JSC-PR-03-026

DEPARTMENT OF DEFENSE

JOINT SPECTRUM CENTER

ANNAPOLIS, MARYLAND 21402

PREDATOR UAV C-BAND DATA LINK EMC WITH 5-GHZ CFR 47 PART 15 AND PART 90 DEVICES

Prepared for

Air Combat Command UAV Special Mission Office (ACC/DR-UAV)
216 Sweeney Blvd, Room 109
Langley AFB, VA 23665

JSC Project Engineer

Capt Heather White

NOVEMBER 2003

PROJECT REPORT

Prepared by

Steve Bonter and Clifford Price

Alion Science and Technology
Under Contract to
Department of Defense

This report was prepared by Alion Science and Technology under Contract DCA100-00-C-4012 in support of the DoD Joint Spectrum Center (JSC) in Annapolis, Maryland.

This report has been reviewed by the following Alion personnel:

Steven W. Bonter

STEVEN W. BONTER
Project Manager, SENTEL

Robert F. D[illegible] for THOMAS L. SHANHOLTZ
Division Manager, Alion

This report is approved for publication.

Pete Mager

for SAMUEL G. CARBAUGH
Colonel, USAF
Chief, Acquisition Support Division
Joint Spectrum Center

Richard Larson

RICHARD B. LARSON
Technical Director
Joint Spectrum Center

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
11-2003	Project Report	

4. TITLE AND SUBTITLE
Predator UAV C-Band Data Link EMC With 5-GHz CFR 47 Part 15 and Part 90 Devices

5a. CONTRACT NUMBER
DCA100-00-C-4012

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Bonter, Steve and Price, Clifford

5d. PROJECT NUMBER
P2043

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) AND ADDRESS(ES)
Joint Spectrum Center
Acquisition Support Division (JSC/J8)
2004 Turbot Landing
Annapolis, MD 21402-5064

8. PERFORMING ORGANIZATION REPORT NUMBER
JSC-PR-03-026

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Air Combat Command
UAV Special Mission Office (ACC/DR-UAV)
216 Sweeney Blvd, Room 109
Langley AFB, VA 23665

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Distribution authorized to US Government agencies only; Operational Use; November 2003. Other requests shall be referred to the ACC/DR-UAV Program Office.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The Predator Unmanned Aerial Vehicle (UAV) line-of-sight command link and return link frequency assignments are authorized for simultaneous operations of four General Atomics Aeronautical Systems Incorporated Predator air vehicles at Indian Springs Air Force Auxiliary Field. With increased operational tempo of RQ-1/MQ-1 Predator and the introduction of MQ-9 Hunter-Killer (Predator B®) operations, requirements have been identified for simultaneous operations of seven Predator air vehicles at Indian Springs Air Force Auxiliary Field. As part of the RQ-1/MQ-1/9 beddown of communications architecture, ACC/DR-UAV requested the JSC to perform electromagnetic compatibility (EMC) analyses to ensure EMC with unlicensed devices operating under the Code of Federal Regulations (CFR), specifically CFR 47 Parts 15.245, 15.247, 15.249, 15.401, and Part 90.

A first cull noise-limited analysis was performed. A detailed interference-limited analysis was performed for cases where electromagnetic interference (EMI) was predicted by the noise-limited analysis. No EMI problems were identified for the analyzed operational location. The data in this report was current as of 15 July 2003.

15. SUBJECT TERMS
Predator, UAV, C-Band, Data Link, FM, FSK, CFR 47 Part 15, CFR 47 Part 90, FCC, ISAFAF, intersite analysis

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Capt Heather White
U	U	U	SAR	33	19b. TELEPHONE NUMBER *(include area code)* (410) 293-2681, DSN 281-2681

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

PREFACE

The Joint Spectrum Center (JSC), a field activity of the Defense Information Systems Agency (DISA), was established to provide advice and assistance on all matters regarding the electromagnetic battle space. Support is provided to the Secretary of Defense, the Joint Staff, the military departments, combatant commands, defense agencies, and other agencies of the US Government. The JSC works closely with the Joint Staff, Director for Command, Control, Communications, and Computer Systems, and the Assistant Secretary of Defense for Networks and Information Integration on spectrum matters. Direct support is provided to the Unified Commands and Joint Task Force Commanders on electromagnetic battle space issues, including spectrum management and electronic warfare deconfliction. Support to Department of Defense (DoD) components and the US Government is provided through a sponsor-reimbursed, electromagnetic compatibility (EMC) program that provides EMC analyses for specific projects.

Comments regarding this report should be submitted to the Commander, JSC, 2004 Turbot Landing, Annapolis, MD 21402-5064

EXECUTIVE SUMMARY

The Predator Unmanned Aerial Vehicle (UAV) line-of-sight command link and return link frequency assignments are authorized for simultaneous operations of four General Atomics Aeronautical Systems Incorporated Predator air vehicles at Indian Springs Air Force Auxiliary Field (ISAFAF). With increased operational tempo of RQ-1/MQ-1 Predator and the introduction of MQ-9 Hunter-Killer (Predator B®) operations, requirements have been identified for simultaneous operations of seven Predator air vehicles at IAFAF. As part of the RQ-1/MQ-1/9 beddown of communications architecture, ACC/DR-UAV requested the Joint Spectrum Center to perform electromagnetic compatibility (EMC) analyses to ensure EMC with unlicensed devices operating under the Code of Federal Regulations (CFR), specifically CFR 47 Parts 15.245, 15.247, 15.249, 15.401, and Part 90.

Systems representative of CFR 47 Part 15 and Part 90 devices that operate in the 5250-5850 megahertz band were identified for analysis as follows:

- 15.245 industrial point-to-point microwave
- 15.247 residential indoor and industrial outdoor radio local area network (RLAN)
- 15.249 outdoor video surveillance
- 15.401 outdoor industrial unlicensed national information infrastructure (U-NII)
- 90 outdoor industrial dedicated short range communications (DSRC) systems

A first cull noise-limited analysis was performed. A detailed interference-limited analysis was performed for cases where electromagnetic interference (EMI) was predicted. A signal-to-noise ratio threshold (S/N_T) was determined for each modulation. Signal-to-interference-plus-noise (S/(I+N)) was calculated. S/(I+N) was compared to S/N_T to quantify interference potential.

