ENGINEERING TEST REPORT

Milltronics Radar Level Gauge (6.3 GHz)
With Concrete & Other Non-Conductive Tanks
MODEL NO.: IQ RADAR 160

FCC ID: NJA-IQ160

In Accordance With

FCC PART 15, SUBPART C, PARA. 15.209
LOW POWER COMMUNICATION DEVICE TRANSMITTER
OPERATING AT 6.3 GHz

(FCC AUTHORIZATION FOR CLASS II PERMISSIVE CHANGES)

UltraTech FILE NO.: MIL-183FTX

Tested for:

MILLTRONICS
P.O. Box 4225, 1954 Technology Drive
Peterborough, Ontario
Canada, K9J 7B1

Tested by:

ULTRATECH GROUP OF LABS
3000 Bristol Circle
Oakville, Ontario
Canada L6H 6G4

REPORT PREPARED BY: Mr. Tri M. Luu, P.Eng.

DATE: July 08, 1999

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1. EXHIBIT 1 - SUMMARY OF TEST RESULTS & GENERAL STATEMENT OF CERTIFICATION

FCC PARAGRAPH.	TEST REQUIREMENTS	COMPLIANCE (YES/NO)
15.209	Transmitter Radiated Emissions	Yes
15.109	AC Power Conducted Emissions	Not required for this Class II Permissive Change

TESTIMONIAL AND STATEMENT OF CERTIFICATION

THIS IS TO CERTIFY:

1) *THAT the application was prepared either by, or under the direct supervision of the undersigned.*

2) *THAT the measurement data supplied with the application was taken under my direction and supervision.*

3) *THAT the data was obtained on representative production units.*

4) *THAT, to the best of my knowledge and belief, the facts set forth in the application and accompanying technical data are true and correct.*

Certified by:

____

Tri Minh Luu, P. Eng.
V.P., Engineering

DATE: July 08, 1999

2. EXHIBIT 2 - GENERAL INFORMATION

2.1. APPLICANT

MILLTRONICS
P.O. Box 4225, 1954 Technology Drive
Peterborough, Ontario
Canada, K9J 7B1

Applicant's Representative: Mr. Craig Merchant

2.2. MANUFACTURER

MILLTRONICS
P.O. Box 4225, 1954 Technology Drive
Peterborough, Ontario
Canada, K9J 7B1

2.3. DESCRIPTION OF EQUIPMENT UNDER TEST

OPERATIONAL DESCRIPTIONS:

Milltronics IQ-Radar 160 is intended for use in process industries for the determination of material level in the metal, concrete and other non-conductive tanks and process vessels. The metal, concrete and other non-conductive tanks/vessels can be vented or non-vented and with or without internal stilling wells. The principle used is pulse radar. The device is mounted at the top of the tank or vessel and its antenna is pointed directly downward to the liquid/material to be measured. A short pulse of microwave energy is transmitted towards the surface of the material to be measured. This pulse is reflected from the material surface, and re-transmitted back towards the antenna. The time of flight of the pulse is measured, and hence the distance of the material surface from the antenna is determined (Radar principle). This is then used to calculate the level and/or volume of material in the tank or vessel. It was experiment that during the process of transmission and reflection of pulse in the direct manner from point to point. There is no significant rf emissions were found at the distance of 3 meters or further.

PULSE DESENSITIZATION:

Refer to the attached Exhibit for schematic diagram and Technical description of the Microwave Transmitter operation. This information is submitted with the application under confidentiality filing

Please note that the transmitter circuit is designed with a notch filter at a microstrip transmission line to block any transmission below 5.45 GHz from the rf output to the antenna (which is a restricted band).

