ENGINEERING TEST REPORT

STARTRAK
Model No.: STARTRAK-RF
FCC ID: OXI1C0175

Applicant: **Polhemus Inc.**
P.O. Box 560, 1 Hercules Drive
Colchester, Vermont
U.S.A., 05446

In Accordance With

FEDERAL COMMUNICATIONS COMMISSION (FCC)
PART 15, SUBPART C, SEC. 15.247
Direct Sequence Spread Spectrum Transmitters operating in the frequency band 2412 - 2462 MHz

UltraTech's File No.: PHM1-TX

This Test report is Issued under the Authority of Tri M. Luu, Professional Engineer, Vice President of Engineering UltraTech Group of Labs ………………………………………………………… Date: ………………………	
Report Prepared by: Dan Huynh , BASc. …………………………………………………………	Tested by: Mr. Hung Trinh, RFI/EMI Technicain …………………………………………………………
Issued Date: March 13, 2000	Test Dates: Dec. 11 – 14, 1999 & Feb. 23, 2000

The results in this Test Report apply only to the sample(s) tested, and the sample tested is randomly selected.

UltraTech

3000 Bristol Circle, Oakville, Ontario, Canada, L6H 6G4
Telephone (905) 829-1570 Facsimile (905) 829-8050
Website: www.ultrat4ech-labs.com Email: vhk.ultratech@sympatico.ca

TABLE OF CONTENTS

EXHIBIT 1. INTRODUCTION

1.1. SCOPE

Reference:	FCC Part 15, Subpart C, Section 15.247:1998
Title	Telecommunication - Code of Federal Regulations, CFR 47, Part 15
Purpose of Test:	To gain FCC Certification Authorization for Direct Sequence Spread Spectrum Transmitters operating in the Frequency Band 2412 - 2462 MHz .
Test Procedures	Both conducted and radiated emissions measurements were conducted in accordance with American National Standards Institute ANSI C63.4 - American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz.
Environmental Classification:	• Light-industry, Commercial • Industry

1.2. RELATED SUBMITAL(S)/GRANT(S)

None

1.3. NORMATIVE REFERENCES

Publication	YEAR	Title
FCC CFR Parts 0-19	1998	Code of Federal Regulations – Telecommunication
ANSI C63.4	1992	American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz
CISPR 22 & EN 55022	1997 1998	Limits and Methods of Measurements of Radio Disturbance Characteristics of Information Technology Equipment
CISPR 16-1		Specification for Radio Disturbance and Immunity measuring apparatus and methods

EXHIBIT 2. PERFORMANCE ASSESSMENT

2.1. CLIENT INFORMATION

APPLICANT:	
Name:	Polhemus Inc.
Address:	P.O. Box 560, 1 Hercules Drive Colchester, Vermont U.S.A., 05446
Contact Person:	Mr. Keith Hanf Phone #: 802-655-3159 Fax #: 802-655-1439 Email Address: khanf@polhemus.com

MANUFACTURER:	
Name:	Polhemus Inc.
Address:	P.O. Box 560, 1 Hercules Drive Colchester, Vermont U.S.A.,
Contact Person:	Mr. Keith Hanf Phone #: 802-655-3159 Fax #: 802-655-1439 Email Address: khanf@polhemus.com

2.2. EQUIPMENT UNDER TEST (EUT) INFORMATION

The following information (with the exception of the Date of Receipt) has been supplied by the applicant.

Brand Name	Polhemus Inc.
Product Name	STARTRAK
Model Name or Number	STARTRAK-RF
Serial Number	E790001 (Starpak), E990001 (Stardrive), 002972451 (Starserve)
Type of Equipment	Direct Sequence Spread Spectrum Transmitters
External Power Supply	N/A
Transmitting/Receiving Antenna Type	Non-integral
Primary User Functions of EUT:	The essential function of the EUT is to correctly communicate data to and from radios over RF link.

2.3. EUT'S TECHNICAL SPECIFICATIONS

TRANSMITTER	
Equipment Type:	▪ Mobile ▪ Base station (fixed use)
Intended Operating Environment:	▪ Commercial, light industry & heavy industry
Power Supply Requirement:	12Vdc (Starpak) and Power from host PC (Starlink)
RF Output Power Rating:	23 mWatts
Operating Frequency Range:	2412 - 2462 MHz
RF Output Impedance:	50 Ohms
Channel Spacing:	5 MHz
Duty Cycle:	28 %
6 dB Bandwidth:	9.86 MHz (Starlink Slot 1) 4.00 MHz (Starlink Slot 2) 11.64 MHz (Starpak)
Emission Designation:	DSSS, Modulation Type: DQPSK
Chip/Symbol Rate:	Harris Chip set: ▪ For 2 Mb/s: 11 Mchips/s, 2 bit/symbol
Oscillator Frequencies:	40 MHz, 12.288 MHz, 44 MHz
Antenna Connector Type:	SMA (the antennas are permanently fixed to the unit at the factory, for details of assemblies refer to attached RF antenna securing)
Antenna Description:	Manufacturer: M/A-COM Inc. Type: collinear dipole, vertically polarized and omnidirectional in azimuth Model: AND-C-107 Frequency Range: 2400 – 2485 MHz In/Out Impedance: 50 Ohms Gain: 1.9 dBi

2.4. LIST OF EUT'S PORTS

StarLink				
Port Number	**EUT's Port Description**	**Number of Identical Ports**	**Connector Type**	**Cable Type (Shielded/Non-shielded)**
1	StarLink RF	1	SCSI	Shielded
2	Antenna	2	DB9	--

NOTE:

- ***Ports of the EUT which in normal operation*** *were connected to ancillary equipment through interconnecting cables via a representative interconnecting cable to simulate the input/output characteristics. RF input/output was correctly terminated to the associated antenna.*
- ***Ports which are not connected to cables during normal intended operation****: None*

StarPak				
Port Number	**EUT's Port Description**	**Number of Identical Ports**	**Connector Type**	**Cable Type (Shielded/Non-shielded)**
1	DC Power	1	2 wires	Non-shielded
2	Tether (connect to StarSever)	1	RF45	Shielded
3	Sensor	16	--	Non-shielded
4	RF45 (Not use)	1	--	--
5	Antenna	2	--	--

NOTE:

- ***Ports of the EUT which in normal operation*** *were connected to ancillary equipment through interconnecting cables via a representative interconnecting cable to simulate the input/output characteristics. RF input/output was correctly terminated to the associated antenna.*
- ***Ports which are not connected to cables during normal intended operation****: None*

2.5. ANCILLARY EQUIPMENT

The EUT was tested while connected to the following representative configuration of ancillary equipment necessary to exercise the ports during tests:

Ancillary Equipment # 1	
Description:	Modem
Brand name:	GVC
Model Name or Number:	SM-24N/S
FCC ID:	DK4FSM24NS
Cable Type:	Shielded
Connected to EUT's Port:	DB9

Ancillary Equipment # 2	
Description:	Modem
Brand name:	GVC
Model Name or Number:	DK4SM96R
Cable Type:	Shielded
Connected to EUT's Port:	DB9

Ancillary Equipment # 3	
Description:	Printer
Brand name:	Digital Dec Writer 100i
Model Name or Number:	LJ100-A2
Serial Number:	OV44352056
Cable Type:	Shielded
Connected to EUT's Port:	DB25

EXHIBIT 3. EUT OPERATING CONDITIONS AND CONFIGURATIONS DURING TESTS

3.1. CLIMATE TEST CONDITIONS

The climate conditions of the test environment are as follows:

Temperature:	21°C
Humidity:	51%
Pressure:	102 kPa
Power input source:	12Vdc (Starpak) and Power from host PC (Starlink)

3.2. OPERATIONAL TEST CONDITIONS & ARRANGEMENT FOR TESTS

Operating Modes:	▪ Each of lowest, middle and highest channel frequencies transmits continuously for emissions measurements. ▪ The EUT operates in normal Direct Sequence mode for occupancy duration, and frequency separation.
Special Test Software:	▪ Special software is provided by the Applicant to select and operate the EUT at each channel frequency continuously. For example, the transmitter will be operated at each of lowest, middle and highest frequencies individually continuously during testing.
Special Hardware Used:	N/A
Transmitter Test Antenna:	The EUT is tested with the antenna fitted in a manner typical of normal intended use as non-integral antenna equipment.

Transmitter Test Signals:	
Frequencies: ▪ 2412 - 2462 MHz band:	Lowest, middle and highest channel frequencies tested:
Transmitter Wanted Output Test Signals: ▪ RF Power Output (measured maximum output power): ▪ Normal Test Modulation ▪ Modulating signal source:	 ▪ 23 mWatts ▪ Each channel is DQPSK modulated with data @ 2 Mbps ▪ Internal

EXHIBIT 4. SUMMARY OF TEST RESULTS

4.1. LOCATION OF TESTS

All of the measurements described in this report were performed at Ultratech Group of Labs located in the city of Oakville, Province of Ontario, Canada.

- AC Powerline Conducted Emissions were performed in UltraTech's shielded room, 16'(L) by 12'(W) by 12'(H).
- Radiated Emissions were performed at the Ultratech's 3 Meter Open Field Test Site (OFTS) situated in the Town of Oakville, province of Ontario.

The above sites have been calibrated in accordance with ANSI C63.4, and found to be in compliance with the requirements of Sec. 2.948 of the FCC Rules. The descriptions and site measurement data of the Oakville Open Field Test Site has been filed with FCC office (FCC File No.: 31040/SIT 1300B3) and Industry Canada office (Industry Canada File No.: IC2049). Last Date of Site Calibration: Sep. 20, 1999.

4.2. APPLICABILITY & SUMMARY OF EMC EMISSION TEST RESULTS

FCC PARAGRAPH.	TEST REQUIREMENTS	COMPLIANCE (YES/NO)
15.107, 15.109	AC Power Conducted Emissions & Radiated Emissions for Receiver and Digital Circuit Portions	(Note 1)
15.247(a)(2)	Spectrum Bandwidth of a Direct Sequence Spread Spectrum System	Yes
15.247(b) & 1.1310	Maximum Peak Power and RF Exposure Limits	Yes
15.247(c)	RF Conducted Spurious Emissions at the Transmitter Antenna Terminal	Yes
15.247(c), 15.209 & 15.205	Transmitter Radiated Emissions	Yes
15.247(d)	Transmitted Power Density of a Direct Sequence Spread Spectrum System	Yes
15.247(e)	Processing Gain of Direct Sequence Spread Spectrum System	Yes

Note 1: Compliance tests of Radiated Emissions for Receiver and Digital Circuit Portions to be perform by the manufacturer (refer to attached Certificate of Conformity).

4.3. MODIFICATIONS INCORPORATED IN THE EUT FOR COMPLIANCE PURPOSES

None

EXHIBIT 5. MEASUREMENTS, EXAMINATIONS & TEST DATA FOR EMC EMISSIONS

5.1. TEST PROCEDURES

This section contains test results only. Details of test methods and procedures can be found in Exhibit 7 of this report

5.2. MEASUREMENT UNCERTAINTIES

The measurement uncertainties stated were calculated in accordance with requirements of UKAS Document NIS 81 with a confidence level of 95%. Please refer to Exhibit 6 for Measurement Uncertainties.

5.3. MEASUREMENT EQUIPMENT USED:

The measurement equipment used complied with the requirements of the Standards referenced in the Methods & Procedures ANSI C64.3:1992, FCC 15.247 and CISPR 16-1.

5.4. ESSENTIAL/PRIMARY FUNCTIONS AS DECLARED BY THE MANUACTURER:

The essential function of the EUT is to correctly communicate data to and from radios over RF link.

5.5. AC POWERLINE CONDUCTED EMISSIONS @ FCC PART 15, SUBPART B, PARA.15.107(A)

5.5.1. Limits

The equipment shall meet the limits of the following table:

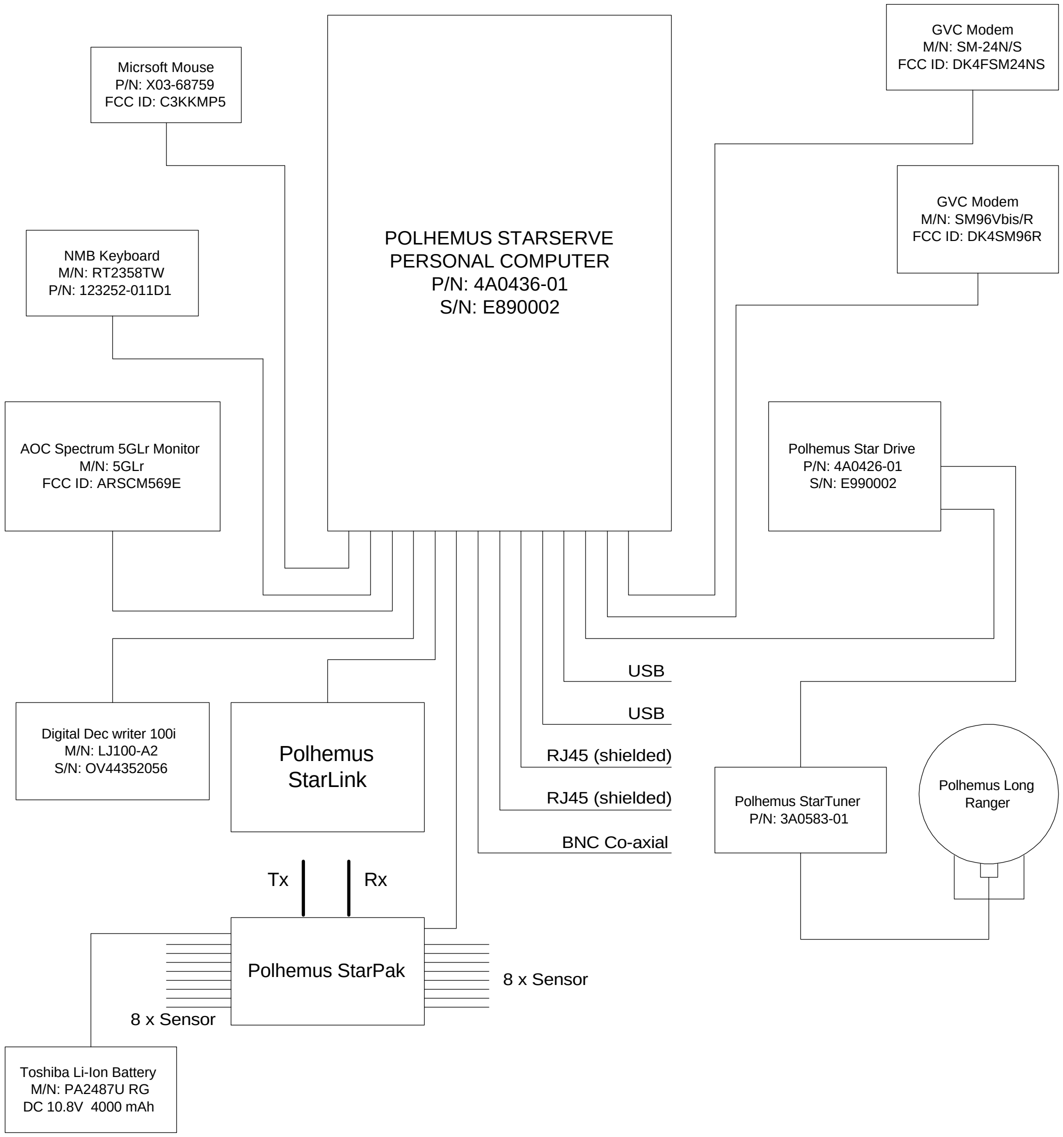
Test Frequency Range (MHz)	Test Limits	EMI Detector Used	Measuring Bandwidth
0.45 to 1.705	60 dBμV 73 dBμV	Quasi-Peak (Narrow band) Quasi-Peak (Broad band)	QP: RBW = 9 kHz, VBW > 9 kHz QP: RBW = 9 kHz, VBW > 9 kHz
1.705 to 30	69.5 dBμV 82.5 dBμV	Quasi-Peak (Narrow band) Quasi-Peak (Broad band)	QP: RBW = 9 kHz, VBW > 9 kHz QP: RBW = 9 kHz, VBW > 9 kHz

5.5.2. Method of Measurements

Refer to Exhibit 7, Sec. 7.2 of this test report & ANSI C63.4:1992

5.5.3. Test Arrangement

The following drawing shows details of the test setup for emission measurements.



