TRMS No. 8–ES–685–IED–002
USAEPG Publication No. ATR04–04–012

Abbreviated Test Report for Blue Force Communications Electromagnetic Compatibility (EMC) with WARLOCK-Green, WARLOCK-Red, and Self-screening Vehicle Jammer Systems (FOUO)

Submitted by James Smith and James Billingsley
Test and Measurement Branch, Test Engineering Division
US Army Electronic Proving Ground, Fort Huachuca, Arizona 85613–7063

Approved for External Coordination by Alan Morris
Chief, Test and Measurement Branch, Test Engineering Division
US Army Electronic Proving Ground, Fort Huachuca, Arizona 85613–7063

May 2004

Period:
March through April 2004

Prepared for:
Program Manager, Signals Warfare
ATTN: SFAE–IEW&S–SG (LTC John Masterson)
296 Sherrill Avenue
Fort Monmouth, NJ 07703–5303

Distribution authorized to US Government agencies and their contractors; critical technology, May 2004. Other requests for this document shall be referred to the Product Manager, FIREFINDER, ATTN: SFAE–IEW&S–FF, Fort Monmouth, NJ 07703–5303

Not releasable to DTIC

CLASSIFIED BY: WARLOCK Security Classification Guide, 11 March 2004
REASON: 4.1(A)(g)
DECLASSIFY ON: X1

US Army Developmental Test Command
Aberdeen Proving Ground, MD 21005–5055

(U) The views, opinions, and findings contained in this document reflect those of the US Army Electronic Proving Ground and the authors and should not be construed as an official Department of the Army position, policy, or decision unless so designated by official documentation.

(U) This document was prepared using Security Classification Guide, WARLOCK, Interim DRAFT, US Army Communications-Electronics Command, 11 March 2004 (SECRET).

TABLE OF CONTENTS (U)

INTENTIONALLY BLANK

SECTION 1. EXECUTIVE DIGEST (U)

1.1 (U) SUMMARY

a. (S) The US Army Electronic Proving Ground (USAEPG), Fort Huachuca, Arizona, conducted electromagnetic compatibility (EMC) testing on the effect of Self-screening Vehicle Jammer (SSVJ) and WARLOCK-Green and WARLOCK-Red Improvised Explosive Device (IED) countermeasure systems on Blue Force command and control (C^2) communications. The testing was performed at the US Army Yuma Proving Ground (YPG), Yuma, Arizona, during March and April 2004. Follow-on testing, encompassing Blue Force Tracking (BFT), was performed at USAEPG, April 2004.

b. (S) Use of WARLOCK-Red and SSVJ IED countermeasure systems prevented usable Blue Force C^2 communications. Usable is defined as 80 percent of messages received and understood. This could be mitigated by using the jammer standoff method or by shortening communications links and providing communications relay.

1.2 (U) TEST OBJECTIVE

(S) To determine the effect the SSVJ, WARLOCK-Green, and WARLOCK-Red IED countermeasure systems have on Blue Force C^2 communications systems performance when co-located in the same vehicle or in close proximity to a vehicle and operated simultaneously during convoy operations, or when in close proximity to a major communications node; e.g., tactical operations center (TOC).

1.3 (U) TESTING AUTHORITY

(S) USAEPG was tasked, through the US Army Developmental Test Command (DTC), to conduct the Blue Force C^2 communications EMC testing for SSVJ, WARLOCK-Green, and WARLOCK-Red IED countermeasure systems in the Internal Test Directive FY04-040, and Test Resource Management Information System (TRMS) No. 8-ES-685-IED-002.

1.4 (U) TEST CONCEPT

(S) Two high mobility, multipurpose wheeled vehicles (HMMWVs) [M1035 softtop with armor survivability kit (ASK) and M1026 hardtop], equipped with Blue Force C^2 systems and the SSVJ and WARLOCK-Green and WARLOCK-Red IED countermeasure systems, were used to assess the effects of simultaneous Blue Force C^2 communications and SSVJ and WARLOCK-Green and WARLOCK-Red IED operations within a convoy. Blue Force C^2 systems that were installed in both HMMWVs consisted of the Single Channel Ground and Airborne Radio System (SINCGARS); Enhanced Position Location Reporting System (EPLRS) with Force XXI Battle Command, Brigade and Below (FBCB2); BFT with FBCB2; SPITFIRE AN/PSC-5 Enhanced Manpack Ultrahigh Frequency (UHF) Terminal (EMUT); and Precision Lightweight Global Positioning System (GPS) Receiver (PLGR). In addition to the above Blue Force C^2 systems, testing was conducted using handheld Motorola XTS 3000 and Garmin RINO Family Radio Service (FRS)/General Mobile Radio Service (GMRS) systems. Internal and external convoy C^2 communications were replicated and included intraconvoy and interconvoy scenarios.

(1) (U) The intraconvoy scenario replicated communications within a convoy; i.e., lead vehicle-to-trail-vehicle communications. For intraconvoy operations, a convoy length distance of 2 kilometers (km) was assumed as a realistic operational distance from the lead vehicle to the trail vehicle.

(2) (S) The interconvoy scenario replicated communications between a TOC and a convoy. A C^2 communications link distance of 20 km was assumed as a realistic operational distance from the TOC to convoy. Transmitter output power scaling and/or transmit link attenuation was used to replicate the 20-km communications link and provide realistic signal levels to the destined receivers. During the interconvoy scenario execution, four IED countermeasure system configurations were tested. Table 1 provides the IED countermeasure systems configurations for the interconvoy scenario.