PRODUCT NAME:	Milltronics Radar Level Gauge (6.3 GHz)
SERIAL NUMBER:	Pre-production
TYPE OF EQUIPMENT:	LOW POWER COMMUNICATION DEVICE TRANSMITTER
OPERATING FREQ.:	6.3 GHz
BANDWIDTH:	2.7 GHz
	BW_n = 4/T = 4/1.5nS = 2.7 GHz
POWER RATING:	N/A
EMISSION DESIGNATION:	N/A
DUTY CYCLE:	0.075% (Duty Cylce = T_{on}/T_{on+off} = $1.5x10^{-9}/2x10^{-6}$ = 0.00075)
OSC. FREQUENCY(IES):	500 kHz, 8 MHz and 6.3 GHz
CPU SPEED:	2 MHz
INPUT SUPPLY:	120V 60Hz or 24 Vdc
ASSOCIATED DEVICES:	N/A
INTERFACE PORTS:	(1) RSS-485 Port (2) DC Loop Current

2.4. RELATED SUBMITTAL(S)/GRANT

Not applicable

2.5. TEST METHODOLOGY

These tests were conducted on a sample of the equipment for the purpose of certification compliance with Code of Federal Regulations (CFR47-1991), Part 15, Subpart C, Para. 15.209, Low Power Communication Device Transmitters operating at 6.3 GHz.

Both conducted and radiated emissions measurements were conducted in accordance with American National Standards Institute 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.

2.6. TEST FACILITY

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 3-10 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, 1998.

The above test site is also filed with Interference Technology International Ltd (ITI - An EC Directive on EMC).

2.7. UNITS OF MEASUREMENTS

Measurements of conducted emissions are reported in units of dB referenced to one microvolt [dB(μV)].

Measurements of radiated emissions are reported in units of dB referenced to one microvolt per meter [dB(μV)/m] at the distance specified in the report, wherever it is applicable.

3. EXHIBIT 3 - SYSTEM TEST CONFIGURATION

3.1. TEST SYSTEM DETAILS

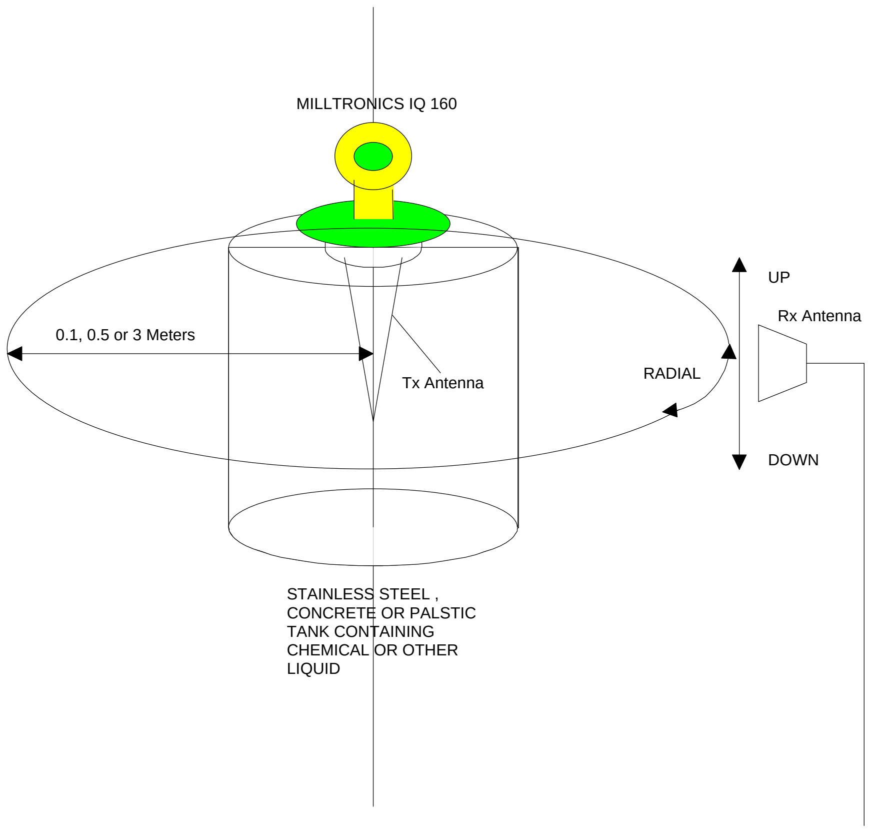
The following peripherals, FCC identifiers and types interconnecting cables were used with the EUT for testing:

