TECHNICAL INFORMATION

TEST REPORT ON THE PERFORMANCE OF MARINE RADAR

Brand Name : FURUNO

Transceiver Type : RTR-083

Report no.: FLI 12-05-045

Date of issue: October 17, 2005

Furuno Labotech International Co., Ltd.

9-52 Ashihara-cho, Nishinomiya City, Hyogo 662-8580, Japan

Tel: +81-798-63-1094 Fax: +81-798-63-1098

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All tests were performed in Furuno Labotech International Co., Ltd.
All data herein contained is true and correct to our best knowledge.

All tests were performed and reported by:

Tested by:	Katsumi Imamura/Assistant Chief, Technical Section
Review by:	Sadatomo Kuwahara/Chief Engineer, Technical Section
Approved by:	Mitsuyoshi Komori/Manager, Technical Section

Date:	October 17, 2005
Name:	Mitsuyoshi Komori Manager, Technical Section
Signature:	

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1 General Information

1.1 General

(a) Manufacturer: Furuno Electric Co., Ltd.
Ashihara-cho 9-52, Nishinomiya-city, 662-8580 Japan

(b) Model: FAR-2157

	Type	Serial Number	Note
Display unit	MU-201CR	0701	
Antenna unit Scanner: (*)	RSB-106	R153-0001	Antenna rotation rate: 16/20 rpm
	RSB-107		20 rpm
Transceiver:	RTR-083		Contained in Scanner
Radiator:	XN-4A		8-ft Type
(*)	XN-5A		10-ft Type
Processor Unit:	RPU-013	4317-0786	
Power Supply Unit:	PSU-006	R158-0001	

Note: (*) - 1 (one) selectable.

(c) Primary Function: Search, Navigation and anticollison

(d) Discrimination

Range Discrimination: 26 meters on a range scale of 1.5 nm

Bearing Discrimination: on a range scale of 1.5 nm

Radiator type:	XN-4A	XN-5A
Discrimination (°):	1.18	0.98

(e) Minimum Range: 22 meters on a range scale of 0.25 nm

(f) Frequency Range: Fixed frequency, X-band

Type of Emission: P0N

(g) Power Supply: 100 - 115/220 - 230 VAC (for Processor Unit),
100 - 115/220 - 230 VAC (for Power Supply Unit),
24 VDC (for RSB-107 Antenna motor via Power Supply Unit),
200 VAC, 3Φ , 50 Hz/220 VAC, 3Φ , 60 Hz
(for RSB-106 Antenna motor via Power Supply Unit),
100 - 230 VAC (for Display Unit).

1.2 Antenna Unit

1.2.1 Transceiver

Type: RTR-083

(1) Transmitter

(a) Assignable Frequency for Shipborne Radar:

Between 9300 and 9500 MHz (FCC Rule, 80.375 (d)-(1))

(b) Type of RF Generator

Magnetron Type: 9M31

Peak Output Power: 50 kW nominal

(c) Magnetron Ratings

Center frequency of Magnetron: 9410 MHz

Tolerances

	9M31
Manufacturing:	±30 MHz
Pulling:	15 MHz

Tolerance for 20°C temperature variation: -4 MHz

(d) Guard Band:

Guard Band is specified to be equal to 1.5/T MHz, where "T" is the pulselength in microseconds. See para (e). (FCC Rule, 80.209(b))

(e) Pulse Characteristics:

Range Scale (nm)	(Short)	(Middle 1)	(Middle 2)	(Long 1)	(Long 2)
	0.125				
	0.25				
	0.5				
	0.75	0.75			
	1.5	1.5			
		3	3		
			6	6	
			12	12	
			16	16	
			24	24	
				32	
				48	
					96
Pulselength (μs)	0.08	0.2	0.6	1.2	1.2
P.R.R.(Hz)	1900	1100	600	600	500
Duty cycle	$1.52X10^{-4}$	$2.20X10^{-4}$	$3.90X10^{-4}$	$7.2X10^{-4}$	$6.0X10^{-4}$
Guard Band (MHz)	18.75	7.5	2.5	1.25	1.25

Note 1: Tests were carried out for the underlined Range Scales.

(2) Modulator

(a) SCR Type: RU-9509

Trigger Voltage: Approx. + 12 VDC positive

(3) Receiver

(a) Passband (MHz)

RF Stage: 100 MHz

IF Stage:

Pulselength	Short	Middle 1	Middle 2	Long 1	Long 2
(MHz)	40	10	10	3	3

(b) Gain (overall) (dB): Sufficient to cause limiting, approximately 130

(c) Overall Noise Figure (dB): 6 (typical)

(d) Video Output Voltage (V): 2 V negative

(e) Features Provided:

Sensitivity Time Controls (Anti-clutter Sea),
Fast Time Constant (Anti-clutter Rain)

(f) If receiver is tunable, describe method of adjusting frequency:

Adjustment of tuning voltage of receiver local oscillator
(Automatic and manual)

1.2.2 Antenna

(a) Antenna Rotation ON-OFF Switch: Provided.

(b) Reflector: Slot array antenna

Radiator type:	XN-4A	XN-5A
Length (cm):	257	321
Length (ft):	8	10

(c) Type of Beam: Vertical fan

(d) Beam Width (between half-Radiator power points)

Radiator type:	XN-4A	XN-5A
Horizontal (°)	0.95	0.75
Vertical (°)	20	20

(e) Polarization: Horizontal

(f) Antenna Gain:

Radiator type:	XN-4A	XN-5A
Ant. Gain (dB):	31.5	33.0

(g) Attenuation of Major Side Lobes with respect to main beam:

Radiator type:	XN-4A	XN-5A
Within ±10°	-28 dB or less	-26 dB or less
Outside ±10°	-32 dB or less	-30 dB or less

(h) Scanning (rotating or oscillating):
Rotating over 360° continuously clockwise

(i) Antenna Rotation Rate: 16/20 rpm for RSB-106
20 rpm for RSB-107

(j) Number of Degrees Scanned: 360°

(k) Sector Scan: Not provided.

(l) Type of Transmission System: Contained in scanner unit

(m) Rated Loss of Transmission System per hundred feet:
None. Transmission path is only in the antenna scanner unit.

1.3 Display Unit

(a) Type: 20.1 (in.) Color LCD,
1024 X 1280 pixels

(b) Size of Indicator: 20.1 in. diagonal
effective dia.: > 250 mm

(c) Sweep Linearity: 2 % on all ranges

(d) Range Scales:

Range (nm)	Number of Range Rings	Range Ring Interval (nm)
0.125	5	0.0250
0.25	5	0.050
0.5	5	0.100
0.75	3	0.25
1	4	0.25
1.5	6	0.25
2	4	0.5
3	6	0.5
4	4	1
6	6	1
8	4	2

Range (nm)	Number of Range Rings	Range Ring Interval (nm)
12	6	2
16	4	4
24	6	4
32	4	8
48	6	8
72	6	12
96	6	16

(e) Range Ring Accuracy: Better than 0.9 % of maximum scale in use or 8 m, whichever is the greater

(f) Overall Bearing Accuracy from Scanner to Display: Better than 1°

(g) Target Plot Facility: Simulated afterglow in low shade

(h) Heading Indicator: Provided, automatic alignment. Heading Line and Heading Marker

(i) True Bearing Indicator: Provided

1.4 Functional Controls

Range selector	Power Switch	FTC switch
A/C rain	A/C sea	Gain control
Panel dimmer [2)]		
Heading line off	Echo stretch [2)]	MENU
Guard zone set/Audio alarm off		Range ring on/off
Interference rejector [2)]	ST-BY/TX	Arrow keys (VRM/EBL/GUARD)
Trackball		
VRM on/off	SHIFT (Offcenter)	Range set [2)]
Zoom	EBL on/off	Echo Trail
Brilliance [2)]	Navigation on/off [1),2)]	Anchor watch [2)]
Display brilliance	PLOT color [2)]	TRU/REL [2),3)]
Mode [2),3)]	Chart display [2)]	Waypoint [2)]
HU/HUTB/CU/NU/TM		

Note: [1)] Valid when interfaced with navaid
[2)] Selected on menu
[3)] Valid when interfaced with gyrocompass

1.5 Operational Features

(a) Is positive means provided to indicate whether or not the overall operation of the equipment is such that it may be relied upon to provide effective operation in accordance with its primary function:

Yes (Magnetron/Xtal checker)

(b) Is the equipment for continuous operation: Yes

(c) Is provision made for operation with shore based radar beacons (RACONS):

Yes (RACONS and SART)

1.6 Line Power Supply Requirements

Unit	Power supply voltage	Power drain (current consumption)
Display Unit	100 - 230 VAC	0.7 A
Processor Unit	100 - 115 VAC	3 A
	220 - 230 VAC	1.5 A
Antenna Unit (*)	24 VDC for RSB-107	4 A
	200 VAC, 3Φ , 50 Hz for RSB-106	2 A
	220 VAC, 3Φ , 50 Hz	2 A

Note: (*) - Power supply voltage is supplied via Power Supply Unit PSU-006.