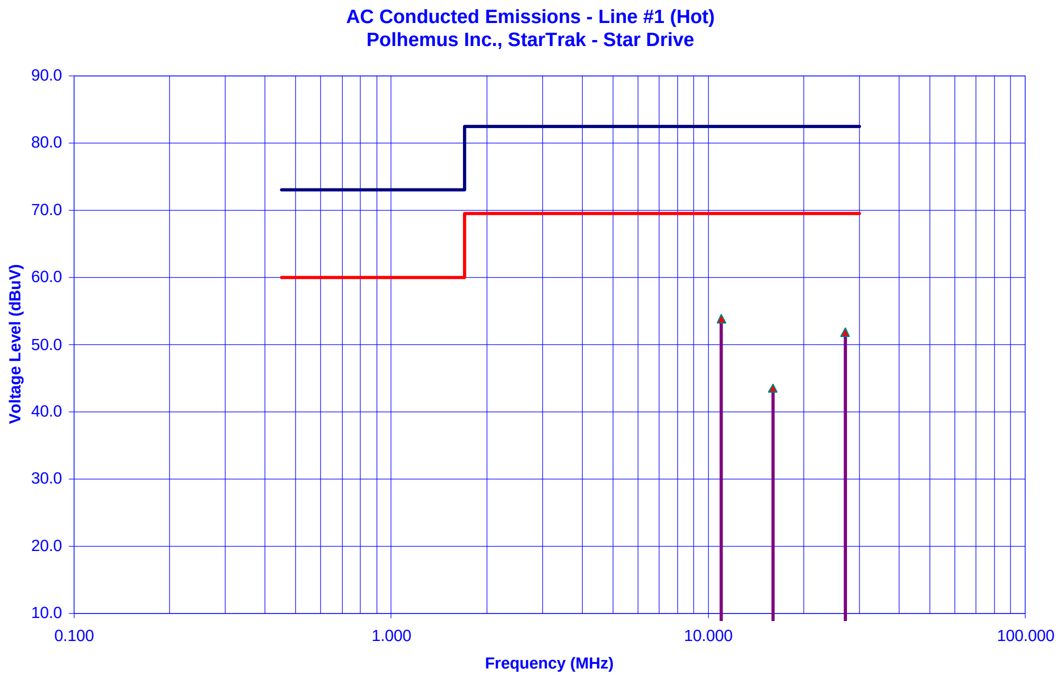
5.5.4. Test Equipment List

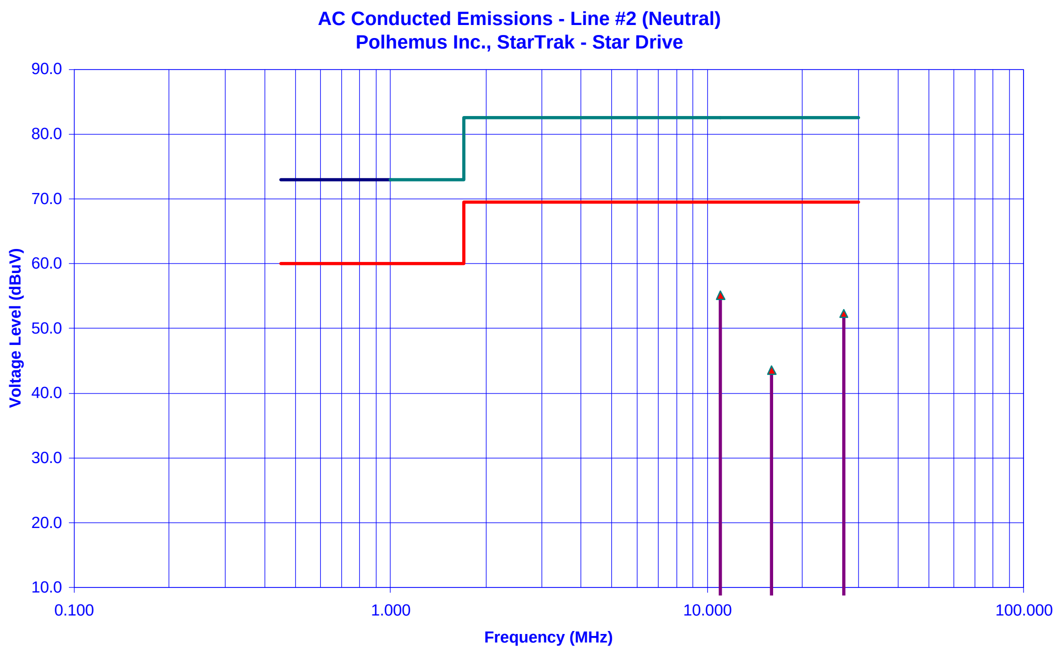
Test Instruments	Manufacturer	Model No.	Serial No.	Frequency Range
Spectrum Analyzer/ EMI Receiver	Hewlett Packard	HP 8593EM	3412A00103	9 kHz – 26.5 GHz
Transient Limiter	Hewlett Packard	11947A	310701998	9 kHz – 200 MHz 10 dB attenuation
L.I.S.N.	EMCO	3825/2	89071531	9 kHz – 200 MHz 50 Ohms / 50 µH
12'x16'x12' RF Shielded Chamber	RF Shielding	…	..	…

5.5.5. Test Data

5.5.5.1. Test Configuration #1: Star Drive

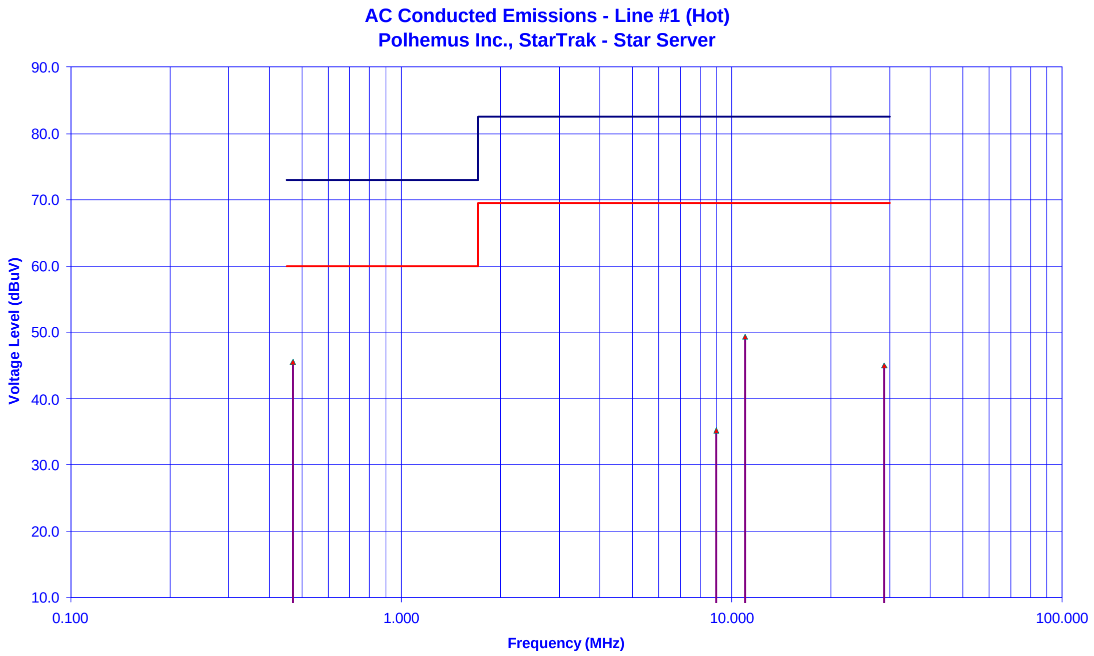
FREQUENCY (MHz)	RF LEVEL (dBuV)	RECEIVER DETECTOR (P/QP/AVG)	QP/NB LIMIT (dBuV)	QP/BB LIMIT (dBuV)	MARGIN (dB)	PASS/ FAIL	LINE TESTED (L1/L2)
11.009	53.8	QP	69.5	82.5	-15.7	PASS	L1
16.000	43.5	QP	69.5	82.5	-26.0	PASS	L1
26.999	51.8	QP	69.5	82.5	-17.7	PASS	L1
11.009	55.1	QP	69.5	82.5	-14.4	PASS	L2
16.000	43.6	QP	69.5	82.5	-25.9	PASS	L2
26.999	52.3	QP	69.5	82.5	-17.2	PASS	L2

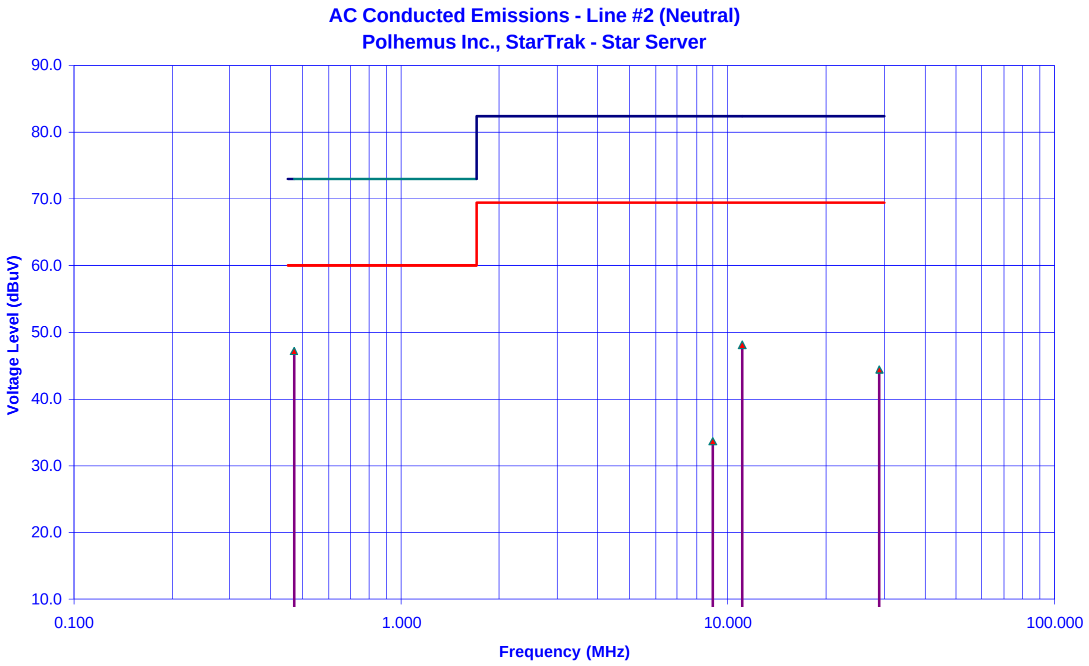

AC Conducted Emissions - Line #1 (Hot)
Polhemus Inc., StarTrak - Star Drive
Voltage Level (dBuV)
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.100
1.000
10.000
100.000
Frequency (MHz)


AC Conducted Emissions - Line #2 (Neutral)
Polhemus Inc., StarTrak - Star Drive
Voltage Level (dBuV)
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.100
1.000
10.000
100.000
Frequency (MHz)

5.5.5.2. Test Configuration #2: Star Server

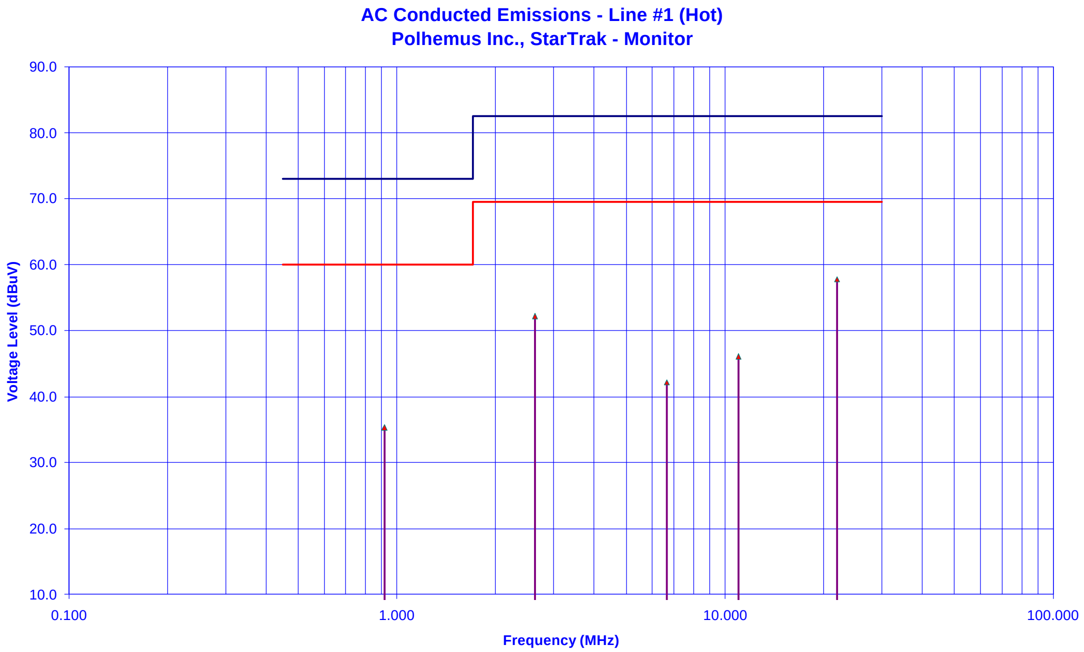
FREQUENCY (MHz)	RF LEVEL (dBuV)	RECEIVER DETECTOR (P/QP/AVG)	QP/NB LIMIT (dBuV)	QP/BB LIMIT (dBuV)	MARGIN (dB)	PASS/ FAIL	LINE TESTED (L1/L2)
0.469	45.5	QP	60.0	73.0	-14.5	PASS	L1
9.001	35.2	QP	69.5	82.5	-47.3	PASS	L1
11.022	49.3	QP	69.5	82.5	-33.2	PASS	L1
29.001	44.9	QP	69.5	82.5	-37.6	PASS	L1
0.469	47.3	QP	60.0	73.0	-12.7	PASS	L2
9.001	33.7	QP	69.5	82.5	-48.8	PASS	L2
11.022	48.2	QP	69.5	82.5	-34.3	PASS	L2
29.001	44.4	QP	69.5	82.5	-38.1	PASS	L2

