



## **FCC Part 15 Subpart C**

### **Frequency Hopping Spread Spectrum Transmitter**

### **Certification Test Report**

**Manufacturer: Neptune Technology Group**

**Model: R900-v2**

**Variants:** ♦ **Pit Mounted MIU with External Antenna**  
♦ **Wall Mounted MIU with Integrated Antenna**

**Rules Section: 15.247**

**Test Begin Date: September 1, 2002**

**Test End Date: October 2, 2002**

**Report Issue Date: November 26, 2002**

**ACS Report Number: 02-0177-15C**

**Test Result: PASS**

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## 1.0 GENERAL

### 1.1 Introduction

The purpose of this report is to demonstrate compliance with Part 15, Subpart C of the FCC's Code of Federal Regulations.

### 1.2 Product Description

#### 1.2.1 General

The Equipment Under Test(EUT) is the Model RF900-v2. This report covers 2 variants of the product that are identified as the Wall Mounted Meter Interface Unit (MIU) and the Pit Mounted MIU. Both variants are electrically identical and differ only in their antennas, mounting scheme and enclosure. The Wall mounted MIU uses an integrated folded dipole antenna and is usually wall mounted. The PIT Mounted MIU is usually mounted in a pit underground and uses a durable external patch antenna that is flush mounted to the surface above the pit.

Detailed photographs of the EUT are filed separately with this filing.

#### 1.2.2 Intended Use

##### Wall Mount MIU

The R900 Wall Meter Interface Unit (MIU) is a compact electronic device that collects meter-usage data from an encoder register and transmits the data for collection by the meter reader. The R900 wall MIU provides water utilities with a reliable and economical RF reading solution. Data transmitted by the MIU is received by the Neptune walk-by or drive-by data collection system and stored for downloading at the utility office. The R900 wall MIU is a one-way communication device that transmits data using frequency-hopping spread-spectrum technology to ensure data security and improve meter reading accuracy. The R900 automatically detects the encoder without programming, reducing inventory and installation time. It can be easily mounted to most flat wall surfaces or pipe. The R900 wall MIU can be installed as far as 200 to 500 feet from the encoder register depending on the encoder register's manufacturer and model. The R900 wall MIU is compatible with Neptune ARB® V and ProRead AutoDetect encoder registers as well as Invensys ECR II® encoders. The MIU automatically detects the encoder type and adjusts to read the encoder. Connected to the encoder register by a three-conductor wire, the R900 Wall MIU reads the encoder register automatically, once an hour and transmits that data every four seconds. The MIU is designed to easily upgrade existing probe-based systems that use ARB V, ProRead AutoDetect, or Invensys ECR II encoder registers. The MIU simply connects to the existing three-conductor wire and will reuse the existing mounting holes.

##### Pit Mount MIU

The R900 Pit Meter Interface Unit (MIU) is a compact electronic device that collects meter-usage data from an encoder register and transmits the data from the meter pit for collection by the meter reader. The R900 pit MIU provides water utilities with a reliable and economical RF reading solution. It has been specifically engineered to withstand the water meter pit environment. Data transmitted by the MIU is received by the Neptune walk-by or drive-by data collection system and stored for downloading at the utility office. The R900 pit MIU is a one-way communication device that transmits data using frequency-hopping spread-spectrum technology to ensure data security and improve meter reading accuracy. The R900 automatically detects the encoder without programming, reducing inventory and installation time. The antenna is mounted through the industry-standard 1-3/4" lid hole. Its metallic design allows installation in traffic areas. The antenna is coupled to the electronic assembly which goes under the lid. The assembly is fully potted to allow submersion (flooding of pits). The R900 pit MIU is compatible with the ARB® V and ProRead AutoDetect encoder registers as well as Invensys ECR II® encoders. The MIU automatically detects the encoder type and adjusts to read the encoder. Connected to the encoder register by a three-conductor wire, the R900 pit MIU reads the encoder register automatically once an hour and transmits that data every four seconds. The MIU is designed to easily upgrade existing probe-based systems that use ProRead pit receptacles since it can be installed in the existing predrilled 1-3/4" pit lid.

### 1.2.3 Technical Specifications

**Table 1.2.3-1: Specifications**

Frequency Band	902-928
Number of Channels	50
Channel Bandwidth	92kHz Nominal
Channel Spacing	N/A
Output power	18dBm nominal
Antenna Type	Dipole and Patch
Antenna Gain	Dipole is -4dBi, Patch is -5dBi
Antenna Connector Type	Dipole Permanently Attached, Patch uses F type connector

### 1.2.4 Antennas

The Wall Antenna is a folded dipole antenna. Wauconda manufactures it with a Neptune Technology Group Inc. model number of 12524-00X. The maximum gain is -4dB. This antenna will be soldered to the PCB.

The Pit Antenna is a patch antenna. Applied Power manufactures it with a Neptune Technology Group Inc. model number of 12527-000. The maximum gain is -5dB. This antenna has an F-type male connector with custom water seal and strain relief bracket.

## 2.0 LOCATION OF TEST FACILITY

All testing was performed by qualified ACS personnel located at the following address:

ACS, Inc.  
5015 B.U. Bowman Drive  
Buford, GA 30518

### 2.1 DESCRIPTION OF TEST FACILITY

Both the Open Area Test Site(OATS) and Conducted Emissions site have been fully described, submitted to, and accepted by the FCC, Industry Canada and the Japanese Voluntary Control Council for Interference by information technology equipment.

The following certification numbers have been issued in recognition of these accreditations and certifications:

FCC Registration Number: 89450  
Industry Canada Lab Code: IC 4175  
VCCI Member Number: 1831

- VCCI OATS Registration Number R-1526
- VCCI Conducted Emissions Site Registration Number: C-1608

#### 2.1.1 Open Area Test Site

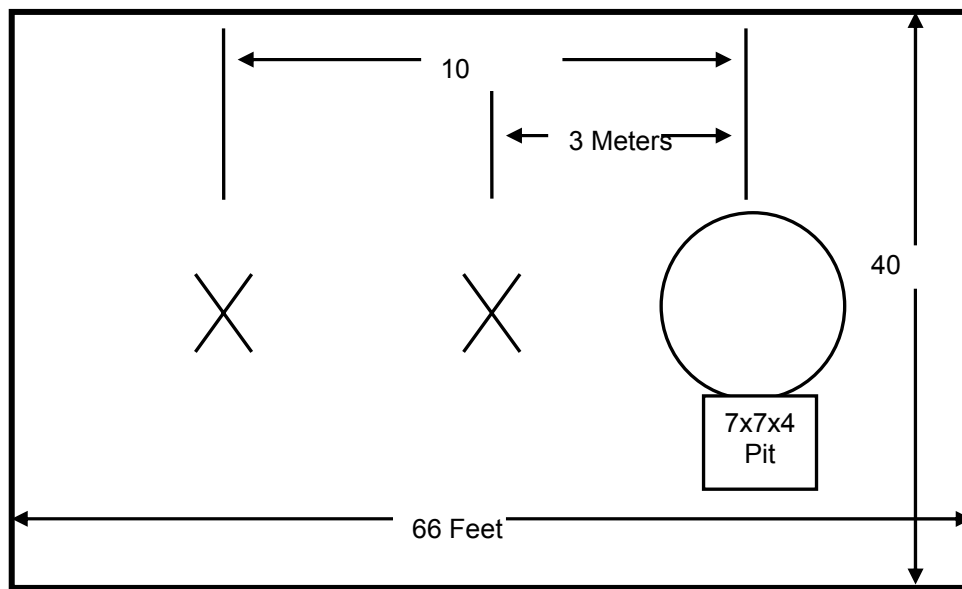
The open area test site consists of a 40' x 66' concrete pad covered with a perforated electro-plated galvanized sheet metal. The perforations in the sheet metal are 1/8" holes that are staggered every 3/16". The individual sheets are placed to overlap each other by 1/4" and are riveted together to provide a continuous seam. Rivets are spaced every 3" in a 3 x 20 meter perimeter around the antenna mast and EUT area. Rivets in the remaining area are spaced as necessary to properly secure the ground plane and maintain the electrical continuity.