Table 1. (S) IED Countermeasure System Interconvoy Configurations

IED Countermeasure System	IED Countermeasure System Configurations			
	Configuration 1	Configuration 2	Configuration 3	Configuration 4
SSVJ	Off	Off	On	Off
WARLOCK-Green	Off	Off	Off	On
WARLOCK-Red	Off	On	Off	Off

SECRET

(3) (S) Communication link quality was measured for both intraconvoy and interconvoy scenarios. Table 2 provides the quality metrics used to assess the Blue Force C^2 communications transmission performance during simultaneous operations with the IED countermeasure systems.

Table 2. (U) Blue Force C^2 Communications Transmission Success Quality Metrics

Blue Force C^2 System	Performance Standard
SINCGARS	Message Completion Rate (MCR), Radio SYNC
EPLRS/FBCB2	MCR, Final MCR (60 seconds after last C^2 message was transmitted)
BFT/FBCB2	MCR, Final MCR (60 seconds after last C^2 message was transmitted)
SPITFIRE	Subjective Voice Quality Measurement
Motorola XTS 3000	Subjective Voice Quality Measurement
Garmin RINO FRS/GMRS	Subjective Voice Quality Measurement

SECRET

1.5 (U) SYSTEM DESCRIPTION

1.5.1 (U) IED Countermeasure Systems

1.5.1.1 (S) SSVJ. The SSVJ is a programmable, active (always on) IED jammer. It currently operates in various frequency bands from approximately 20 megahertz (MHz) to approximately 1,000 MHz. It transmits at 1 watt (W) of power using a single antenna.

1.5.1.2 (S) WARLOCK-Green. The WARLOCK-Green is a programmable, passive IED jammer. It scans a series of target frequency bands, and then transmits a jamming signal upon detection of activity in that frequency band. It currently operates from approximately 20 MHz to approximately 500 MHz. It transmits at 25 W of power using a single antenna.

1.5.1.3 (S) WARLOCK-Red. The WARLOCK-Red is a programmable, active IED jammer. It comprises two basic units each of which targets different frequency bands. The WARLOCK-Red low band operates from approximately 20 MHz to approximately 100 MHz. It transmits at 5 W of power using a modified SINCGARS whip antenna. The WARLOCK-Red midband operates from approximately 250 MHz to approximately 500 MHz. It transmits at 1 W of power using the same antenna as the WARLOCK-Green system.

1.5.2 (U) Blue Force Communications Systems Tested

1.5.2.1 (U) SINCGARS. The SINCGARS is a very high frequency (VHF) radio. It has capability for both voice and data; however, it is primarily used for voice C^2. SINCGARS operates using two modes: frequency hopping (FH) and single channel (SC). The system can operate on any of the 2,320 available frequencies in the 30–87.975 MHz band, and can transmit up to 50 W.

1.5.2.2 (U) EPLRS/FBCB2. EPLRS/FBCB2 is a part of Blue Force communications equipment. EPLRS/FBCB2 displays situational awareness (SA) on the computer monitor and uses the UYK-128. It uses a PLGR to obtain its location and an EPLRS to send the data out. The EPLRS 1720-B radio is used for data communications; it operates in the UHF band 420–450 MHz. The output power modes are 0.4, 3, 20, and 100 W. EPLRS has spread spectrum capability to prevent jamming effects. Additionally, each radio in the network serves as an automatic repeater to ensure reliable delivery of messages.

1.5.2.3 (U) Motorola XTS 3000 Handheld Radio. The XTS 3000 is an analog/digital handheld radio that provides two-way communication. It is a programmable, multichannel analog radio capable of operating in the 400-MHz frequency range. The radio can function in either split frequency, trunked repeater networks or in peer-to-peer LOS applications. The XTS 3000 provides both single- and dual-digital encryption. The XTS 3000 can operate under two basic modes, line of sight (LOS) point-to-point and in a trunked repeater network. The three frequency ranges that the XTS 3000 transmits under are very high frequency (VHF) 136–174 MHz, 1–5 W, ultrahigh frequency (UHF), 403–470 MHz (Range 1), 450–520 MHz (Range 2), 1–4 W, and the 800 MHz, 806–824 MHz (Range 1), 851–870 MHz (Range 2), 3 W.

1.5.2.4 (U) Garmin RINO FRS/GMRS Handheld Radio. The RINO is an integrated GPS handheld radio that provides two-way communication. It is a 22-channel consumer product radio

SECRET//REL TO USA, AUS, CAN, GBR, AND NZL//X1

capable of operating in both the FRS band and the GMRS band. The radio functions only in nonrepeater LOS terrestrial mode. It is capable of using the FRS band, 462.5625–467.7125 MHz and the GMRS band, 462–467 MHz. The RINO has 22 communication channels, 14 FRS channels and 8 GMRS channels. The RINO can transmit 0.5 W on low power using FRS, and 1 W on high power using GMRS.

1.5.2.5 (U) BFT. BFT/FBCB2 is a part of Blue Force communications equipment that displays SA on the computer monitor. The BFT consists of a UYK-128, which consists of the computer, the monitor, and the display, and an MT2011 mobile satellite transceiver with power module. The MT2011 sends the situational data back and forth between the transceivers. The MT2011 has embedded GPS capabilities, operates in the L-Band frequency range, 1.530–2.700 GHz, and can transmit up to 5 W.