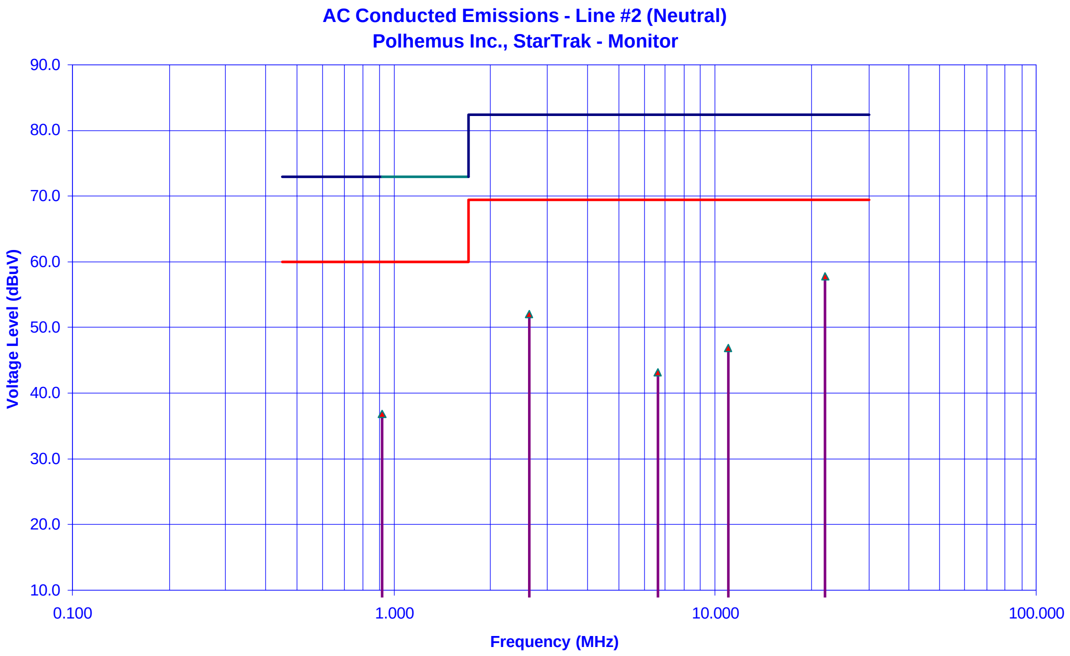

AC Conducted Emissions - Line #1 (Hot)
Polhemus Inc., StarTrak - Star Server
Voltage Level (dBuV)
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.100
1.000
10.000
100.000
Frequency (MHz)


AC Conducted Emissions - Line #2 (Neutral)
Polhemus Inc., StarTrak - Star Server
Voltage Level (dBuV)
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.100
1.000
10.000
100.000
Frequency (MHz)

5.5.5.3. Test Configuration #3: Monitor

FREQUENCY (MHz)	RF LEVEL (dBuV)	RECEIVER DETECTOR (P/QP/AVG)	QP/NB LIMIT (dBuV)	QP/BB LIMIT (dBuV)	MARGIN (dB)	PASS/ FAIL	LINE TESTED (L1/L2)
0.916	35.3	QP	60.0	73.0	-24.7	PASS	L1
2.628	52.2	QP	69.5	82.5	-17.3	PASS	L1
6.653	42.1	QP	69.5	82.5	-27.4	PASS	L1
10.993	46.1	QP	69.5	82.5	-36.4	PASS	L1
22.000	57.7	QP	69.5	82.5	-24.8	PASS	L1
0.916	36.8	QP	60.0	73.0	-23.2	PASS	L2
2.628	52.0	QP	69.5	82.5	-17.5	PASS	L2
6.653	43.1	QP	69.5	82.5	-26.4	PASS	L2
10.993	46.8	QP	69.5	82.5	-35.7	PASS	L2
22.000	57.8	QP	69.5	82.5	-24.7	PASS	L2


AC Conducted Emissions - Line #1 (Hot)
Polhemus Inc., StarTrak - Monitor
Voltage Level (dBuV)
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.100
1.000
10.000
100.000
Frequency (MHz)


AC Conducted Emissions - Line #2 (Neutral)
Polhemus Inc., StarTrak - Monitor
Voltage Level (dBuV)
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.100
1.000
10.000
100.000
Frequency (MHz)

5.5.6. Plots

Please refer to attached AC Powerline Conducted Emissions Plots in Exhibit 8 Sec. 8.1 for actual measurement plots

5.5.7. Photographs of Test Setup

Please refer to attached AC Powerline Conducted Emissions photograph(s) in Exhibit 9 for setup and arrangement of equipment under tests and its ancillary equipment.

5.6. 6 DB BANDWIDTH @ FCC 15.247(A)(2)

5.6.1. Limits

For a direct sequence spread spectrum system, the minimum 6 dB bandwidth shall be at least 500 KHz.

5.6.2. Method of Measurements

Refer to FCC 15.247(c) & ANSI C63.4:1992

The transmitter output was connected to the spectrum analyzer through an attenuator. The bandwidth of the fundamental frequency was measured with the spectrum analyzer using 30 KHz RBW, VBW = 100 KHz,. The 6 dB bandwidth was measured and recorded.

5.6.3. Test Arrangement

5.6.4. Test Equipment List

Test Instruments	Manufacturer	Model No.	Serial No.	Frequency Range
Spectrum Analyzer/ EMI Receiver	Hewlett Packard	HP 8593EM	3412A00103	9 kHz – 26.5 GHz

5.6.5. Test Data

Test Configuration #1: StarLink (Slot1)			
CHANNEL FREQUENCY (MHz)	**6 dB BANDWIDTH (MHz)**	**MINIMUM LIMIT (MHz)**	**PASS/FAIL**
2412	5.07	0.5	PASS
2437	8.50	0.5	PASS
2462	9.86	0.5	PASS

Test Configuration #2: StarLink (Slot2)			
CHANNEL FREQUENCY (MHz)	**6 dB BANDWIDTH (MHz)**	**MINIMUM LIMIT (MHz)**	**PASS/FAIL**
2412	3.50	0.5	PASS
2437	3.00	0.5	PASS
2462	4.00	0.5	PASS

Test Configuration #3: StarPak			
CHANNEL FREQUENCY (MHz)	**6 dB BANDWIDTH (MHz)**	**MINIMUM LIMIT (MHz)**	**PASS/FAIL**
2412	11.14	0.5	PASS
2437	11.64	0.5	PASS
2462	11.21	0.5	PASS

5.6.6. Plots

Please refer to section 8.2 for measurement data.

5.7. PEAK OUTPUT POWER & EFFECTIVE RADIATED POWER (EIRP) @ FCC 15.247(B) AND RF EXPOSURE LIMIT FCC 1.1310

5.7.1. Limits

- **FCC 15.247(b)(1):** Maximum peak output power of the transmitter shall not exceed 1 Watt.
- **FCC 15.247(b)(3):** If the antenna of directional gain greater than 6 dBi are used, the power shall be reduced by the amount in dB that the directional gain of the antenna exceeds 6 dBi.
- **FCC 15.247(b)(3)(i):** Systems operating in the 2400 - 2483.5 MHz band that are used exclusively for fixed, point-to-point operations may employ transmitting antennas with directional gain greater than 6 dBi provided the maximum peak output power of the intentional radiator is reduce by 1 dB for every 3 dB that the directional gain of the antenna exceeds 6 dBi..
- **FCC 1.1310:-** The criteria listed in the following table shall be used to evaluate the environmental impact of human exposure to radio-frequency (RF) radiation as specified in 1.1307(b).

LIMITS FOR MAXIMUM PERMISSIBLE EXPOSURE (MPE)

Frequency Range (MHz)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (mW/cm^2)	Average Time (minutes)
(A) Limits for Occupational/Control Exposures				
300-1500	...	...	F/300	6
1500-100,000	...	...	5	6
(B) Limits for General Population/Uncontrolled Exposure				
300-1500	...	...	F/1500	6
1500-100,000	...	...	1.0	30

F = Frequency in MHz

5.7.2. Method of Measurements

Refer to Exhibit 7, Sec. 7.3 of this test report, FCC 15.247(b)(1)&(3), ANSI C63.4:1992, FCC @ 1.1310 & OST Bulletin No. 65-October 1985

$S = PG/4\Pi r^2 = EIRP/4\Pi r^2$

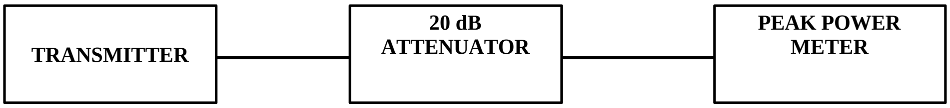
Where:
P: power input to the antenna in mW
EIRP: Equivalent (effective) isotropic radiated power.
S: power density mW/cm^2
G: numeric gain of antenna relative to isotropic radiator
r: distance to centre of radiation in cm

FCC radio frequency exposure limits may be exceeded at distances closer than r cm from the antenna of this device

$r = \sqrt{PG/4\Pi S}$

FCC radio frequency exposure limits may not be exceeded at distances closer than r cm from the antenna of this device

5.7.3. Test Arrangement



5.7.4. Test Equipment List

Test Instruments	Manufacturer	Model No.	Serial No.	Frequency Range
Spectrum Analyzer/ EMI Receiver	Hewlett Packard	HP 8593EM	3412A00103	9 kHz – 26.5 GHz
Peak Power Meter & Peak Power Sensor	Hewlett Packard	8900 8481A	2131A00124 2551A01965	0.1-18 GHz 50 Ohms Input
Microwave Amplifier	Hewlett Packard	HP 83017A		1 GHz to 26.5 GHz
Horn Antenna	EMCO	3155	9701-5061	1 GHz – 18 GHz
Horn Antenna	EMCO	3155	9911-5955	1 GHz – 18 GHz

5.7.5. Test Data

5.7.5.1. Test Antenna #1: StarLink (Slot 1)

EIRP MEASUREMENTS - CALCULATION METHOD

Duty cycle: 28%
Duty Cycle X = 10*log(0.28) = -5.5 dB. (Please refers to plots in Exhibit 8 Section 8.3 of this test report.)

Transmitter Channel	Frequency (MHz)	Antenna Gain G (dBi)	(wideband) Peak Power P @ Antenna Port (dBm)	(wideband) Average EIRP (P+G+X) (dBm)	Limit (dBm)
Lowest	2412	1.9	13.6	10.0	30
Middle	2437	1.9	11.8	8.2	30
Highest	2462	1.9	12.3	8.7	30

EIRP MEASUREMENTS – SUBSTITUTION METOD

- Wideband Measuring BW = 15.1 MHz
- Duty Cycle: X = -5.5 dB
- EUT's Antenna Gain = 1.9 dBi

Frequency (MHz)	E-Field E1 in 1 MHz BW @ 3m (dBμV/m)	Antenna Polarization (V/H)	Power from Signal GEN. + Cable Loss (S) (dBm)/MHz	Substitution Antenna Gain G (dBi)	(Wideband) Measured Peak EIRP = S+G+10log(BW) (dBm)	(Wideband) Average EIRP= Peak EIRP+X (dBm)
2412	103.8	V	-4.9	8.2	15.1	9.6
2412	110.3	H	-1.7	8.2	18.3	12.8
2437	107.2	V	-2.3	8.2	17.7	12.2
2437	104.2	H	-3.8	8.2	16.2	10.7
2462	101.7	V	-4.1	8.2	15.9	10.4
2462	106.9	H	-1.5	8.2	18.5	13.0

RF EXOSURE LIMIT

Transmitter Channel	Frequency (MHz)	Antenna Gain G (dBi)	(wideband) Average EIRP (dBm)	Power Desity Limit (mW/cm^2)	Safety Distance Limit (*) (cm)
Lowest	2412	1.9	12.8	1.0	1.2
Middle	2437	1.9	12.2	1.0	1.1
Highest	2462	1.9	13.0	1.0	1.3

REMARK: The substitution method yielded higher EIRP than the calculated method. This maybe due to the discrepancy of the EUT antenna gain specified by the antenna 's manufacturer or the effect of antenna gain by its mounting method.

5.7.5.2. Test Antenna #2: StarLink (Slot 2)

EIRP MEASUREMENTS - CALCULATION METHOD

Duty cycle: 28%
Duty Cycle X = 10*log(0.28) = -5.5 dB. (Please refers to plots in Exhibit 8 Section 8.3 of this test report.)

Transmitter Channel	Frequency (MHz)	Antenna Gain G (dBi)	(wideband) Peak Power P @ Antenna Port (dBm)	(wideband) Average EIRP (P+G+X) (dBm)	Limit (dBm)
Lowest	2412	1.9	13.6	10.0	30
Middle	2437	1.9	11.8	8.2	30
Highest	2462	1.9	12.3	8.7	30

EIRP MEASUREMENTS – SUBSTITUTION METOD

- Wideband Measuring BW = 15.1 MHz
- Duty Cycle: X = -5.5 dB
- EUT's Antenna Gain = 1.9 dBi

Frequency (MHz)	E-Field E1 in 1 MHz BW @ 3m (dBμV/m)	Antenna Polarization (V/H)	Power from Signal GEN. + Cable Loss (S) (dBm)/MHz	Substitution Antenna Gain G (dBi)	(Wideband) Measured Peak EIRP = S+G+10log(BW) (dBm)	(Wideband) Average EIRP = Peak EIRP+X (dBm)
2412	104.4	V	-4.6	8.2	15.4	9.9
2412	111.2	H	-1.2	8.2	18.8	13.3
2437	106.1	V	-2.9	8.2	17.1	11.6
2437	102.8	H	-4.5	8.2	15.5	10.0
2462	102.3	V	-3.8	8.2	16.2	10.7
2462	106.3	H	-1.8	8.2	18.2	12.7

RF EXOSURE LIMIT

Transmitter Channel	Frequency (MHz)	Antenna Gain G (dBi)	(wideband) Average EIRP (dBm)	Power Desity Limit (mW/cm^2)	Safety Distance Limit (*) (cm)
Lowest	2412	1.9	13.3	1.0	1.3
Middle	2437	1.9	11.6	1.0	1.1
Highest	2462	1.9	12.7	1.0	1.2

REMARK: The substitution method yielded higher EIRP than the calculated method. This maybe due to the discrepancy of the EUT antenna gain specified by the antenna 's manufacturer or the effect of antenna gain by its mounting method.