No EMI problems were identified for the analyzed operational location. Operations in closer proximity to residential and industrial areas may cause interference to potential victim systems analyzed in this report.

TABLE OF CONTENTS

Figures

Tables

GLOSSARY

ACC	Air Combat Command
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
CAL	Calculation
CFR	Code of Federal Regulations
CL	Command Link
dB	Decibel
dBm	Decibels relative to a Milliwatt
DSRC	Dedicated Short Range Communications
DTED	Digital Terrain Elevation Data
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
FCC	Federal Communications Commission
FDR	Frequency-Dependent Rejection
FDRCAL	Frequency-Dependent Rejection Calculation
FM	Frequency Modulated
FSK	Frequency Shift Keyed
GA-ASI	General Atomics Aeronautical Systems Incorporated
GCS	Ground Control Station
GDT	Ground Data Terminal
GHz	Gigahertz
I	Interference Power Received at the output of the IF filter
IEEE	Institute of Electrical and Electronics Engineers, Incorporated
IF	Intermediate Frequency
I/N	Interference-to-Noise Ratio
ISAFAF	Indian Springs Air Force Auxiliary Field
ITS	Intelligent Transportation System
JSC	Joint Spectrum Center
kbps	Kilobytes per second
km	Kilometer
LAN	Local Area Network
LNA	Low Noise Amplifier
LOS	Line-of-Sight

m	Meters
MHz	Megahertz
mW	Milliwatts
NIB	Non-Interference Basis
NII	National Information Infrastructure
NTSC	National Television System Committee
OFR	Off-Frequency Rejection
OTR	On-Tune Rejection
PCN	Personal Communications Network
PCS	Personal Communications Service
PTZ	Pan-Tilt-Zoom
QAM	Quadrature Amplitude Modulation
QPSK	Quaternary Phase Shift Keying
RF	Radio Frequency
RL	Return Link
RLAN	Radio Local Area Network
S	Desired Received Power
S/(I+N)	Signal-to-Interference-plus-Noise Ratio
S/N	Signal-to-Noise Ratio
S/N_T	Signal-to-Noise Ratio Interference Threshold
SUPERNet	Shared Unlicensed Personal Radio Network
TIREM	Terrain Integrated Rough Earth Model
UAV	Unmanned Aerial Vehicle
U-NII	Unlicensed National Information Infrastructure
W	Watts
WAN	Wide Area Network

SECTION 1 – INTRODUCTION

1.1 BACKGROUND

The Predator Unmanned Aerial Vehicle (UAV) line-of-sight (LOS) command link (CL) and return link (RL) frequency assignments are authorized for simultaneous operations of four General Atomics Aeronautical Systems Incorporated (GA-ASI) Predator air vehicles at Indian Springs Air Force Auxiliary Field (ISAFAF). The Predator C-Band link operations are authorized on an unprotected non-interference basis (NIB). With increased operational tempo of RQ-1/MQ-1 Predator and the introduction of MQ-9 Hunter-Killer (Predator B®), requirements have been identified for simultaneous operations of seven Predator air vehicles at ISAFAF. With the proliferation of unlicensed devices and the increased spectrum requirements for predator operations, the potential for electromagnetic interference (EMI) has steadily increased. To address these concerns, the Air Combat Command (ACC/DR-UAV) asked the Joint Spectrum Center (JSC) to perform an electromagnetic compatibility (EMC) analysis to assess the potential for EMC with unlicensed devices operating under the Code of Federal Regulations (CFR), specifically CFR 47 Parts 15.245, 15.247, 15.249, 15.401, and 90 as part of the RQ-1/MQ-1/9 communications infrastructure development at ISAFAF.

1.2 OBJECTIVE

The objective of this task was to quantify the level of EMI between the Predator UAV C-Band data links and coincident frequency CFR 47 Part 15 and Part 90 devices.

1.3 APPROACH

Systems representative of CFR 47 Part 15 and Part 90 devices that operate in the 5250-5850 megahertz (MHz) band were identified for analysis. These include:

- 15.245 industrial point-to-point microwave
- 15.247 residential indoor and industrial outdoor radio local area network (RLAN)
- 15.249 outdoor video surveillance
- 15.401 outdoor industrial unlicensed national information infrastructure (U-NII)
- 90 outdoor industrial dedicated short range communications (DSRC) systems

According to database records, the Predator ground data terminal (GDT) antenna height at ISAFAF is 12-meters (m) and the GDT is located at 36°35'12" N latitude, 115°40'24" W longitude.[1-1] The Predator UAV altitude of 9.144 kilometers (km) was also extracted from Reference 1-1. Residential and industrial antenna heights were assumed to be 5-m and 10-m, respectively. The Predator UAV operates primarily north and west of ISAFAF.[1-2] Since the residential and industrial areas are located to the south and east of the ISAFAF, assuming that the UAV operating location was the same as the GDT location on ISAFAF, constituted a worst case scenario. The minimum distance from the Predator data link terminals to the nearest major residential area (36°21'25" N latitude, 115°21'26" W longitude) and major industrial area (36°18'44" N latitude, 115°17'53" W longitude) was 38.1-kilometers (km) and 45.4-km, respectively, as shown in Figure 1-1.

The interference power received at the output of the intermediate frequency (IF) filter (I), was calculated by determining the propagation loss, antenna gains, frequency-dependent rejection (FDR), transmitter system loss (L_{ST}), and receiver system loss (L_{SR}).