1.5.2.6 (U) SPITFIRE. The AN/PSC-5D Multiband Multimission Radio (MBMMR) is a radio that has capabilities for UHF/VHF Manpack LOS communications and satellite communications/demand assigned multiple access (SATCOM/DAMA). The PSC-5D, which has voice and data capabilities, operates in the 30–512 MHz range. The PSC-5D has embedded communications security (COMSEC) using a variety of encryption modes. The PSC-5D can transmit up to 10 W in amplitude modulation (AM) and frequency modulation (FM) mode and up to 20 W in SATCOM mode.

1.6 (U) CONCLUSIONS

a. (S) *Impact on SINCGARS.* Operation of WARLOCK-Red or the SSVJ in the same vehicle prevented communications using SINCGARS. Using the WARLOCK-Red or SSVJ in vehicles located 50 meters distant from vehicles using Blue Force communications allows usable communications. Greatly shortening the LOS terrestrial (nonsatellite) radio frequency (RF) link distance allows use of the WARLOCK-Red or SSVJ within the same vehicle.

b. (S) *Impact on EPLRS/FBCB2.* Operation of WARLOCK-Red or the SSVJ in the same vehicle prevented communications using EPLRS/FBCB2. Using the WARLOCK-Red located 50 meters distant (100 meters for SSVJ) allows usable communications. Greatly reducing the LOS terrestrial (nonsatellite) RF links allows use of the WARLOCK-Red or the SSVJ within the same vehicle.

c. (S) *Impact on BFT/FBCB2.* Operation of WARLOCK-Red in the same vehicle prevented communications using BFT/FBCB2. SSVJ and WARLOCK-Green impact on BFT/FBCB2 was not tested. Using the WARLOCK-Red in vehicles located 50 meters distant allows usable communications.

d. (S) *Impact on Motorola XTS 3000 Handheld Radios.* Operation of WARLOCK-Red, SSVJ, or the WARLOCK-Green within 50 meters of the Motorola handhelds prevented usable communications. Jammer standoff distances greater than 50 meters were not tested due to insufficient time.

e. (S) *Impact on Garmin RINO FRS/GMRS Handheld Radios.* Operation of WARLOCK-Red or the SSVJ in the same vehicle prevented communications using the RINO radios. Jammer standoff distances greater than 50 meters were not tested.

f. (S) *Impact on SPITFIRE (AN/PSC-5).* Communications were not affected by any of the IED jammers.

g. (S) *Impact on GPS PLGR.* Operation can be severely degraded if the WARLOCK-Red or SSVJ antennas are mounted too close to the GPS PLGR antenna.

1.7 (U) RECOMMENDATIONS

a. (S) The SINCGARS and EPLRS used Iraq frequency resources for this test effort. The SINCGARS hopsets and EPLRS channel resources contained frequencies used by the IED jammer. The option of Blue Force communications frequency management should be explored through follow-on EMC testing of the IED jammer systems with SINCGARS and EPLRS.

b. (S) The IED jammers should be mounted in vehicles that do not require Blue Force communications, assuming the IED jammers can protect multiple vehicles.

c. (S) Additional EPLRS-equipped vehicles should be added to the convoys to provide automatic relay capabilities for Blue Force SA and C^2 digital messaging.

d. (S) Maintain as much physical separation between GPS PLGR antennas and IED jammer antennas as possible when both systems are mounted on the same vehicle.

INTENTIONALLY BLANK

SECTION 2. DETERMINATION OF FINDINGS (U)

2.1 (S) IED COUNTERMEASURES SYSTEMS IMPACT ON INTRACONVOY COMMUNICATIONS

2.1.1 (S) Objective. To determine the effect the SSVJ, WARLOCK-Green, and WARLOCK-Red IED countermeasure systems have on Blue Force C^2 communications systems performance when co-located in the same vehicle or in close proximity to a vehicle and operated simultaneously during convoy operations, or when in close proximity to a major communications node; e.g., TOC. Additional objectives were to determine mitigation techniques that allow simultaneous operations when both types of systems were co-located.

2.1.2 (S) Criteria. Simultaneous operation of co-located IED jammers and Blue Force communications equipment shall not degrade Blue Force communications.

2.1.3 (S) Test Procedures. Test personnel postulated that one of the most likely communications scenarios would be communications between the lead and tail elements of a convoy. Convoy length was postulated to be 2 km, 40 vehicles at 50-meter intervals. The Blue Force was expected to have SINCGARS, EPLRS/FBCB2, and various handheld radios (XTS3000 and RINO) available for intraconvoy communications. While satellite systems (BFT/FBCB2 and SPITFIRE) were expected to be used for intraconvoy communications, their testing was deferred to the base-to-convoy communications test scenario. This was allowable because they used satellite RF links rather than LOS terrestrial RF links.

2.1.3.1 (U) Baseline Link Configuration

2.1.3.1.1 (S) General. Two vehicles were configured with the Blue Force communications equipment outlined in paragraph 2.1.3 and the IED jammer systems. Antenna placements are shown in figure 1. A HMMWV with a hardtop (M1026) was used to play the role of the lead vehicle at the head of the convoy. A softtop HMMWV (M1035) with an ASK installed was used to play the role of the last vehicle at the tail of the convoy. The vehicles (facing west) were sited 2 km from each other along a flat, straight, desert road at the YPG test area. Voice and data messages were sent from the lead vehicle to the tail vehicle. Reverse message traffic was not sent in order to accelerate the condensed test schedule.