Note:

*** RF EXPOSURE DISTANCE LIMITS: $r = (PG/4\pi S)^{1/2} = (EIRP/4\pi S)^{1/2}$**

For mobile or base transmitters, the minimum RF safety distance of 20 cm from the transmitting antenna to the body of a user shall be maintained. The user's manual shall contain the RF exposure warning as follows:

RF EXPOSURE FOR ACCESSIBLE ANTENNA

WARNING: For compliance with the RF exposure requirements regulated by the FCC (Federal Communications Commission), the separation distance of more than 20 cm shall be maintained between the transmitter, and any part of the user's body.

5.8. SPURIOUS EMISSIONS (CONDUCTED), FCC CFR 47, PARA. 15.247(C)

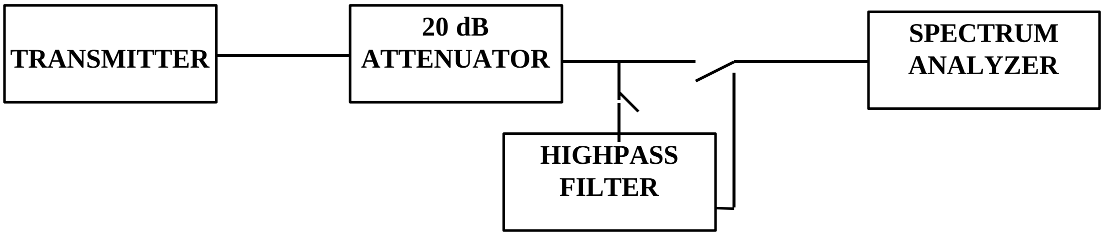
5.8.1. Limits

In any 100 KHz bandwidth outside the operating frequency band, the radio frequency power that is produced by modulation products of the spreading sequence, the information sequence and the carrier frequency shall be at least 20 dB below that in any 100 KHz bandwidth within the band that contains the highest level of the desired power.

5.8.2. Method of Measurements

Refer to Exhibit 7, Sec. 7.4 of this test report, FCC 15.247(c) & ANSI C63.4:1992

5.8.3. Test Arrangement



5.8.4. Test Equipment List

Test Instruments	Manufacturer	Model No.	Serial No.	Frequency Range
Spectrum Analyzer/ EMI Receiver	Hewlett Packard	HP 8593EM	3412A00103	9 kHz – 26.5 GHz

5.8.5. Test Data

5.8.5.1. Test Configuration #1: StarLink Slot 1

Tests were performed at lowest (2412 MHz), middle (2437 MHz) and highest (2463 MHz) frequencies from 10 MHz to 25 GHz and no significant signal were found in all cases.

5.8.5.2. Test Configuration #1: StarLink Slot 2

Tests were performed at lowest (2412 MHz), middle (2437 MHz) and highest (2463 MHz) frequencies from 10 MHz to 25 GHz and no significant signal were found in all cases.

5.8.5.3. Test Configuration #1: StarPak

Tests were performed at lowest (2412 MHz), middle (2437 MHz) and highest (2463 MHz) frequencies from 10 MHz to 25 GHz and no significant signal were found in all cases.

5.8.6. Plots

Please refer to EXHIBIT 8, Section 8.4 for measurement data.

5.9. SPURIOUS EMISSIONS (RADIATED @ 3 METERS), FCC CFR 47, PARA. 15.247(C), 15.209 & 15.205

5.9.1. Limits

In any 100 KHz bandwidth outside the operating frequency band, the radio frequency power that is produced by modulation products of the spreading sequence, the information sequence and the carrier frequency shall be either at least 20 dB below that in any 100 KHz bandwidth within the band that contains the highest level of the desired power or shall not exceed the general levels specified in @ 15.209(a), which lesser attenuation.

All other emissions inside restricted bands specified in @ 15.205(a) shall not exceed the general radiated emission limits specified in @ 15.209(a)

Remarks:

- Applies to harmonics/spurious emissions that fall in the restricted bands listed in Section 15.205. The maximum permitted average field strength is listed in Section 15.209.
- **@ FCC CFR 47, Para. 15.237(c) -** The emission limits as specified above are based on measurement instrument employing an average detector. The provisions in **@15.35** for limiting peak emissions apply.

FCC CFR 47, Part 15, Subpart C, Para. 15.205(a) - Restricted Frequency Bands

MHz	MHz	MHz	GHz
0.090 - 0.110	162.0125 - 167.17	2310 - 2390	9.3 - 9.5
0.49 – 0.51	167.72 - 173.2	2483.5 - 2500	10.6 - 12.7
2.1735 - 2.1905	240 - 285	2655 - 2900	13.25 - 13.4
8.362 - 8.366	322 - 335.4	3260 - 3267	14.47 - 14.5
13.36 - 13.41	399.9 - 410	3332 - 3339	14.35 - 16.2
25.5 – 25.67	608 - 614	3345.8 - 3358	17.7 - 21.4
37.5 – 38.25	960 - 1240	3600 - 4400	22.01 - 23.12
73 - 75.4	1300 - 1427	4500 - 5250	23.6 - 24.0
108 – 121.94	1435 - 1626.5	5350 - 5460	31.2 - 31.8
123 – 138	1660 - 1710	7250 - 7750	36.43 - 36.5
149.9 – 150.05	1718.8 - 1722.2	8025 - 8500	Above 38.6
156.7 – 156.9	2200 - 2300	9000 - 9200	

FCC CFR 47, Part 15, Subpart C, Para. 15.209(a)
-- Field Strength Limits within Restricted Frequency Bands --

FREQUENCY (MHz)	FIELD STRENGTH LIMITS (microvolts/m)	DISTANCE (Meters)
0.009 - 0.490	2,400 / F (KHz)	300
0.490 - 1.705	24,000 / F (KHz)	30
1.705 - 30.0	30	30
30 – 88	100	3
88 – 216	150	3
216 – 960	200	3
Above 960	500	3

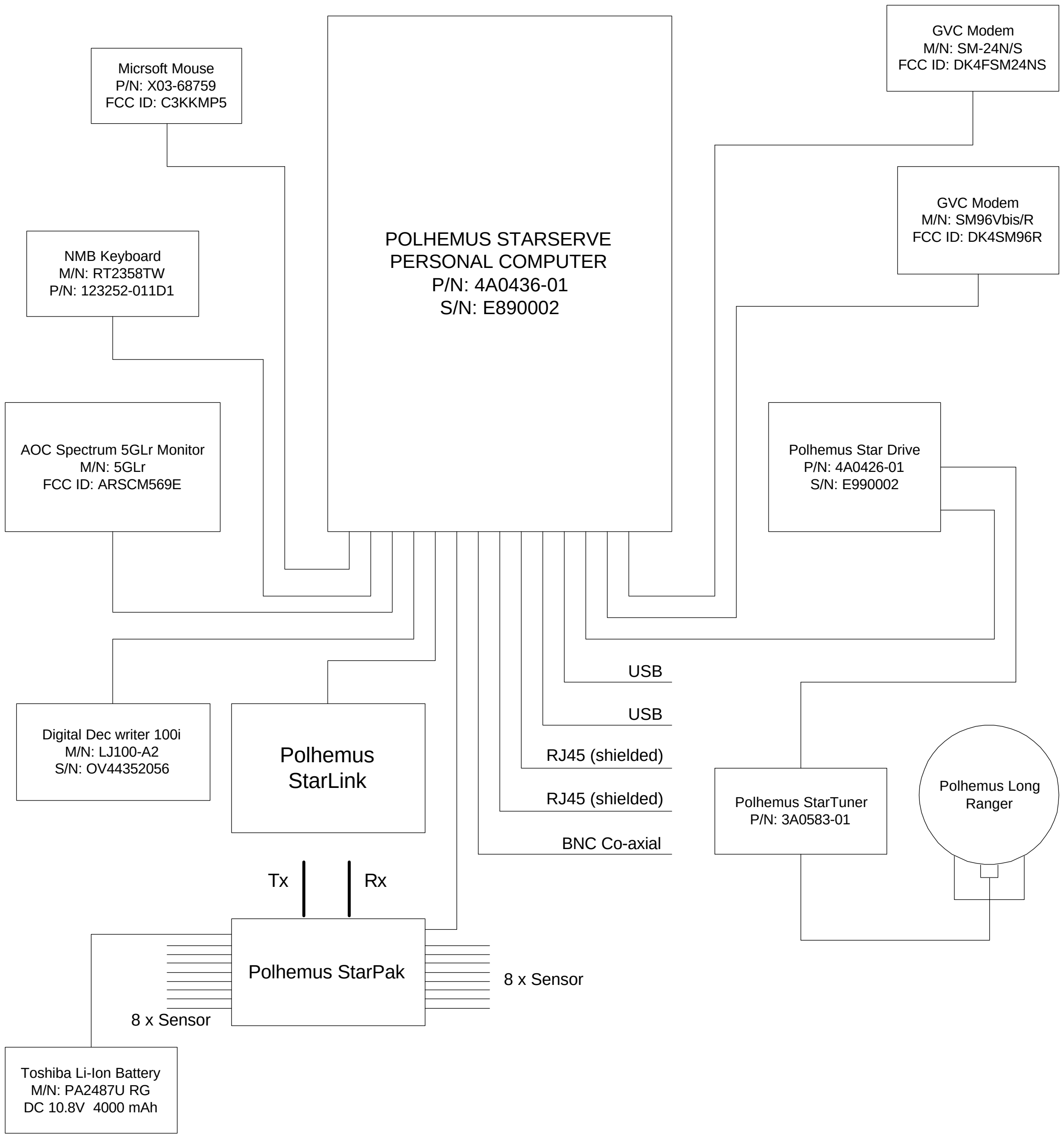
5.9.2. Method of Measurements

Refer to Exhibit 7, Sec. 7.4 of this test report and **ANSI 63.4-1992, Para. 8** for detailed radiated emissions measurement procedures.

The following measurement procedures were also applied:

- Applies to harmonics/spurious that fall in the restricted bands listed in Section 15.205. the maximum permitted average field strength is listed in Section 15.209. A Pre-Amp and highpass filter are used for this measurement.
- For measurement below 1 GHz, set RBW = 100 KHz, VBW $\geq$ 100 KHz, SWEEP=AUTO.
- For measurement above 1 GHz, set RBW = 1 MHz, VBW = 1 MHz (Peak) & VBW = 10 Hz (Average), SWEEP=AUTO.
- If the emission is pulsed, modified the unit for continuous operation, then use the settings above for measurements, then correct the reading by subtracting the peak-average correction factor derived from the appropriate duty cycle calculation. See Section 15.35(b) and (c).

5.9.3. Test Arrangement



5.9.4. Test Equipment List

Test Instruments	Manufacturer	Model No.	Serial No.	Frequency Range
Spectrum Analyzer/ EMI Receiver	Advantest	R3271	15050203	100 Hz to 32 GHz with external mixer for frequency above 32 GHz
Microwave Amplifier	Hewlett Packard	HP 83017A		1 GHz to 26.5 GHz
Biconilog Antenna	EMCO	3143	1029	20 MHz to 2 GHz
Horn Antenna	EMCO	3155	9701-5061	1 GHz – 18 GHz
Horn Antenna	EMCO	3160-09	..	18 GHz – 26.5 GHz
Horn Antenna	EMCO	3160-10	..	26.5 GHz – 40 GHz
Mixer	Tektronix	118-0098-00	..	18 GHz – 26.5 GHz
Mixer	Tektronix	119-0098-00	..	26.5 GHz – 40 GHz

5.9.5. Test Data

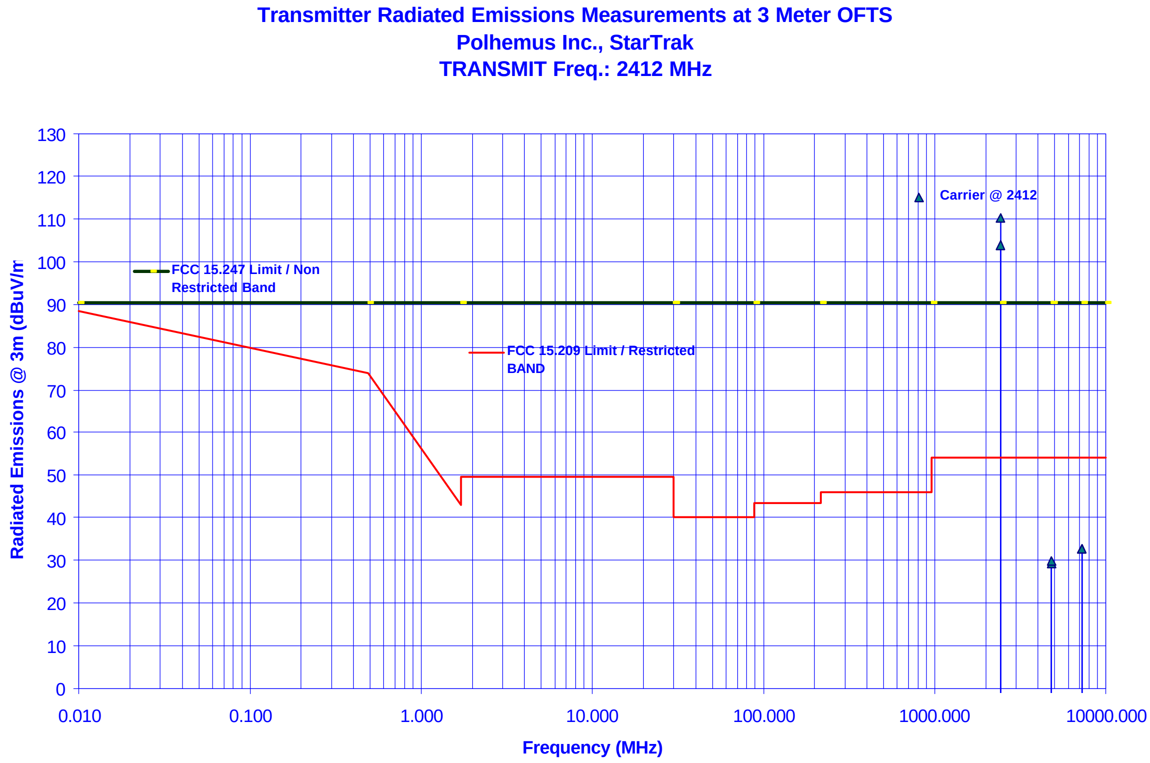
5.9.5.1. Test Configuration #1: StarLink Slot 1

Channel #: 1
Tx Frequency: 2412 MHz (lowest frequency)
Modulation: 2 Mbps DQPSK

FREQUENCY (MHz)	RF PEAK LEVEL (dBuV/m)	RF AVG LEVEL (dBuV/m)	ANTENNA PLANE (H/V)	LIMIT 15.209 (dBuV/m)	LIMIT 15.247 (dBuV/m)	MARGIN (dB)	PASS/ FAIL
2412	103.84	--	V	--	--	--	--
2412	110.31	--	H	--	--	--	--
*4824	54.78	29.44	V	54.0	90.3	-24.6	PASS
*4824	56.00	29.88	H	54.0	90.3	-24.1	PASS
7236	63.84	32.75	V	54.0	90.3	-57.6	PASS
7236	61.97	32.66	H	54.0	90.3	-57.7	PASS

The emissions were scanned from 10 MHz to 25 GHz and all emissions less 40 dB below the limits were recorded.