1.7 Construction Features

(a) Does equipment embody replacement units with chassis type assembly: Yes

(b) Are fuse alarms provided: Fuses are provided.

(c) State units that are weatherproof: Antenna Unit (IEC 60529 - IPX6)

(d) If all units are not housed in a single container, indicate number and give description of individual units:

1 X Display Unit	Type:	MU-201CR
1 X Antenna Unit		
1 X Scanner	Type:	RSB-106 (16 or 20 rpm)
	Type:	RSB-107 (20 rpm)
1 X Radiator	Type:	XN-4A
	Type:	XN-5A
1 X Transceiver	Type:	RTR-083 (contained in the Scanner)
1 X Processor Unit	Type:	RPU-013
1 X Power supply Unit	Type:	PSU-006

(e) Approximate Weight of Complete Installation:

Display Unit:	18.3 kg
Antenna Unit:	74 kg (for RSB-106/-107 with Radiator XN-4A)
	77 kg (for RSB-106/-107 with Radiator XN-5A)
Processor Unit:	10 kg
Power Supply Unit:	5.2 kg

(f) Approximate space required for installation excluding scanner

Display Unit:	734 mm (W) X 510 mm (H) X 452 mm (D)
Processor Unit:	564 mm (W) X 498 mm (H) X 459 mm (D)
Power supply Unit:	344 mm (W) X 440 mm (H) X 115 mm (D)

2 Identification of Equipment (FCC Rule, 2.925)

(See separate covers)

3 Test data

3.1 RF Power Output (FCC Rule, 2.1046)

3.1.1 Microwave characteristics

The peak voltage was determined using the divider having a ratio of 1000 to 1 and the oscilloscope. Current pulse was viewed across the wideband current transformer with output voltage per ampere 1.00.

(1) Nominal values

Pulselength	Short	Middle 1	Middle 2	Long 1	Long 2
Range scale (nm)	0.125	3	12	48	96
Pulselength (µs)	0.08	0.20	0.60	1.20	1.20
PRR (Hz)	1900	1100	600	600	500
Duty cycle	1.52×10^{-4}	2.20×10^{-4}	3.60×10^{-4}	7.20×10^{-4}	6.00×10^{-4}
Guard band (MHz)	18.75	7.50	2.50	1.25	1.25

(2) Measured values

Magnetron input pulse voltage

Magnetron input pulse voltage was measured at its cathode using the oscilloscope and divider with ratio 1000 to 1.

Pulselength	Short	Middle 1	Middle 2	Long 1	Long 2
Directional coupler attenuation (dB)	40.51	40.51	40.51	40.51	40.51
Magnetron input voltage (kV)	13.0	13.0	13.5	13.5	13.5
Pulselength (µs) (50 % amplitude)	0.358	0.488	0.960	1.580	1.580
Rise time (µs) (10 - 90 % amplitude)	0.098	0.098	0.104	0.096	0.096
Decay time (µs) (90 - 10 % amplitude)	0.394	0.384	0.368	0.260	0.260

Magnetron input pulse current
Magnetron input pulse current was observed across the wideband current transformer with output voltage per ampere 1.00.

Pulselength	Short	Middle 1	Middle 2	Long 1	Long 2
Magnetron input current (A)	8.0	8.5	11.0	11.8	11.8
Pulselength (µs) (50 % amplitude)	0.074	0.190	0.700	1.290	1.290
Rise time (µs) (10 - 90 % amplitude)	0.026	0.034	0.184	0.180	0.180
Decay time (µs) (90 - 10 % amplitude)	0.181	0.188	0.290	0.432	0.432

RF envelope of the magnetron output pulse
The RF envelope of the magnetron output pulse was measured using a diode and the oscilloscope with the following results:

Pulselength	Short	Middle 1	Middle 2	Long 1	Long 2
Pulselength (µs) (-3 dB points)	0.074	0.175	0.656	1.288	1.288
Rise time (µs) (10 - 90 % amplitude)	0.012	0.012	0.044	0.042	0.042
Decay time (µs) (90 - 10 % amplitude)	0.095	0.128	0.202	0.267	0.267

Estimated efficiency
The estimated efficiency of the RF generator (magnetron) was determined by the following measurements and calculation. Power output from magnetron was measured using the directional coupler, power meter and the oscilloscope.

Pulselength	Short	Middle 1	Middle 2	Long 1	Long 2
Range scale (nm)	0.125	3	12	48	96
P.R.R (Hz)	1913.7	1105.1	603.6	603.6	503.0
Duty cycle	1.41×10^{-4}	1.93×10^{-4}	3.95×10^{-4}	7.77×10^{-4}	6.47×10^{-4}
Magnetron input, av. (W)	14.73	21.37	58.80	123.85	103.20
Magnetron input, peak (kW)	104.0	110.5	148.5	159.3	159.3
Power meter reading (mW)	0.480	0.739	1.800	3.720	3.080
Magnetron output, av. (W)	5.398	8.311	20.243	41.835	34.638
Spurious response limits (dB)	-50.32	-52.20	-56.06	-59.22	-58.40

Pulselength	Short	Middle 1	Middle 2	Long 1	Long 2
Magnetron Output, peak (kW):	38.1	43.0	51.1	53.8	53.5
Magnetron efficiency (%):	36.7	38.9	34.4	33.8	33.6

Peak Power Input to RF Generator : 136.3 kW
Estimated Efficiency of RF Generator : 35.5 %

3.2 Modulation Characteristics (FCC Rule, 2.1047)

3.2.1 SCR Trigger Pulse

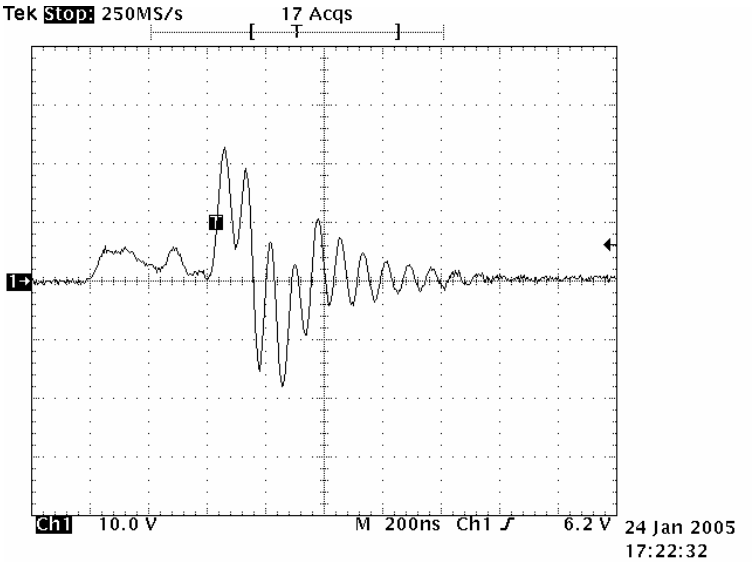


Fig. 3.2.1.1 Typical waveform of Trigger Pulse Scale: 10 V/div., 200 ns/div.