(1) **EUT**: MILLTRONICS, Milltronics Radar Level Gauge (6.3 GHz), Model : IQ RADAR 160,, S/N: Pre-production, OSC. FREQ: 500 kHz, 8 MHz and 6.3 GHz.
I/O Cable: All I/O cables were shielded
Power Supply Cable: Non-shielded

(2) **PERIPHERAL**:
I/O Cable: All I/O Cables were shielded
Power Supply Cable: Non-shielded

3.2. BLOCK DIAGRAMS FOR TEST SETUP OF THE TRANSMITTER MOUNTED ON TOP OF ANY TYPE OF TANK (MADE OF METAL, CONCRETE AND OTHER NON-CONDUCTIVE MAETRIALS)

Note: Per our measurements, the radio signal transmission and reflection were found to be limited within a small geographical area of less than 3 meters in radius, directly between the antenna and the material contained in the tank; therefore there was no significant signal was found at the distance of 3 meters.



3.3. PHOTOGRAPH OF TEST SETUP FOR THE TRANSMITTER MOUNTED ON TOP OF A CONCRETE TANK.

EUT was scanned when it was removed from the concrete tank, and its radiating antenna pointed toward the measuring antenna. The signal was found at its rated value.

EUT was scanned when it was removed from the concrete tank, and its radiating antenna pointed toward the measuring antenna. The signal was found at its rated value.

EUT was scanned when it was mounted and secured on top of the concrete tank, and its antenna pointed downward the material inside the concrete tank. The signal was not found in this normal intended configuration.

Picture of the concrete tank from further view

3.4. PHOTOGRAPH OF TEST SETUP FOR THE TRANSMITTER MOUNTED ON TOP OF A PLASTIC TANK (A REPRESENTATIVE TANK FOR ALL OTHER NON-CONDCUTIVE TANKS).

Location of the EUT on top of the plastic tank.


3 Meters

3.5. JUSTIFICATION

No deviation, in both configuration and operation manners, different from normal operation were required.

3.6. EUT OPERATING CONDITION

The Milltronics IQ Radar 160 was mounted on top of a concrete tank and plastic tank alternatively. I was powered on and transmit the 6.3 GHz microwave signal in a pulse spectrum mode directly to the material to be measured. The measuring resolution bandwidth (RBW) of 3 MHz is used for testing and the corresponding pulse desensitization factor of 43 dB at 1.5 nS pulse width from Figure 28 of HP 150-2 is used for calculation of the peak rf levels.

RF emissions were scanned at 3 meters distance away from the IQ-160 and around the tank.

3.7. SPECIAL ACCESSORIES

No special accessories were required.

3.8. EQUIPMENT MODIFICATIONS

Not required.

4. EXHIBIT 4 - TEST DATA

4.1. TRANSMITTER RADIATED EMISSIONS @ 3 METERS, FCC CFR 47, PARA. 15.209

PRODUCT NAME: **Milltronics Radar Level Gauge (6.3 GHz), Model No.: IQ RADAR 160**

FCC REQUIREMENTS:

- The rf spectrum carrier shall not fall inside the restricted bands specified in the following table.

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	

- Fundamental and Spurious/harmonic emissions shall not exceed the limits specified in the following table:

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

CLIMATE CONDITION:

Standard Temperature and Humidity:

- Ambient temperature: 23 ^{o}C
- Relative humidity: 43 %

POWER INPUT: 120V 60 Hz.