* Frequency in restricted band specified at FCC CFR 47, Part 15, subpart C, Para. 15.205(a)

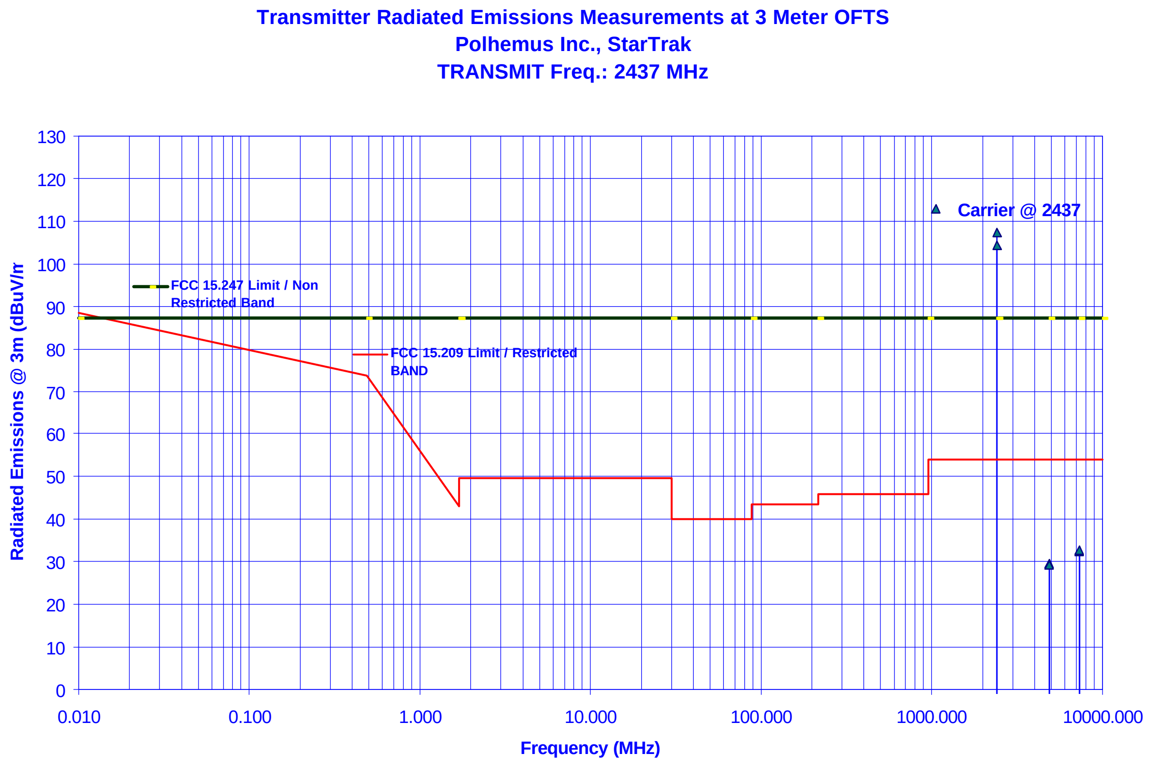


Channel #: 6
Tx Frequency: 2437 MHz (middle frequency)
Modulation: 2 Mbps DQPSK

FREQUENCY (MHz)	RF PEAK LEVEL (dBuV/m)	RF AVG LEVEL (dBuV/m)	ANTENNA PLANE (H/V)	LIMIT 15.209 (dBuV/m)	LIMIT 15.247 (dBuV/m)	MARGIN (dB)	PASS/ FAIL
2437	107.19	--	V	--	--	--	--
2437	104.22	--	H	--	--	--	--
*4874	53.06	29.53	V	54.0	87.2	-24.5	PASS
*4874	53.69	29.41	H	54.0	87.2	-24.6	PASS
*7311	61.78	32.56	V	54.0	87.2	-21.4	PASS
*7311	65.84	32.63	H	54.0	87.2	-21.4	PASS

The emissions were scanned from 10 MHz to 25 GHz and all emissions less 40 dB below the limits were recorded.

* Frequency in restricted band specified at FCC CFR 47, Part 15, subpart C, Para. 15.205(a)

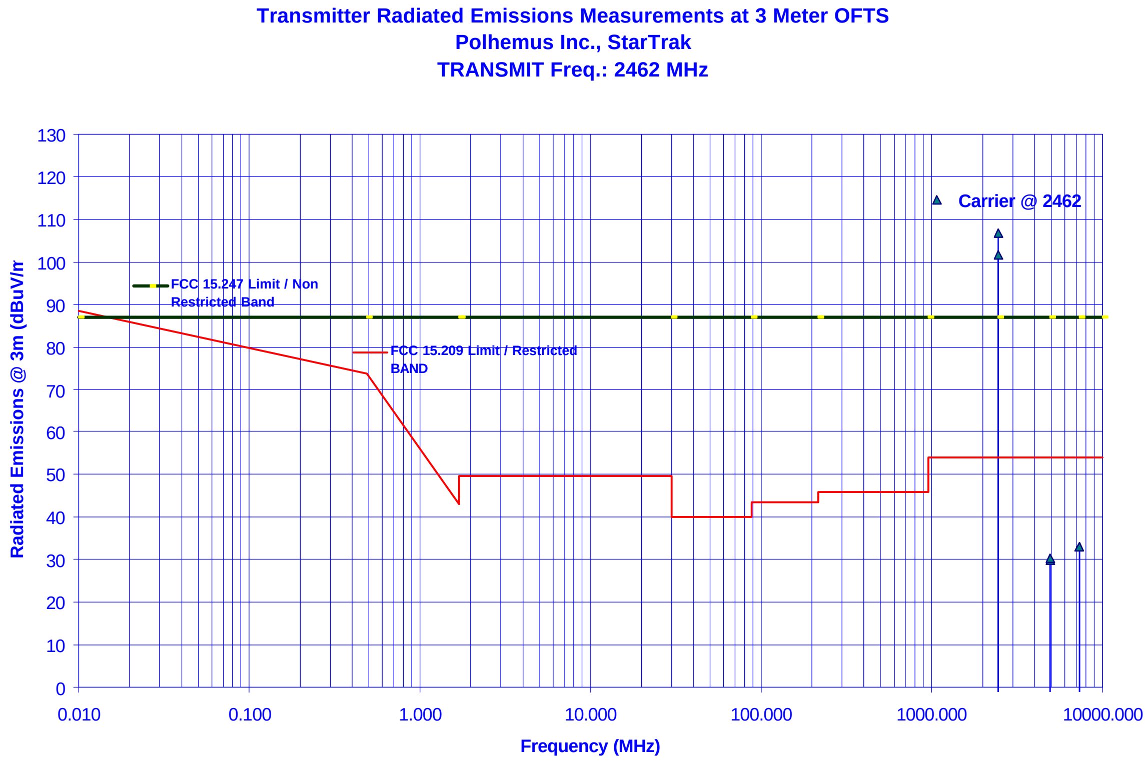


Channel #: 11
Tx Frequency: 2462 MHz (highest frequency)
Modulation: 2 Mbps DQPSK

FREQUENCY (MHz)	RF PEAK LEVEL (dBuV/m)	RF AVG LEVEL (dBuV/m)	ANTENNA PLANE (H/V)	LIMIT 15.209 (dBuV/m)	LIMIT 15.247 (dBuV/m)	MARGIN (dB)	PASS/ FAIL
2462	101.69	--	V	--	--	--	--
2462	106.88	--	H	--	--	--	--
*4924	54.59	29.89	V	54.0	86.9	-24.1	PASS
*4924	56.84	30.19	H	54.0	86.9	-23.8	PASS
*7386	65.66	33.06	V	54.0	86.9	-20.9	PASS
*7386	62.63	33.03	H	54.0	86.9	-21.0	PASS

The emissions were scanned from 10 MHz to 25 GHz and all emissions less 40 dB below the limits were recorded.

* Frequency in restricted band specified at FCC CFR 47, Part 15, subpart C, Para. 15.205(a)



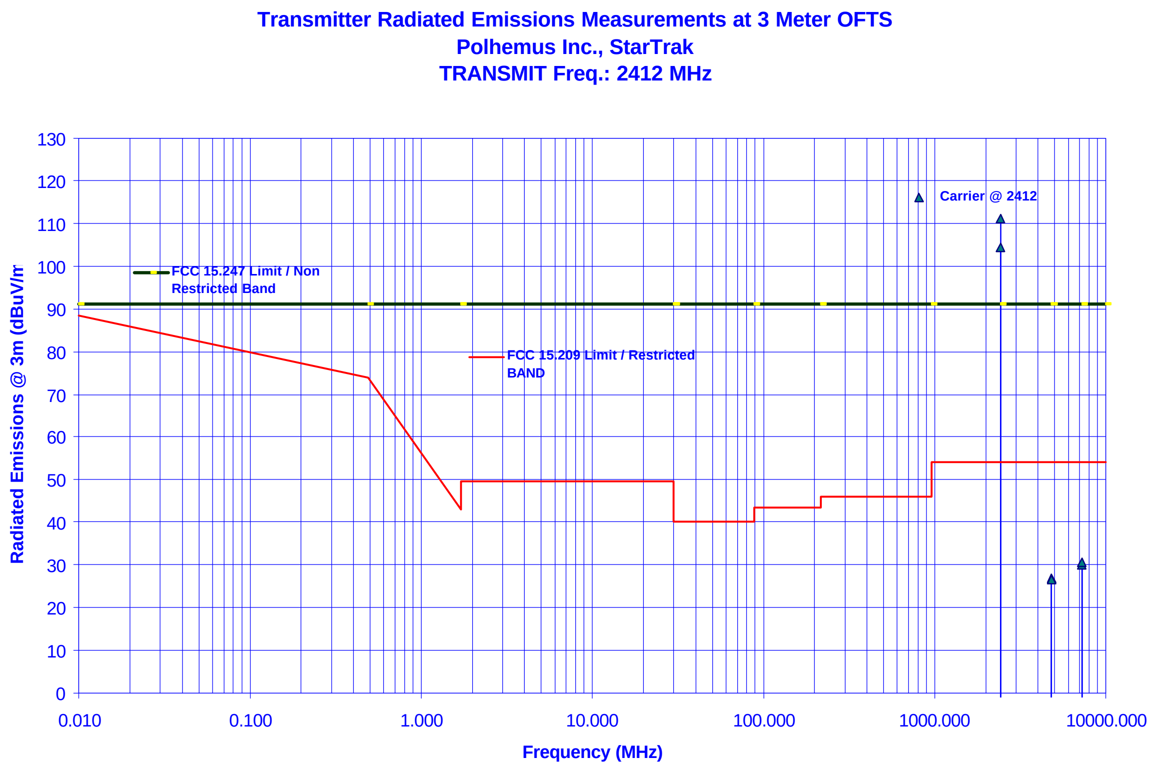
5.9.5.2. Test Configuration #2: StarLink Slot 2

Channel #: 1
Tx Frequency: 2412 MHz (lowest frequency)
Modulation: 2 Mbps DQPSK

FREQUENCY (MHz)	RF PEAK LEVEL (dBuV/m)	RF AVG LEVEL (dBuV/m)	ANTENNA PLANE (H/V)	LIMIT 15.209 (dBuV/m)	LIMIT 15.247 (dBuV/m)	MARGIN (dB)	PASS/ FAIL
2412	104.41	--	V	--	--	--	--
2412	111.16	--	H	--	--	--	--
*4824	53.59	26.84	V	54.0	91.2	-27.2	PASS
*4824	54.09	26.66	H	54.0	91.2	-27.3	PASS
7236	58.78	29.94	V	54.0	91.2	-61.2	PASS
7236	59.66	30.53	H	54.0	91.2	-60.6	PASS

The emissions were scanned from 10 MHz to 25 GHz and all emissions less 40 dB below the limits were recorded.

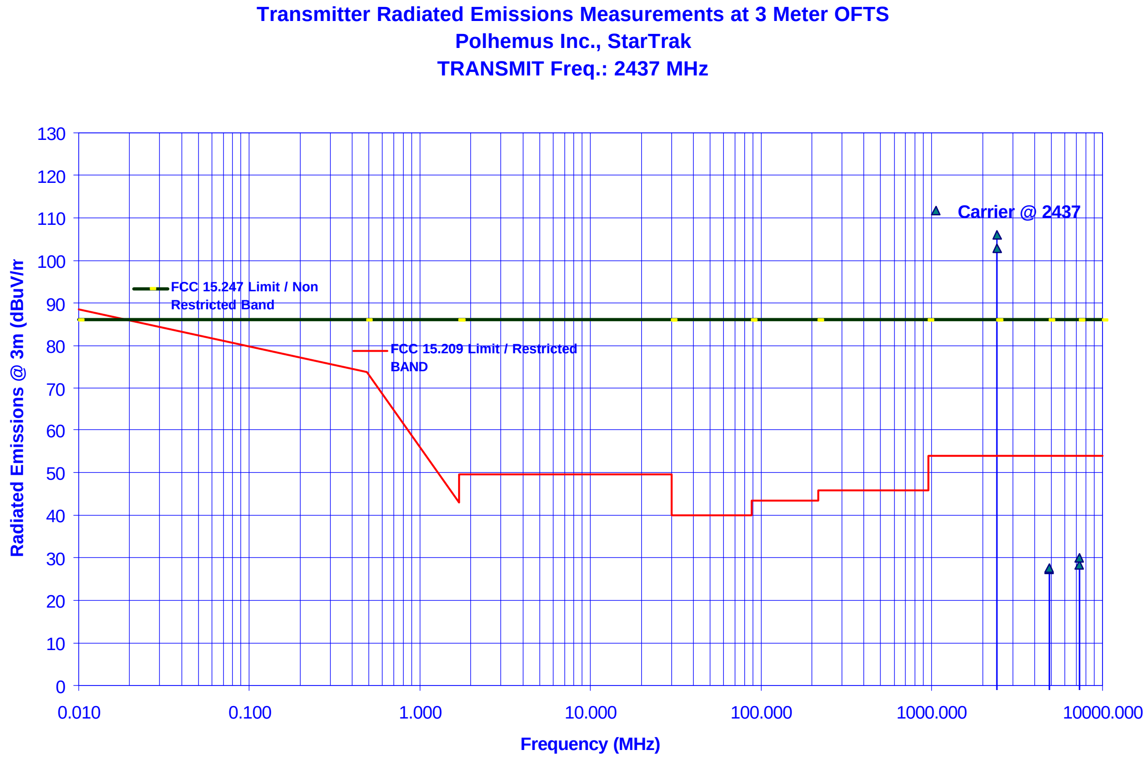
* Frequency in restricted band specified at FCC CFR 47, Part 15, subpart C, Para. 15.205(a)



Channel #: 6
Tx Frequency: 2437 MHz (middle frequency)
Modulation: 2 Mbps DQPSK

FREQUENCY (MHz)	RF PEAK LEVEL (dBuV/m)	RF AVG LEVEL (dBuV/m)	ANTENNA PLANE (H/V)	LIMIT 15.209 (dBuV/m)	LIMIT 15.247 (dBuV/m)	MARGIN (dB)	PASS/ FAIL
2437	106.06	--	V	--	--	--	--
2437	102.78	--	H	--	--	--	--
*4874	51.44	27.44	V	54.0	86.1	-26.6	PASS
*4874	53.91	27.63	H	54.0	86.1	-26.4	PASS
*7311	59.72	28.41	V	54.0	86.1	-25.6	PASS
*7311	61.50	29.94	H	54.0	86.1	-24.1	PASS
The emissions were scanned from 10 MHz to 25 GHz and all emissions less 40 dB below the limits were recorded.							