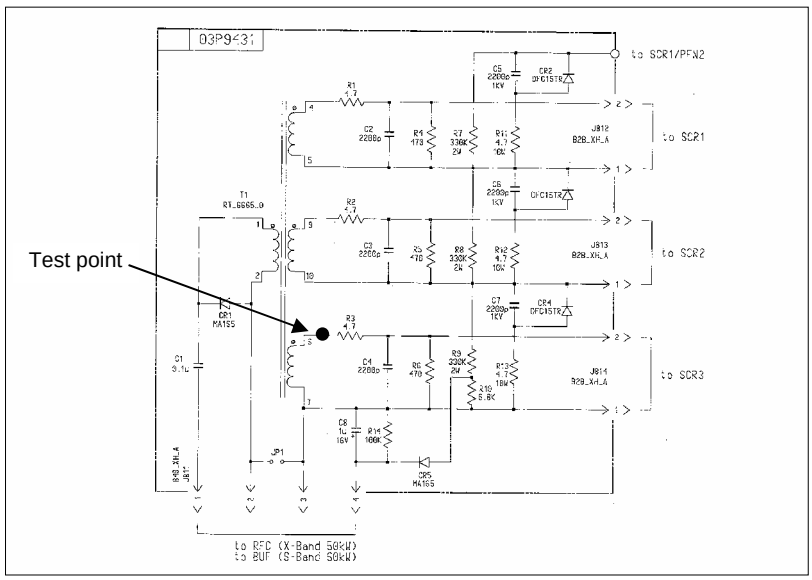


Fig. 3.2.1.2 Test Point for Trigger Pulse
(in MD board (03P9431) of Radar Antenna Unit)

3.2.2 Trigger Pulse at Magnetron Cathode

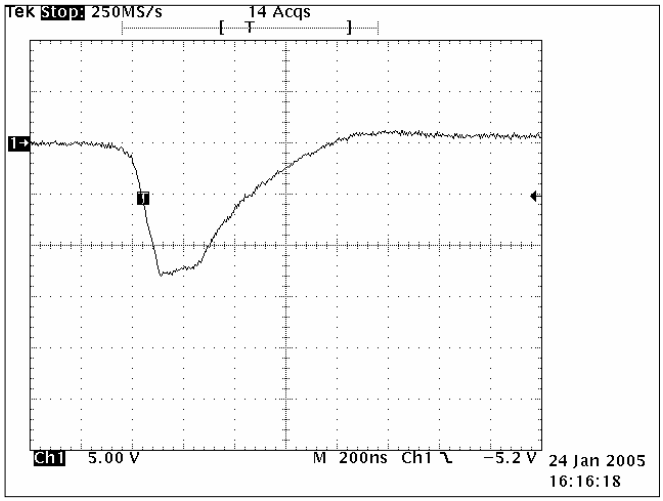


Fig. 3.2.2.1 Short Pulse (0.125 nm Range) Scale: 5 kV/div. 200 ns/div.

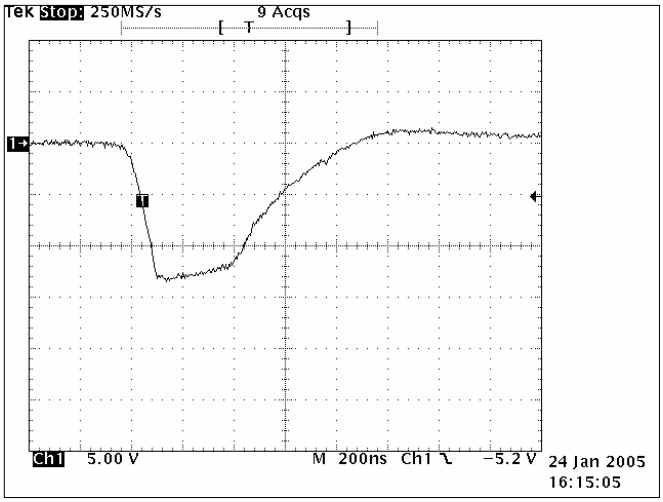


Fig. 3.2.2.2 Middle 1 Pulse (3 nm Range) Scale: 5 kV/div. 200 ns/div.

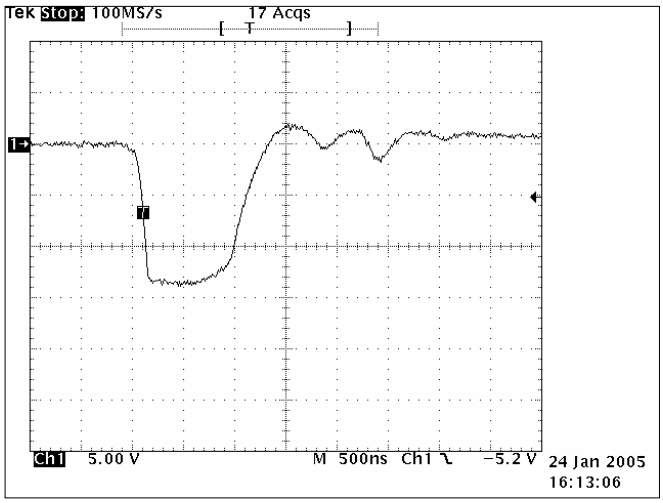


Fig. 3.2.2.3 Middle 2 Pulse (12 nm Range) Scale: 5 kV/div. 500 ns/div.

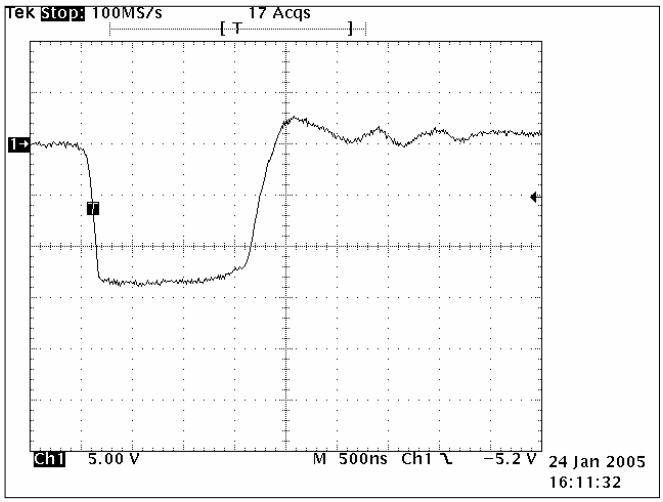


Fig. 3.2.2.4 Long 1 Pulse (48 nm Range) Scale: 5 kV/div. 500 ns/div.

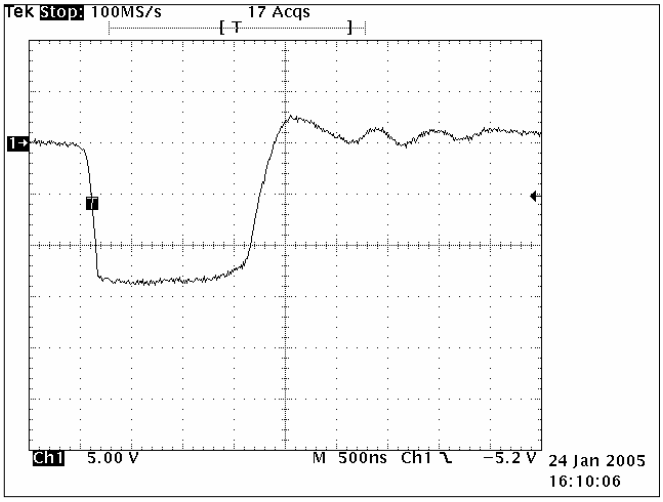


Fig. 3.2.2.5 Long 2 Pulse (96 nm Range) Scale: 5 kV/div. 500 ns/div.

3.2.3 **Magnetron Output** (detected):

3.2.3.1 Setup for Measurement:

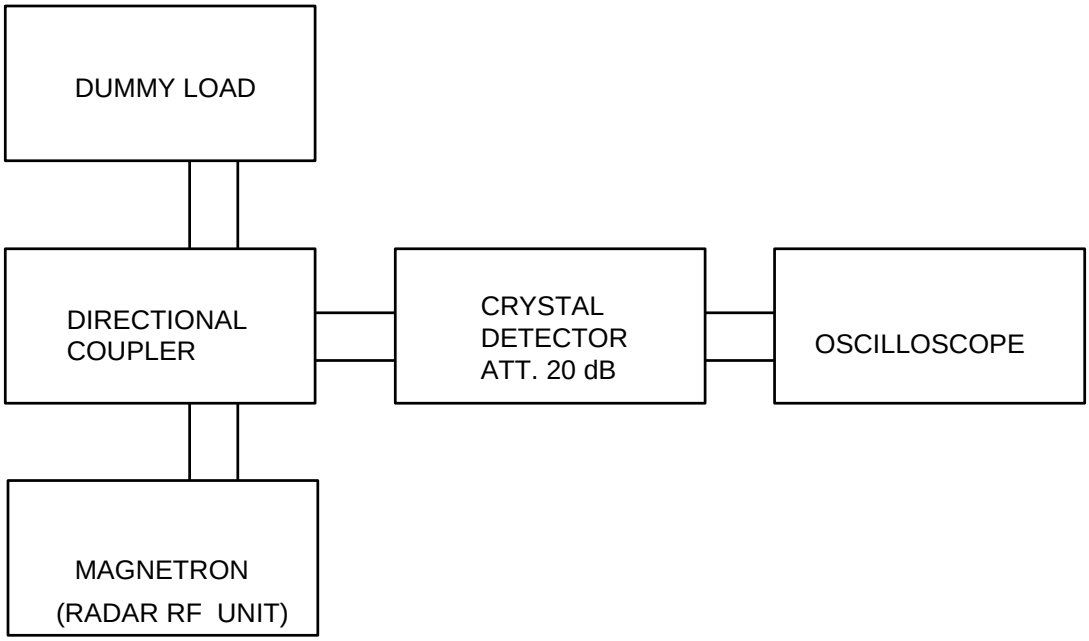


Fig. 3.2.3.1

3.2.3.2 Measuring Equipment List:

See Attachment D [List of Test/Measuring Equipment].