The propagation loss term was calculated using the JSC Terrain Integrated Rough Earth Model (TIREM).[1-3] TIREM is designed to calculate propagation loss by taking into account the effects of irregular terrain along the propagation path. The model considers the effects of free-space spreading, earth-reflected wave, surface-wave propagation, diffraction, and atmospheric absorption. TIREM does not take into account man-made obstructions or foliage. The digital terrain elevation data (DTED) used by TIREM in this analysis was 15-second data. Attenuation from propagation through walls was taken into account for RLANs by adding 8.4 decibel (dB) to the path loss value.[1-4] The gain of the data link terminal transmitter antenna in the direction of the receiver antenna, and the gain of the receiver antenna in the direction of the data link terminal, were calculated using a statistical gain model and the assumption that 80 percent of the time the antenna mainbeams would be off-axis to each other by more than 36 degrees.[1-5] Appropriate FDR models were used to calculate loss as the data link terminal emissions pass through the victim receiver filters (Reference 1-3). The L_{ST} and L_{SR} were assumed to be 3-dB.

[1-1] Standard Frequency Action Format Database Record AF992503, Government Master File, 17 March 1999.

[1-2] Jatho, Derek, ACC/DR-UAV, e-mail to Steve Bonter, Sentel. Subject: *C-Band Frequency Congestion at Indian Springs AFAF NV*. 17 March 2003

[1-3] Kenneth Clubb, et al., *Technology Transfer Programs for IBM-Compatible Personal Computers: User's Manual*, ECAC-UM-87-045, Annapolis, MD: ECAC (now DoD JSC), September 1987. Includes Change 1, September 1988.

[1-4] *Characteristics of broadband radio local area networks, Draft Revision of Recommendation ITU-R M.1450-1 (Questions ITU-R 212/8 and ITU-R 142/9*, Geneva: Radiocommunication Study Group 8, 27 February 2003.

[1-5] W.R. Klocko and T.L. Strickland, *Environmental Analysis System (EASY) Statistical Gain Model for Fixed-Azimuth Antennas*, ECAC-TN-85-023, Annapolis, MD: ECAC (now DoD JSC), April 1979.

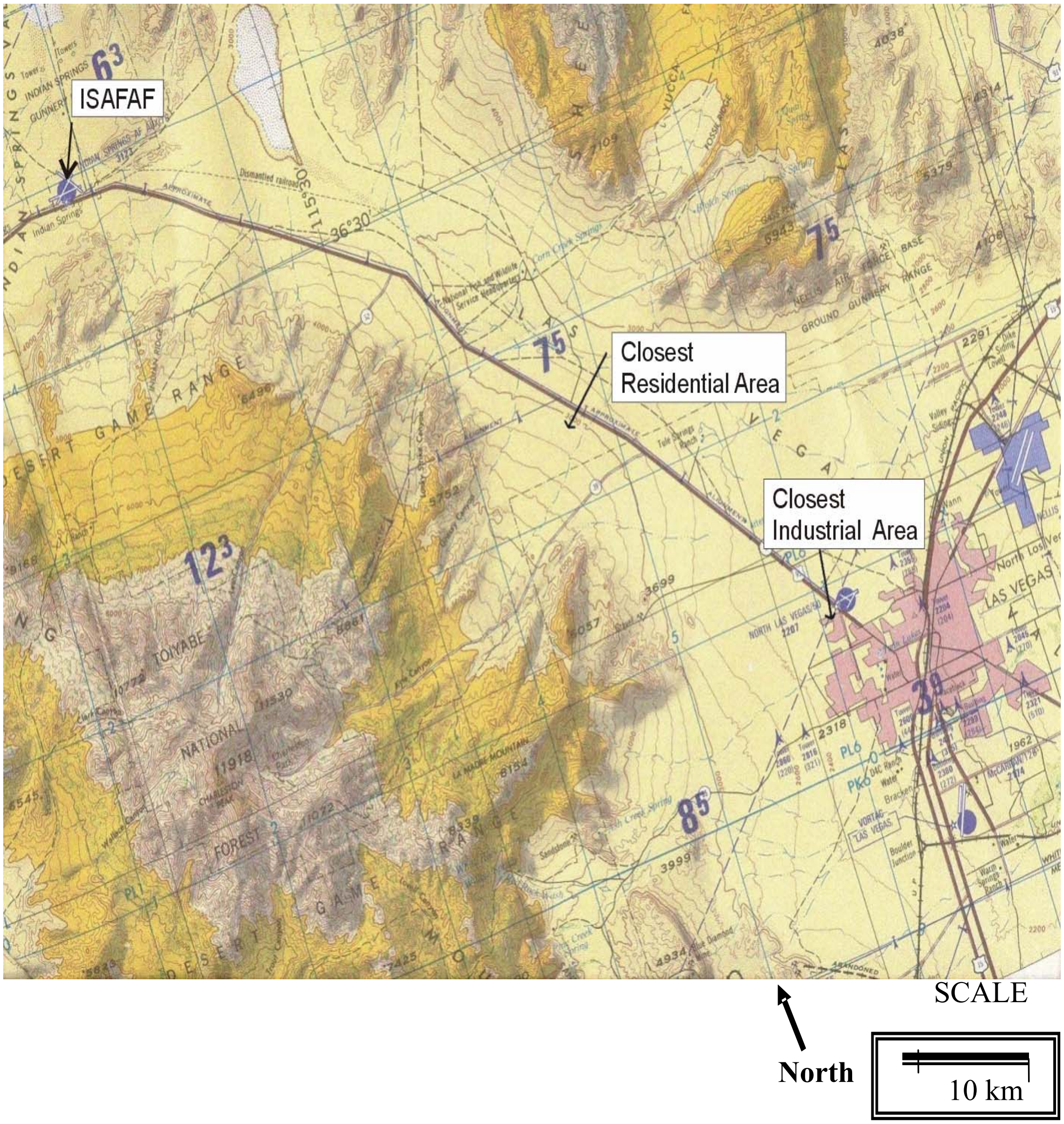

Figure 1-1. Nearest Residential and Industrial Areas

The necessary bandwidth of the system was used to estimate the 3-dB IF bandwidth of the receiver by assuming a 40 dB/decade slope. When the noise figure for systems was not available, 5-dB was assumed. I was calculated utilizing the widest victim receiver bandwidth mode. An interference-to-noise ratio (I/N) degradation threshold (I/N_T) of -9 dB was used. The -9 dB I/N_T corresponds to an increase in the receiver thermal noise floor by approximately 0.5 dB. A degradation power threshold I_T was calculated by adding the noise power in the receiver IF bandwidth (N) to I/N_T. I was compared to I_T to quantify the interference potential.

