -105 dBm to achieve audio; severe intermod interference heard in audio.
-25	-37	**No audio output**, receiver desensed Desired signal power, P (Desired) increased to -75 dBm to achieve audio; severe intermod interference heard in audio.
-23	-37	**No audio output**, receiver desensed Desired signal power, P (Desired) increased to -73 dBm to achieve audio; severe intermod interference heard in audio.

Test 2

To determine the affects of two frequency, third order intermodulation interference, a desired signal was generated on 867.9875 MHZ, with a modulating tone of 3 kHz, deviation of 2.4 kHz and a DCS code of 306 deviated at 1 kHz. The desired signal was adjusted to squelch threshold (-113 dBm for portable A and -111 dBm for portable B). Two other signals were generated on frequencies (cellular phones transmit frequencies) determined to produce an intermod within the passband of 867.9875 MHZ. They were modulated with 1 kHz and a deviation of 8 kHz (standard test modulation - RSS 118, section 5.8). The levels of these signals were increased to see the affects of the desired signal. The following tables are the results of those tests.

Table 11: Portable A - The affects of two frequency, third order intermodulation interference from cellular phone frequencies		
F1 level (-dBm) 846.480 MHZ	F2 Level (-dBm) 824.970 MHZ	Affects on Desired Audio Output
-50	-50	No affect
-40	-40	No affect
-37	-37	Slight intermod heard in audio
-30	-37	Increased intermod heard in audio
-25	-37	Intermittent squelch breaks, intermod heard in audio

Table 12: Portable B - The affects of two frequency, third order intermodulation interference from cellular phone frequencies		
F1 level (-dBm) 846.480 MHZ	F2 Level (-dBm) 824.970 MHZ	Affects on Desired Audio Output
-50	-50	No affect
-40	-40	No affect
-30	-37	Intermittent squelch breaks, intermod heard in audio
-25	-37	Increased intermittent squelch breaks, intermod heard in audio

Test 3

To determine the affects of three frequency, third order intermodulation interference, three signals were generated on frequencies (cellular base transmit frequencies) determined to produce an intermod within the passband of 867.9875 MHz. The signals were input to two different portables. The levels of these signals were increased to determine the level at which they are able to break the squelch threshold. In this test, no desired signal was generated and the DCS was disabled. All generated signals were modulated with a 1 kHz tone and 8 kHz deviation (standard test modulation - RSS 118, section 5.8). Listed below are the selected frequencies and the level required to break squelch and produce intermod interference.

Portable A: Squelch threshold (-113 dBm)

I) Using Sub-band A Frequencies

879.420	+	878.820	-	890.250	= 867.990 MHz
(@ -36dBm)		(@ -42dBm)		(@ -37dBm)	➔*Critical levels that produced internally generated intermodulation interference.*

II) Using Sub-band B Frequencies

880.140	+	880.290	-	892.440	=867.990 MHz
(@ -40dBm)		(@ -42dBm)		(@ -39dBm)	➔*Critical levels that produced internally generated intermodulation interference.*

Portable B: Squelch threshold (-111 dBm)

I) Using Sub-band A Frequencies

879.420	+	878.820	-	890.250	= 867.990 MHz
(@ -42dBm)		(@ -42dBm)		(@ -40dBm)	➔*Critical levels that produced internally generated intermodulation interference.*

II) Using Sub-band B Frequencies

880.140	+	880.290	-	892.440	=867.990 MHz
(@ -41dBm)		(@ -42dBm)		(@ -43dBm)	➔*Critical levels that produced internally generated intermodulation interference.*

Measured Spurious Response Characteristics of North York Fire Portables

North York Fire portables were tested to determine if they receive frequencies (in the band 806 to 894 MHZ) other than the desired and what affect they have on the desired as their level is increased. A desired signal was generated on 867.9875 MHZ, with a modulating tone of 3 kHz, deviation of 2.4 kHz and a DCS code of 306 deviated at 1 kHz. The desired signal was adjusted to squelch threshold (-113 dBm for portable A and -115 dBm for portable B). A signal was also generated with a modulating tone of 1.5 kHz and deviated at 3 kHz. This second signal was then swept from 806 MHz to 896 MHz. The following tables contain the results and the affects on the desired signal as the input levels of spurious response frequencies are increased. Input levels were selected according to normally expected field levels and audio quality was subjectively evaluated. Because audio outputs were not obtainable on the portables tested, the results are not expressed in terms of degradation to 12 dB Sinad.