The entire ground plane extends 12' beyond the turntable edge and 16' beyond the antenna mast when set to a 10 meter measurement distance. The ground plane is grounded via 4 - 8' copper ground rods, each installed at a corner of the ground plane and bound to the ground plane using 3/4" stainless steel braided cable.

The turntable is an all aluminum 10' flush mounted table installed in an all aluminum frame. The table is remotely operated from inside the control room located 40' from the range. The turntable is electrically bonded to the surrounding ground plane via steel fingers installed on the edge of the turn table. The steel fingers make constant contact with the ground plane during operation.

Adjacent to the turntable is a 7' x 7' square and 4' deep concrete pit used for support equipment if necessary. The pit is equipped with 5 - 4" PVC chases from the pit to the control room that allow for cabling to the EUT if necessary. The underside of the turntable can be accessed from the pit so cables can be supplied to the EUT from the pit. The pit is covered with 2 sheets of 1/4" diamond style re-enforced steel sheets. The sheets are painted to match the perforated steel ground plane, however the underside edges have been masked off to maintain the electrical continuity of the ground plane. All reflecting objects are located outside of the ellipse defined in ANSI C63.4.

A diagram of the Open Area Test Site is shown in Figure 3.2-1 below:



**Figure 3.2-1: Open Area Test Site**

### 2.1.2 Conducted Emissions Test Site Description

The AC mains conducted EMI site is a shielded room with the following dimensions:

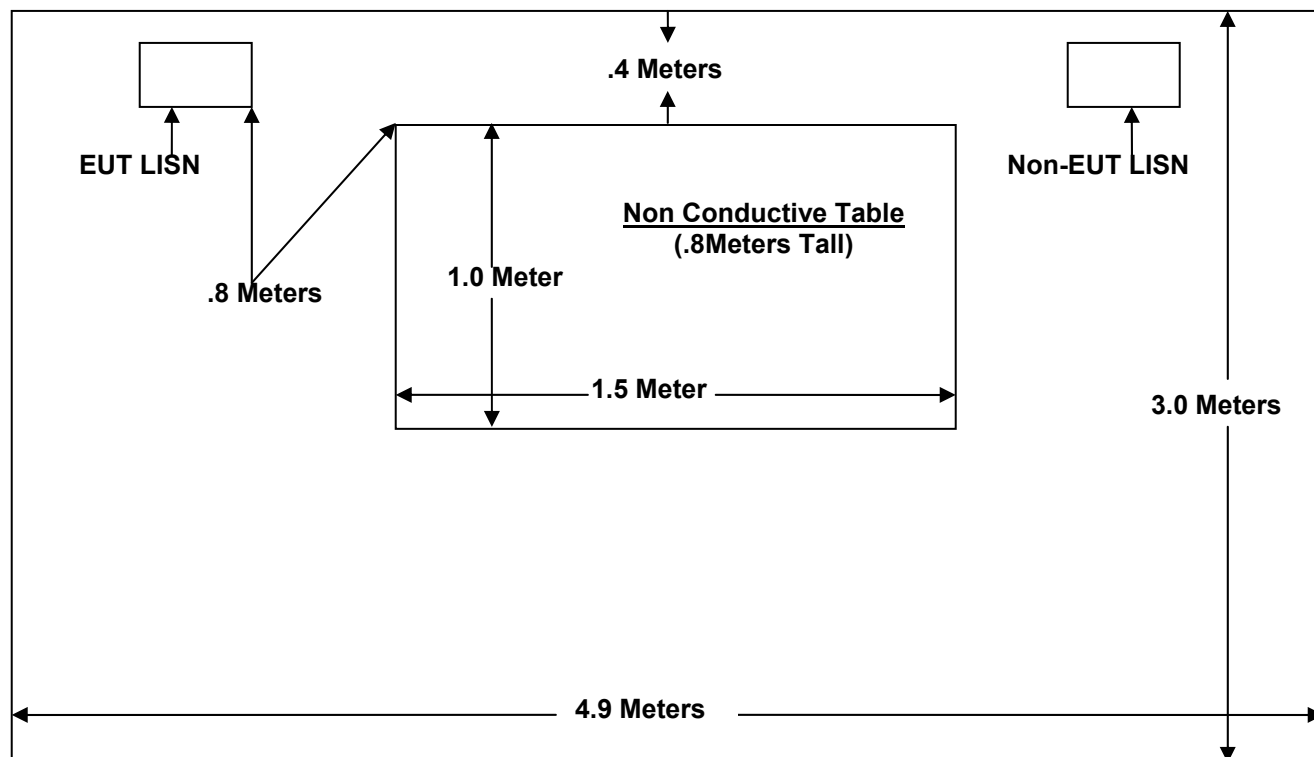
- Height: 3.0 Meters
- Width: 3.6 Meters
- Length: 4.9 Meters

The room is manufactured by Rayproof Corporation and installed by Panashield, Inc. Earth ground is provided to the room via an 8' copper ground rod. Each panel of the room is connected electrically at intervals of 4".

Power to the room is filtered to prevent ambient noise from coupling to the EUT and measurement equipment. Filters are models 1B42-60P manufactured by Rayproof Corporation.

The room is of sufficient size to test table top and floor standing equipment in accordance with section 6.1.4 of ANSI C63.4.

A diagram of the room is shown below in figure 2.1.2-1:



**Figure 3.3-1: AC Mains Conducted EMI Site**

### 3.0 APPLICABLE STANDARD REFERENCES

The following standards were used:

- 1 - ANSI C63.4-1992: Method of Measurements of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the 9KHz to 40GHz
- 2 - US Code of Federal Regulations (CFR): Title 47, Part 15, Subpart C: Radio Frequency Devices, Intentional Radiators (October 2000)
- 3 - FCC OET Bulletin 65 Appendix C - Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields

#### 4.0 LIST OF TEST EQUIPMENT

All test equipment used for regulatory testing is calibrated yearly or according to manufacturer's specifications.

**Table 4-1: Test Equipment**

Equipment Calibration Information					
Mfg.	Eq. type	Model	S/N	ACS #	Cal. Due
Rohde & Schwarz	Spectrum Analyzer	1032.5640.53	833827/003	4	8/16/03
Rohde & Schwarz	Display Unit	804.8932.52	839379/011	3	8/16/03
Rohde & Schwarz	Spectrum Analyzer	1032.5640.53	839587/003	2	12/26/02
Rohde & Schwarz	Display Unit	804.8932.52	839379/011	1	12/26/02
Chase	Bi-Log	CBL6111	1044	26	8/26/03
Microwave Circuits	Hi-Pass Filter	H1G810G1	2123-01 DC0225	105	6/20/03
ACS	Cable	RG8	16	16	3/1/03
ACS	Cable	RG8	23	23	12/13/02
ACS	Cable	Heliac	24	24	12/13/02
ACS	Cable	LL-335	None	5	7/31/03
ACS	Cable	LL-335	None	6	7/31/03
Agilent	Pre-Amplifier	8449B	3008A00526	22	9/21/03
EMCO	Horn Antenna	RGA-60	6166	N/A	5/02/03

