FUTURECOM® SYSTEMS GROUP, ULC
a Motorola Solutions Company

Futurecom Systems Group, ULC

Introduction to In-Band Operation

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1. INTRODUCTION

The DVRS and VRX1000's vehicle repeaters are used to extend portable radio communications. When portable radios or Portable Subscriber Units **(PSU**) have difficulty reaching a radio tower site, a vehicle repeater can help by linking the PSU to a higher power mobile radio or Mobile Subscriber Unit **(MSU)**.

Motorola Solutions, Inc. collaborates with Futurecom Systems Group, ULC in the design and Futurecom manufactures the industry standard P25 DVRS - Digital Vehicular Repeater System and VRX1000 – Vehicle Radio Extender. Over 800 public safety agencies have deployed these solutions as a key component in their radio systems.

Figure 1: VEHICLE MOUNT DVRS

The DVRS acts as a miniature 10 watt full-duplex base station that integrates with the Motorola APX™ series MSU. The VRX1000 is a scaled down version of the DVRS. It is simplex only, has a lower transmit power of 3 watts, but otherwise offers the same extensive feature set as the DVRS.

Figure 2: VRX1000

2. INTERFERENCE FREE OPERATION

With two radios operating in close proximity, care must be taken to achieve interference free operation. Users must ensure that the DVRS/VRX1000 transmitter doesn't interfere with the MSU receiver and that the MSU transmitter does not interfere with the DVRS/VRX1000 receiver. This interference is referred to as **desense**. To do this, the transmitters must be isolated from the receivers.

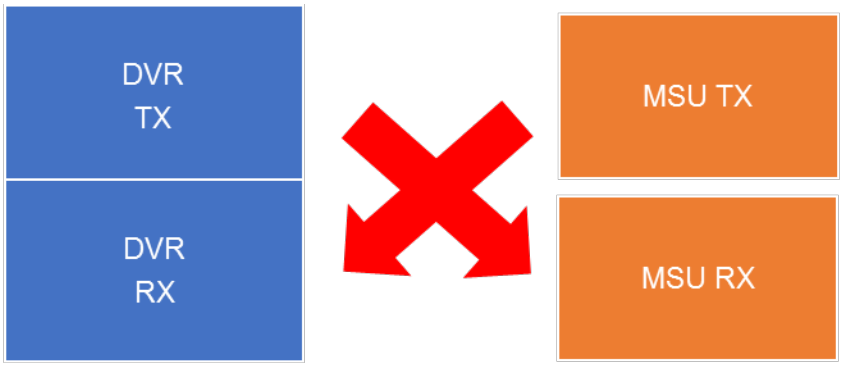

Figure 3: Interference Avoidance Diagram

What is a desense?

When the signal from a nearby transmitter enters the front-end stage of the receiver. The receiver performance is degraded.

The goal is to get at least 70dB of isolation through a combination of

A. Frequency separation
B. Physical antenna separation
C. Filtering

What is a dB?

A dB is a logarithmic measurement used to describe the ratio of a signal level.

A. Frequency Separation – If the MSU and DVRS/VRX1000 are hundreds of MHz apart (such as the DVRS/VRX1000 operating in 700 MHz and the MSU in VHF – see figure 4) then it is a “Cross-Band” arrangement where antenna physical separation can be minimal and no filters are required.