3.2.3.3 Measured Data:

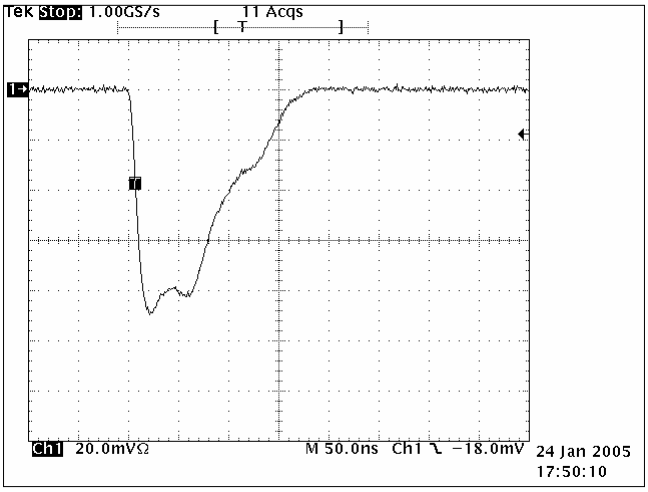


Fig. 3.2.3.2 Short Pulse (0.125 nm Range) Scale: 20 mV/div. 50 ns/div.

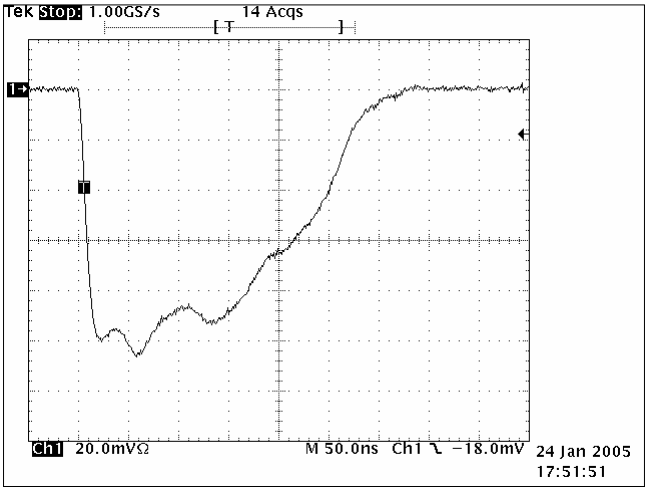


Fig. 3.2.3.3 Middle 1 Pulse (3 nm Range) Scale: 20 mV/div. 50 ns/div.

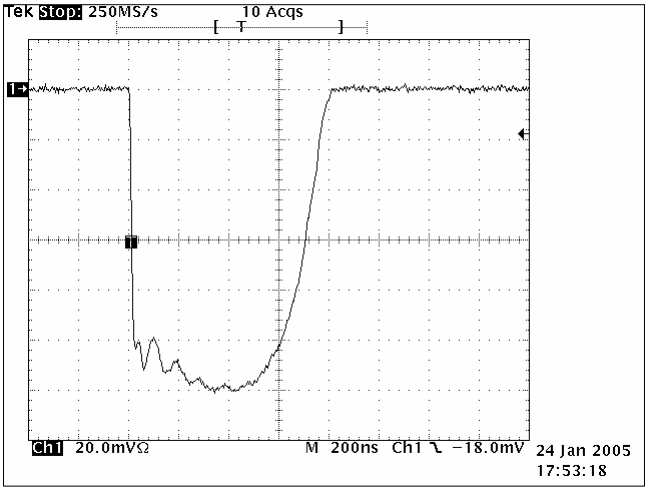


Fig. 3.2.3.4 Middle 2 Pulse (12 nm Range) Scale: 20 mV/div. 200 ns/div.

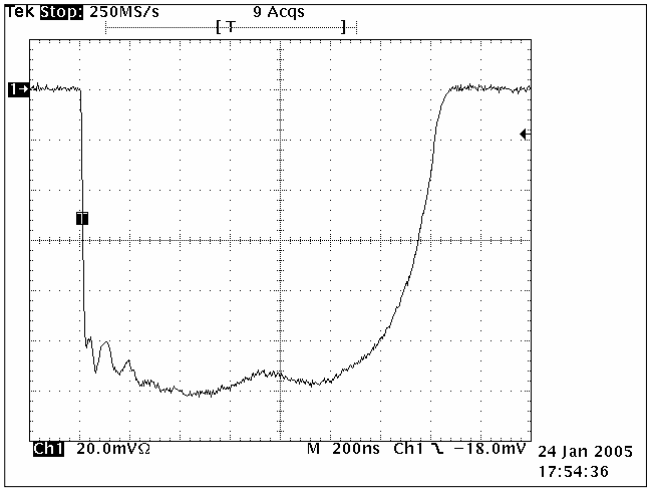


Fig. 3.2.3.5 Long 1 Pulse (48 nm Range) Scale: 20 mV/div. 200 ns/div.

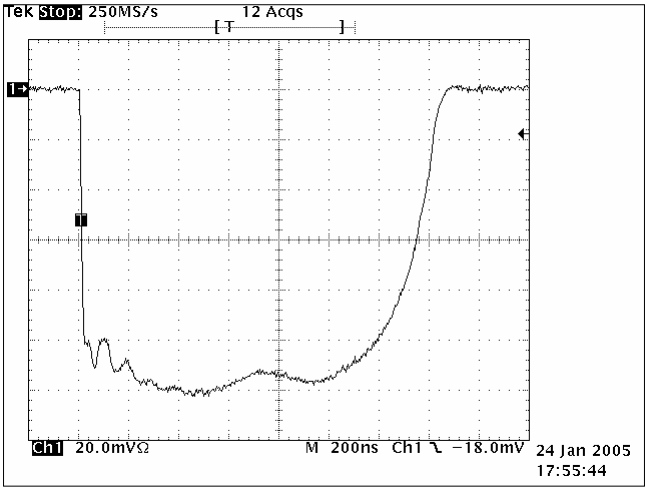


Fig. 3.2.3.6 Long 2 Pulse (96 nm Range) Scale: 20 mV/div. 200 ns/div.

3.2.4 Radar Pulse Spectrum:

Measured by the spectrum analyzer.

(Test Equipment Setup and Measuring Equipment List are same as Clause 3.4.1 and 3.4.2.)