2.1.3.1.2 (S) SINCGARS. The network was operated using a 1,000-frequency hopset structurally similar to the one used in Iraq operations. Frequencies conflicting with those used by the IED jammers were not removed from the hopset. The SINCGARS transmit power levels were set to high power (4.5 W) because standard SINCGARS installations are not expected to have RF power amplifiers. High power was also chosen to provide a worst-case scenario and reduce the number of test variables given the limited available test time. Probability of radio link synchronization was measured by sending 10 short data messages and manually counting the receptions. End-to-end message quality was determined by measuring the bit error rate (BER) of the above 10 short data messages. BERs of 8 percent or less indicate that usable voice or data message operations are possible. No IED jammers were turned on during this scenario portion.

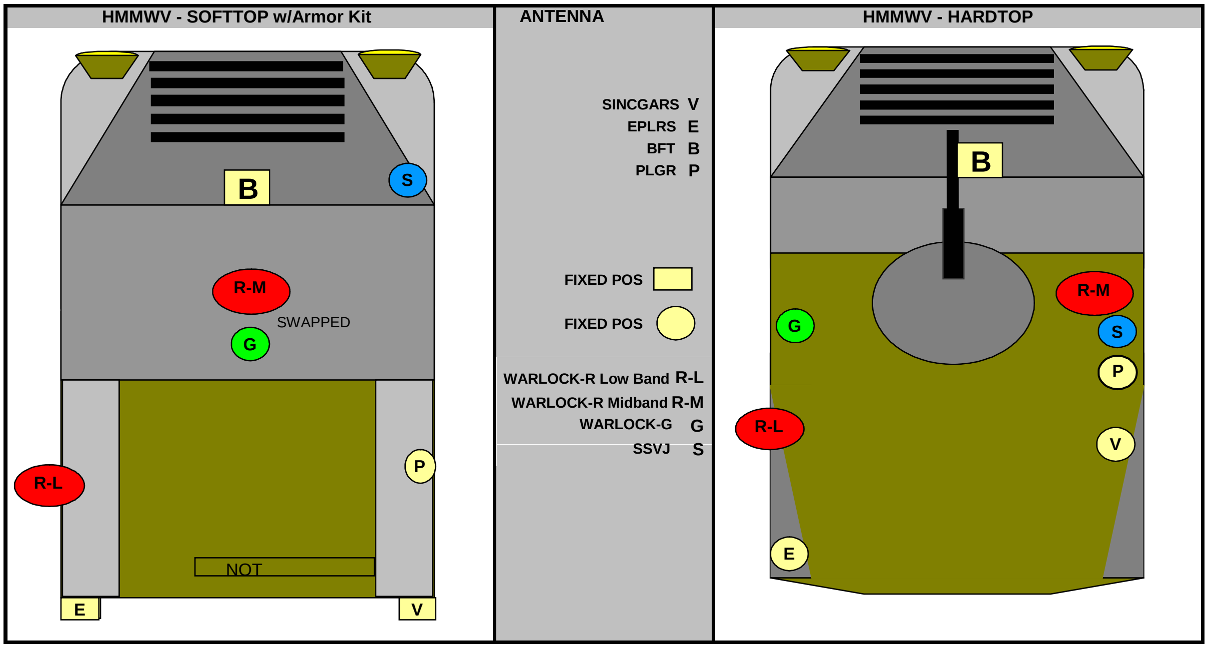

Figure 1. (U) Antenna Locations

2.1.3.1.3 (S) EPLRS/FBCB2. The network was operated with the EPLRS radio programmed to use all available channels. Channels whose frequencies would conflict with those used by the IED jammers were not removed. Transmitter power levels were set to 20 W. End-to-end message quality was determined counting the number of messages accepted by the receive end (tail) FBCB2. The lead end FBCB2 was used to create and send 50 free-text messages via the EPLRS radio link to the tail site. No IED jammers were turned on during this scenario portion.

2.1.3.1.4 (S) Motorola XTS 3000 Handheld Radio. Test personnel operated the radio in peer-to-peer LOS mode and used 416.300 MHz as the RF link frequency for this test. End-to-end message quality was subjectively determined by counting the number of received voice message of usable and understandable quality. Test personnel sitting in the lead HMMWV's passenger seat transmitted 20 voice messages to other test personnel sitting in the tail HMMWV's passenger seat. No IED jammers were turned on during this scenario portion.

2.1.3.1.5 (S) Garmin RINO FRS/GMRS Handheld Radio. Test personnel used one of the RINO's GMRS channels (462.550 MHz) for this test, so that the radio would use its highest transmit power setting of 1 W. End-to-end message quality was subjectively determined by counting the number of received voice message of usable and understandable quality. The RINO radio was not capable of communicating over the 2-km convoy link with personnel sitting in the HMMWV passenger seats. A third HMMWV was used to create a 400-meter RF link to the lead vehicle at the convoy head site. Test personnel sitting in the passenger seat of the third HMMWV transmitted 20 voice messages in the reverse direction to other test personnel sitting in the lead HMMWV's passenger seat at the convoy head site. No IED jammers were turned on during this scenario portion.

2.1.3.2 (S) Baseline Link with IED Countermeasures Co-located in Same Vehicle. In this scenario, the IED jammers and communications equipment are installed in the same vehicle. Each of the above baseline performance tests was repeated while the IED jammers were turned on, one at a time. Only one IED jammer was operational at any time.