TEST EQUIPMENT:

- **Spectrum Analyzer**, Advantest, Model R3271, S/N: 15050203, 100 Hz to 32 GHz)
- **Microwave Amplifier**, HP, Model 83017A, Frequency Range 1 to 26.5 GHz, 34-38 dBdB gain nominal.
- **Active Loop Antenna**, Emco, Model 6507, SN 8906-1167, Frequency Range 1 KHz - 30 MHz, @ 50 Ohms
- **Log Periodic/Bow-Tie Antenna**, Emco, Model 3143, SN 1029, 20 - 1000 MHz, @ 50 ohms.
- **Horn Antenna,** Emco, Model 3115, SN 9701-5061, Frequency Range: 1 - 18 GHz, @ 50 Ohms.
- **Horn Antenna**, Emco, Model 3160-09, 18-26.5GHz
- **Horn Antenna**, Emco, Model 3160-09, 18-26.5GHz
- **Horn Antenna**, Emco, Model 3160-10, 26.5-40GHz
- **Mixer**, Tektronix, P/N 118-0098-00, 18-26.5GHz
- **Mixer**, Tektronix, P/N 119-0098-00, 26.5-40GHz

METHOD OF MEASUREMENTS:

Prescans: The EUT will be pre-scanned in the following order to determine its characteristics at different distances before final measurements since its un-corrected emissions are too low to observe at 3 meters distance when it is mounted on top of the metal, concrete and other non-conductive tank:

1. **Pre-scans** at 3 m distance in the frequency range from 30 MHz to 8 GHz and pre-scans at 1 m distance in the frequency range from 8 GHz to 40 GHz when the IQ-Radar 160 was not mounted on top of the tank. These tests were carried in the Anechoic Room.
2. **Final Measurements** at 3 m distance in the frequency range from 30 MHz to 8 GHz and at 1 m distance in the frequency range from 8 GHz to 40 GHz when the IQ-Radar 160 was mounted on top of the tank. These tests were carried at Milltronics' Clients' facilities where the concrete and other non-conductive tank was installed.

Desensitization for Pulse Emissions: Since the Milltronics IQ Radar 160 transmits pulse RF energy with Ton = 1.5 nS, the desensitization factor (αp) shall be included in the calculation for the final peak value.

With the measuring resolution bandwidth (RBW) of 3 MHz, the corresponding pulse desensitization factor (αp) of 43 dB at pulse width τeff = 1.5 nS can be derived from Figure 28 of HP 150-2.

For measurement below 1 GHz, set RBW = 100 KHz, VBW ≥ 100 KHz, SWEEP=AUTO.

For measurement above 1 GHz, set RBW = 3 MHz, VBW = 3 MHz (Peak)

The average rf level is calculated by the peak reading by subtracting the peak-average correction factor derived from the appropriate duty cycle calculation. See Section 15.35(b) and (c).

DUTY CYCLE: 0.075% (Duty Cylce = $T_{on}/T_{on+off} = 1.5x10^{-9}/2x10^{-6} = 0.00075$)

Peak-to-Average Factor = 20*log (0.00075) = -62.5 dB

There are several conditions which must be satisfied if Eq. (10) is to be valid:

1. The IF bandwidth-pulse width product must be less than two-tenths:

$$B \cdot \tau_{eff} < 0.2 \text{ or } B < \frac{0.2}{\tau_{eff}}$$

2. The normalized scan rate (NSR) of the analyzer must be less than one:

$$\text{NSR} = \frac{\text{Scan Width } [Hz/\text{Div}]}{\text{Scan Time } [s/\text{Div}] \cdot (B[Hz])^2} < 1$$

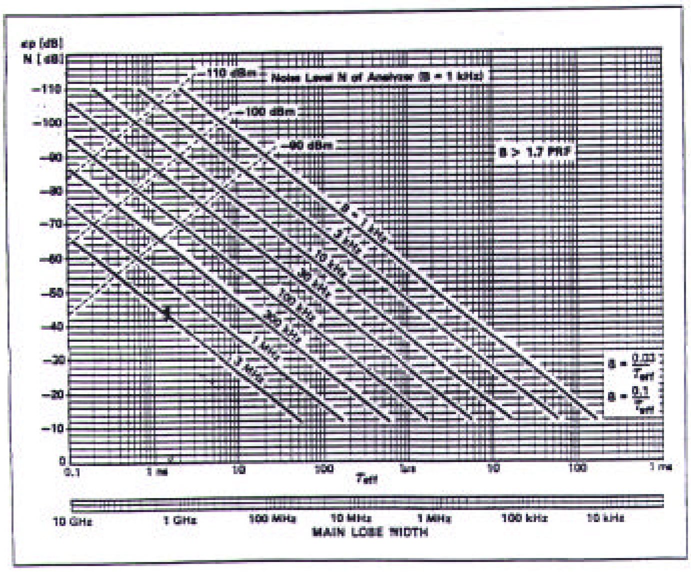
3. The IF bandwidth must be greater than the PRF: $B > \text{PRF}$