For those cases where EMI was predicted using an I/N_T of –9 dB, further analysis was performed. A signal-to-noise ratio threshold (S/N_T) was determined for each modulation. Desired communications range was estimated based on type of system. Desired received power (S) was calculated utilizing free-space path loss. Signal-to-interference-plus-noise (S/(I+N)) was calculated. S/(I+N) was compared to S/N_T to quantify interference potential. Mitigation techniques were recommended for those cases where EMI was predicted.

SECTION 2 – SYSTEM DESCRIPTION

2.1 PREDATOR UAV C-BAND LOS DATA LINK SYSTEM

The Predator data link system provides command and control information from the ground control station (GCS) to the UAV using the CL and payload data and status information from the UAV to the GCS using the RL. The transmitter and receiver units can be software configured to perform CL or RL functions. The Predator data link system utilizes two CLs and two RLs. The data link system uses 16 bit messages. The CL-configured terminals are capable of transferring data at 19.2 kilobytes per second (kbps) and 200 kbps using frequency shift keyed (FSK) modulation. The RL-configured terminals are capable of transferring either National Television System Committee (NTSC) formatted video with data subcarriers at 6.8-MHz and 7.5-MHz offset or 3.2-Mbps FSK data without the subcarriers.

The GCS contains computers, voice communications equipment, displays, and user interfaces, as well as accommodations for the pilot and payload operator. The GCS is connected to the GDT, which consists of the antenna system, a diplexer, a custom-built low noise amplifier (LNA), transmitters, and receivers. The antenna system contains three antennas: a 33-dBi parabolic dish, a 15-dBi horn, and a 6-dBi stacked dipole array. The parabolic dish is used when the UAV is beyond approximately 48-km in range. The horn is used when the UAV is within 48 km. The stacked dipole array is typically not used. The diplexer permits full-duplex operation. The GDT radio frequency (RF) configurations are shown in Figure 2-1. The data link component RF characteristics are listed in Table 2-1.[2-1]

The UAV data link system contains antennas, diplexer, computer, transmitters, and receivers. The antennas utilized by the UAV are: a 15-dBi horn, a 3-dBi stacked-dipole array, and a 0.3-dBi stub antenna. The horn is used by the primary data link. The stacked-dipole array is used by the secondary data link. The stub can be used with the primary data link, although it is typically not used. The diplexer permits full-duplex operation. The computer parity checks data, selects the optimum CL, and discards erroneous messages.

The final amplifier stage of the UAV and GDT data link transmitter can be software-controlled to switch between 1-mW and 10-W output power. The 1-mW low power mode is used for ground testing. The UAV transmitter will automatically revert to 10-W if the link cannot be maintained at 1-mW.

[2-1] *Application for Equipment Frequency Allocation (DD Form 1494) for Predator C-Band MAE UAV Medium Altitude Endurance Unmanned Aerial Vehicle*, J/F-12/7253, Washington, DC: MCEB, 9 April 2003.

Table 2-1. Predator UAV C-Band Data Link Characteristics

Characteristics	Specifications			
Transmitter				
Tuning Range, MHz	5250-5850			
Tuning Increment, MHz	1			
Transmitter Power, dBm	40			
Link Type	CL		RL	
Emission Designators	560KF1D	88K3F1D	17M0F9F	4M72F1D
Emission Bandwidth, MHz				
-3-dB	0.34	0.063	8.5	2.8
-20-dB	0.42	0.088	18.0	20.0
-40-dB	NA	0.219	NA	NA
-60-dB	1.2	0.671	46.2	66.0
Diplexer				
Low-Band Port Frequency Band, MHz	5250-5475			
Cross-Over Frequency Band, MHz	5475-5625			
High-Band Port Frequency Band, MHz	5625-5850			
GDT Parabolic Dish Antenna				
Gain, dBi	33.0			
Antenna Illumination Type	Cosecant Squared			
UAV Horn Antenna				
Manufacturer	Technical Associates, Inc.			
Model Number	11572			
Gain, dBi	15.0			
Azimuth/Elevation Beamwidth, degrees	30/30			