#### 5.0 SUPPORT EQUIPMENT

**Table 5-3: Support Equipment**

Manufacturer	Equipment Type	Model Number	Serial Number	FCC ID
	EUT Was Self Supporting			

## 6.0 EQUIPMENT UNDER TEST SETUP BLOCK DIAGRAM

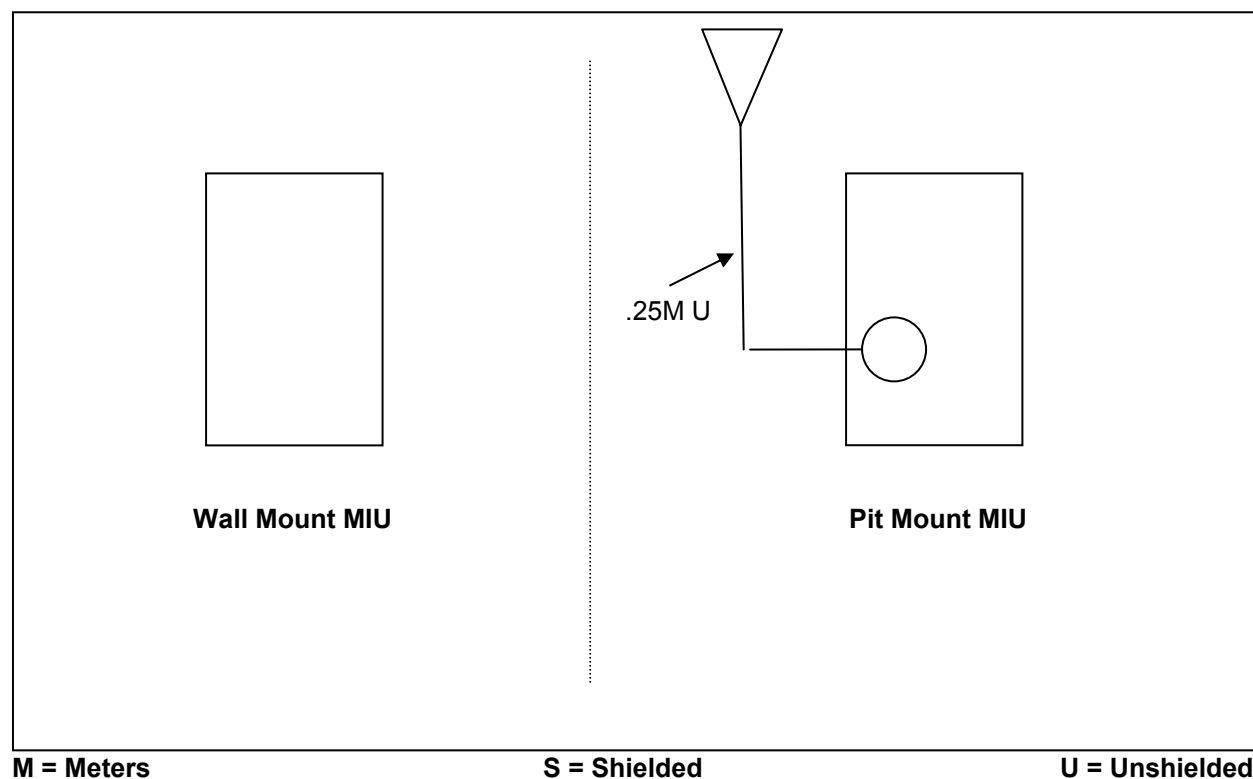


Figure 6-1: EUT Test Setup

## 7.0 SUMMARY OF TESTS

Along with the tabular data shown below, plots were taken of all signals deemed important enough to document.

### 7.1 Antenna Requirement - FCC Section 15.203

Both the wall and pit mounted MIU are professionally installed equipment. The wall unit antenna is integrated and soldered to the board. The Pit mounted unit is installed underground and the antenna is flush mounted into the surface above the pit in which the MIU is installed.



**7.2 Power Line Conducted Emissions - FCC Section 15.207**

Conducted emissions were performed from 450kHz to 30MHz with the spectrum analyzer's resolution bandwidth set to 9kHz and the video bandwidth set to 30kHz. Results of the test are shown below in figure 1 and tables 7.2-1 and 7.2-2.

**Table 7.2-1: Line 1 Conducted EMI Results (Quasi-Peak)**

Frequency MHz	Level	Transducer dBμV	Limit dB	Margin dBμV	Line dB	PE
<b>Both Variants are Battery Powered – Conducted Emissions Not Required</b>						

**Table 7.2-2: Line 2 Conducted EMI Results(Average)**

Frequency MHz	Level	Transducer dBμV	Limit dB	Margin dBμV	Line dB	PE
<b>Both Variants are Battery Powered – Conducted Emissions Not Required</b>						

### 7.3 Radiated Emissions - FCC Section 15.209(Unintentional Radiation)

Radiated emissions tests were performed over the frequency range of 30MHz to 10GHz, 10 times the highest fundamental frequency. Measurements of the radiated field strength were made at a distance of 3m from the boundary of the equipment under test (EUT) and the receiving antenna. The antenna height was varied from 1m to 4m so that the maximum radiated emissions level would be detected. Radiated measurements were made with the Spectrum Analyzer's resolution bandwidth set to 120KHz for measurements above 30MHz.

The EUT was caused to go into a "Receive Only" mode of operation for this test. Results of the test are given in Table 7.3-1 below:

**Table 7.3-1: Radiated Emissions Tabulated Data**

Frequency (MHz)	Uncorrected Reading (dBμV)	Antenna Polarity (H/V)	Antenna Height (cm)	Turntable Position (°)	Total Correction Factor (dB)	Corrected Reading (dBμV)	Limit (dBμV)	Margin (dB)	Results
95.7	10.42	h	100	0	11.73	22.15	43.5	21.4	Pass
106.4	6.59	h	100	0	13.18	19.77	43.5	23.7	Pass
114.1	8.21	h	100	0	13.89	22.10	43.5	21.4	Pass
152.8	5.24	h	100	0	13.53	18.77	43.5	24.7	Pass
229.1	8.14	h	100	0	14.14	22.28	46	23.7	Pass

### 7.4 Peak Output Power Requirement - FCC Section 15.247(b)

The peak output power of the EUT was made at the antenna connector using an 8560E Spectrum Analyzer. The 20dB bandwidth of the device was measured to be 91.7kHz, therefore a spectrum analyzer with the RBW set to 1MHz was used to measure the output power of the device. For the measurement, the EUT was caused to generate a constant carrier. A 75 to 50Ohm adapter was used to compensate for the impedance mismatch of the EUT and measurement equipment. A correction factor of 6dB was added to the measured result and is reflected below. Results are shown below in Table 7.4-1 and Figure 7.4-1.