The conditions in 1 to 3 are automatically accomplished if the equations (5), (8), and (7) are satisfied.

4. The peak pulse amplitude at the broadband input mixer of the analyzer must stay below the saturation point (1 dB compression). The typical saturation point for HP spectrum analyzers is between −10 dBm and −5 dBm:

$$P_{peak} \leq -10\ dBm \qquad (11)$$

Figure 28 is a diagram showing the pulse desensitization α_p in relation to IF bandwidth B and pulse width τ_{eff}. We see that the PRF does not appear, since it is of no significance for the display amplitude as long as $B >$ PRF. The shaded area between the $B = \frac{0.03}{\tau_{eff}}$ and $B = \frac{0.1}{\tau_{eff}}$ represents the optimum bandwidth range for an analysis of a pulsed signal. There are also three dotted lines which show different noise levels of an analyzer for a fast determination of the dynamic range.



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αp = 43 dB for 1.5 nS pulse width pulse desensitization signal, measurement BW = 3 MHz RBW

Description of A Concrete Tank Used for Testing

The tests were carried out in a typical metal chemical reactor tank. The tank included an agitator and several access flanges.

The IQ Radar 160 was mounted on one of the flanges, with no special gasketing and with the holding screws not tightened. All piping on the inlet and outlet of the tank comprised plastic pipe. A transparent plastic sight tube is located on the side of the tank.

We believe this type of tank represents a typical installation in tanks made mostly of metal but including vents, sight glasses and openings.

Description of A Plastic Tank Used for Testing

TEST RESULTS: Conforms.

TEST PERSONNEL: Mr. Tri Luu, P.Eng.

DATE: July 07 & 08, 1999

MEASUREMENT DATA

RADIATED EMISSIONS MEASUREMENTS @ 3 METERS

TEST CONFIGURATION

- *For measuring radiated emissions at frequencies below 1 GHz, the Spectrum Analyzer was set as 100 KHz RBW, VBW ≥ RBW, SWEEP TIME: AUTO, PEAK DETECTOR.*
- *For measuring radiated emissions at frequencies above 1 GHz, the Spectrum Analyzer was set as 3 MHz RBW, VBW ≥ RBW, SWEEP TIME: AUTO, PEAK DETECTOR.*
- *The receiving antenna is used to probed around, up and down the EUT and the metal, concrete and other non-conductive tank to search for maximum rf emissions levels.*
- ***RF Peak Level**: Maximum level readings are added by 43 dB*
- ***RF Average Level**: the average rf levels were calculated by subtracting the Peak readings added by the duty cycle correction factor.* ***DUTY CYCLE FACTOR = 20LOG$_{10}$(0.00075) = -62.5dB***