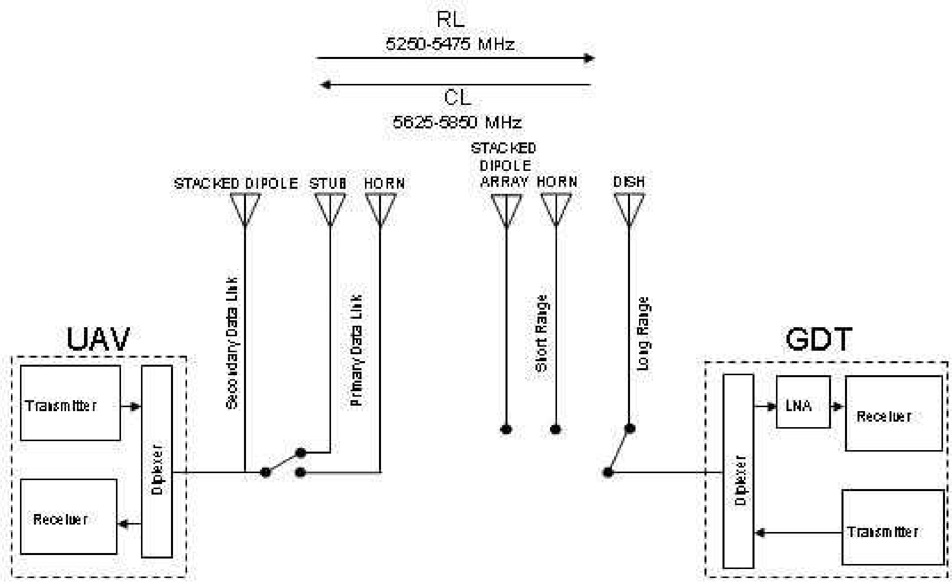

Figure 2-1. Predator System Configuration

2.2 5-GHz UNLICENSED DEVICES

Systems representative of CFR 47 Parts 15.245, 15.247, 15.249, 15.401, and 90 were selected. These include industrial point-to-point microwave, residential indoor and industrial outdoor RLAN, outdoor industrial video surveillance, outdoor industrial U-NII, and outdoor industrial DSRC.

2.2.1 CFR 47 Part 15.245 Point-to-Point Microwave

Point-to-point microwave enables operation of wireless links from 1-km to over 50-km. This service is used by government, mobile and emergency services, private wireless users, cellular and Personal Communications Service (PCS)/Personal Communications Network (PCN) providers, local area networks (LAN), and wide area networks (WAN), and internet access providers. Direct sequence spread spectrum technology is utilized to reduce interference susceptibility. Point-to-point microwave also provides wireless interconnection for private wireless access, internet service access, LAN/WAN remote bridging, cellular, and PCS/PCN systems. Point-to-point microwave utilizes both E1 and T1 digital interfaces. The frequency plans are shown in Table 2-2.[2-2]

Table 2-2. CFR 47 Part 15.245 Channel Plans

Frequency Pair Designation	Frequency
E1	
A	5.735 and 5.800 GHz
B	5.755 and 5.820 GHz
C	5.775 and 5.840 GHz
2xT1	
A	5.741 and 5.803 GHz
B	5.772 and 5.834 GHz

Aurora™ is a family of point-to-point digital microwave radios employing spread spectrum technology that conform to CFR 47 Part 15.245. These radios offer E1/T1 wireless service for LOS distances covering approximately 50-km. Aurora™ radios operate in the 5.8 GHz frequency band and provide wireless interconnection for private wireless access, internet service, LAN/WAN, cellular and PCS/PCN systems. The technical characteristics for the Aurora™ 5800 are shown in Table 2-3 (Reference 2-2).

[2-2] *Specification Sheet, Aurora 5800 5.8 GHz E1/T1 Spread Spectrum Digital Radio*, Redwood Shores, CA: Harris Microwave Communications Division. Available from http://www.harris.com; INTERNET.

Table 2-3. CFR 47 Part 15.245 Point-to-Point Microwave Radio Characteristics

Characteristics	Specifications		
General			
Frequency Range, MHz	5725-5850		
Data Capacity, Mbit/s	2.048 (E1)	1.544 (T1)	
Maximum Range, km	50 (LOS)		
Transmitter Power, dBm	18.5		
Radio Frequency (RF) Channel Bandwidth, MHz	18 (E1)	30 (T1)	
Modulation	Differential Quaternary Phase Shift Keying		
Receiver			
Receiver Selectivity, MHz -3 dB -20 dB -40 dB	(E1) 0.8* 2.0* 6.3*		
Noise Figure, dB	7.0		
I_T, dBm	-117.0 (E1)		
$(S/N)_T$, dB	20*		
Sensitivity, dBm		Outage Point	Operating Point
	T1	-89 (-90 typical)	-87 (-88 typical)
	E1	-87 (-88 typical)	-85 (-86 typical)
Antenna			
Gain, dBi	28.5		
Polarization	Linear*		
* Estimated			

2.2.2 CFR 47 Part 15.247 RLAN

RLANs enable portability. New laptop and palmtop computers are very portable, providing interactive services when connected to a wired LAN. However, when connected to a wired LAN, the portability feature is lost. Broadband RLANs permit computing devices to remain portable while operating at maximum potential. Technical characteristics of the Institute of Electrical and Electronics Engineers (IEEE) Standard 802.11a systems are provided in Table 2-4 (Reference 1-4).

Table 2-4. IEEE Standard 802.11a RLAN Characteristics

Characteristics	Specifications	
General		
Frequency Range, MHz	5150-5250 5250-5350 5725-5825	
Communication Range, km	0.02*	
Modulation	64-Quadrature Amplitude Modulation (QAM) Orthogonal Frequency-Division Multiplexing (OFDM) 16-QAM-OFDM Quaternary Phase Shift Keying (QPSK) OFDM Binary Phase Shift Keying (BPSK) OFDM	
Data Capacity, Mbit/s	6, 9, 12, 18, 24, 36, 48, and 54	
Transmitter Power, dBm	30	
Channel Increments, MHz	20	
Receiver		
Receiver Selectivity, MHz -3 dB -20 dB -40 dB	6-Mbps BPSK 4.4* 12.0* 38.0*	36-Mbps 16-QAM 3.4* 9.0* 28.0*
Noise Figure, dB	5.0*	
I_T, dBm	-111.6*	-112.7*
$(S/N)_T$, dB	-31*	
Sensitivity, dBm	-85.0	-73.0
Antenna		
Type	Omni-directional	
Gain, dBi	0.0*	
Polarization	Linear*	
* estimated		

2.2.3 CFR 47 Part 15.249 Video Surveillance

Video surveillance devices deliver high-resolution, real-time, full-motion video for up to seven miles LOS and are popular due to lower operational/installation costs compared to licensed microwave systems and fiber networks. The representative system considered for this analysis has 12 user-selectable channels, is capable of transmitting up to 9.6 kbps audio, sensor data alarm and detector data, and can be used to control pan-tilt-zoom (PTZ) cameras. Technical characteristics are provided in Table 2-5.[2-3, 2-4, 2-5, 2-6]