**Table 7.4-1: Peak Output Power**

Frequency (MHz)	Output Power (dBm)
911.09	18

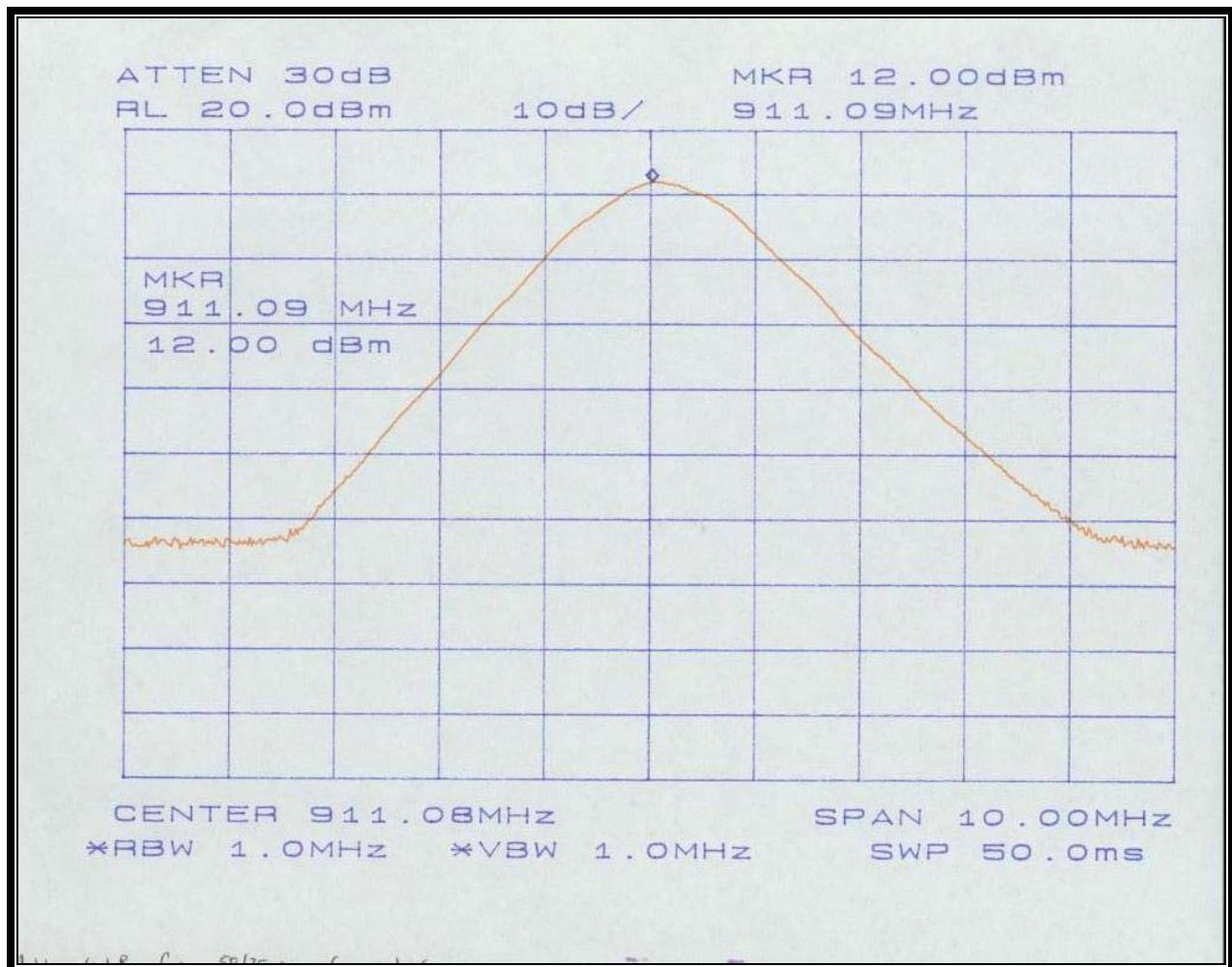


Figure 7.4-1: Output power

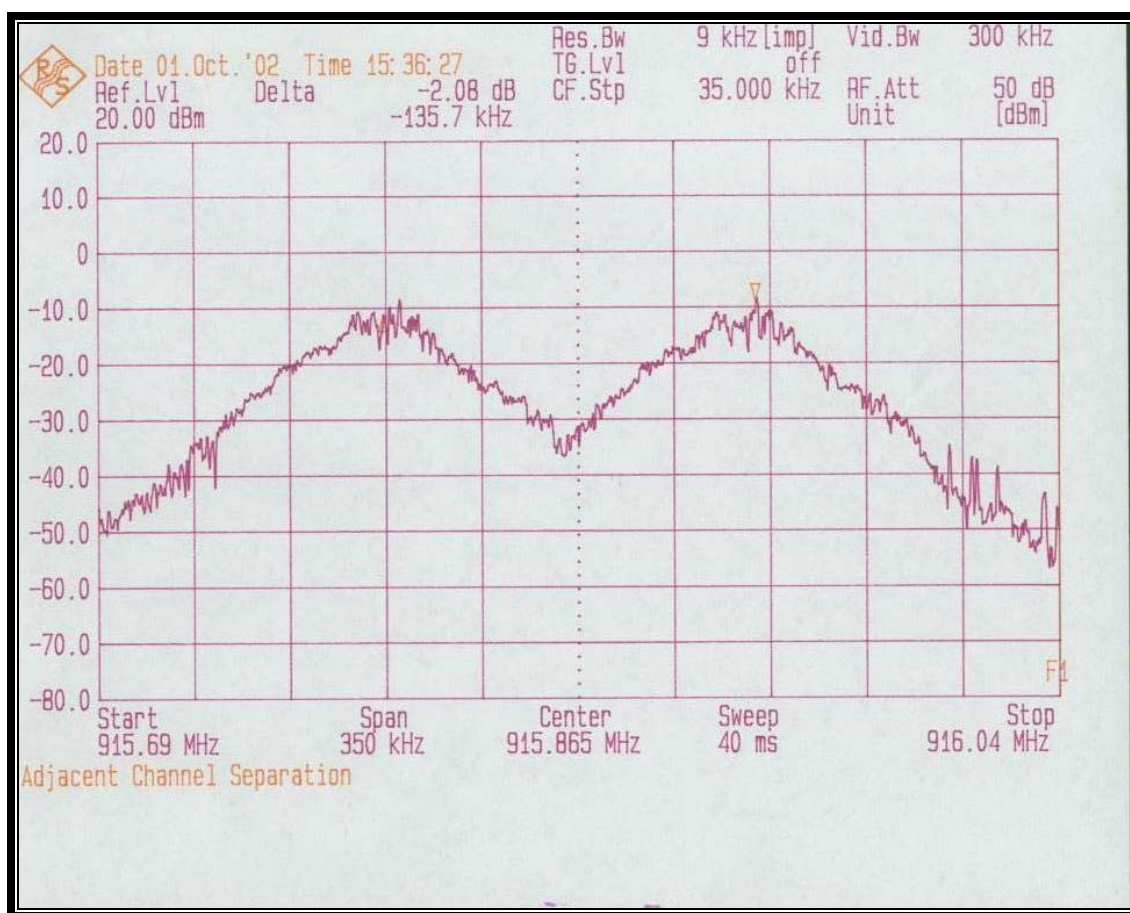
## 7.5 Channel Usage Requirements - FCC Section 15.247(a)(1)

**15.247(a)(1):** Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hopping channel, whichever is greater. The system shall hop to channel frequencies that are selected at the system hopping rate from a pseudorandomly ordered list of hopping frequencies. Each frequency must be used equally on the average by each transmitter. The system receivers shall have input bandwidths that match the hopping channel bandwidths of their corresponding transmitters and shall shift frequencies in synchronization with the wanted signal.

**15.247(a)(1)(i):** For frequency hopping systems operating in the 902-928 MHz band: if the 20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 20 second period; if the 20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 10 second period. The maximum allowed 20 dB bandwidth of the hopping channel is 500 kHz.