2.1.3.3 (S) Baseline Link with IED Countermeasures Located In Different Vehicle. This scenario was an excursion to evaluate a mitigation method to lessen the Blue Force communications degradation caused by operating the IED jammers. In this scenario, the jammers are placed in a separate vehicle and stood off some distance from the victim vehicle containing the Blue Force communications equipment. The intent is to allow communications across the 2-km-long convoy while keeping the communications vehicle within the protection zone provided by a nearby IED jammer in a different vehicle. Standoff distances of 50 meters and 100 meters were chosen because they corresponded to postulated convoy vehicle intervals. After moving the IED jammer to another vehicle, each of the above baseline performance tests were repeated while the IED jammers were turned on, one at a time. Only one IED jammer was operational at any time.

2.1.3.4 (S) Shortened Link with IED Countermeasures Co-located in Same Vehicle. Again, this scenario was an excursion to evaluate a mitigation method to lessen the Blue Force communications degradation caused by operating the IED jammers. In this scenario, the jammers and communications equipment are within the same vehicle. The intent is to determine whether communications could be relayed over a series of short (less loss) RF links within the 2-km-long convoy. The role of the HMMWV playing the lead vehicle was changed to that of one located within the body of the convoy, to support message relay capability. Test personnel moved the hardtop HMMWV (M1026) to successively closer distances to the tail HMMWV until they could establish reliable communications on the communications system being tested. After moving the vehicle to a usable distance, each of the above baseline performance tests was repeated while the IED jammers were turned on, one at a time. Only one IED jammer was operational at any time.

2.1.4 (U) Test Findings

2.1.4.1 (S) Baseline Link with IED Countermeasures Co-located in Same Vehicle

2.1.4.1.1 (S) SINCGARS. No communications across the 2-km convoy radio link were possible when either the WARLOCK-Red or the SSVJ was operating within the same vehicle. The WARLOCK-Green did not prevent usable communications.

2.1.4.1.2 (S) EPLRS/FBCB2. No communications across the 2-km convoy radio link were possible when either the WARLOCK-Red or the SSVJ was operating within the same vehicle. The WARLOCK-Green did not prevent usable communications.

2.1.4.1.3 (S) Motorola XTS 3000 Handheld Radio. No communications across the 2-km convoy radio link were possible when any of the three IED jammers were operating within the same vehicle.

2.1.4.1.4 (S) Garmin RINO FRS/GMRS Handheld Radio. No communications across a 400-meter intraconvoy radio link were possible when either the WARLOCK-Red or the SSVJ was operating within the same vehicle. The WARLOCK-Green did not prevent usable communications.

2.1.4.1.5 (S) Additional Information. Use of either the WARLOCK-Red or the SSVJ on the hardtop HMMWV (M1026) caused the GPS PLGR figure of merit (FOM) to degrade to a "9," thereby preventing the FBCB2 from sending an accurate position update. The GPS PLGR installed in the softtop HMMWV (M1035) was not affected by operation of any of the IED jammers.

2.1 (S) Baseline Link with IED Countermeasures Located in Different Vehicle

2.1.4.2.1 (S) SINCGARS. Using a 50-meter jammer standoff distance between the communications vehicle and the IED jammer vehicle allowed usable communications when either the WARLOCK-Red or SSVJ was operated in the jammer vehicle.

2.1.4.2.2 (S) EPLRS/FBCB2. Using a 50-meter jammer standoff distance between the communications vehicle and the IED jammer vehicle allowed usable communications when the WARLOCK-Red was operated in the jammer vehicle. The SSVJ required a 100-meter standoff distance.

2.1.4.2.3 (U) Motorola XTS 3000 Handheld Radio. No results are available. This test was omitted due to lack of available time.

2.1.4.2.4 (U) Garmin RINO FRS/GMRS Handheld Radio. No results are available. This test was canceled due to radio hardware failure.

2.1.4.3 (S) Shortened Link with IED Countermeasures Co-located in Same Vehicle

2.1.4.3.1 (S) SINCGARS. Communications were possible once the radio link was shortened to 250 meters when either the WARLOCK-Red or SSVJ was operated within the same vehicle.

2.1.4.3.2 (S) EPLRS/FBCB2. Communications were possible once the radio link was shortened to 400 meters when either the WARLOCK-Red or SSVJ was operated within the same vehicle.

2.1.4.3.3 (S) Motorola XTS 3000 Handheld Radio. Communications were possible once the radio link was shortened to 400 meters when the SSVJ was operated within the same vehicle. The radio link distance for usable communication when operating a WARLOCK-Red within the same vehicle was not determined. Further investigation was canceled due to lack of available time.

2.1.4.3.4 (U) Garmin RINO FRS/GMRS Handheld Radio. No results are available. This test was canceled due to radio hardware failure.

2.1.5 (U) Technical Analysis

2.1.5.1 (S) General discussion. The major element affecting usable communications is the signal-to-noise ratio (S/N) at the radio receiver. Raising the S/N increases receiver performance, lowering it degrades performance. The ratio can be increased by raising the desired signal strength or by lowering the undesirable noise presented to the receiver's antenna. Shortening the radio link in the above shortened link excursion reduces the RF path loss of the desired signal, hence increases its strength at the receivers antenna. Standing off the IED jammer decreases the undesired noise presented to the receiver's antenna.