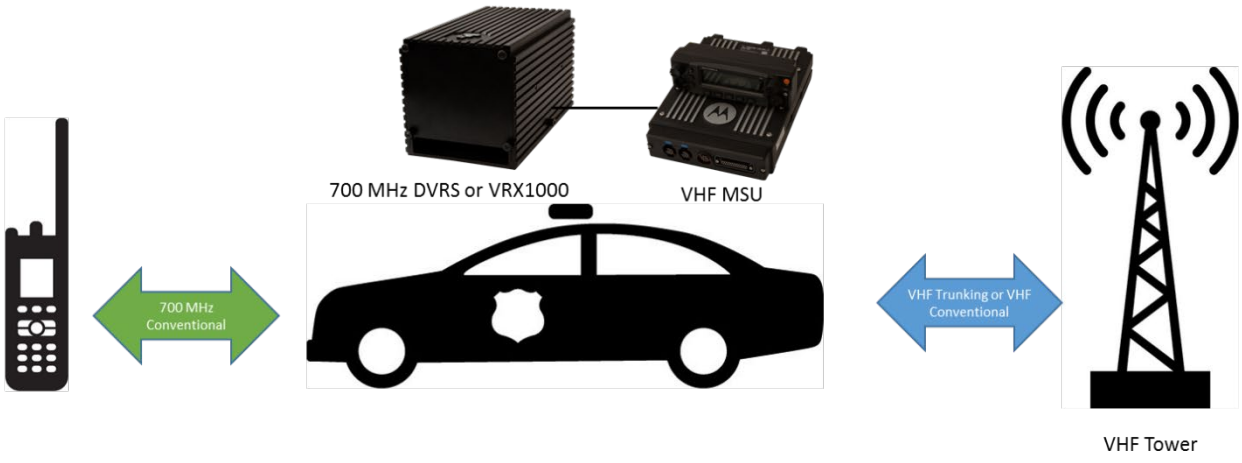

Figure 4: Cross-Band Operation

B. Physical Antenna Separation – It is difficult to get more than a few feet of antenna separation from a vehicle, so the isolation is somewhat limited but does contribute to the overall isolation. However, some permanent installations such as on a water tower, can provide the required isolation through antenna separation alone.

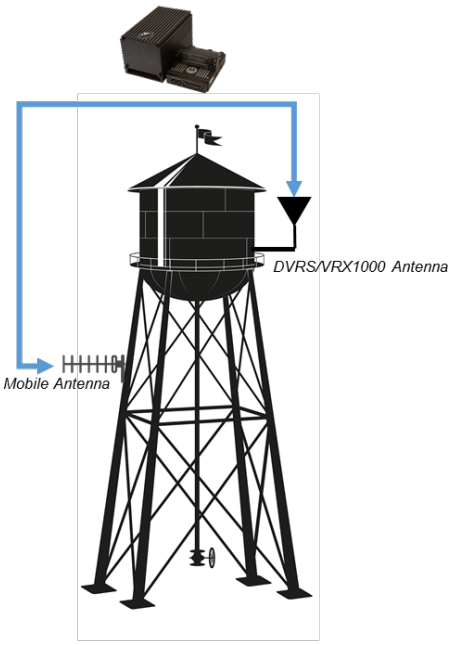

Figure 5: Antenna Separation Between Mobile Antenna & DVRS/VRX1000 Antenna

C. Filtering – If the Frequency Separation is only a few MHz, and the antennas are mounted on a vehicle, then filters will be required. This is referred to as In-Band Operation.

3. IN-BAND OPERATION

In-band operation is when the MSU and the DVRS/VRX1000 operate in the same frequency bands a few MHz apart. From an interference/isolation point of view, 700 MHz and 800 MHz are in the same band and additional filters are required within this frequency range.