### 7.5.1 Adjacent Channel Separation

**Results:** The 20dB bandwidth of the hopping channel was measured to be 91.7 kHz (See figure 7.5.4-1 below). The adjacent channel separation was measured to be 135.7kHz. Results are shown in figure 7.5.1-1 below:



**Figure 7.5.1-1: Adjacent Channel Separation**

### 7.5.2 Number of Hopping Channels

**Result:** The 20dB bandwidth of the device is less than 250kHz. The device employs 50 hopping channels as required. Results are shown in figure 7.5.2-1 below

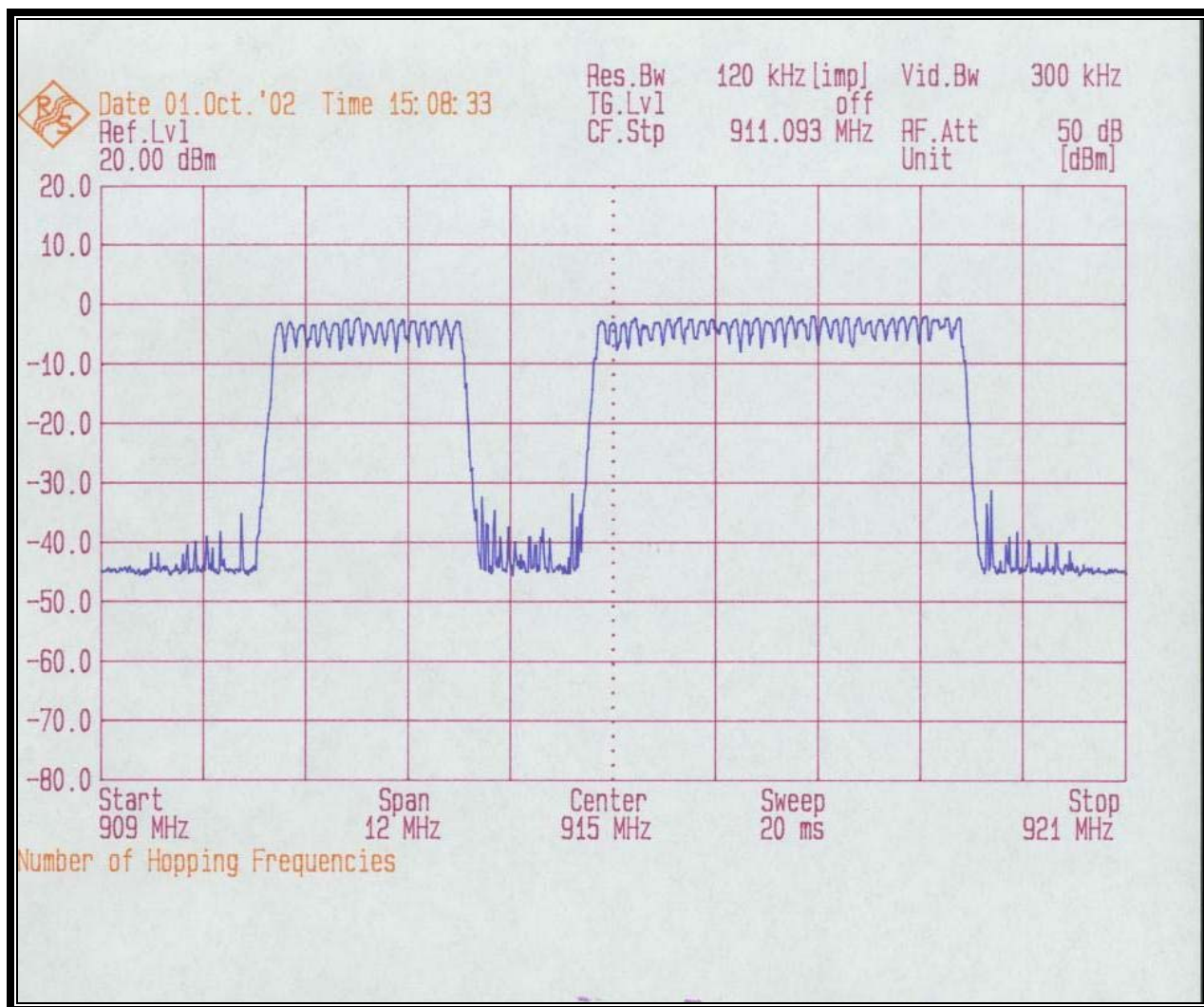


Figure 7.5.2-1: Number of Hopping Channels



### 7.5.3 Channel Dwell Time

**Result:** The duration of the RF transmission is 7.05 ms followed by a 10 second rest period in which the device hops to another channel according to the pseudorandom frequency table before transmitting another 7.05mS burst. Therefore the average time of occupancy on any channel in a 20 second period is 7.05mS. See theory of operation in appendix I of this report for further details. A single transmission is shown in figure 7.5.3-1 below:

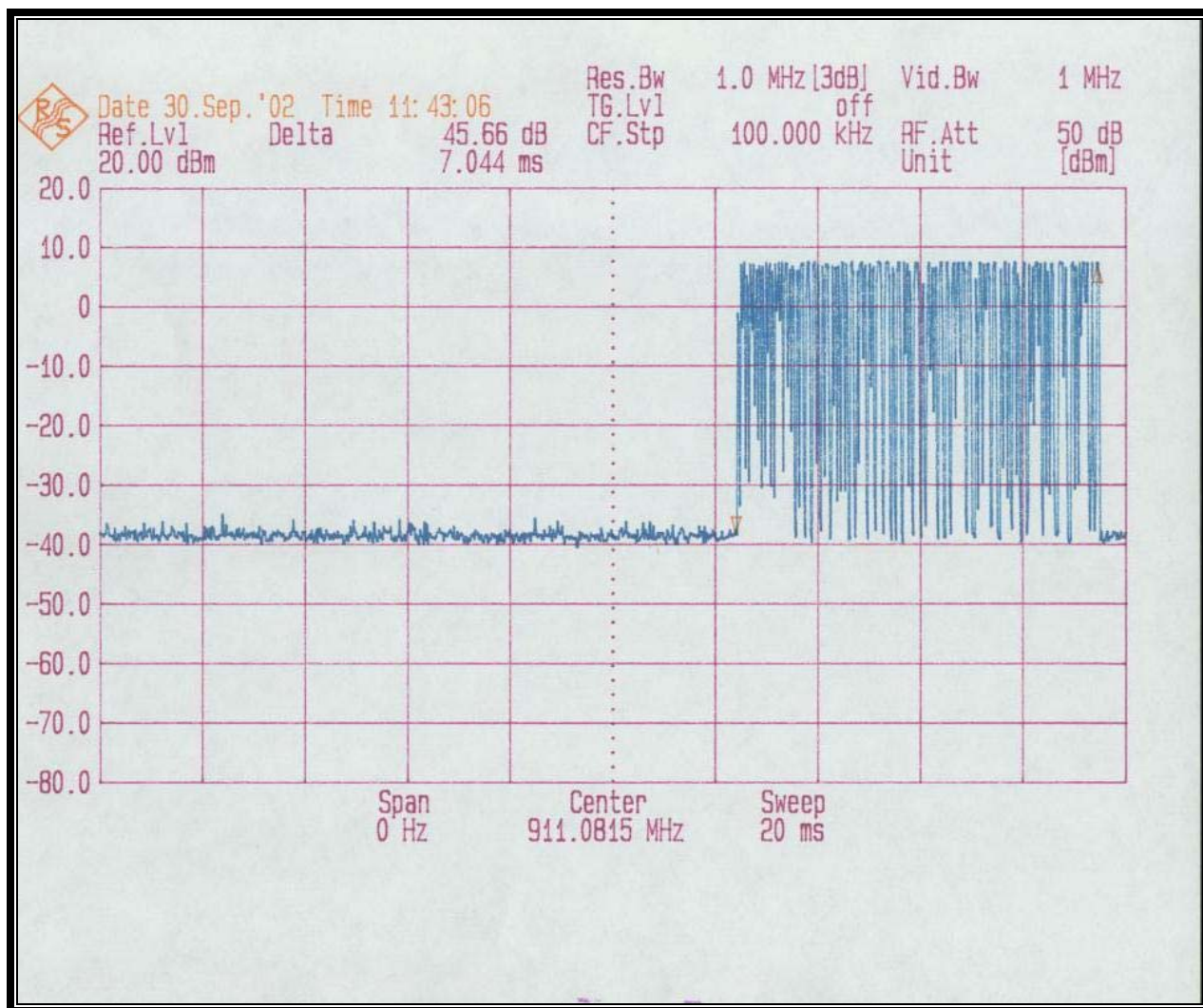


Figure 7.5.3-1: Channel Dwell Time

#### 7.5.4 20dB Bandwidth

**Result:** The 20dB bandwidth was found to be less than 500kHz as required. Results are shown below in figure 7.5.4-1.

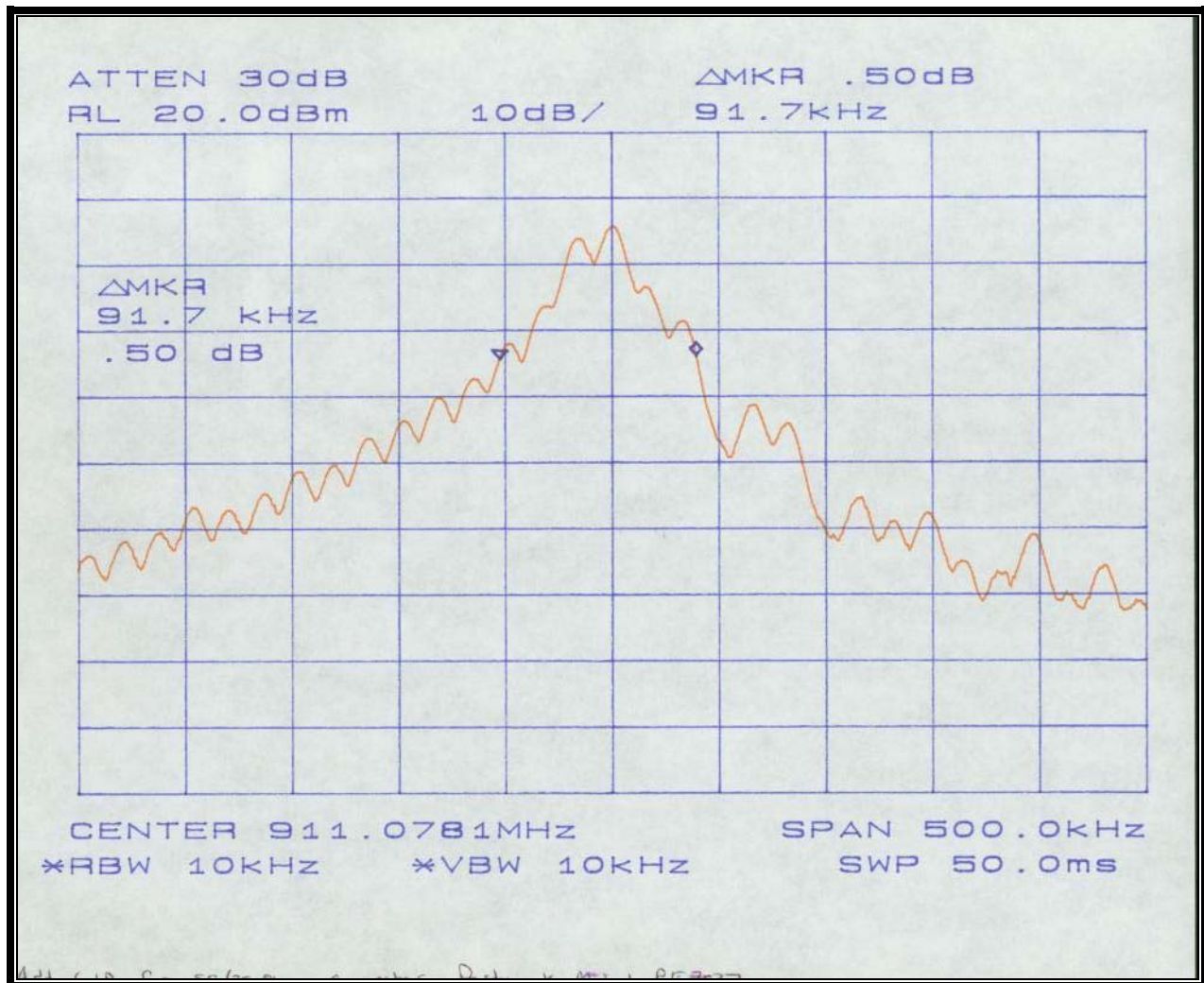


Figure 7.5-1: 20dB Bandwidth

## 7.6 Spurious Emissions - FCC Section 15.247(c)

### 7.6.1 RF Conducted Spurious Emissions

The EUT was investigated for conducted spurious emissions from 30MHz to 10GHz, 10 times the highest fundamental frequency. For each measurement, the spectrum analyzer's VBW was set to 100kHz and the RBW was set to 1MHz.

#### 7.6.1.2 Test Results

**Result:** All emission found were greater than 20dB down from the fundamental carrier. The RF conducted spurious emissions found in the band of 30MHz to 10GHz are reported in Figures 7.6.1.2-1 through 7.6.1.2-3 below. Each emission was compared to the fundamental reference level to determine if they were at least 20dB below the reference level.