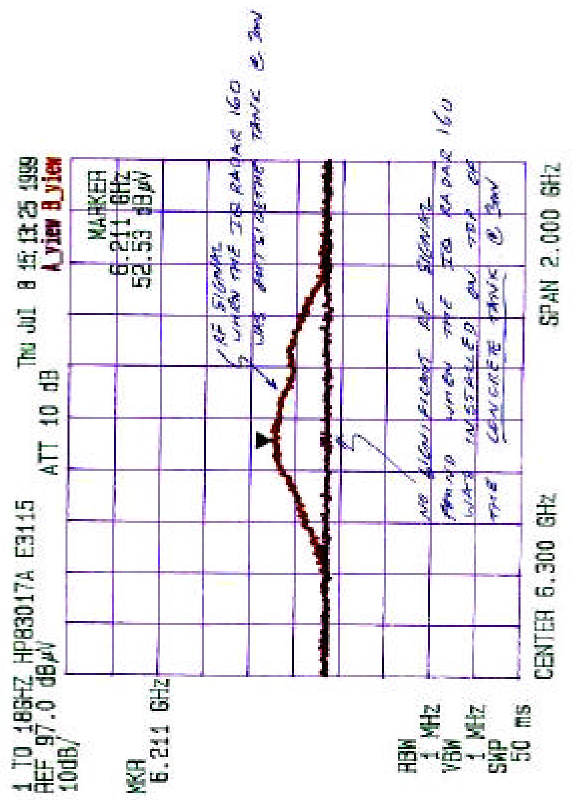
4.1.1. Test Configuration #1: Milltronics IQ Radar 160 installed on top of a Concrete Tank

FREQUENCY (MHz)	RF LEVEL READING @3m (dBuV/m)	RF PEAK LEVEL (dBuV/m)	RF AVG LEVEL (dBuV/m)	ANTENNA PLANE (H/V)	LIMIT @3m 15.209 (dBuV/m)	MARGIN (dB)	PASS/ FAIL
6300	**	**	**	H & V	54.0	**	Pass

** No significant spurious/harmonic emissions from the transmitters were found in the frequency from 30 MHz to 40 GHz when the unit was scanned at 3 meters distance. The attached plot showed the differences of the signal appearance when the IQ-160 was mounted on top of the concrete tank and when it was removed from the concrete tank.

NOTE: Per our measurements, the radio signal transmission and reflection, directly between the antenna and the material contained in the tank, were found to be limited within a small geographical area of less than 3 meters in radius; therefore there was no significant signal was found at the distance of 3 meters.

The Pulse Desensitization Factor (+43 dB) and Duty Cycle Factor (-62.5 dB) of -19.5 dB was used for correction of the final measurements.


1 TO 18GHZ HP83017A E3115
REF 97.0 dBµV
10dB/
ATT 10 dB
THU JUL 8 15:13:25 1999
MARKER
6.211 GHz
52.53 dBµV
MKR
6.211 GHz
RBW
1 MHz
VBW
1 MHz
SWP
50 ms
CENTER 6.300 GHz
SPAN 2.000 GHz

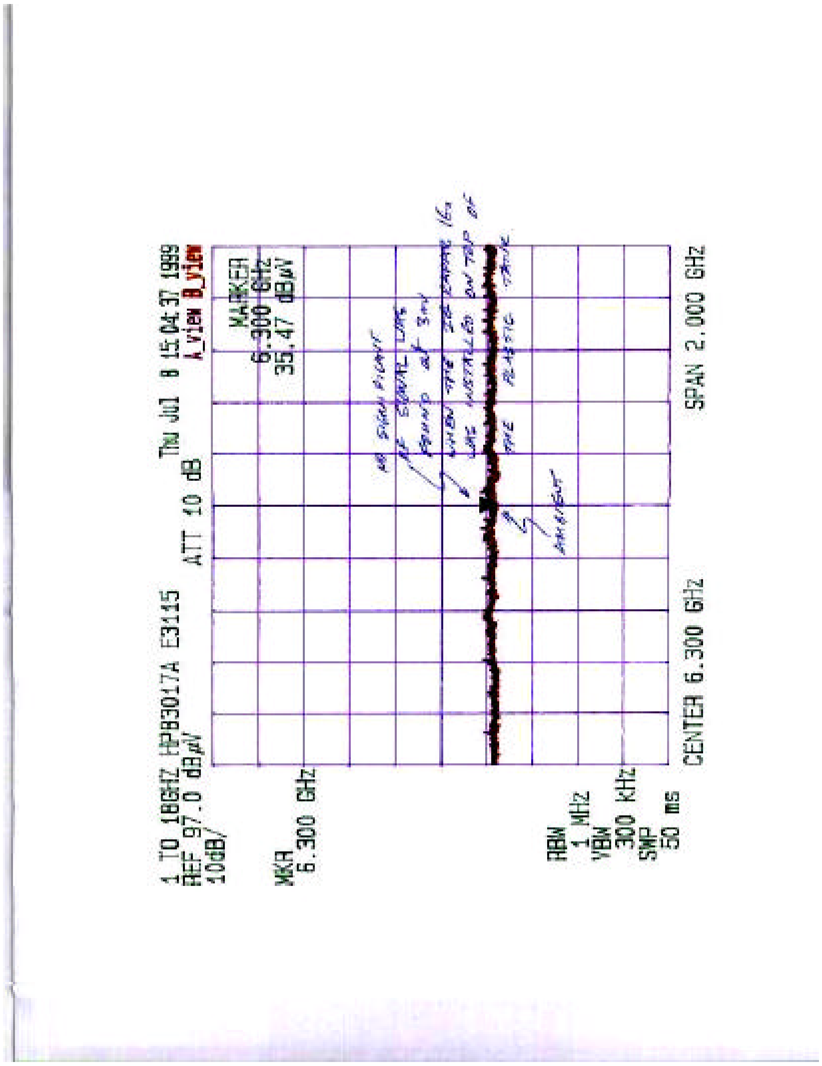
4.1.2. Test Configuration #2: Milltronics IQ Radar 160 installed on top of a Plastic Tank