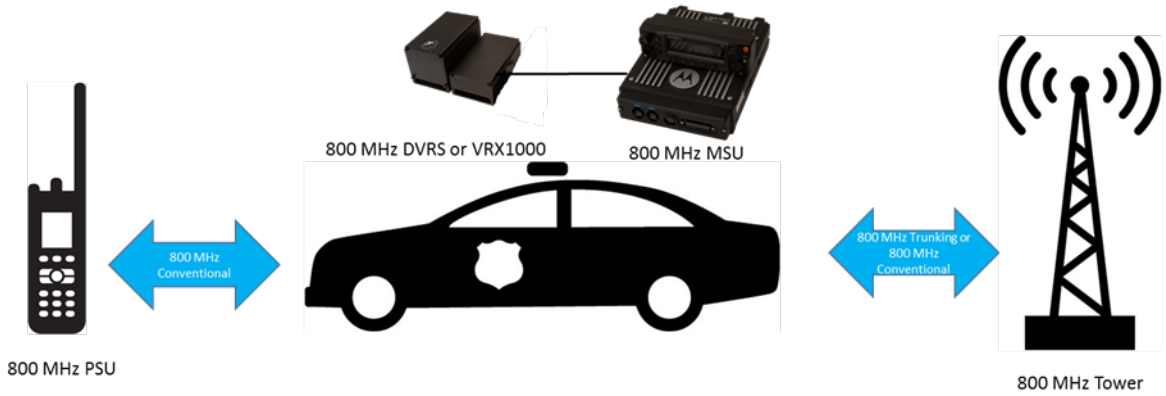

Figure 6: In-Band Operation

Separating the antennas by approximately six feet provides around 30dB of isolation. Additional filters are required to obtain the additional 40dB to reach the 70dB isolation.

In-band operation may require 2 filters.

A – A set of notch filters installed in the antenna line of the MSU. This rejects the DVR/VRX1000 transmit/receive frequencies and protects the MSU receiver.

B – A duplexer provides isolation to prevent desense when the DVR/VRX1000 is transmitting and/or receiving.

Figure 7 outlines the locations for the in-band notch filters and the duplexer.

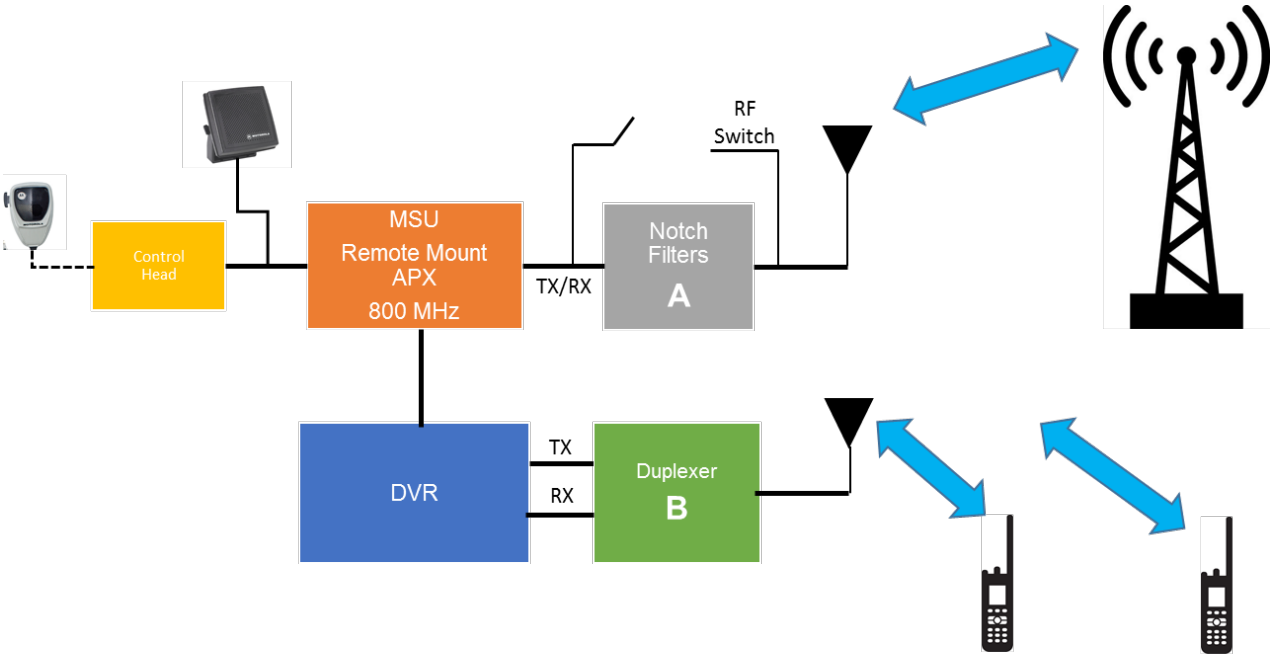

Figure 7: In-Band Configuration Layout

What is a Notch Filter?