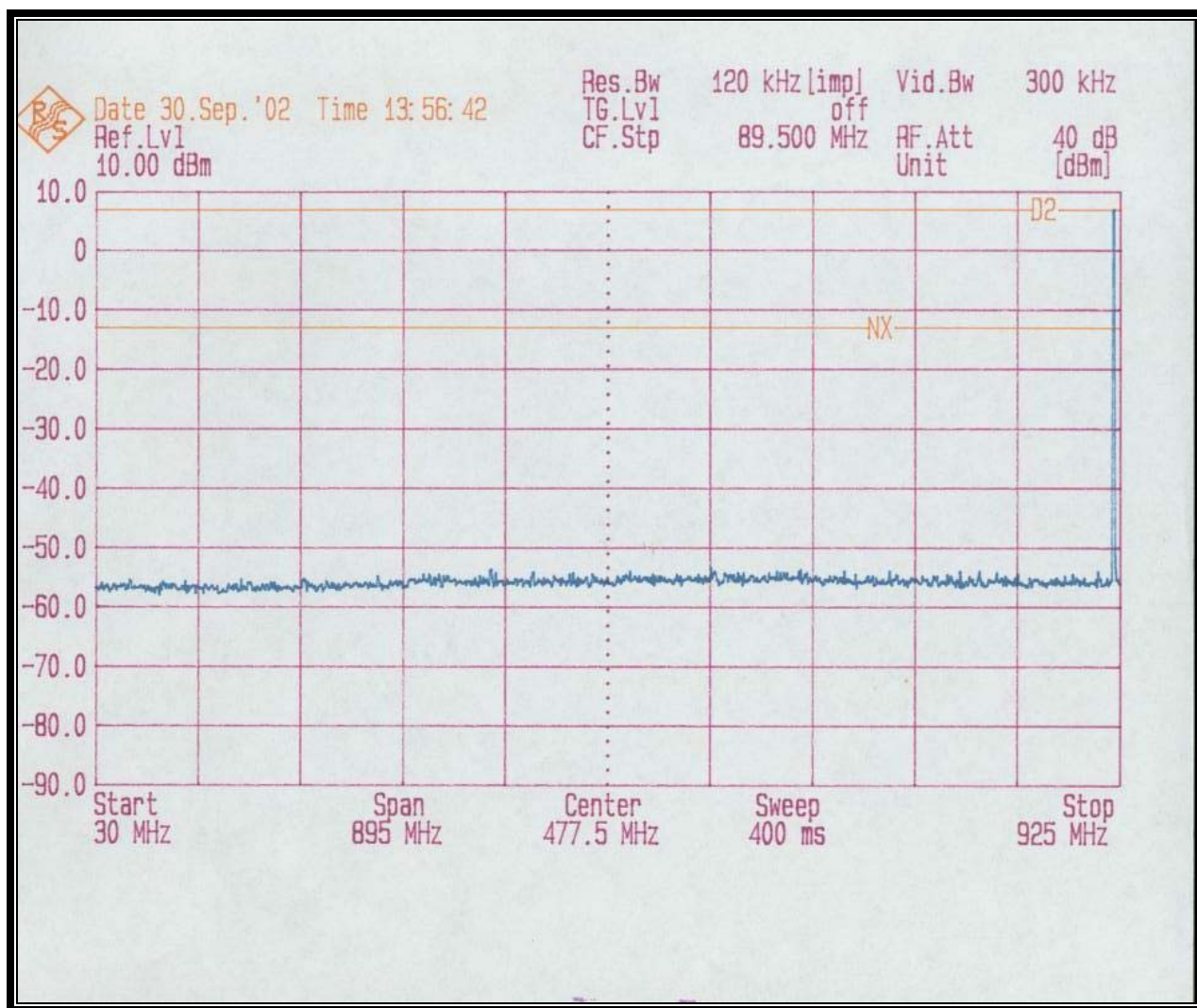


Figure 7.6.1.2-1: Conducted spurious from 30MHz to 925MHz



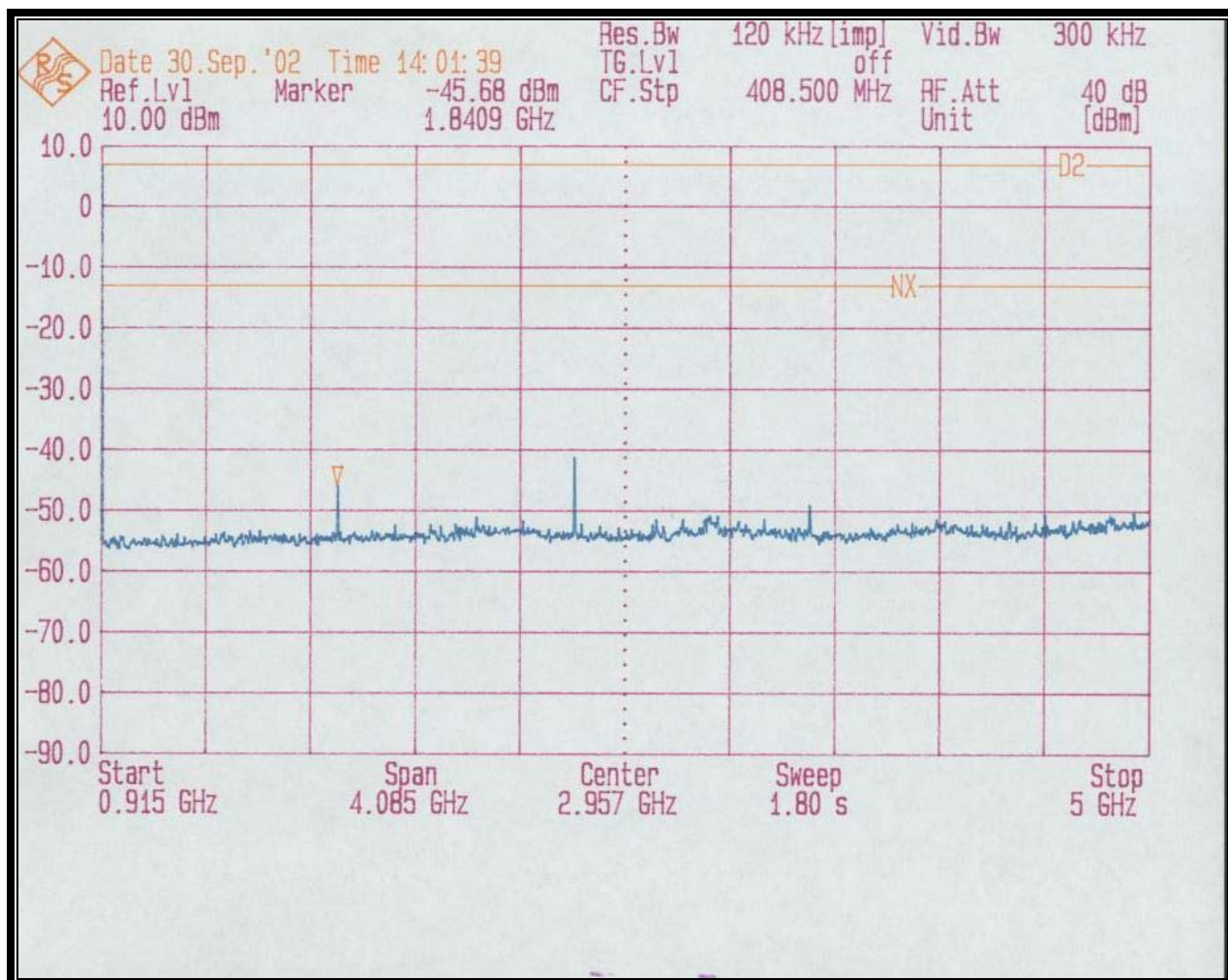


Figure 7.6.1.2-2: Conducted spurious emissions from 915MHz to 5.0GHz

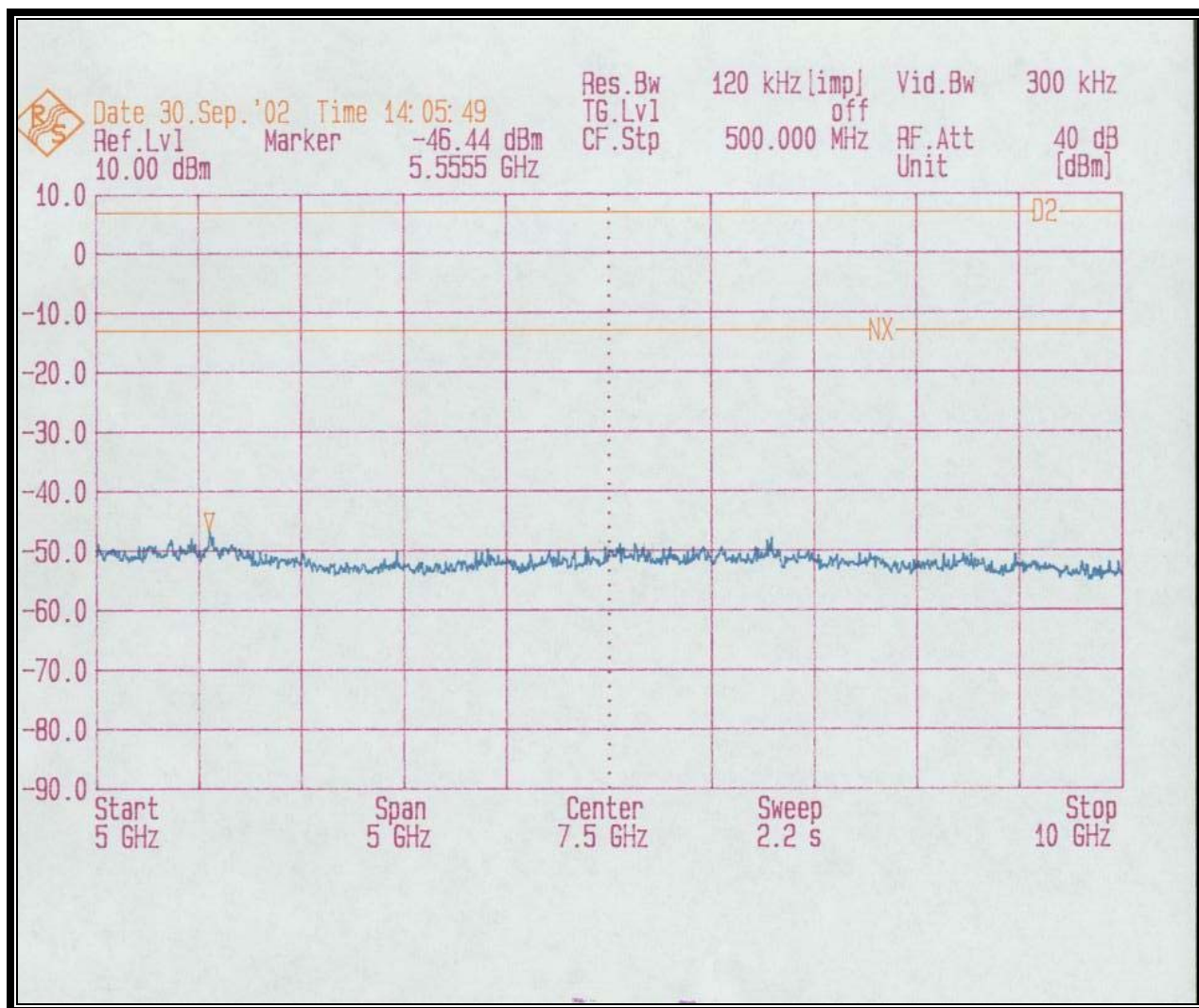


Figure 7.7.1.2-3: Conducted spurious from 5.0GHz to 10GHz

### 7.6.2 Radiated Spurious Emissions(Restricted Bands) - FCC Section 15.205

Radiated emissions tests were made over the frequency range of 30MHz to 10GHz, 10 times the highest fundamental frequency on each antenna given in section 1.2.3.

The EUT was rotated through 360° and the receive antenna height was varied from 1m to 4m so that the maximum radiated emissions level would be detected. For frequencies below 1000MHz, quasi-peak measurements were made using a resolution bandwidth(RBW) of 120kHz and a video bandwidth(VBW) of 300kHz. For frequencies above 1000MHz, average measurements were made using an RBW of 1MHz and a VBW of 10Hz and peak measurements were made with RBW of 1MHz and a VBW of 1MHz.

The EUT was caused to generate a carrier signal on the hopping channel.

#### 7.6.2.1 Duty Cycle Correction

For average measurements, the measured level was reduced by a factor 23dB to account for the duty cycle of the EUT. The EUT transmits for 7.05mS on a channel and does not return to the same channel for over 500 seconds. Therefore the duty cycle is 7.05%. The duty cycle correction factor is determined using the formula:  $20\log(.705) = -23\text{dB}$ . See figure 7.5.3-1 and appendix I for further details.

**7.6.2.2 Test Results**

Radiated spurious emissions found in the band of 30MHz to 10GHz are reported in Table 7.6.2.2-1 and 7.6.2.2-2. Plots of these emissions are also presented separately in Appendix A of this filing. Each emission found to be in a restricted band as defined by section 15.205, was compared to the radiated emission limits for a class B device defined in section 15.209.

**Table 7.6.2.2-1: Radiated Spurious Emissions – Pit Unit(Integrated Antenna)**

Frequency (MHz)	Level (R <sub>U</sub> ) (dBuV)	Detector (P/A)	Antenna Polarity (H/V)	Correction Factors(CF <sub>T</sub> ) (dB)	Corrected Level(R <sub>C</sub> ) (dBuV)	Limit (dBuV)	Margin (dB)	Final Result (Pass/Fail)