2.1.5.2 (S) SINCGARS. At least three methods are readily available to allow usable communications via SINCGARS within the convoy scenario.

a. (S) *Frequency Coordination and Hopset Tailoring.* The first, which was not explored in this time-constrained test, is frequency coordination and SINCGARS hopset tailoring around IED jammers frequencies. After reviewing the in-country hopset, there appears to be sufficient RF spectrum available to trade off frequencies for jammer use. One potential problem will be the RF spectral purity and spurious signals and harmonics generated by the jammers in addition to their intended transmit frequencies. This could be resolved by trading off more SINCGARS frequencies and/or cleaning up the jammer signals via better internal filters or commercial off-the-shelf (COTS) external filters. Another potential problem could be chaos within the SINCGARS networks if there are continuous changes to the SINCGARS hopsets and their distribution is not timely and thorough throughout the affected units.

b. (S) *Jammer Standoff.* Easily implemented if the jammers can protect multiple vehicles.

c. (S) *Radio Repeater over Shortened Radio Links.* This is probably the least desirable due to the increased hardware requirements, radios and antennas. Manual operator message relay could also be employed but would be labor intensive and prone to error. Operation at RF power amplifier power (50 W) could increase the link distance and reduce hardware requirements.

2.1.5.3 (S) EPLRS/FBCB2. Again, at least three methods are readily available to allow usable communications via EPLRS/FBCB2 within the convoy scenario.

a. (S) *Frequency Coordination and EPLRS Channel Tailoring.* The principles discussed in the above SINCGARS method are applicable.

b. (S) *Jammer Standoff.* Easily implemented if the jammers can protect multiple vehicles.

c. (S) *Radio Repeater over Shortened Links.* This option is more desirable for EPLRS because every EPLRS within the network automatically functions as a repeater. Additionally, the usable link distance is greater—400 meters. Only five EPLRS in a 2-km-long convoy would be required to provide end-to-end data communications. Positional data and SA would be supported. Voice communications are not supported.

2.1.5.4 (S) Motorola XTS 3000 Handheld Radio. Frequency coordination and using a channel whose frequency is outside the jammer's band is the only readily available recommendation.

2.1.5.5 (S) Garmin RINO FRS/GMRS Handheld Radio. Frequency coordination and using a channel whose frequency is outside the jammer's band is the only readily available recommendation.

2.1.5.6 (S) Additional Information Regarding GPS PLGR. Given the limited observation data available, the most readily available method for preventing GPS position degradation is separation between the GPS and jammer antennas. This is the most likely explanation of why the GPS was affected only on the hardtop HMMWV (M1026) installation. The antennas on the softtop HMMWV (M1035) installation were farther apart and the GPS antenna was somewhat shielded from the jammer antennas by the rear panel of the ASK.

2.2 (S) IED COUNTERMEASURES SYSTEMS IMPACT ON BASE-TO-CONVOY COMMUNICATIONS

2.2.1 (S) Objective. The objective was to determine whether operating IED jammer systems (WARLOCK-Red, WARLOCK-Green, or SSVJ) degraded Blue Force communications between a TOC and convoy. Additional objectives were to determine mitigation techniques that allow simultaneous operations when both types of systems were co-located.

2.2.2 (S) Criteria. Simultaneous operation of co-located IED jammers and Blue Force communications equipment.

2.2.3 (S) Test Procedures. Test personnel postulated that one of the most likely communications scenarios would be communications between a headquarters element, or base site, and an element within the convoy. The Blue Force was expected to have SINCGARS, EPLRS/FBCB2, BFT/FBCB2, and SPITFIRE (satellite mode) available for base-to-convoy communications. A LOS terrestrial radio link to the convoy of 20 km for SINCGARS and EPLRS was postulated based on previous testing at USAEPG on SINCGARS and EPLRS radio networks. Additionally, it was postulated that jammers would be installed only in vehicles within the convoy, not at any base site. The BFT/FBCB2 and SPITFIRE systems use satellite RF links rather than LOS terrestrial RF links. A satellite link was available for the BFT/FBCB2 scenario. Testing for SPITFIRE scenarios used LOS terrestrial link, manipulated to simulate a satellite down link.

2.2.3.1 (U) Baseline Link Configuration

2.2.3.1.1 (S) General. The HMMWVs from the previous intraconvoy test scenarios and a USAEPG Joint Tactical Radio System (JTRS) test trailer were utilized to construct the various radio links. The hardtop HMMWV (M1026) and a USAEPG JTRS test trailer played the role of the base site. The softtop HMMWV (M1035) played the role of a convoy element and remained at the test site previously used by the tail vehicle in the intraconvoy scenarios. The base site and convoy elements were sited 4 km from each other at the YPG test area. Voice and data messages were sent from the base site to the convoy element. Reverse message traffic was not sent because the IED jammers were located only within the convoy.

2.2.3.1.2 (S) SINCGARS. The network was operated using a 1,000-frequency hopset structurally similar to the one used in Iraq operations. Frequencies conflicting with those used by the IED jammers were not removed from the hopset. The base site SINCGARS transmitted out of the JTRS test trailer using a 10-meter high OE-254 antenna set. The base site SINCGARS transmit power levels were set to high power (4.5 W), then further attenuated to provide a received signal level (RSL) of -85 decibels referenced to 1 milliwatt (dBm) at the receiving convoy element site. The RSL was derived from experience in past SINCGARS testing. The convoy element vehicle was configured as in the previous intraconvoy scenarios. Antenna placements remained the same as depicted in figure 1. Probability of radio link synchronization was measured by sending 10 short data messages and manually counting the receptions. End-to-end message quality was determined by measuring the BER of the above 10 short data messages. BERs of 8 percent or less indicate that usable voice or data message operations are possible. No IED jammers were turned on during this scenario portion.