Table 13: Portable A - Affects of Spurious Response from frequencies in the 806 to 894 MHz Band				
Spurious Response Frequency	Affects on desired audio at different output levels of Spurious Response Frequencies			
	- 50 dBm	- 40 dBm	- 30 dBm	- 22 dBm
855.6875	no affect	noise and squelch breaks	**No audio output** P (Desired) increased to -106 dBm to achieve audio; severe interference heard in audio.	**No audio output** P (Desired) increased to -102 dBm to achieve audio; severe interference heard in audio.
859.8875	no affect	noise and squelch breaks	**No audio output** P (Desired) increased to -110 dBm to achieve audio; severe interference heard in audio.	**No audio output** P (Desired) increased to -104 dBm to achieve audio; severe interference heard in audio.
861.9875	no affect	noise and squelch breaks	**No audio output** P (Desired) increased to -108 dBm to achieve audio; severe interference heard in audio.	**No audio output** P (Desired) increased to -98 dBm to achieve audio; severe interference heard in audio.
864.0875	no affect	noise and squelch breaks	**No audio output** P (Desired) increased to -106 dBm to achieve audio; severe interference heard in audio.	**No audio output** P (Desired) increased to -100 dBm to achieve audio; severe interference heard in audio.
865.8875	no affect	noise and squelch breaks	**No audio output** P (Desired) increased to -108 dBm to achieve audio; severe interference heard in audio.	**No audio output** P (Desired) increased to -104 dBm to achieve audio; severe interference heard in audio.
869.040	no affect	no affect	noise and squelch breaks	noise and squelch breaks
870.390	no affect	noise and squelch breaks	**No audio output** P (Desired) increased to -104 dBm to achieve audio; severe interference heard in audio.	**No audio output** P (Desired) increased to -96 dBm to achieve audio; severe interference heard in audio.
872.490	no affect	no affect	noise and squelch breaks	**No audio output** P (Desired) increased to -108 dBm to achieve audio; severe interference heard in audio.

Table 14: Portable B -Affects of Spurious Response from frequencies in the 806 to 894 MHZ Band				
Spurious Response Frequency	Affects on desired audio at different output levels of Spurious Response Frequencies			
	- 50 dBm	- 40 dBm	- 30 dBm	- 22 dBm
855.6875	no affect	noise and squelch breaks	**No audio output** P (Desired) increased to -112 dBm to achieve audio; severe interference heard in audio.	**No audio output** P (Desired) increased to -106 dBm to achieve audio; severe interference heard in audio.
859.8875	no affect	noise and squelch breaks	**No audio output** P (Desired) increased to -110 dBm to achieve audio; severe interference heard in audio.	**No audio output** P (Desired) increased to -104 dBm to achieve audio; severe interference heard in audio.
861.9875	no affect	noise and squelch breaks	**No audio output** P (Desired) increased to -106 dBm to achieve audio; severe interference heard in audio.	**No audio output** P (Desired) increased to -98 dBm to achieve audio; severe interference heard in audio.
864.0875	no affect	no affect	noise and squelch breaks	**No audio output** P (Desired) increased to -110 dBm to achieve audio; severe interference heard in audio.
865.8875	no affect	noise and squelch breaks	**No audio output** P (Desired) increased to -106 dBm to achieve audio; severe interference heard in audio.	**No audio output** P (Desired) increased to -96 dBm to achieve audio; severe interference heard in audio.
869.040	no affect	noise and squelch breaks	**No audio output** P (Desired) increased to -112 dBm to achieve audio; severe interference heard in audio.	**No audio output** P (Desired) increased to -106 dBm to achieve audio; severe interference heard in audio.
870.390	no affect	no affect	noise and squelch breaks	**No audio output** P (Desired) increased to -108 dBm to achieve audio; severe interference heard in audio.
872.490	no affect	no affect	noise and squelch breaks	**No audio output** P (Desired) increased to -108 dBm to achieve audio; severe interference heard in audio.