Table 2-5. CFR 47 Part 15.249 Video Surveillance Link Characteristics

Characteristics	Specifications		
General			
Frequency Range, MHz	5725-5875		
Modulation	Frequency Modulated (FM)		
Number Channels	12		
Range, km	1.6 with 15 dBi receiver antenna 6.4 with 28 dBi receiver antenna 11.2 with 31 dBi receiver antenna		
Transmitter Power, dBm	-1.5*		
Video Bandwidth, MHz	5.8		
Receiver			
Noise Figure, dB	5.0*		
Sensitivity, dBm	-80.0		
Sensitivity Criterion, BER	$1x10^{-6}$		
Receiver Selectivity, MHz -3 dB -20 dB -40 dB	 6.5 17.0* 56.0*		
I_T, dBm	-109.8*		
$(S/N)_T$	-21*		
Antennas			
Manufacturer	Trango Systems, Inc		
Model Number	AD5900-15	AD5900-28	AD5900-31
Type	Patch	Parabolic	Parabolic
Gain	15.0	28.0	31.0
Polarization	Circular		
* estimated			

2.2.4 CFR 47 Part 15.401 U-NII/SUPERNet

An amendment to Part 15 was proposed, making available 350 MHz of spectrum at 5.15-5.35 GHz and 5.725-5.875 GHz for use by a new category of high speed, wireless, digital communications on an

---

2-3 "Manufacturer Specification Sheet for 5.8 GHz Falcon Plus™," New Ipswich, NH: Airlinx Communications, Inc.; 25 July 2003. Available from Electronic Source; INTERNET, www.airlinx.com/products.cfm/product/1-113-230.htm.

2-4 "Manufacturer Specification Sheet for AD5900-15™," San Diego, CA: Trango Systems, Inc.; 18 August 2003. Available from Electronic Source; INTERNET, www.trangosys.com/DataSheets/DSW_AD590015.pdf.

2-5 "Manufacturer Specification Sheet for AD5900-28™," San Diego, CA: Trango Systems, Inc.; 18 August 2003. Available from Electronic Source; INTERNET, www.trangosys.com/DataSheets/DSW_AD5900-28.pdf.

2-6 "Manufacturer Specification Sheet for AD5900-31™," San Diego, CA: Trango Systems, Inc.; 18 August 2003. Available from Electronic Source; INTERNET, www.trangosys.com/DataSheets/DSW-AD-5900-31.pdf.

unlicensed basis. The U-NII/Shared Unlicensed Personal Radio Network (SUPERNet) devices will support the creation of new wireless LANs, facilitating wireless access to the U-NII.[2-7]

U-NII systems provide high-speed, wide-band, wireless access to the U-NII, and other computer networks at data rates up to 100-Mbps. This service supports ad hoc peer-to-peer communications, LANs, community networks, and other communications over 10 to 15 km. U-NII frequency bands are 5.15-5.35 GHz and 5.725-5.875 GHz. The U-NII band will be limited to asynchronous packet-based transmissions. Technical characteristics of a representative U-NII system are provided in Table 2-6.[2-8]

Table 2-6. U-NII Characteristics

Characteristics	Specifications		
System			
Frequency, MHz	5150-5250	5250-5350	5725-5825
Use	Indoors	Indoors/Outdoors	Indoors/Outdoors
Range, km	Not Available	3	6
Transmitter Power, dBm	28*		
Modulation	64-QAM*		
Digital Capacity, Mbps	100.0		
Receiver			
Receiver Selectivity, MHz			
-3 dB	9.2*		
-20 dB	25.0*		
-40 dB	80.0*		
Noise Figure, dB	5.0*		
I_T, dBm	-108.4*		
$(S/N)_T$, dB	-23*		
Antenna			
Gain, dBi	6.0		
Polarization	Linear		
* estimated			

2.2.5 CFR 47 Part 90 DSRC

Seventy-five MHz of spectrum is allocated to DSRC for Intelligent Transportation Systems (ITS). DSRC systems are being designed that require a short range, wireless link to transfer information

2-7 *Amendment of the Commission's Rules to Provide for Unlicensed NII/SUPERNet Operations in the 5 GHz Frequency Range*, Washington DC: ET Docket No. 96-102 RM-8653, Federal Communications Commission.

2-8 "*Specification Sheet for Stratum*™ *100 High Capacity Wireless Transport*," New Ipswich, NH: Air Link Communications, Inc., 25 July 2003. Available from Electronic Source, INTERNET.

between vehicles and roadside systems. ITS services are expected to improve traveler safety, decrease traffic congestion, and facilitate reduction of air pollution and conservation of fossil fuels.[2-9] Technical Characteristics of DSRC devices are provided in Table 2-7.[2-10]

Table 2-7. CFR 47 Part 90 DSRC Characteristics

Characteristics	Specifications
General	
Frequency Range, MHz	5850-5925
Communication Range, km	0.2*
Transmitter Power, dBm	28.8
Modulation	BPSK, QPSK, 16-QAM, 64-QAM
Data Capacity, Mbit/s	3, 4.5, 6, 9, 12, 18, 24, and 27
Channels, MHz	5860, 5870, 5875, 5880, 5890, 5900, 5905, 5910, 5920
Receiver	
Receiver Selectivity, MHz -3 dB -20 dB -40 dB	(27-Mbps 64-QAM) 2.6* 6.8* 21.2*
Noise Figure, dB	10
I_T, dBm	-113.9*
$(S/N)_T$, dB	-23*
Antenna	
Transmitter Antenna Gain, dBi	6.0*
Receiver Antenna Gain, dBi	0.0*
Polarization	Right Hand Circular
* estimated	

2-9 *Amendment of Parts 2 and 90 of the Commission's Rules to Allocate the 5.850-5.925 GHz Band to the Mobile Service for Dedicated Short Range Communications of Intelligent Transportation Services*, ET Docket No. 98-95 RM-9096, Washington DC: Federal Communications Commission, 11 June 1998.