This electronic device rejects all frequencies between two specific frequencies while allowing all others to pass. Think of it as you are throwing a party and denying only people who are wearing hats and allowing all others inside.

What is a Duplexer?

This electronic device can be used to connect the transmitter and receiver to a single antenna in such a manner that both units can be operated at the same time.

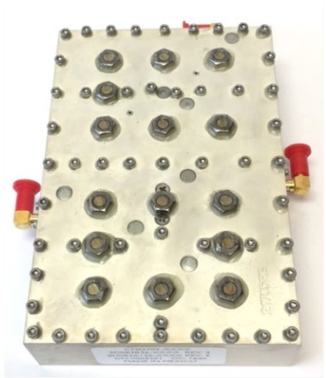

Figure 8: In-Band Filter Duplexer

The filters used by Futurecom are designed for mobile use, and are smaller in design compared to the larger sized infrastructure base station filters. Base station filters allow for increased selectivity for greater TX/RX isolation. In-Band filters are mechanical and not software configurable therefore cannot be retuned in the field. The Cross-Band DVRS typically includes a duplexer which can accommodate full duplex and simplex DVR operation.

4. FREQUENCY SEPARATION IS KEY

If In-Band operation is chosen for the DVRS or VRX1000, the key is to find a dedicated channel(s) that is far away enough from the system (MSU) frequencies for the filtering to be effective, but without negatively impacting the MSU. If the frequencies are too close, then not enough RF energy gets filtered, resulting in receiver desense, and significant insertion loss experienced by the MSU.

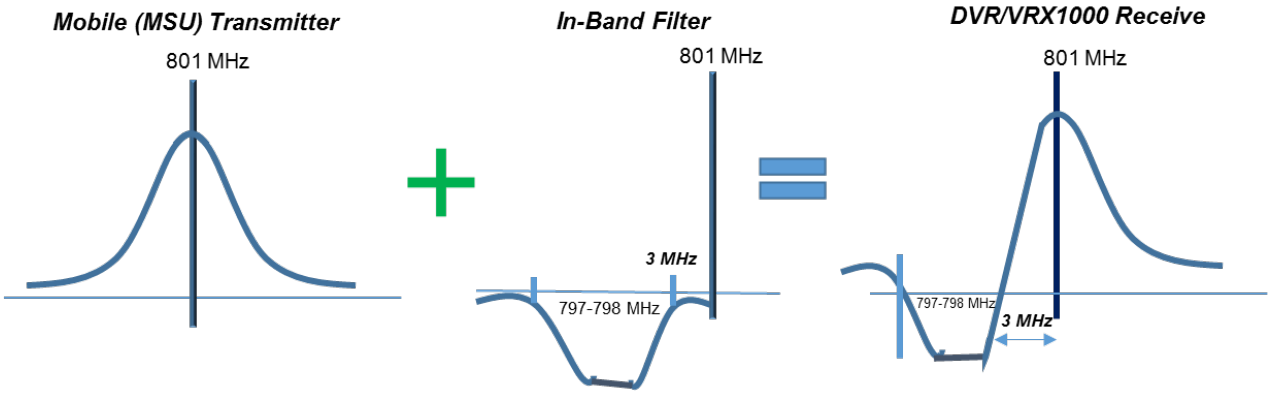

Figure 9: FM Transmission with Filters in Use (700 MHz Example)

The first step to ensuring adequate frequency separation is to compare the MSU radio frequencies with the DVRS/VRX1000 frequencies. On a radio infrastructure system (trunked system) there may be a large number of frequencies in use, but the lowest and highest for both transmit and receive are key. The DVRS/VRX1000 needs to be **"X"** MHz above or below this block of MSU frequencies. Both MSU/system frequencies and those in the DVRS/VRX1000 are required at time of order to ensure for proper filter tuning. See supplemental form (Appendix A)

System Frequencies
Transmit
Lowest
Highest
Receive
Lowest
Highest

The chart below provides the required frequency separation from either the system lowest Transmit or the Highest Receive frequency.