* Frequency in restricted band specified at FCC CFR 47, Part 15, subpart C, Para. 15.205(a)

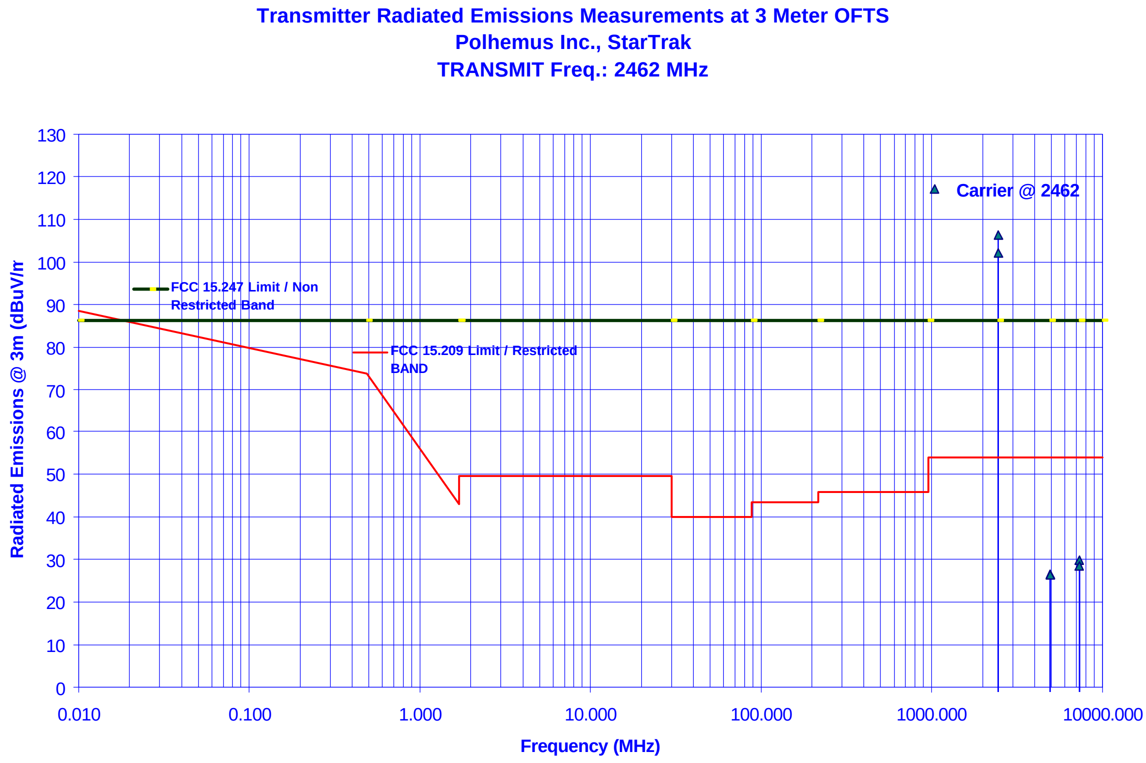


Channel #: 11
Tx Frequency: 2462 MHz (highest frequency)
Modulation: 2 Mbps DQPSK

FREQUENCY (MHz)	RF PEAK LEVEL (dBuV/m)	RF AVG LEVEL (dBuV/m)	ANTENNA PLANE (H/V)	LIMIT 15.209 (dBuV/m)	LIMIT 15.247 (dBuV/m)	MARGIN (dB)	PASS/ FAIL
2462	102.25	--	V	--	--	--	--
2462	106.34	--	H	--	--	--	--
*4924	55.44	26.63	V	54.0	86.3	-27.4	PASS
*4924	55.59	26.31	H	54.0	86.3	-27.7	PASS
*7386	61.31	29.72	V	54.0	86.3	-24.3	PASS
*7386	63.72	28.66	H	54.0	86.3	-25.3	PASS

The emissions were scanned from 10 MHz to 25 GHz and all emissions less 40 dB below the limits were recorded.

* Frequency in restricted band specified at FCC CFR 47, Part 15, subpart C, Para. 15.205(a)



5.9.6. Plots

Please refer to EXHIBIT 8 Section 8.5 for measurement data.

5.9.7. Photographs of Test Setup

Please refer to Exhibit 9 for setup and arrangement of equipment under tests and its ancillary equipment.

5.10. TRANSMITTED POWER DENSITY OF A DSSS SYSTEM, FCC CFR 47, PARA. 15.247(D)

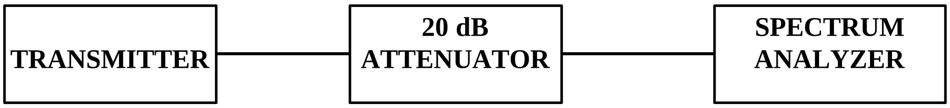
5.10.1. Limits

For a direct sequence system, the transmitted power density average over any 1 second interval shall not be greater than 8 dBm in any 3 KHz bandwidth within this band.

5.10.2. Method of Measurements

Refer to Exhibit 7, Sec. 7.5 of this test report for detailed measurement procedures

5.10.3. Test Arrangement



5.10.4. Test Equipment List

Test Instruments	Manufacturer	Model No.	Serial No.	Frequency Range
Spectrum Analyzer/ EMI Receiver	Hewlett Packard	HP 8593EM	3412A00103	9 kHz – 26.5 GHz

5.10.5. Test Data

CHANNEL NUMBER	CHANNEL FREQUENCY (MHz)	RF POWER LEVEL IN 3 KHz BW (dBm)	LIMIT (dBm)	MARGIN (dB)	COMMENTS (PASS/FAIL)
1	2412	-16.06	8.0	-24.1	PASS
6	2437	-11.84	8.0	-19.8	PASS
11	2462	-12.91	8.0	-20.9	PASS

Note: The above test results was performed on StarPak unit, since the StarPak and StarLink uses the same radio, the transmitted power density need only be perform on one of the unit.

5.10.6. Plots

Please refer to Exhibit 8, Section 8.6 for measurement plots

5.11. PROCESSING GAIN OF A DIRECT SEQUENCE SPREAD SPECTRUM, FCC CFR 47, PARA. 15.247(E)

5.11.1. Limits

The processing gain of a direct sequence system shall be at least 10 dB. The processing gain shall be determined from the ratio in dB of the signal-to-noise ratio with the system spreading code turned off to the signal-to-noise ratio with the system spreading code turned on, as measured at the demodulated output of the receiver.

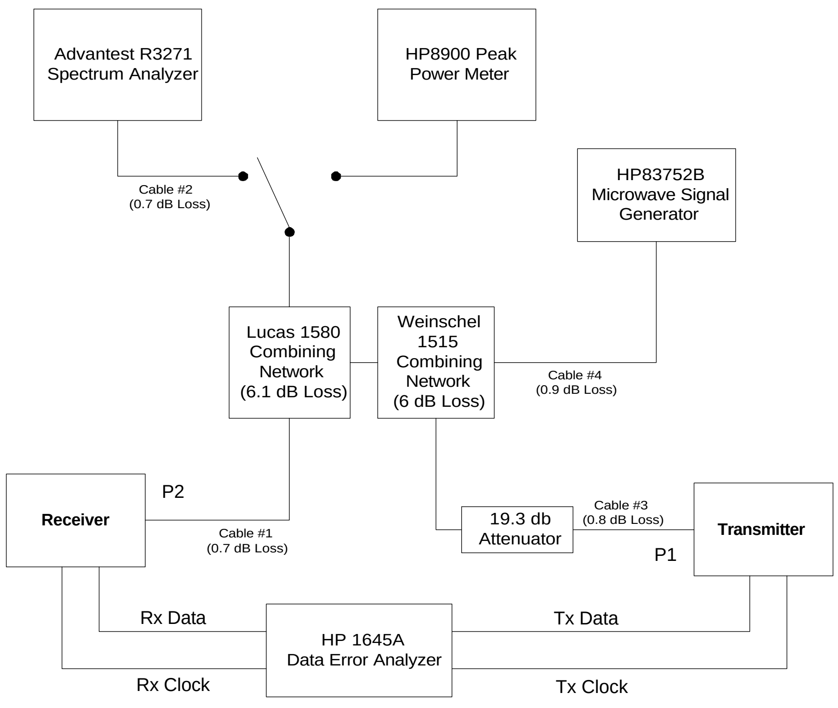
5.11.2. Method of Measurements

Refer to Exhibit 7, Sec. 7.6 of this test report for detailed measurement procedures.

5.11.3. Test Equipment List

- Advantest Spectrum Analyzer, Model R3271, S/N: 15050203
- HP Synthesized Sweeper, Model HP83752B, S/N: 3610A00457, Freq. Range: 10 kHz – 20 GHz.
- HP 8900 RF Peak Power Meter, Measuring Frequency Range: 100 MHz - 18 GHz.
- HP 1645A Data Error Analyzer

5.11.4. Test Arrangement



Loss from P1 to P2 = 32.9

5.11.5. Test Data

Test Configuration: DQPSK MODULATION, 11 Mb/s Data Rate

Theoretical Process Gain = $\frac{\text{11 MHz}}{\text{(2 Mb/s)/(2bits/symbol)}}$ = 11 numeric or 10.4 dB

THEORETICAL PROCESS GAIN : 10.4dB				MIN. MEASURED PROCESSING GAIN: 11.0 dB after discarding 20 % of the worst readings (shaded row are the discarded reading)			
Test Point	Jammer Signal Freq. +/- Fc (MHz)	(BER) x 10^{-5}	(S/N)o (dB)	System Loss Lsys (dB)	Jammer to Signal Radio Mj (dB)	Measured Processing Gain (dB)	Discarded Readings
1	-2.50	0.9	12.4	2.0	-5.74	8.7	1
2	-2.45	0.4	12.8	2.0	-4.24	10.6	2
3	-2.40	1.3	12.1	2.0	-4.43	9.7	3
4	-2.35	0.8	12.5	2.0	-4.06	10.4	4
5	-2.30	0.9	12.4	2.0	-4.49	9.9	5
6	-2.25	0.5	12.7	2.0	-4.12	10.6	6
7	-2.20	0.5	12.7	2.0	-3.18	11.6	
8	-2.15	0.4	12.8	2.0	-2.84	12.0	
9	-2.10	0.5	12.7	2.0	-3.65	11.1	
10	-2.05	0.7	12.6	2.0	-2.43	12.2	
11	-2.00	0.3	12.9	2.0	-2.31	12.6	
12	-1.95	0.8	12.5	2.0	-3.09	11.4	
13	-1.90	0.9	12.4	2.0	-2.74	11.7	
14	-1.85	0.9	12.4	2.0	-4.06	10.4	7
15	-1.80	0.7	12.6	2.0	-3.21	11.4	
16	-1.75	0.6	12.7	2.0	-4.43	10.2	8
17	-1.70	0.6	12.7	2.0	-4.96	9.7	9
18	-1.65	0.6	12.7	2.0	-3.96	10.7	10
19	-1.60	0.7	12.6	2.0	-3.74	10.8	11
20	-1.55	0.5	12.7	2.0	-5.74	9.0	12
21	-1.50	0.5	12.7	2.0	-4.77	10.0	13
22	-1.45	0.6	12.7	2.0	-4.43	10.2	14
23	-1.40	0.5	12.7	2.0	-3.46	11.3	
24	-1.35	0.5	12.7	2.0	-1.84	12.9	
25	-1.30	0.6	12.7	2.0	-1.27	13.4	
26	-1.25	0.9	12.4	2.0	-1.74	12.7	
27	-1.20	0.5	12.7	2.0	-1.21	13.5	
28	-1.15	0.5	12.7	2.0	-3.31	11.4	
29	-1.10	0.6	12.7	2.0	-2.24	12.4	
30	-1.05	0.6	12.7	2.0	-2.31	12.3	
31	-1.00	0.7	12.6	2.0	-2.68	11.9	
32	-0.95	0.5	12.7	2.0	-1.87	12.9	

Test Point	Jammer Signal Freq. +/- Fc (MHz)	(BER) x 10^{-5}	(S/N)o (dB)	System Loss Lsys (dB)	Jammer to Signal Radio Mj (dB)	Measured Processing Gain (dB)	Discarded Readings
33	-0.90	0.6	12.7	2.0	-2.06	12.6	
34	-0.85	0.5	12.7	2.0	-2.27	12.5	
35	-0.80	0.5	12.7	2.0	-2.71	12.0	
36	-0.75	0.5	12.7	2.0	-2.60	12.1	
37	-0.70	0.4	12.8	2.0	-2.70	12.1	
38	-0.65	0.9	12.4	2.0	-2.09	12.3	
39	-0.60	0.6	12.7	2.0	-2.40	12.3	
40	-0.55	0.6	12.7	2.0	-2.52	12.1	
41	-0.50	0.4	12.8	2.0	-2.24	12.6	
42	-0.45	0.9	12.4	2.0	-3.55	10.9	15
43	-0.40	0.4	12.8	2.0	-3.31	11.5	
44	-0.35	0.6	12.7	2.0	-2.99	11.7	
45	-0.30	0.6	12.7	2.0	-2.27	12.4	
46	-0.25	0.6	12.7	2.0	-3.37	11.3	
47	-0.20	0.4	12.8	2.0	-4.09	10.7	16
48	-0.15	0.6	12.7	2.0	-4.12	10.5	17
49	-0.10	0.4	12.8	2.0	-3.84	11.0	
50	-0.05	0.9	12.4	2.0	-4.21	10.2	18
51	0.00	0.6	12.7	2.0	-4.02	10.6	19
52	0.05	0.5	12.7	2.0	-3.87	10.9	20
53	0.10	0.6	12.7	2.0	-3.49	11.2	
54	0.15	0.4	12.8	2.0	-3.74	11.1	
55	0.20	0.4	12.8	2.0	-2.24	12.6	
56	0.25	0.6	12.7	2.0	-2.56	12.1	
57	0.30	0.5	12.7	2.0	-2.18	12.6	
58	0.35	0.6	12.7	2.0	-2.27	12.4	
59	0.40	0.4	12.8	2.0	-1.68	13.1	
60	0.45	0.6	12.7	2.0	-1.37	13.3	
61	0.50	0.6	12.7	2.0	-2.71	11.9	
62	0.55	0.5	12.7	2.0	-2.27	12.5	
63	0.60	0.6	12.7	2.0	-2.71	11.9	
64	0.65	0.5	12.7	2.0	-2.43	12.3	
65	0.70	0.5	12.7	2.0	-2.60	12.1	
66	0.75	0.7	12.6	2.0	-3.12	11.5	
67	0.80	0.6	12.7	2.0	-2.56	12.1	
68	0.85	0.6	12.7	2.0	-2.27	12.4	
69	0.90	0.6	12.7	2.0	-2.87	11.8	
70	0.95	0.4	12.8	2.0	-2.27	12.5	
71	1.00	0.5	12.7	2.0	-1.06	13.7	
72	1.05	0.5	12.7	2.0	-0.96	13.8	
73	1.10	0.6	12.7	2.0	-0.77	13.9	