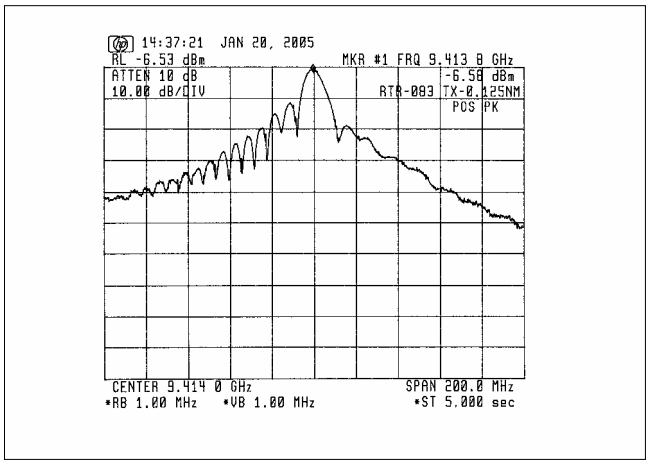


Fig. 3.2.4.1 For Short Pulse (0.125 nm Range)

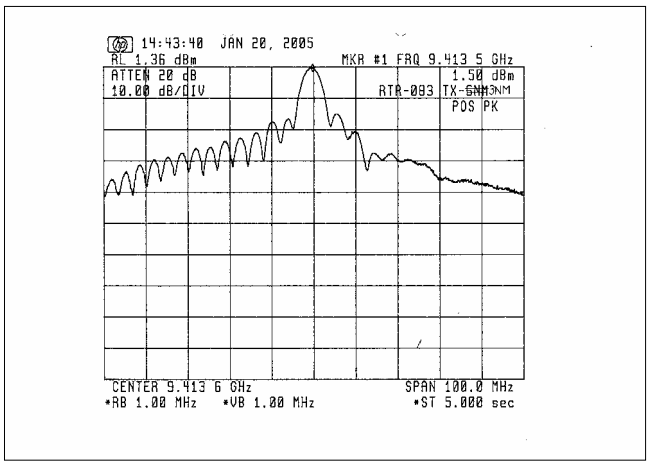


Fig. 3.2.4.2 For Middle 1 Pulse (3 nm Range)

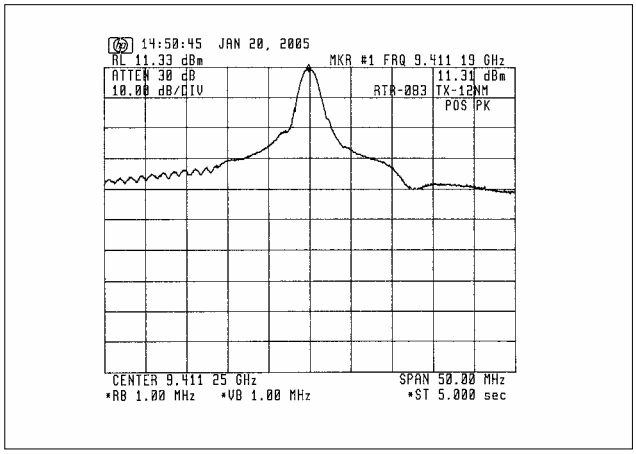


Fig. 3.2.4.3 For Middle 2 Pulse (12 nm Range)

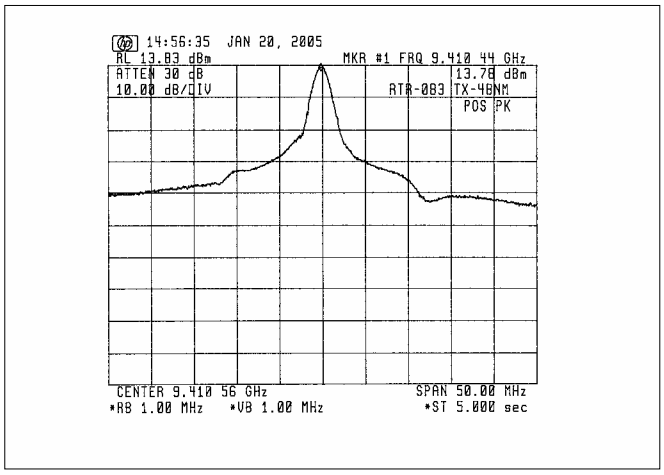


Fig. 3.2.4.4 For Long 1 Pulse (48 nm Range)

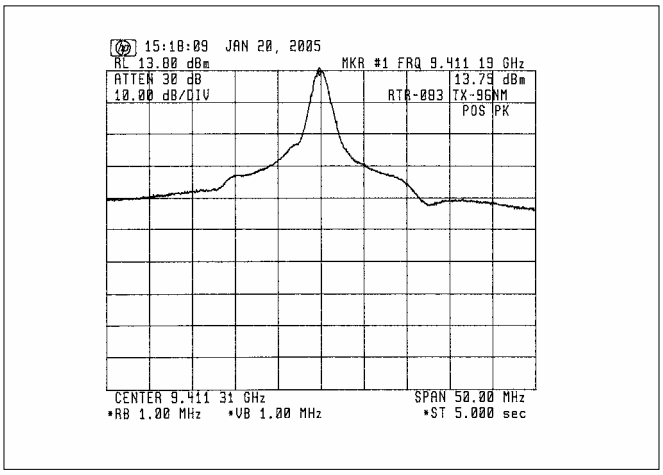


Fig. 3.2.4.5 For Long 2 Pulse (96 nm Range)

3.3 Occupied Bandwidth (FCC Rule, 2.1049)

3.3.1 Measuring Method

FCC rule 47 CFR 2.1049 requires measurements of the occupied bandwidth which is defined in the same section as "the frequency bandwidth such that, below its lower and above its upper frequency limits, the mean powers radiated are each equal to 0.5 percent of the total mean power radiated by a given emission." To obtain the occupied bandwidth of the radar transmitter, a special program (program list shown below) was loaded to the Hewlett-Packard spectrum analyzer and run by entering the HP-provided POWER BANDWIDTH calculation command [PWRBW].

The result was automatically displayed on the screen on the spectrum analyzer as:

POWER_BW=----- MHz

```
10   ! HP_71000 DOWNLOAD PROGRAM
20   ASSIGN @Sa TO 718
30   CLEAR @Sa
40   CALL M_ain(@Sa)
50   LOCAL @Sa
60   END
70   !
80    SUB M_ain(@Sa)
90   M_ain:       !
100  CALL Pwr_bw(@Sa)
110  CALL Limit_line(@Sa)
120  !
130  OUTPUT @Sa;"VARDEF K_ey,0;";
140  !
150  OUTPUT @Sa;"FUNCDEF D_LP,^";
160  OUTPUT @Sa;"MOV K_ey,0;";
170  !
180  Main_menu:   !
190  OUTPUT @Sa;"REPEAT;";
200  OUTPUT @Sa;"READMENU K_ey,";
210  !   location: %Top----Bottom-%
220  OUTPUT @Sa;" l,%Limit   line   %,";
230  OUTPUT @Sa;" 2,%Power   bw      %,";
240  OUTPUT @Sa;"14,%     Exit%;";
250  !
260  OUTPUT @Sa;"IF K_ey,EQ,1;THEN;LIMIT_LINE;";
270  OUTPUT @Sa;"ELSIF K_ey,EQ,2;THEN;PWR_BW;";
280  OUTPUT @Sa;"ELSIF K_ey,EQ,l4;THEN;ABORT;";
290  OUTPUT @Sa;"ENDIF;";
300  OUTPUT @Sa;"UNTIL K_ey,EQ,14;";
310  OUTPUT @Sa;"IP;TS;";
320  OUTPUT @Sa;"ADORT;";
330  OUTPUT @Sa;"^"
340  !
350  Define_keydef:   !
360  OUTPUT @Sa;"KEYDEF 7,D_LP, %DLP      TEST%;";
370  !
380  OUTPUT   @Sa;"FUNCDEF D,^";
390  OUTPUT   @Sa;"KEYPST;";
400  OUTPUT   @Sa;"^"
410  !
420  SUBEND
430  !
440  SUB Limit_line(@Sa)
450  Limit_line:     !
460  OUTPUT @Sa;"CLRDSP;";
470  OUTPUT@Sa;"FUNCDEF LIMIT_LINE,^";
480  OUTPUT   @Sa;"PU;PA   0,654;";
490  OUTPUT   @Sa;"LINET 1;";
500  OUTPUT   @Sa;"PD;PA 100,654;";
510  OUTPUT   @Sa;"PU;PA 201,654;";
520  OUTPUT   @Sa;"PD;PA 300,654;";
530  OUTPUT   @Sa;"PU;PA 105,630;";
540  OUTPUT   @Sa;"TEXT @-35dB@;";
550  OUTPUT   @Sa;"PU;PA 205,720;";
560  OUTPUT   @Sa;"TEXT @-25dB@;";
570  OUTPUT   @Sa;"PU;PA 301,743;";
580  OUTPUT   @Sa;"LINET 1;";
590  OUTPUT   @Sa;"PD;PA 400,743;";
600  OUTPUT   @Sa;"PU;PA 601,743;";
610  OUTPUT   @Sa;"LINET l;";
620  OUTPUT   @Sa;"PD;PA 700,743;";
630  OUTPUT   @Sa;"PU;PA 701,654;";
640  OUTPUT   @Sa;"LINET l;";
650  OUTPUT@Sa;"PD;PA 1000,654;HD;";
660  OUTPUT   @Sa;"^"
670  SUBEND
680  SUB Pwr_bw(@Sa)
690  Pwr_bw:       !
700  !      Calculating Power band width
710  OUTPUT @Sa;   "VARDEF P_bw,0;";
720  OUTPUT @Sa;"FUNCDEF PWR_BW,^";
730  OUTPUT @Sa;"CLRW TRA;";
740  OUTPUT @Sa;"CLRDSP;";
750  OUTPUT @Sa;"SNGLS;";
760  OUTPUT @Sa;"MXMH   TRA;TS;TS;TS;";
770  OUTPUT @Sa;"MOV   P_bw,PWRBW   TRA,99.0;";
780  OUTPUT@Sa;"DIV P__bw,P_bw,1000000;";
790  OUTPUT @Sa;"PU;PA 10,800;HD;";
800  OUTPUT @Sa;"TEXT @POWER_BW = @;";
810  OUTPUT @Sa;"DSPLY P_bw,8,3;";
820  OUTPUT @Sa;"TEXT @ MHz @;";
830  OUTPUT @Sa;"^"
840  SUBEND
```