VRX1000/DVRS - 700 or 800 MHz **3 MHz Separation**	DVRS VHF or UHF Full Duplex **5 MHz Separation**
VRX1000 – VHF or UHF **2 MHz Separation**	DVRS VHF SIMPLEX **2 MHz Separation**

In-band operation also limits the passband of the DVRS. Passband is the range of frequencies the transmitter can transmit or the range of frequencies that it can receive. For 700 MHz and 800 MHz operation this is 1 MHz. For VHF and UHF it is and 0.3 MHz. Calculating the passband is determined by taking the Highest TX and subtracting the Lowest TX or subtracting the Lowest RX from the Highest RX. See example below.

Example:

Lowest DVRS TX: 856.0125 MHz RX 811.0125

Highest DVRS TX: 856.5625 MHz RX 811.5625

Calculation: 856.5625 MHz – 856.0125 MHz = DVRS Passband 0.55 MHz

5. IN-BAND FREQUENCY CASE STUDIES

Case #1 – Fire Department

A large city fire department is planning to purchase a DVRS to improve fireground communication and improve in-building coverage. The fire department needs to apply for DVRS frequencies to allow for fireground operation. They currently have a 800 MHz P25 trunked system that operates at TX: 808.0125-810.0125 MHz / RX: 853.0125 MHz – 855.0125 MHz.

Figure 10 – City Fire Department Current Trunked Frequencies

For in-band operation configuration the fire department could look at two scenarios for acquiring frequencies on their fireground. At 3MHz frequency separation the in-band filter provides the required isolation with a 1MHz bandpass.

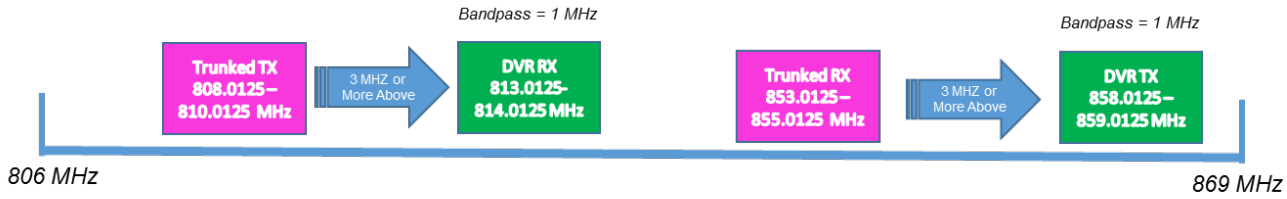

Figure 11 – Scenario 1- 800 MHz DVRS 3 MHz Above Trunked Frequencies with a 1 MHz Band Bandpass

Scenario 1: The fire department can look to acquire DVR channels that are 3 MHz or more above their current 800 MHz trunked frequencies. The green box highlights a potential frequency plan that provides enough frequency separation between the DVRS channel and the trunked frequencies.

Scenario 2: Even though the 700 MHz appears in another frequency band, 700 MHz and 800 MHz frequencies are considered In-Band due to their proximity. The fire department could consider 700 MHz DVRS frequencies. The bonus with 700 MHz is that this can generally also allow for some of the national interoperability channels in the selected 1 MHz bandpass. Several fire agencies use this frequency configuration for their fireground communications especially if there is no room for DVRS channels in 800 MHz spectrum.