Analysis:

Our testing has found that the portables tested responded to three frequencies within the cellular base band (869.000 to 894.000 MHZ). They experience problems when the receive signal levels of the three frequencies exceeds -40 dBm. According to the manufacturer's specifications the spurious response rejection of North York's portable receiver is 78 dB. Given a sensitivity of -118 dBm, and spurious response rejection of 78 dB, signals above -40 dBm (according to the specification, -118 dBm + 78 dB) may cause spurious response interference.

Overall Observations and Conclusions

Our study has determined the following:

- the theoretical existence of numerous intermodulation products from the cellular frequency bands that fall within the passband of North York Fire's channel 5 receive frequency.

- North York Fire portables suffered from interference when subjected to received signal levels above -45 dBm, during the intermodulation spurious response test using cellular base frequencies. Levels of this magnitude were measured within 0.9 km of a cellular base station.

- North York Fire portables suffered from interference when subjected to received signal levels above -37 dBm, during the intermodulation spurious response test using cellular mobile frequencies. Levels of this magnitude were measured within 15 metres of a cellular phone

- North York Fire portables respond to the same three frequencies (869.040 MHZ, 870.390 MHZ, 872.480 MHZ) in the cellular base band, during the spurious response test. They were found to suffer from interference when subjected to receive signal levels above -40 dBm. Levels of this magnitude were measured within 0.7 km of a cellular base station.

- during the testing, the interference experienced was diminished with an increase in receive signal level of the desired frequency. In all cases the interference initially prohibited the correct decoding of the DCS and eventually muted the audio output. Increasing the desired signal level re-established the DCS decoding and audio was recaptured.

Our study concludes that North York Fire's portable operations can be adversely affected by the operation of cellular phones and cellular base stations when given the appropriate signal levels and frequencies. The intermodulation spurious response study has revealed that if the portables under test were subject to receive signal levels from a *cellular base station* greater than -45 dBm and the correct combination of cellular frequencies were received, the portables would experience episodes of background noise, intermittent squelch breaks and if receive levels were made higher, periods of no received audio. Also, the study has shown that if the portables under test were subject to receive signal levels from *cellular phones* greater than -37 dBm and the correct combination of cellular frequencies were received, the portables would also experience episodes of background noise, intermittent squelch breaks and if receive levels were made higher, periods of no received audio. The levels required to cause intermodulation interference were measured within approximately 900 metres of the tested cellular base station and 15 metres from the tested cellular phone, during our field measurements. We conclude that it is possible for portables to experience communication problems related to intermodulation spurious response, given the high saturation of cell sites and cellular phone use in the North York area. The spurious response study found three frequencies (869.040, 870.390 and 872.490 MHz) in the cellular band that can adversely affect the receive quality of a portables we tested, if the received signal levels were above -40 dBm. Our field measurements found these levels can be achieved within 700 metres of the cellular base station we tested in our field measurements.

The study also revealed other frequencies within the 800 MHZ band that the portables under test responded to, but they fell outside the cellular bands. The conditions stated above are not absolute and will vary depending on a number of factors. However, according to our findings and identified coincidence between the operation of the cellular phones, it is our belief that the interference reported by North York Fire during their training exercise was most likely due to received intermodulation produced in part by the operation of the cellular phones within the training grounds.