2-10 *Standard Specification for Telecommunications and Information Exchange Between Roadside and Vehicle Systems – 5 GHz Band Dedicated Short Range Communications (DSRC) Medium Access Control (MAC) and Physical Layer (PHY) Specifications*, West Conshohocken, PA: Designation E2213-02, ASTM International, November 2002.

SECTION 3 – ANALYSIS METHODOLOGY

3.1 RECEIVED INTERFERENCE POWER CALCULATIONS

Equation 3-1 was used to calculate the received interference power, I, at the output of the IF filter.

$$I = P_T + G_T - L_{ST} - L_P + G_R - L_{SR} - FDR \tag{3-1}$$

where I = interference power after the IF filter, in dBm
P_T = transmitter power, in dBm
G_T = gain of the transmitter antenna in the direction of the receiver antenna, in dBi
L_{ST} = transmitter system loss (e.g., cable loss, polarization mismatch, etc.), 3-dB
L_P = path loss, in dB
G_R = gain of the receiver antenna in the direction of the transmitter antenna, in dBi
L_{SR} = receiver system loss (e.g., cable loss, polarization mismatch, etc.), 3-dB
FDR = frequency-dependent rejection, in dB

The terms in Equation 3-1 are described in subsections 3.1.1 through 3.1.5. Calculations are shown in Table 3-1.

3.1.1 Transmitter Power

The transmitter powers of 40 dBm were obtained from Reference 2-1.

3.1.2 Transmitter and Receiver Antenna Gain

The gain of the data link terminal transmitter antenna in the direction of the receiver antenna, and gain of the receiver antenna in the direction of the data link terminal were calculated using the JSC statistical antenna gain model (Reference 1-5). It was assumed that 80 percent of the time the antenna mainbeams would be off-axis to each other by more than 36 degrees.

3.1.3 Transmitter and Receiver System Losses

Transmitter and receiver system losses consist of cabling losses, component losses and antenna polarization mismatch of 3-dB were assumed.

Table 3-1. Received Interference Power Calculations

Victim	Frequency (MHz)	P_T (dBm)	G_T (dBi)	L_{ST} (dB)	L_P (dB)	G_R (dBi)	L_{SR} (dB)	FDR (dB)	I (dBm)
560KF1D Command Link to Residential Victim									
RLAN	5250	40	-2	3	210	0	3	0	-178
Video Surveillance	5725	40	-2	3	203	-1	3	0	-173
88K3F1D Command Link to Residential Victim									
RLAN	5250	40	-2	3	210	0	3	0	-178
Video Surveillance	5725	40	-2	3	203	-1	3	0	-173
17M0F9F Return Link to Residential Victim									
RLAN	5250	40	4	3	147	0	3	4	-113
Video Surveillance	5725	40	4	3	140	-1	3	1	-104
4M72F1D Return Link to Residential Victim									
RLAN	5250	40	4	3	147	0	3	1	-110
Video Surveillance	5725	40	4	3	140	-1	3	1	-103
560KF1D Command Link to Industrial Victim									
Point-to-Point Microwave	5725	40	-2	3	226	0	3	0	-194
RLAN	5250	40	-2	3	224	0	3	0	-193
Video Surveillance	5725	40	-2	3	226	-1	3	0	-195
U-NII	5250	40	-2	3	224	0	3	0	-193
DSRC	5850	40	-2	3	226	0	3	0	-194
88K3F1D Command Link to Industrial Victim									
Point-to-Point Microwave	5725	40	-2	3	226	0	3	0	-194
RLAN	5250	40	-2	3	224	0	3	0	-193
Video Surveillance	5725	40	-2	3	226	-1	3	0	-195
U-NII	5250	40	-2	3	224	0	3	0	-193
DSRC	5850	40	-2	3	226	0	3	0	-194
17M0F9F Return Link to Industrial Victim									
Point-to-Point Microwave	5725	40	4	3	141	0	3	10	-113
RLAN	5250	40	4	3	140	0	3	4	-106
Video Surveillance	5725	40	4	3	141	-1	3	1	-105
U-NII	5250	40	4	3	140	0	3	0	-102
DSRC	5850	40	4	3	141	0	3	5	-108
4M72F1D Return Link to Industrial Victim									
Point-to-Point Microwave	5725	40	4	3	141	0	3	6	-109
RLAN	5250	40	4	3	140	0	3	1	-103
Video Surveillance	5725	40	4	3	141	-1	3	1	-105
U-NII	5250	40	4	3	140	0	3	0	-102
DSRC	5850	40	4	3	141	0	3	2	-105

3.1.4 Path Loss

The propagation loss term was calculated using the TIREM model (Reference 1-3). TIREM is designed to calculate propagation loss by taking into account the effects of irregular terrain along the propagation path. The model considers the effects of free-space spreading, earth-reflected wave, surface-wave propagation, diffraction, and atmospheric absorption. TIREM does not take into account man-made obstructions or foliage. The DTED used by TIREM in this analysis was 15-second data.

3.1.5 Frequency-Dependent Rejection

FDR was calculated for in-band system interactions using the JSC FDR Calculation (FDRCAL) model. FDR can be defined as the attenuation of a received signal passing through RF and IF filter stages of a receiver. This attenuation includes on-tune rejection (OTR) when the transmitted signal emission bandwidth is greater than the receiver filter bandwidth and the additional off-frequency rejection (OFR) due to frequency separation between the transmitted signal carrier frequency and the receiver tuned frequency.

Emission bandwidths and RF/IF selectivity curves for the source and victim systems listed in Tables 2-1 and Tables 2-2 through 2-6, respectively, were used as inputs to the FDRCAL model. The output generated by the FDRCAL model was a tabular data set describing OFR and OTR as a function of the frequency off-tuning. These values were entered into Equation 3-2.