Test Point	Jammer Signal Freq. +/- Fc (MHz)	(BER) x 10^{-5}	(S/N)o (dB)	System Loss Lsys (dB)	Jammer to Signal Radio Mj (dB)	Measured Processing Gain (dB)	Discarded Readings
74	1.15	0.5	12.7	2.0	-1.70	13.0	
75	1.20	0.5	12.7	2.0	-1.46	13.3	
76	1.25	0.6	12.7	2.0	-0.74	13.9	
77	1.30	0.4	12.8	2.0	-0.43	14.4	
78	1.35	0.3	12.9	2.0	-1.59	13.3	
79	1.40	0.5	12.7	2.0	-1.12	13.6	
80	1.45	0.5	12.7	2.0	-2.15	12.6	
81	1.50	0.5	12.7	2.0	-2.74	12.0	
82	1.55	0.5	12.7	2.0	-2.49	12.2	
83	1.60	0.4	12.8	2.0	-2.93	11.9	
84	1.65	0.6	12.7	2.0	-2.68	12.0	
85	1.70	0.5	12.7	2.0	-2.65	12.1	
86	1.75	0.6	12.7	2.0	-2.81	11.8	
87	1.80	0.6	12.7	2.0	-2.00	12.7	
88	1.85	0.9	12.4	2.0	-1.90	12.5	
89	1.90	0.6	12.7	2.0	-2.05	12.6	
90	1.95	0.8	12.5	2.0	-2.10	12.4	
91	2.00	0.5	12.7	2.0	-1.99	12.7	
92	2.05	0.5	12.7	2.0	-2.65	12.1	
93	2.10	0.4	12.8	2.0	-2.65	12.2	
94	2.15	0.5	12.7	2.0	-1.27	13.5	
95	2.20	0.4	12.8	2.0	-2.52	12.3	
96	2.25	0.6	12.7	2.0	-1.31	13.3	
97	2.30	0.6	12.7	2.0	-1.62	13.0	
98	2.35	0.6	12.7	2.0	-1.71	12.9	
99	2.40	0.5	12.7	2.0	-2.66	12.1	
100	2.45	0.9	12.4	2.0	-2.27	12.2	
101	2.50	0.8	12.5	2.0	-2.58	11.9	

EXHIBIT 6. MEASUREMENT UNCERTAINTY

The measurement uncertainties stated were calculated in accordance with the requirements of NIST Technical Note 1297 and NIS 81 (1994)

6.1. LINE CONDUCTED EMISSION MEASUREMENT UNCERTAINTY

CONTRIBUTION (Line Conducted)	PROBABILITY DISTRIBUTION	UNCERTAINTY (dB)	
		9-150 kHz	0.15-30 MHz
EMI Receiver specification	Rectangular	±1.5	±1.5
LISN coupling specification	Rectangular	±1.5	±1.5
Cable and Input Transient Limiter calibration	Normal (k=2)	±0.3	±0.5
Mismatch: Receiver VRC Γ_1 = 0.03 LISN VRC Γ_R = 0.8(9 kHz) 0.2 (30 MHz) Uncertainty limits $20Log(1\pm\Gamma_1\Gamma_R)$	U-Shaped	±0.2	±0.3
System repeatability	Std. deviation	±0.2	±0.05
Repeatability of EUT	--	--	--
Combined standard uncertainty	Normal	±1.25	±1.30
Expanded uncertainty U	Normal (k=2)	±2.50	±2.60

Sample Calculation for Measurement Accuracy in 450 kHz to 30 MHz Band:

$$u_c(y) = \sqrt{\sum_{I=1}^{m} u_i^2(y)} = \pm\sqrt{(1.5^2 + 1.5^2)/3 + (0.5/2)^2 + (0.05/2)^2 + 0.35^2} = \pm 1.30 \text{ dB}$$

$$U = 2u_c(y) = \pm 2.6 \text{ dB}$$

6.2. RADIATED EMISSION MEASUREMENT UNCERTAINTY

CONTRIBUTION (Radiated Emissions)	PROBABILITY DISTRIBUTION	UNCERTAINTY (± dB) 3 m	UNCERTAINTY (± dB) 10 m
Antenna Factor Calibration	Normal (k=2)	±1.0	±1.0
Cable Loss Calibration	Normal (k=2)	±0.3	±0.5
EMI Receiver specification	Rectangular	±1.5	±1.5
Antenna Directivit	Rectangular	+0.5	+0.5
Antenna factor variation with height	Rectangular	±2.0	±0.5
Antenna phase center variation	Rectangular	0.0	±0.2
Antenna factor frequency interpolation	Rectangular	±0.25	±0.25
Measurement distance variation	Rectangular	±0.6	±0.4
Site imperfections	Rectangular	±2.0	±2.0
Mismatch: Receiver VRC Γ_1 = 0.2 Antenna VRC Γ_R = 0.67(Bi) 0.3 (Lp) Uncertainty limits $20Log(1\pm\Gamma_1\Gamma_R)$	U-Shaped	+1.1 -1.25	±0.5
System repeatability	Std. Deviation	±0.5	±0.5
Repeatability of EUT		-	-
Combined standard uncertainty	Normal	+2.19 / -2.21	+1.74 / -1.72
Expanded uncertainty U	Normal (k=2)	+4.38 / -4.42	+3.48 / -3.44

Calculation for maximum uncertainty when 3m biconical antenna including a factor of k=2 is used:

$U = 2u_c(y) = 2x(+2.19) = +4.38$ dB And $U = 2u_c(y) = 2x(-2.21) = -4.42$ dB

EXHIBIT 7. MEASUREMENT METHODS

7.1. GENERAL TEST CONDITIONS

The following test conditions shall be applied throughout the tests covered in this report.

7.1.1. Normal temperature and humidity

- Normal temperature: +15°C to +35°C
- Relative Humidity: +20% to 75%

The actual values during tests shall be recorded in the test report.

7.1.2. Normal power source

7.1.2.1. Mains Voltage

The nominal test voltage of the equipment to be connected to mains shall be the nominal mains voltage which is the declared voltage or any of the declared voltages for which the equipment was designed.

The frequency of test power source corresponding to the AC mains shall be between 59 Hz and 61 Hz.

7.1.2.2. Battery Power Source.

For operation from battery power sources, the nominal test voltage shall be as declared by the equipment manufacturer. This shall be recorded in the test report.

7.1.3. Operating Condition of Equipment under Test

- All tests were carried out while the equipment operated at the following frequencies:
  - The lowest operating frequency,
  - The middle operating frequency and
  - The highest operating frequency
- Modulation were applied using the Test Data sequence
- The transmitter was operated at the highest output power, or in the case the equipment able to operate at more than one power level, at the lowest and highest output powers

7.2. METHOD OF MEASUREMENTS - AC MAINS CONDUCTED EMISSIONS

- AC Mains conducted emissions measurements were performed in accordance with the standard against appropriate limits for each detector function.
- The test was performed in the shielded room, 16'(L) by 16'(W) by 12'(H).
- The test was performed were made over the frequency range from 450 kHz to 30 MHz to determine the line-to-ground radio noise voltage which was conducted from the EUT power-input terminals that were directly connected to a public power network.
- The EUT normally received power from another device that connects to the public utility ac power lines, measurements would be made on that device with the EUT in operation to ensure that the device continues to comply with the appropriate limits while providing the EUT with power.
- If the EUT operates only from internal or dedicated batteries, with no provisions for connection to the public utility ac power lines, AC Mains conducted measurements are not required.
- Table-top devices were placed on a platform of nominal size 1 m by 1.5m raised 80 cm above the conducting ground plane.
- The EUT current-carrying power lead, except the ground (safety) lead, was individually connected through a LISN to the power source. All unused 50-Ohm connectors of the LISN was terminated in 50-ohm when not connected to the measuring instruments.
- The line cord of the EUT connected to one LISN which was connected to the measuring instrument. Those power cords for the units of devices not under measurement were connected to a separate multiple ac outlet. Drawings and photographs of typically conducted emission test setups were shown in the Test Report. Each current-carrying conductor of the EUT shall be individually tested.
- The EUT was normally operated with a ground (safety) connection, the EUT was connected to the ground at the LISN through a conductor provided in the lead from the ac power mains to the LISN.
- The excess length of the power cord was folded back and forth in an 8-shape on a wooden strip with a vertical prong located on the top of the LISN case.
- The EUT was set-up in its typical configuration and operated in its various modes as described in this test report.
- A preliminary scan was made by using spectrum analyzer system with the detector function set to PEAK mode (9 KHz RBW, VBW > RBW), frequency span 450 kHz to 30 MHz.

- The maximum conducted emission for a given mode of operation was found by using the following step-by-step procedure:

  Step1. Monitor the frequency range of interest at a fixed EUT azimuth.

  Step2. Manipulate the system cables and peripheral devices to produce highest amplitude signal relative to the limit. Note the amplitude and frequency of the suspect signal.

  Step3. The effects of various modes of operation is examined. This is done by varying equipment operation modes as step 2 is being performed.

  Step4. After completing step 1 through 3, record EUT and peripheral device configuration, mode of operation, cable configuration, signal levels and frequencies for final test.

- Each highest signal level at the maximized test configuration was zoomed in a small frequency span on the spectrum analyzer's display (the manipulation of cables and peripheral devices and EUT operation modes might have to be repeated to obtain the highest signal level with the spectrum analyzer set to PEAK detector mode 10 KHz RBW and VBW > RBW). The spectrum analyzer was then set to CISPR QUASI-PEAK detector mode (9 KHz RBW, 1 MHz VBW) and AVERAGE detector mode (10 kHz RBW, 1 Hz VBW). The final highest RF signal levels and frequencies were record.

- ***Broad-band ac Powerline conducted emissions***:- If the EUT exhibits ac Powerline conducted emissions that exceed the limit with the instrument set to the quasi-peak mode, then measurements should be made in the average mode. If the amplitude measured in the quasi-peak mode is at least 6 dB higher than the amplitude measured in the average mode, the level measured in quasi peak mode may be reduced by 13 dB before comparing it to the limit.

7.3. EFFECTIVE RADIATED POWER

- The following shall be applied to the combination(s) of the radio device and its intended antenna(e).
- I f the RF level is user adjustable, all measurements shall be made with the highest power level available to the user for that combination.
- The following method of measurement shall apply to both conducted and radiated measurements.
- The radiated measurements are performed at the Ultratech Calibrated Open Field Test Site.
- The measurement shall be performed using normal operation of the equipment with modulation.

Test procedure shall be as follows:

Step 1: Duty Cycle measurements

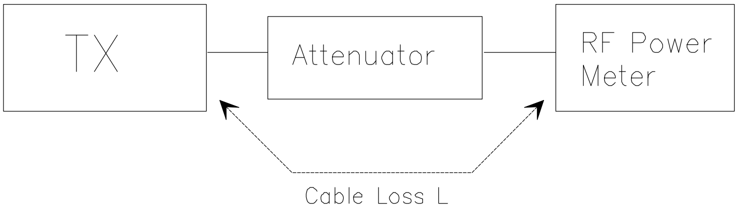
- Using a spectrum analyzer with the frequency span set to 0 Hz and the sweep time set at a suitable value to capture the envelope peaks and the duty cycle of the transmitter output signal;
- The duty cycle of the transmitter, x = Tx on / (Tx on + Tx off) with 0<x<1, is measure and recorded in the test report. For the purpose of testing, the equipment shall be operated with a duty cycle that is equal or more than 0.1.

Step 2: Calculation of Peak and Average EIRP

- The peak output power of the transmitter shall be determined using a wideband, calibrated RF Peak Power Meter with the power sensor with an integration period that exceeds the repetition period of the transmitter by a factor 5 or more. The observed value shall be recorded as “P” (in dBm);
- The Average EIRP. shall be calculated from the above measured power output “A”, the observed duty cycle x, and the applicable antenna assembly gain “G” in dBi, according to the formula:

Peak EIRP = P + G
Average EIRP = Peak EIRP + 10log(1/x)

Figure 1.



Step 3: Substitution Method. See Figure 2

(a) The measurements was performed in the absence of modulation (un-modulated)
(b) Test was performed at listed 3m open area test site (listed with FCC, IC, ITI, NVLAP, ACA & VCCI).
(c) The transmitter under test was placed at the specified height on a non-conducting turntable (80 cm height)
(d) The dipole test antenna was used and tuned to the transmitter carrier frequency.
(e) The spectrum analyzer was tuned to transmitter carrier frequency. The test antenna was lowered or raised from 1 to 4 meters until the maximum signal level was detected.
(f) The transmitter was rotated through 360^{o} about a vertical axis until a higher maximum signal was received.
(g) The test antenna was lowered or raised again from 1 to 4 meters until a maximum was obtained. This level was recorded.
(h) The substitution dipole antenna and the signal generator replaced the transmitter and antenna under test in the same position, and the substitution dipole antenna was placed in vertical polarization. The test dipole antenna was lowered or raised as necessary to ensure that the maximum signal is stilled received.
(i) The input signal to the substitution antenna was adjusted in level until an equal or a known related level to that detected from the transmitter was obtained in the test receiver. The maximum carrier radiated power is equal to the power supply by the generator.
(j) The substitution antenna gain and cable loss were added to the signal generator level for the corrected ERP level.
(k) Repeat steps (c) to (j) with the substitution antenna oriented in horizontal polarization.
(l) Actual gain of the EUT's antenna is the difference of the measured ERP and measured RF power at the RF port. Correct the antenna gain if necessary.