FREQUENCY (MHz)	RF LEVEL READING @3m (dBuV/m)	RF PEAK LEVEL (dBuV/m)	RF AVG LEVEL (dBuV/m)	ANTENNA PLANE (H/V)	LIMIT @3m 15.209 (dBuV/m)	MARGIN (dB)	PASS/ FAIL
6300	**	**	**	H & V	54.0	**	Pass

** No significant spurious/harmonic emissions from the transmitters were found in the frequency from 30 MHz to 40 GHz when the unit was scanned at 3 meters distance. The attached plot showed no significant signal was found when the IQ-160 was mounted on top of a plastic tank.

NOTE: Per our measurements, the radio signal transmission and reflection, directly between the antenna and the material contained in the tank, were found to be limited within a small geographical area of less than 3 meters in radius; therefore there was no significant signal was found at the distance of 3 meters.

The Pulse Desensitization Factor (+43 dB) and Duty Cycle Factor (-62.5 dB) of -19.5 dB was used for correction of the final measurements.


1 TO 18GHZ HPB3017A E3115
REF 97.0 dBµV
10dB/
ATT 10 dB
Thu Jul 8 15:04:37 1999
A_view B_view
MARKER
6.300 GHz
35.47 dBµV
MKR
6.300 GHz
RBW
1 MHz
VBW
300 kHz
SWP
50 ms
CENTER 6.300 GHz
SPAN 2.000 GHz

5. EXHIBIT 5 – MEASUREMENT UNCERTAINTY

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

5.1. LINE CONDUCTED EMISSION MEASUREMENT UNCERTAINTY

CONTRIBUTION (Line Conducted)	PROBABILITY DISTRIBUTION	UNCERTAINTY (dB) 9-150 kHz	UNCERTAINTY (dB) 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 $\Gamma_1 = 0.03$ 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 150 kHz to 30 MHz Band:

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

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

5.2. 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 centre 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 $\Gamma_1 = 0.2$ Antenna VRC $\Gamma_R = 0.67$(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

6. EXHIBIT 7 - INFORMATION RELATED TO EQUIPMENT UNDER TESTS

6.1. FCC ID LABELING AND SKETCH OF FCC LABEL LOCATION

Refer to the original application

6.2. PHOTOGRAPHS OF EQUIPMENT UNDER TEST

Refer to the attached photographs for antennas options

6.3. SYSTEM BLOCK DIAGRAM(S)

Refer to the original application

6.4. SCHEMATIC DIAGRAMS

Refer to the original application

6.5. USER'S MANUAL WITH "FCC INFORMATION TO USER STATEMENTS"

Refer to the original application