2.2.3.1.3 (S) EPLRS/FBCB2. The network was operated with the EPLRS radio programmed to use all available channels. Channels whose frequencies would conflict with those used by the IED jammers were not removed. The base site EPLRS transmitted out of the JTRS test trailer using an AS 3449 EPLRS vehicular antenna mounted to the mast on the trailer. The base site EPLRS transmit power levels were set to 3 W to provide an RSL that replicated those from a distant unit. Manually inserted attenuation could not be used because the EPLRS detects it as an antenna fault and sets its transmit power to the lowest level, which would not have provided a viable test link. End-to-end message quality was determined by counting the number of messages accepted by the receive end (convoy element) FBCB2. The base site FBCB2 was used to create and send 50 free-text messages via the EPLRS radio link to the tail site. No IED jammers were turned on during this scenario portion.

2.2.3.1.4 (S) BFT/FBCB2. Testing was conducted at USAEPG, Fort Huachuca, Arizona, as a post-BPC test effort. USAEPG test personnel installed BFT in each of two softtop command-type HMMWVs (M1035). One played the role of the distant base station, the other the role of a convoy element. One WARLOCK-Red was installed in the HMMWVs playing the role of the convoy element vehicle. WARLOCK-Green and SSVJ were not tested. Real satellite link geometry was used for the communications RF link. End-to-end message quality was determined counting the number of messages accepted by the receive end (convoy element) FBCB2. The base site end FBCB2 was used to create and send 50 free-text messages via the EPLRS radio link to the convoy element HMMWV. No IED jammers were turned on during this scenario portion.

2.2.3.1.5 (S) SPITFIRE. The base site SPITFIRE transmitted out of the hardtop HMMWV (M1026) but used a Near Term Digital Radio (NTDR) antenna mounted to the side of the JTRS test trailer. A simulated satellite downlink to the SPITFIRE radio was created by selecting a frequency in the normal downlink range of 240–270 MHz and attenuating the base site transmit signal to a -85 dBm RSL at the receiving convoy element site. End-to-end message quality was subjectively determined by counting the number of received voice messages of usable and understandable quality. Test personnel at the base site transmitted 20 voice messages to other test personnel sitting in the convoy element HMMWVs. No IED jammers were turned on during this scenario portion.

2.2.3.2 (S) Baseline Link with IED Countermeasures Co-located in Same Vehicle. In this scenario, the IED jammers and communications equipment are installed in the same convoy element vehicle. Each of the above baseline performance tests was repeated while the IED jammers were turned on, one at a time. Only one IED jammer was operational at any time. The BFT/FBCB2 was omitted due to expired test time.

2.2.3.3 (S) Baseline Link with IED Countermeasures Located in Different Vehicle. This scenario was an excursion to evaluate a mitigation method to lessen the Blue Force communications degradation caused by operating the IED jammers. In this scenario, the IED jammers are placed in a separate vehicle and stood off designated distances from the victim vehicle containing the Blue Force communications equipment. The intent is to allow communications at the convoy element vehicle while keeping it within the protection zone provided by a nearby IED jammer in a different vehicle. Standoff distances of 50 meters and 100 meters were chosen because they corresponded to postulated convoy vehicle intervals. After moving the IED jammer to another vehicle, each of the above baseline performance tests was repeated while the IED jammers were turned on, one at a time. Only one IED jammer was operational at any time.

2.2.4 (U) Test Findings

2.2.4.1 (S) Baseline Link with IED Countermeasures Co-located in Same Vehicle

2.2.4.1.1 (S) SINCGARS. No communications across the base-to-convoy radio link were possible when either the WARLOCK-Red or the SSVJ was operating within the same vehicle. The WARLOCK-Green did not prevent usable communications.

2.2.4.1.2 (S) EPLRS/FBCB2. No communications across the base-to-convoy radio link were possible when either the WARLOCK-Red or the SSVJ was operating within the same vehicle. The WARLOCK-Green did not prevent usable communications.

2.2.4.1.3 (S) BFT/FBCB2. No communications across the base-to-convoy radio link were possible when the WARLOCK-Red was operating within the same vehicle. The WARLOCK-Green and SSVJ effects have not been tested. Testing at YPG was canceled due to time constraints. The results presented here are from follow-on testing conducted at USAEPG, Fort Huachuca.

2.2.4.1.4 (S) SPITFIRE. Communications across the base-to-convoy radio link were not affected by operation of any of the three IED jammers.

2.2.4.2 (S) Baseline Link with IED Countermeasures Located in Different Vehicle

2.2.4.2.1 (S) SINCGARS. Using a 50-meter jammer standoff distance between the communications vehicle and the IED jammer vehicle allowed usable communications when either the WARLOCK-Red or SSVJ was operated in the jammer vehicle.

2.2.4.2.2 (S) EPLRS/FBCB2. Using a 50-meter jammer standoff distance between the communications vehicle and the IED jammer vehicle allowed usable communications when the WARLOCK-Red was operated in the jammer vehicle. The SSVJ required a 100-meter standoff distance.