3.2 NOISE-LIMITED INTERFERENCE THRESHOLD

Interference thresholds (I_T) were based on calculated thermal noise power for each of the victim receivers and a -9 dB I/N_T. This threshold corresponds to an increase in receiver noise level of approximately 0.5 dB. I_T was utilized as the threshold for spurious and adjacent-signal calculations, and was calculated using Equation 3-2.

$$I_T = -114 + 10 \log (B_{IF}) + F_N + I/N_T \tag{3-2}$$

where I_T = linear interference power threshold, in dBm
B_{IF} = 3-dB receiver IF bandwidth, in MHz
F_N = receiver noise figure, in dB
I/N_T = interference-to-noise ratio threshold, -9 dB.

3.3 NOISE-LIMITED ANALYSIS RESULTS

I was compared to I_T to quantify the interference potential. In cases where I was greater than I_T, an interference-limited analysis was conducted. Noise-limited results are shown in Table 3-2.

Table 3-2. Noise-Limited Analysis Calculations

Victim	Frequency (MHz)	I (dBm	I_T (dBm)	Additional Isolation Required (dB)
560KF1D Command Link to Residential Victim				
RLAN	5250	-178	-113	0
Video Surveillance	5725	-173	-110	0
88K3F1D Command Link to Residential Victim				
RLAN	5250	-178	-113	0
Video Surveillance	5725	-173	-110	0
17M0F9F Return Link to Residential Victim				
RLAN	5250	-113	-113	0
Video Surveillance	5725	-104	-110	6
4M72F1D Return Link to Residential Victim				
RLAN	5250	-110	-113	3
Video Surveillance	5725	-103	-110	7
560KF1D Command Link to Industrial Victim				
Point-to-Point Microwave	5725	-194	-117	0
RLAN	5250	-193	-113	0
Video Surveillance	5725	-195	-110	0
U-NII	5250	-193	-108	0
DSRC	5850	-194	-114	0
88K3F1D Command Link to Industrial Victim				
Point-to-Point Microwave	5725	-194	-117	0
RLAN	5250	-193	-113	0
Video Surveillance	5725	-195	-110	0
U-NII	5250	-193	-108	0
DSRC	5850	-194	-114	0
17M0F9F Return Link to Industrial Victim				
Point-to-Point Microwave	5725	-113	-117	4
RLAN	5250	-106	-113	7
Video Surveillance	5725	-105	-110	5
U-NII	5250	-102	-108	6
DSRC	5850	-108	-114	6
4M72F1D Return Link to Industrial Victim				
Point-to-Point Microwave	5725	-109	-117	8
RLAN	5250	-103	-113	10
Video Surveillance	5725	-105	-110	5
U-NII	5250	-102	-108	6
DSRC	5850	-105	-114	9

3.4 RECEIVED DESIRED POWER CALCULATIONS

Equation 3-3 was used to calculate the received desired power, S.

$$S = P_T + G_T - L_{ST} - L_P + G_R - L_{SR} \quad (3\text{-}3)$$

where S = desired power, in dBm

and all other terms are as defined previously.

The terms in Equation 3-3 are described in subsections 3.1.1 through 3.1.4. Calculations are shown in Table 3-3.

Table 3-3. Received Desired Power Calculations

System	Frequency (MHz)	P_T (dBm)	G_T (dBi)	L_{ST} (dB)	L_P (dB)	G_R (dBi)	L_{SR} (dB)	S (dBm)
Residential								
RLAN	5250	30	0	3	73	0	3	-49
Video Surveillance	5725	-2	31	3	129	31	3	-74
Industrial								
Point-to-Point Microwave	5725	19	29	3	142	29	3	-72
RLAN	5250	30	0	3	73	0	3	-49
Video Surveillance	5725	-2	31	3	129	31	3	-74
U-NII	5250	28	12	3	116	12	3	-70
DSRC	5850	29	6	3	108	0	3	-79

3.5 INTERFERENCE-LIMITED ANALYSIS RESULTS

S/(I+N) was compared to S/N_T to quantify the interference potential. In cases where S/(I+N) was greater than S/N_T, mitigation techniques would be required. Interference-limited results are shown in Table 3-4. Since there were no cases where S/(I+N) was less than S/N_T, no EMI was predicted.

Table 3-4. Interference-Limited Analysis Calculations

Victim	Frequency (MHz)	S/(I+N) (dBm	$(S/N)_T$ (dBm)	Additional Isolation Required (dB)
17M0F9F Return Link to Residential Victim				
Video Surveillance	5725	25	21	0
4M72F1D Return Link to Residential Victim				
RLAN	5250	54	31	0
Video Surveillance	5725	25	21	0
17M0F9F Return Link to Industrial Victim				
Point-to-Point Microwave	5725	35	20	0
RLAN	5250	33	31	0
Video Surveillance	5725	25	21	0
U-NII	5250	27	23	0
DSRC	5850	24	23	0
4M72F1D Return Link to Industrial Victim				
Point-to-Point Microwave	5725	33	20	0
RLAN	5250	32	31	0
Video Surveillance	5725	25	21	0
U-NII	5250	27	23	0
DSRC	5850	23	23	0

SECTION 4 – RESULTS

No EMI problems were identified for the analyzed operational location. Operations in closer proximity to residential and industrial areas may cause interference to potential victim systems analyzed in this report.

DISTRIBUTION LIST FOR PREDATOR UAV C-BAND DATA LINK EMC WITH 5-GHZ CFR 47 PART 15 AND PART 90 DEVICES JSC-PR-03-026

External	No. of Copies
ACC/DR UAV SMO (Attn: Capt. Freddie R. Rosas) 216 Sweeney Blvd, Room 109 Langley AFB, VA 23665	1
ACC/DR UAV SMO (Attn: Mr. Derek Jatho) 216 Sweeney Blvd, Room 109 Langley AFB, VA 23665	1
ASC/RAB (Attn: Mr. Jeff Brunson) 2640 Loop Road West WPAFB, OH 45433-7106	1

Internal	
J8/Capt. H. White	1
DST/S. Bonter	1
DPS	5
DPS	Camera Ready