Figure 2

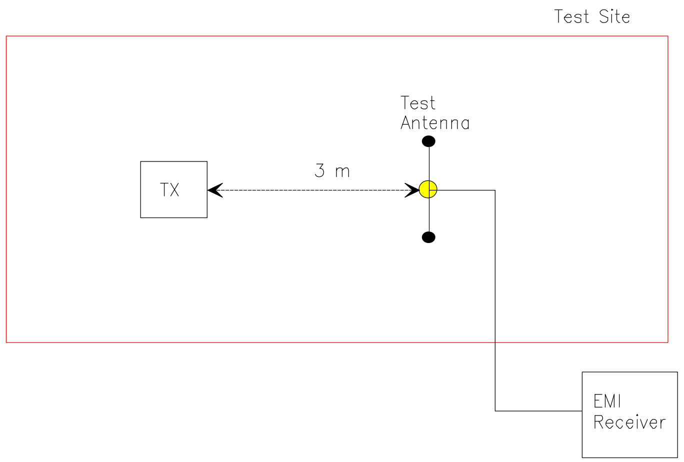
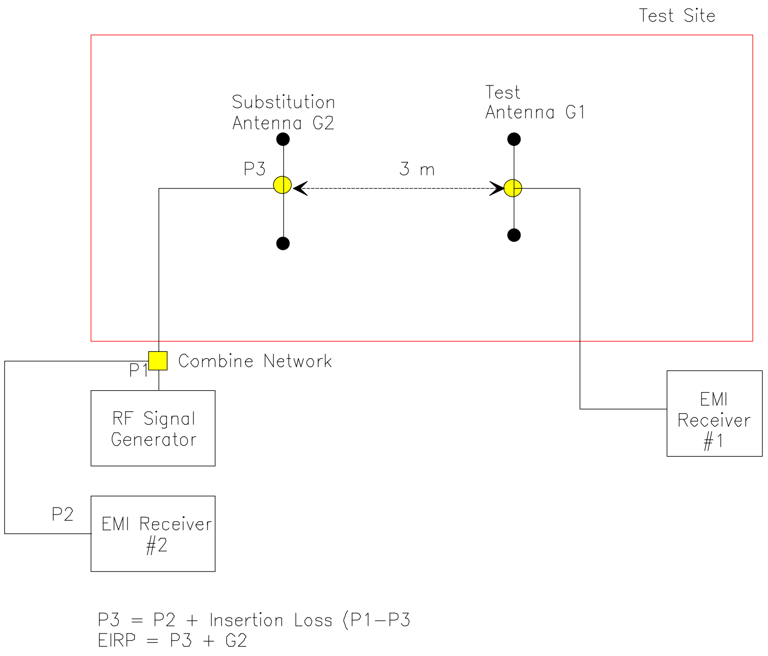


Figure 3


Test Site
Substitution Antenna G2
Test Antenna G1
P3
3 m
Combine Network
P1
RF Signal Generator
EMI Receiver #1
P2
EMI Receiver #2
P3 = P2 + Insertion Loss (P1–P3
EIRP = P3 + G2

7.4. SPURIOUS EMISSIONS (CONDUCTED & RADIATED)

For both conducted and radiated measurements, the spurious emissions were scanned from the lowest frequency generated by the EUT or 10 MHz whichever is lower to 10^{th} harmonic of the highest frequency generated by the EUT.

7.4.1. Spurious Emissions (Conducted)

- The radio was connected to the measuring equipment via a suitable attenuator.
- The spectrum analyzer were used and set as follows:

  - Resolution BW: 100 kHz
  - Video BW: same or greater
  - Detector Mode: Positive Peak
  - Averaging: Off
  - Span: 100 MHz
  - Amplitude: Adjust for middle of the instrument's range
  - Sweep Time: Auto

7.4.2. Spurious Emissions (Radiated)

- The radiated emission measurements were performed at the UltraTech's 3 Meter Open Field Test Site (OFTS) situated in the Town of Oakville, province of Ontario. The Attenuation Characteristics of OFTS have been filed to FCC, Industry Canada, ACA/Austel, NVLap and ITI.
- Radiated emissions measurements were made using the following test instruments:

1. Calibrated EMCO BiconiLog antenna in the frequency range from 30 MHz to 2000 MHz.
2. Calibrated Emco Horn antennas in the frequency range above 1000 MHz (1GHz - 40 GHz).
3. Calibrated Advantest spectrum analyzer and pre-selector were used. The spectrum analyzer would be used as follows:

   For frequencies below 1 GHz:

   - Resolution BW: 100 kHz
   - Video BW: same or greater
   - Detector Mode: Positive Peak
   - Averaging: Off
   - Span: 100 MHz
   - Amplitude: Adjust for middle of the instrument's range
   - Sweep Time: Auto

   For frequencies above 1 GHz:

   - Resolution BW: 1 MHz
   - Video BW: same or greater
   - Detector Mode: Positive Peak
   - Averaging: Off
   - Span: 500 MHz
   - Amplitude: Adjust for middle of the instrument's range
   - Sweep Time: Auto

- The frequencies of emissions was first detected. Then the amplitude of the emissions was measured at the specified measurement distance using required antenna height, polarization, and detector characteristics.
- During this process, cables and peripheral devices were manipulated within the range of likely configuration.
- For each mode of operation required to be tested, the frequency spectrum was monitored. Variations in antenna heights (from 1 meter to 4 meters above the ground plane), antenna polarization (horizontal plane and vertical plane), cable placement and peripheral placement were explored to produce the highest amplitude signal relative to the limit.

The maximum radiated emission for a given mode of operation was found by using the following step-by-step procedure:

Step1: Monitor the frequency range of interest at a fixed antenna height and EUT azimuth.

Step2: Manipulate the system cables to produce highest amplitude signal relative to the limit. Note the amplitude and frequency of the suspect signal.

Step3: Rotate the EUT 360 degrees to maximize the suspected highest amplitude signal. If the signal or another at a different frequency is observed to exceed the previously noted highest amplitude signal by 1 dB or more, go back to the azimuth and repeat Step 2. Otherwise, orient the EUT azimuth to repeat the highest amplitude observation and proceed.

Step4: Move the antenna over its full allowable range of travel (1 to 4 meters) to maximize the suspected highest amplitude signal. If the signal or another at a different frequency is observed to exceed the previously noted highest amplitude signal by 1 dB or more, return to Step 2 with the highest amplitude observation and proceed.

Step5: Change the polarization of the antenna and repeat Step 2 through 4. Compare the resulting suspected highest amplitude signal with that found for the other polarization. Select and note the higher of the two signals. This signal is termed the highest observed signal with respect to the limit for this EUT operational mode.

Step6: The effects of various modes of operation is examined. This is done by varying the equipment modes as steps 2 through 5 are being performed.

Step7: After completing steps 1 through 6, record the final highest emission level, frequency, antenna polarization and detector mode of the measuring instrument.

Calculation of Field Strength:

The field strength is calculated by adding the calibrated antenna factor and cable factor, and subtracting the Amplifier gain (if any) from the measured reading. The basic equation with a sample calculation is as follows:

$$FS = RA + AF + CF - AG$$

Where	FS	=	Field Strength
	RA	=	Receiver/Analyzer Reading
	AF	=	Antenna Factor
	CF	=	Cable Attenuation Factor
	AG	=	Amplifier Gain

Example: If a receiver reading of 60.0 dBuV is obtained, the antenna factor of 7.0 dB/m and cable factor of 1.0 dB are added, and the amplifier gain of 30 dB is subtracted. The actual field strength will be:.

Field Level = 60 + 7.0 + 1.0 - 30 = 38.0 dBuV/m.
Field Level = $10^{(38/20)}$ = 79.43 uV/m.

7.5. TRANSMITTED POWER DENSITY OF A DSSS SYSTEM

- The radio was connected to the measuring equipment via a suitable attenuator.
- Locate and zoom in on emission peak(s) within the passband
- The spectrum analyzer were used and set as follows:

  - Resolution BW: 3 kHz
  - Video BW: same or greater
  - Detector Mode: Normal
  - Averaging: Off
  - Span: 3 MHz
  - Amplitude: Adjust for middle of the instrument's range
  - Sweep Time: 1000 seconds

- Locate and zoom in on emission peak(s) within the passband. Set RBW = 3 KHz, VBW $\geq$ RBW, Sweep = SPAN/3 KHz. For example, a span of 1.5 MHz, the sweep should be $1.6x10^6/3.0x10^3$= 500 seconds. The measured peak level must be no greater than +8 dBm.
- For devices with spectrum line spacing greater than 3 KHz no change is required.
- For devices with spectrum line spacing equal to or less than 3 KHz, the resolution bandwidth must be reduced below 3 KHz until the individual lines in the spectrum are resolved. The measurement data must then be normalized to 3 KHz by summing the power of all the individual spectral lines within 3 KHz band (in linear power units) to determine compliance.
- If the spectrum line spacing cannot be resolved on the available spectrum analyzer, the noise density function on most modern conventional spectrum analyzer will directly measure the noise power density normalized to 1 Hz noise power bandwidth. Add 30 dB for correction to 3 KHz.
- Should all the above fail or any controversy develop regarding accuracy of measurement, the Laboratory will use HP 89440A Vector Signal Analyzer for final measurement unless a clear showing can be made for a further alternate.

7.6. PROCESSING GAIN OF A DIRECT SEQUENCE SPREAD SPECTRUM

The processing gain may be measured using the CW jamming margin method. Figure 1 shows the test configuration. The test consists of stepping a signal generator in 50 KHZ increments across the passband of the system. At each point, the generator level required to produce the recommended Bit Error Rate (BER) is recorded. This level is jammer level. The output power of the transmitting unit is measured at the same point. The Jammer to Signal (J/S) ratio is then calculated. Discard the worst 20% of the J/S data points. The lowest remaining J/S ratio is used when calculating the Process Gain.

The signal to noise ratio for an ideal differentially coherent detetion of a differentially encoded BPSK receiver can be derived from the Bit Error Probability (Pb) versus Signal-to-Noise ratio. See attached plot for detailed information.

For measurement of the $(S/N)_o$ we use the Pb of $1.0x10^{-5}$ minimum.

Ref.: Viterbi, A.J. Principles of Coherent Communications (New York: McGraw-HILL 1966), Pg. 207

Using equation (1) shown above, calculate the signal to noise ratio required for your chosen BER. This value and the measured J/S ratio are used in the following equation to calculate the Process Gain (Gp) of the system.

Gp = (S/N)o+Mj+Lsys

Where:

(S/N)o: Theoretical signal to noise ratio required to maintain the normal operation just before the BER appears. In real measurements the maximum error of 0.001 is allowed in an ideal system using their modulation scheme with all codes turned off (i.e. no spreading or processing gain).

Mj: Maximum jammer to Signal Ratio that recorded at the detected BER.

Lsys: System losses such as non-ideal synchronization, tracking circuitry, non-optimal baseband receiver filtering and etc... These losses can be in excess of 3 dB for each transmitter and receiver pair. For the purpose of this processing gain calculation we assume a Lsys at its minimum value of 2 dB.

Ref.: Dixon, R, Spread Spectrum Systems. (New York: Wiley, 1984), Chapter 1.

- (S/N)o: Refer to attached curcves, BER versus (S/N)o for Differiential Coherent Detection of Differientially Encoded BPSK
- Processing gain Gp = (S/N)o + Lsys + Mj = (S/N)o + 2 + Mj

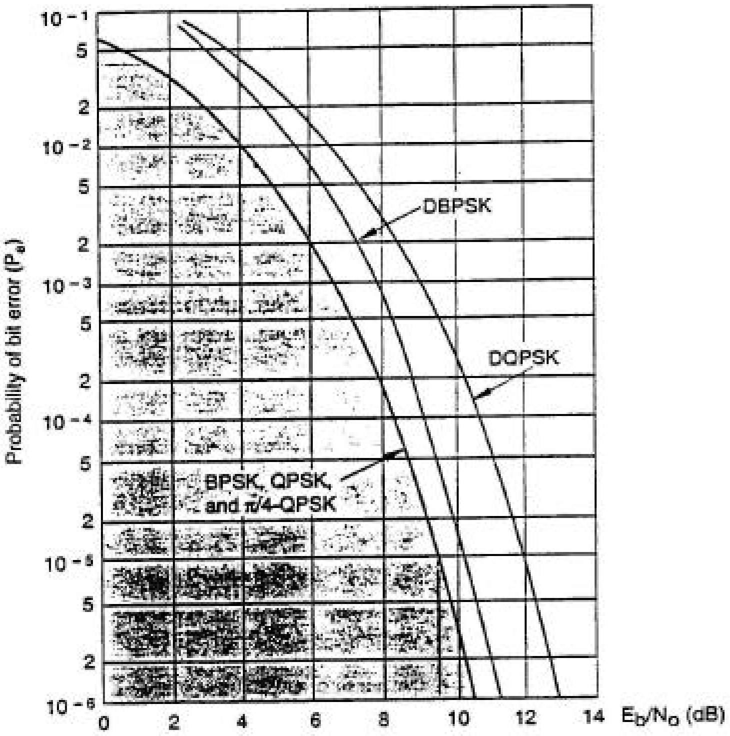


Figure 4.5.1 Theoretical $P_e = f(E_b/N_o)$ performance in a stationary additive white Gaussian noise (AWGN) environment. Ideal, linearly amplified coherent BPSK, QPSK, and differentially demodulated DBPSK systems are illustrated. The performance of non-linearly amplified FQPSK and GMSK is compared to ideal linearly amplified QPSK in Figures 4.3.33 and 4.3.34. (From Proakis, 1989.) See Appendix A.3.

tically equivalent term bit-error rate (BER) is used in applied references and specifications.

Power efficiency of modulated systems is defined as being inversely proportional to the

$$\text{BER} = f(C/N)$$

and/or

$$\text{BER} = f(E_b/N_o)$$

equations and performance curves, where E_b is the average energy of a modulated bit and N_o is the noise power spectral density (the noise power in a normalized 1-Hz bandwidth) at the demodulator input. The higher the probability of error, the lower the power efficiency, since transmitted power is "wasted" on more bad data.

EXHIBIT 8. PLOTS OF MEASUREMENTS

8.1. AC POWERLINE CONDUCTED EMISSIONS PLOTS

Please refer to attached plots.

8.2. 6 dB OCCUPIED BANDWIDTH PLOTS

Please refer to attached plots.

8.3. DUTY CYCLE PLOTS

Please refer to attached plots.

8.4. SPURIOUS EMISSIONS (CONDUCTED) PLOTS

Please refer to attached plots.

8.5. SPURIOUS EMISSIONS (RADIATED @ 3 METERS) PLOTS

Please refer to attached plots.

8.6. TRANSMITTED POWER DENSITY PLOTS

Please refer to attached plots.

EXHIBIT 9. PHOTOGRAPHS OF TEST SETUP

Please refer to attached test setup photograph.

EXHIBIT 10. APPLICANT'S LETTERS & STATEMENT

10.1. APPLICANT'S AUTHORIZATION TO APPOINT ULTRATECH ENGINEERING LABS INC. TO ACT AS AN AGENT

Please refer to attached letter.

10.2. LETTER REQUEST FOR FCC CONFIDENTIALITY FILING

Please refer to attached letter.

10.3. RADIATED EMISSIONS CERTIFICATE OF CONFORMITY

Please refer to attached letter.

10.4. RF ANTENNA SECURING DESCRIPTIONS

Please refer to attached descriptions.

EXHIBIT 11. FCC ID LABEL & SKETCH OF LABEL LOCATION

Please refer to attached FCC ID label.

EXHIBIT 12. "FCC INFORMATION TO USER"

Please refer to user manual (Section 9.3 FCC STATEMENT).

EXHIBIT 13. PHOTOGRAPHS OF EQUIPMENT UNDER TEST

Please refer to attached photographs of Equipment Under Test

EXHIBIT 14. SYSTEM BLOCK DIAGRAM(S), SCHEMATIC DIAGRAMS & BOM

Please refer to attached diagrams.

EXHIBIT 15. USER'S MANUAL

Please refer to attached user manual.