2.2.4.2.3 (S) BFT/FBCB2. Using a 50-meter jammer standoff distance between the communications vehicle and the IED jammer vehicle allowed usable communications when the WARLOCK-Red was operated in the jammer vehicle. The WARLOCK-Green and SSVJ mitigation methods have not been tested. Testing at YPG was canceled due to time constraints. The results presented here are from follow-on testing conducted at USAEPG.

2.2.4.2.4 (S) SPITFIRE. No standoff testing required. Communications across the base-to-convoy radio link were not affected by operation of any of the three IED jammers.

2.2.5 (U) Technical Analysis

2.2.5.1 (S) General Discussion. The major element affecting usable communications is the S/N at the radio receiver. Raising the S/N increases receiver performance, lowering it degrades performance. The ratio can be increased by raising the desired signal strength or by lowering the undesirable noise presented to the receiver's antenna. The only available option to increase the S/N in this scenario was standing off the IED jammer to decrease the undesired noise presented to the receiver's antenna.

2.2.5.2 (S) SINCGARS. At least two methods are readily available to allow usable communications via SINCGARS between base and convoy elements.

a. (S) *Frequency Coordination and Hopset Tailoring.* The first, which was not explored in this time-constrained test, is frequency coordination and SINCGARS hopset tailoring around IED jammer frequencies. After reviewing the in-country hopset, there appears to be sufficient RF spectrum available to trade off frequencies for jammer use. One potential problem will be the RF spectral purity and spurious signals and harmonics generated by the jammers in addition to their intended transmit frequencies. This could be resolved by trading off more SINCGARS frequencies and/or cleaning up the jammers signals via better internal filters or COTS external filters. Another potential problem could be chaos within the SINCGARS networks if there are continuous changes to the SINCGARS hopsets and their distribution is not timely and thorough throughout the affected units.

b. (S) *Jammer Standoff.* Easily implemented if the jammers can protect multiple vehicles.

2.2.5.3 (S) EPLRS/FBCB2. Again, at least two methods are readily available to allow usable communications via EPLRS/FBCB2 between base and convoy elements.

a. (S) *Frequency Coordination and EPLRS Channel Tailoring.* The principles discussed in the above SINCGARS method are applicable.

b. (S) *Jammer Standoff.* Easily implemented if the jammers can protect multiple vehicles.

2.2.5.4 (S) BFT/FBCB2. The WAROCK-Red was not expected to impact BFT operation, since the BFT receives at much higher frequencies than the WARLOCK-Red transmit frequencies. Additional test excursions show that BFT degradation occurs only when both the lowband and midband units are transmitting. Operation of only one-half of the WARLOCK-Red system does not impact BFT communications. Possibilities are that—

a. (S) Combined WARLOCK-Red unwanted spurious emissions have sufficient bandwidth to impact BFT.

b. (S) Combined WARLOCK-Red transmitter energy overloads the BFT receiver.

c. (S) Combined WARLOCK-Red transmitter causes intermodulation products within the active components of the BFT system.

Further testing exploring add-on low pass filtering and antenna separation options should be conducted. Until then, jammer standoff appears to be the only viable mitigation technique, assuming that the WARLOCK-Red can protect multiple vehicles.

2.2.5.5 (S) SPITFIRE. Use frequency coordination if an EMC should occur in the near future.

SECTION 3. APPENDICES (U)

INTENTIONALLY BLANK

APPENDIX A. ABBREVIATIONS (U)

AM	amplitude modulation
ASK	armored survivability kit
BER	bit error rate
BFT	Blue Force Tracking
COMSEC	communications security
COTS	commercial off-the-shelf
C^2	command and control
DAMA	demand assigned multiple access
dBm	decibels referenced to 1 milliwatt
DTC	(US Army) Developmental Test Command
EMUT	Enhanced Manpack Ultrahigh Frequency Terminal
EPLRS	Enhanced Position Location Reporting System
FBCB2	Force XXI Battle Command, Brigade and Below
FH	frequency hopping
FOM	figure of merit
FRS	Family Radio Service
GMRS	General Mobile Radio Service
GPS	Global Positioning System
HMMWV	high mobility, multipurpose, wheeled vehicle
JTRS	Joint Tactical Radio System
km	kilometer
LOS	line of sight
MBMMR	Multiband Multimission Radio
MCR	message completion rate
MHz	megahertz

NTDR	Near Term Digital Radio
PLGR	Precision Lightweight Global Positioning System Receiver
RF	radio frequency
RSL	received signal level
SATCOM	satellite communications
SA	situational awareness
SC	single channel
SINCGARS	Single Channel Ground and Airborne Radio System
SSVJ	Self-screening Vehicle Jammer
S/N	signal-to-noise ratio
TOC	tactical operations center
UHF	ultrahigh frequency
USAEPG	US Army Electronic Proving Ground
VHF	very high frequency
W	watt

APPENDIX B. DISTRIBUTION LIST (U)

Agency	Copies
PROGRAM MANAGER SIGNALS WARFARE ATTN SFAE IEW&S SG LTC JOHN MASTERSON 296 SHERRILL AVENUE FORT MONMOUTH NJ 07703	1
YUMA TEST CENTER ATTN CSTE DTC YP YT AC EA MS MARY BETH WEAVER 301 C ST YUMA AZ 85365-9498	1
DEVELOPMENTAL TEST COMMAND ATTN CSTE DTC CS COL JOHN ROONEY BLDG 314 ROOM 208 ABERDEEN PROVING GROUND MD 21005-5055	1

INTENTIONALLY BLANK