Fig. 3.3.1 Program for Calculation of Occupied Bandwidth

3.3.2 Test Equipment Setup:

Same as Clause 3.4.1.

3.3.3 Measuring Equipment List:

Same as Clause 3.4.2.

3.3.4 Test Result:

The test result is shown below.

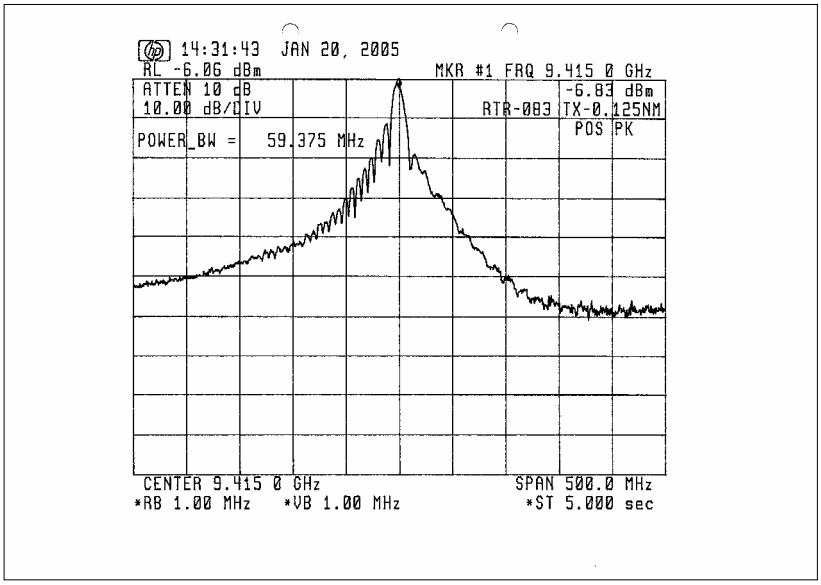
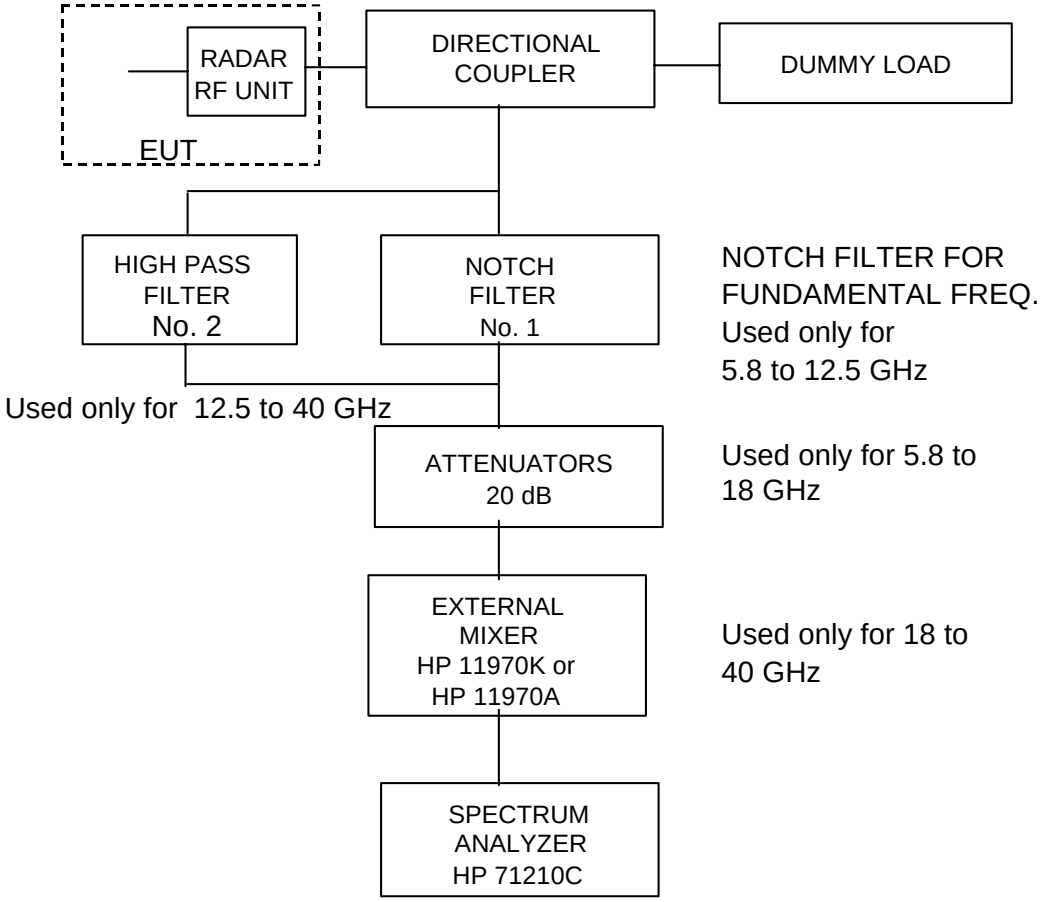


Fig. 3.3.2 Measurement of Occupied Bandwidth

Occupied bandwidth = 59.375 MHz

3.4 Spurious Emissions at Antenna Terminal (FCC Rule, 2.1051)



3.4.1 Test Equipment Setup:

Fig. 3.4.1

3.4.2 Measuring Equipment List:

See Attachment D [List of Test/Measuring Equipment].

Note : (1) The characteristics of Notch Filter (No. 1) are described in Fig. 3.4.2 to Fig. 3.4.5.
(2) The characteristic of High Pass Filter (No. 2) is described in Fig. 3.4.6.

3.4.3 Test Conditions:

Radar Range Settings: 0.125 nm (Short)/3 nm (Middle 1)/ 12 nm (Middle 2)/ 48 nm (Long 1)/96 nm (Long 2)

3.4.4 Emission Limits:

(a) Frequency Range (FCC Rule, 2.1057(1)) : 10 kHz - 40 GHz

(b) Emission Limits (FCC Rule, 80.211) :

Frequency removed from the assigned frequency	Frequency (Hz)	Emission attenuation (mean power ,dB)
50 - 100 % (of the authorized bandwidth)	9310 - 9360 M 9460 - 9510 M	At least 25
100 - 250 %	9160 - 9310 M 9510 - 9660 M	At least 35
more than 250 %	10 k - 9160 M 9660- 40,000 M	At least 43 + 10 log $_{10}$ (mean power in watts)

Note : (1) Assigned frequency (center frequency) = 9410 MHz

(2) Authorized bandwidth = 100 MHz

3.4.5 Test Results:

As shown in Attachment A, the spurious emissions at antenna terminal of EUT are found lower than the specified limits.

(Note: Spurious emissions for 10 kHz to 5 GHz are not found due to the antenna terminal structure. (Waveguide tube)).