2733	69.03	p	h	-1.33	67.70	74.00	6.30	PASS
2733	62.45	a	h	-1.33	38.12	54.00	15.88	PASS
3644	63.95	p	h	5.38	69.33	74.00	4.67	PASS
3644	55.52	a	h	5.38	37.90	54.00	16.10	PASS
4555	60.6	p	v	7.22	67.82	74.00	6.18	PASS
4555	53.38	a	v	7.22	37.60	54.00	16.40	PASS
5466	54.55	p	v	9.49	64.04	74.00	9.96	PASS
5466	48.2	a	v	9.49	34.69	54.00	19.31	PASS
7288	54.25	p	v	14.25	68.50	74.00	5.50	PASS
7288	46.78	a	v	14.25	38.03	54.00	15.97	PASS
8199	50.03	p	v	13.40	63.43	74.00	10.57	PASS
8199	38.88	a	v	13.40	29.28	54.00	24.72	PASS
9110	43.04	p	h	15.34	58.38	74.00	15.62	PASS
9110	31.64	a	h	15.34	23.98	54.00	30.02	PASS

**Table 7.6.2.2-2: Radiated Spurious Emissions – Wall Unit(External Antenna)**

Frequency (MHz)	Level (dBuV)	Detector (P/A)	Antenna Polarity (H/V)	Correction Factors (dB)	Corrected Level (dBuV)	Limit (dBuV)	Margin (dB)	Final Result (Pass/Fail)
2733	60.49	p	v	-1.33	59.16	74.00	14.84	PASS
2733	51.23	a	v	-1.33	26.90	54.00	27.10	PASS
3644	58.03	p	h	5.38	63.41	74.00	10.59	PASS
3644	48.84	a	h	5.38	31.22	54.00	22.78	PASS
4555	66.74	p	v	7.22	73.96	74.00	0.04	PASS
4555	58.79	a	v	7.22	43.01	54.00	10.99	PASS
5466	52.15	p	h	9.49	61.64	74.00	12.36	PASS
5466	47.52	a	h	9.49	34.01	54.00	19.99	PASS
7288	58.64	p	v	14.25	72.89	74.00	1.11	PASS
7288	50.95	a	v	14.25	42.20	54.00	11.80	PASS
8199	47.59	p	h	13.40	60.99	74.00	13.01	PASS
8199	37.92	a	h	13.40	28.32	54.00	25.68	PASS
9110	43.29	p	h	15.34	58.63	74.00	15.37	PASS
9110	32.83	a	h	15.34	25.17	54.00	28.83	PASS

**7.6.2.3 Sample Calculation:**

$$R_C = R_U + CF_T$$

Where:

$CF_T$	=	Total Correction Factor (AF+CA+AG)-DC(Average Measurements Only)
$R_U$	=	Uncorrected Reading
$R_C$	=	Corrected Level
AF	=	Antenna Factor
CA	=	Cable Attenuation
AG	=	Amplifier Gain
DC	=	Duty Cycle Correction Factor

**Example Calculation:**

Corrected Level:  $69.03 + (-1.33) = 67.7$  dBuV

Margin:  $74\text{dBuV} - 67.7\text{dBuV} = 6.3\text{dB}$

**8.0 CONCLUSION**

In the opinion of ACS, Inc. the Enigma RF Module with the Sentinel Meter Direct Sequence spread spectrum module, manufactured by SchlumbergerSema, Inc., meets the requirements of FCC Part 15 subpart C.