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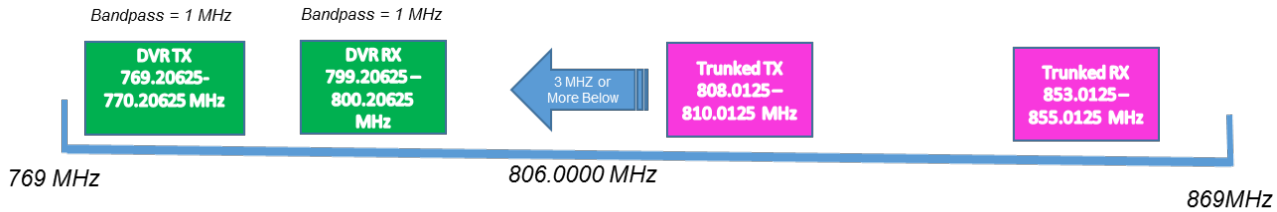


Figure 12 – Scenario 2 – 700 MHz DVRS 3 MHz or More Below Trunked Frequencies, with a 1 MHz Band Bandpass

Case #2 – Sheriff Department

A sheriff department is having difficulty with portable radio coverage in a low-lying area of their county. They currently operate a VHF conventional system that operates in the 150-155 MHz range. They are looking to improve coverage when officers are in this area.

Figure 13 – Conventional VHF System Frequencies

The Sheriff plans to operate their VHF PSU and acquire a VHF simplex frequency for improving coverage. What are the scenarios the sheriff could look at with their frequency coordinator?

Scenario 1: The Sheriff may look to find a frequency 2 MHz or more above their conventional RX system frequency as shown in Figure 12. Anything above 157.0125 is feasible including some of the 172 – 173 frequencies the FCC has designated for mobile repeater use.

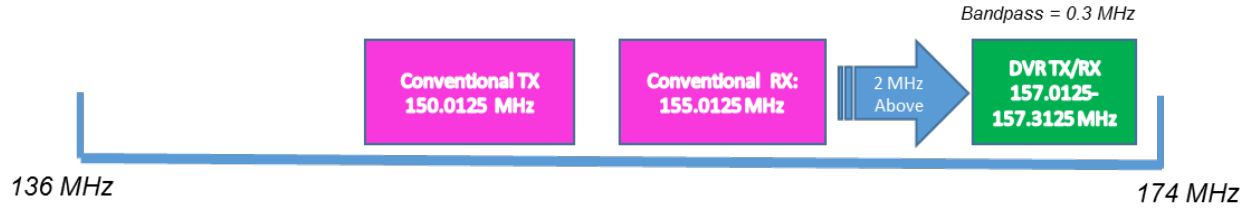


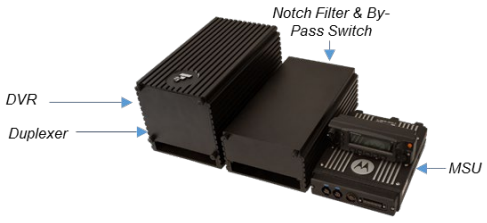
Figure 14 – Scenario 1 - VHF DVRS Simplex Frequency Above Convention RX

Scenario 2: The sheriff may look to find a frequency 2 MHz below their conventional TX frequency. This may prove difficult in the US as this is outside the public safety band, but possible in other countries.

Figure 15 – Scenario 2 - VHF DVRS Simplex Frequency Below Convention TX

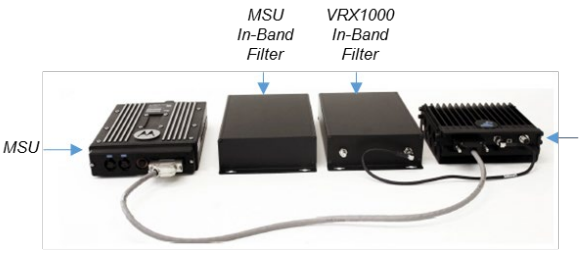
6. IN-BAND VEHICLE CONFIGURATIONS

The DVRS and VRX1000 have various vehicle mounting configurations depending on the frequency and application. It should be noted that the DVR includes a by-pass switch that by-passes the filtering at the output of the MSU when a “DVR-Disabled” talkgroup is selected on the control head.