Characteristic of Filter No.1 (for X-band)

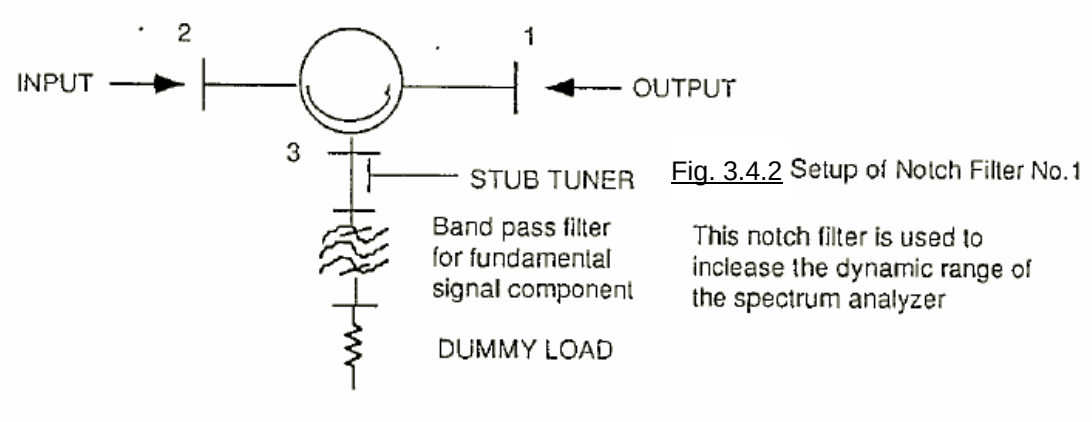


Fig. 3.4.2 Setup of Notch Filter No.1

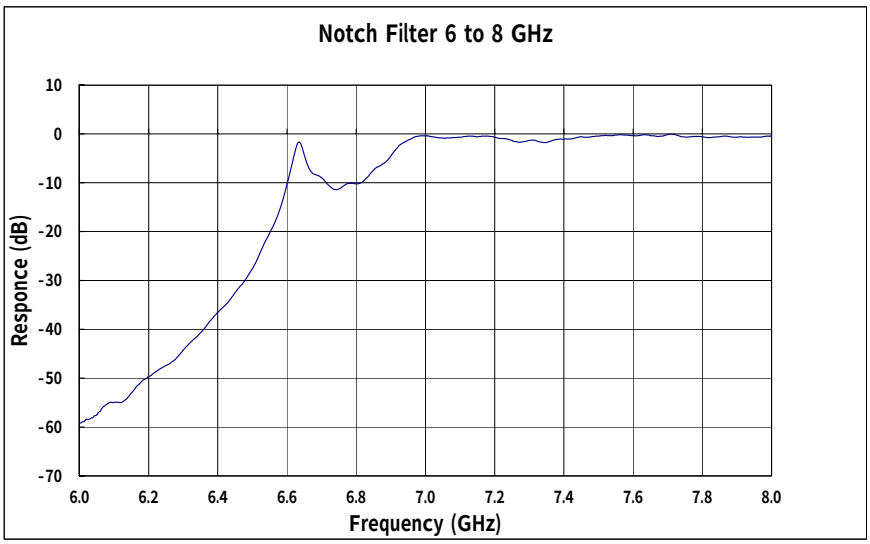


Fig. 3.4.3

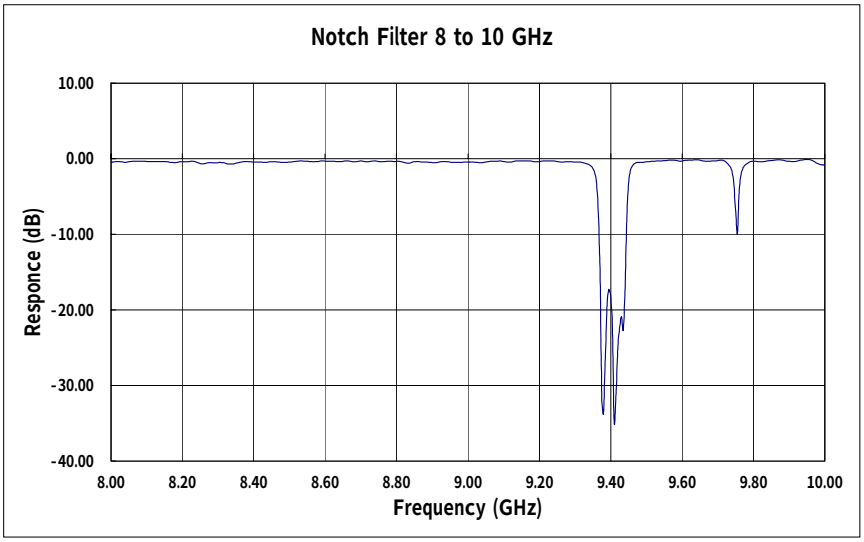


Fig. 3.4.4

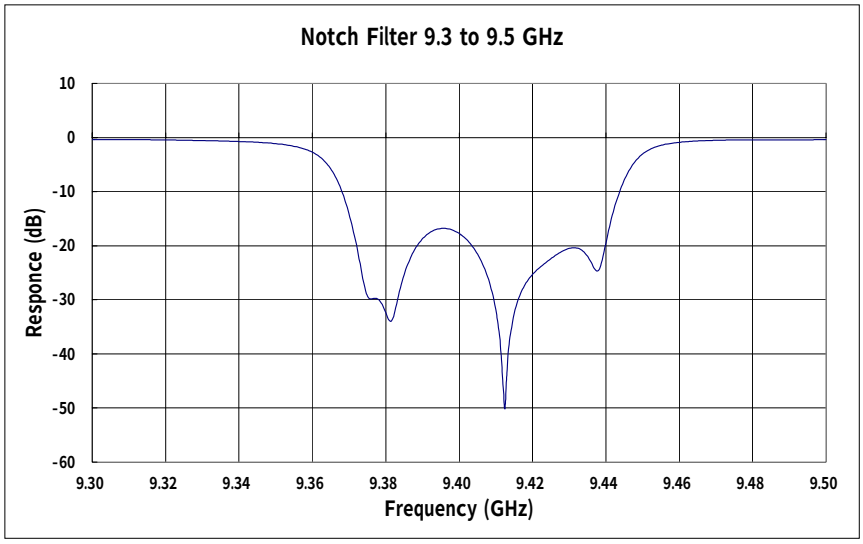
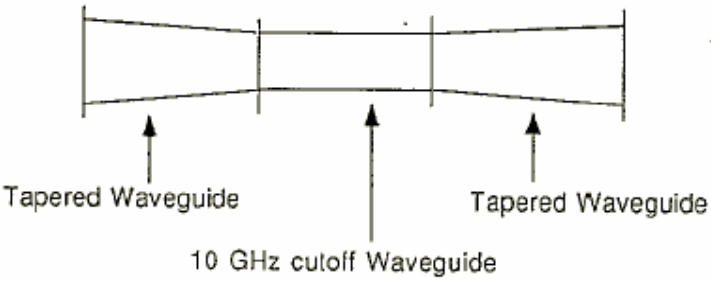


Fig. 3.4.5

Characteristic of Filter No. 2 (for X-band)



This filter is used to filter out the high level fundamental signal to avoid damage to the analyzer.