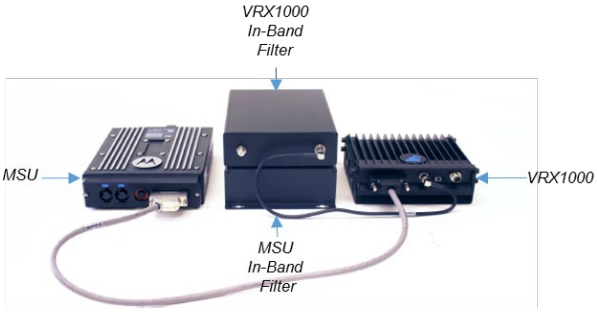


700 or 800 MHz In-Band Vehicle Mount DVRS

VHF or UHF In-Band Vehicle Mount DVRS



VRX1000 Standard Flat Mount Configuration



VRX1000 Optional Stacked Mount Configuration

Futurecom DVRS are also available in suitcase and cabinet configurations and can accommodate in-band filters.

7. BY-PASS SWITCH

Note: The by-pass switch is standard for In-Band DVRS models and is optional for the VRX1000.

Putting a fixed in-band filter in the antenna line of the MSU means that it will not function on certain frequencies. For example, the in-band filters used on a 700/800 MSU connected to a 700 MHz DVRS will, to varying degrees, block some 700 MHz frequencies.

This switch by-passes the in-band filter when a “DVR-Disabled” talkgroup or channel is selected allowing the MSU to operate over its full bandwidth. The by-pass switch is located internally in the filtering housing.

8. CONCLUSION

The DVRS and VRX1000 from Futurecom provide market leading performance for in-band operation. As public safety agencies look to deploy vehicular repeaters as a solution to their portable radio coverage challenges, it is important to work with both local frequency coordinators as well with the Futurecom team early in the process.

The form in Appendix A can be used to capture the proposed frequencies for review. Frequency parameters for both the DVR and VRX can be found by visiting www.Futurecom.com (Support).

APPENDIX A – SUPPLEMENTAL ORDERING FORM

FUTURECOM SYSTEMS GROUP, ULLC
a Motorola Solutions Company

DVRS/VRX1000 SUPPLEMENTAL ORDERING FORM

1. Agency Name:
2. Date (YY/MM/DD):
3. DVRS/VRX Order Code:
4. Select DVR/VRX Configuration: DVRS - Suitcase Black
5. If Suitcase or Cabinet DVR Order Please specify power requirement 120 VAC
6. Specify DVR/VRX Frequencies

Lowest DVR/VRX Transmit (MHz)	
Highest DVR/VRX Transmit (MHz)	
Lowest DVR Receive (MHz)	
Highest DVR Receive (MHz)	

7. Specify Trunked / System Frequencies

	700/800MHz	VHF	UHF
Band enabled in MSU (Mobile Subscriber Unit)?	NO	NO	NO
DVRS/VRX1000 used with this band?	NO	NO	NO
Lowest Mobile Radio Transmit (MHz)			
Highest Mobile Radio Transmit (MHz)			
Lowest Mobile Radio Receive (MHz)			
Highest Mobile Radio Receive (MHz)			

8. Specify Mobile Radio Type APX6500
9. Specify Control Head Type 09
10. Specify MSU (Mobile Subscriber Unit) Antenna Type Single Band

Special Notes:

NOTE: BEFORE PLACING YOUR ORDER PLEASE MAKE SURE YOU FOLLOW-UP WITH FUTURECOM SO THE PROPER FREQUENCY PLAN CAN BE IDENTIFIED AND APPROVED.

PLEASE EMAIL THE COMPLETED FORM TO SALES@FUTURECOM.COM

Version 4.5