High Pass Filter Construction

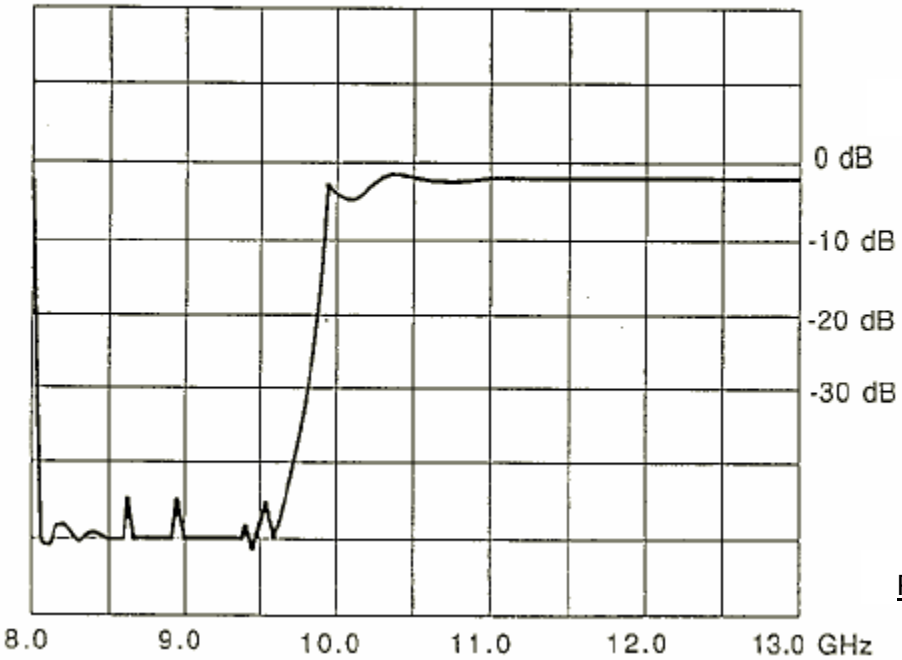


Fig. 3.4.6

3.5 Field Strength of Spurious Radiation (FCC Rule, 2.1053)

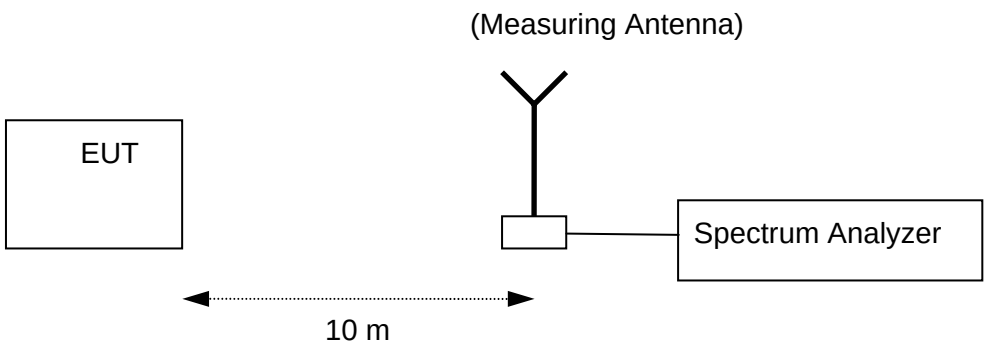
3.5.1 Test Site: Rooftop of 6-story building,
FURUNO ELECTRIC CO., LTD.
Ashihara-cho 9-52, Nishinomiya-city, 662-8580 Japan

3.5.2 Distance between the radar set and measuring antenna: 10 m

3.5.3 Radar Range settings: 0.125 nm (Short)/3 nm (Middle1)/12 nm (Middle2)/
48 nm (Long1)/96 nm (Long2)

3.5.4 Measuring Equipment List:
See Attachment D [List of Test/Measuring Equipment].

3.5.5 Test settings:



3.5.6 Field Strength Limits:

(a) Frequency Range (FCC Rule, 2.1057(1)) : 10 kHz - 40 GHz
(b) Emission Limits (FCC Rule, 80.211) :

Frequency removed from the assigned frequency	Frequency (MHz)	Emission attenuation (mean power, dB)
50 - 100 % (of the authorized bandwidth)	9,310 – 9,360 9,460 – 9,510	At least 25
100 - 250 %	9,160 – 9,310 9,510 – 9,660	At least 35
more than 250 %	0.01 – 9,160 9,660 - 40,000	At least 43 + 10 log $_{10}$ (mean power in watts)

Note : (1) Assigned frequency (center frequency) = 9410 MHz

(2) Authorized bandwidth = 100 MHz

3.5.7 Test Results:

As shown in Attachment B, the field strengths of spurious radiation generated by EUT are found lower than the specified limits.

3.6 Frequency Stability (FCC Rule, 2.1055)

3.6.1 Setup for Measurement

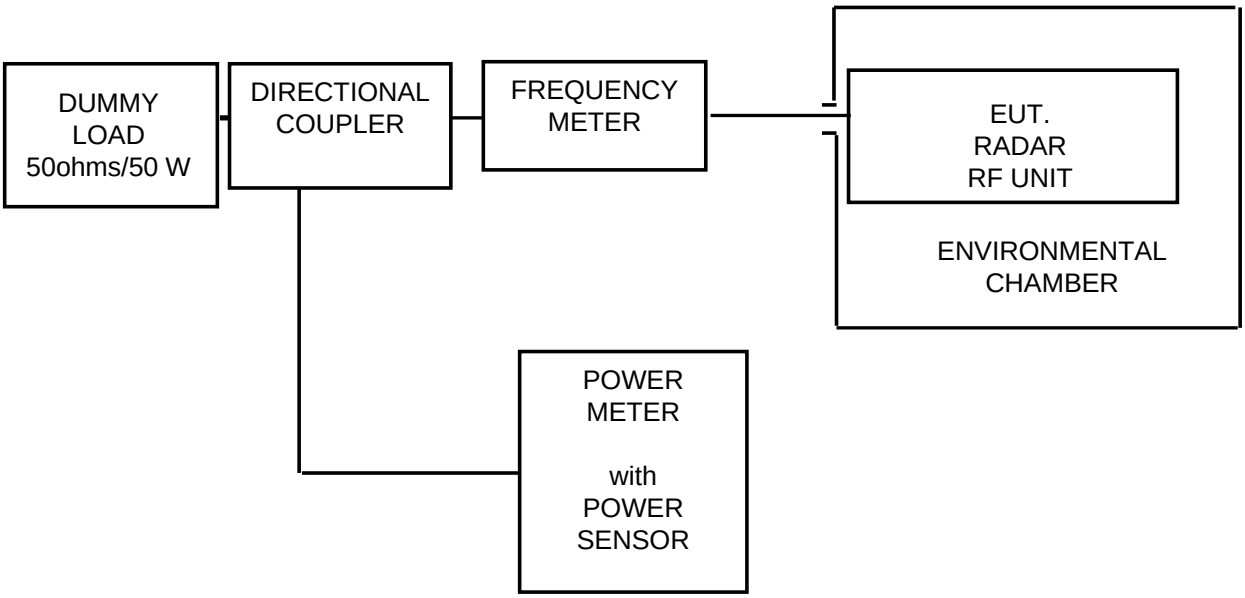


Fig. 3.6.1

3.6.2 Test Conditions:

1) Radar Range settings : 0.125 nm (Short)/3 nm (Middle1)/12 nm (Middle2)/
48 nm (Long1)/96 nm (Long2)
2) Ambient Temperature settings: - 20°C to + 50°C (10°C step)
3) Power Supply Voltage settings: 85 /115 % of nominal voltage (85 VAC to 132.25 VAC)

3.6.3 Measuring Equipment List:

See Attachment D [List of Test/Measuring Equipment].

3.6.4 Frequency Tolerance Limits:

"The frequency at which maximum emission occurs must be within the authorized bandwidth and must not be closer than 1.5/T MHz to the upper and lower limits of the authorized band width, where "T" is the pulse duration in microseconds. "
(FCC Rule, 80.209 (b))

1) Center frequency (f_0): 9410 MHz
2) Authorized bandwidth (f(AUBW)): 100 MHz

"Upper limit frequency of the authorized band", f(UAUBW) = f_0 + f(AUBW)/2 = 9460 MHz

"Lower limit frequency of the authorized band", f(LAUBW) = f_0 - f(AUBW)/2 = 9360 MHz

3) Assignable frequency bandwidth : 200 MHz (between 9300 MHz and 9500 MHz)
(FCC Rule, 80.375 (d)-(1))

"Upper limit frequency of the assignable band", f(UASB) = 9500 MHz
"Lower limit frequency of the assignable band", f(LASB) = 9300 MHz

4) Guard Band (f(1.5/T)) :

Pulselength	Short	Middle 1	Middle 2	Long 1	Long 2
Range Scale (nm)	0.125	3	12	48	96
Pulselength (µsec)	0.08	0.20	0.60	1.20	1.20
Guard Band f(1.5/T) (MHz)	18.75	7.50	2.50	1.25	1.25

3.6.5 Test Results:

Shown on Fig. 3.6.2.
(1) "Upper Tolerance Frequency measured (at - 20°C)", f(U) = 9418.4 MHz
(2) "Lower Tolerance Frequency measured (at + 50°C)", f(L) = 9407.1 MHz
(3)-(a)
f(U) + max. f(1.5/T) = 9437.15 MHz < f(UAUBW) = 9460 MHz ≤ f(UASB) = 9500 MHz
(3)-(b)
f(L) - max. f(1.5/T) =9388.35 MHz > f(LAUBW) = 9360 MHz ≥ f(LASB) = 9300 MHz
So, both are found within the specified limits.

FREQUENCY STABILITY WITH VARIATION OF PRIMARY SUPPLY VOLTAGE:

The built-in voltage regulator allows no frequency variation against variations of ±15 % of nominal power supply voltage (85 VAC to 115 VAC for nominal 100 VAC).

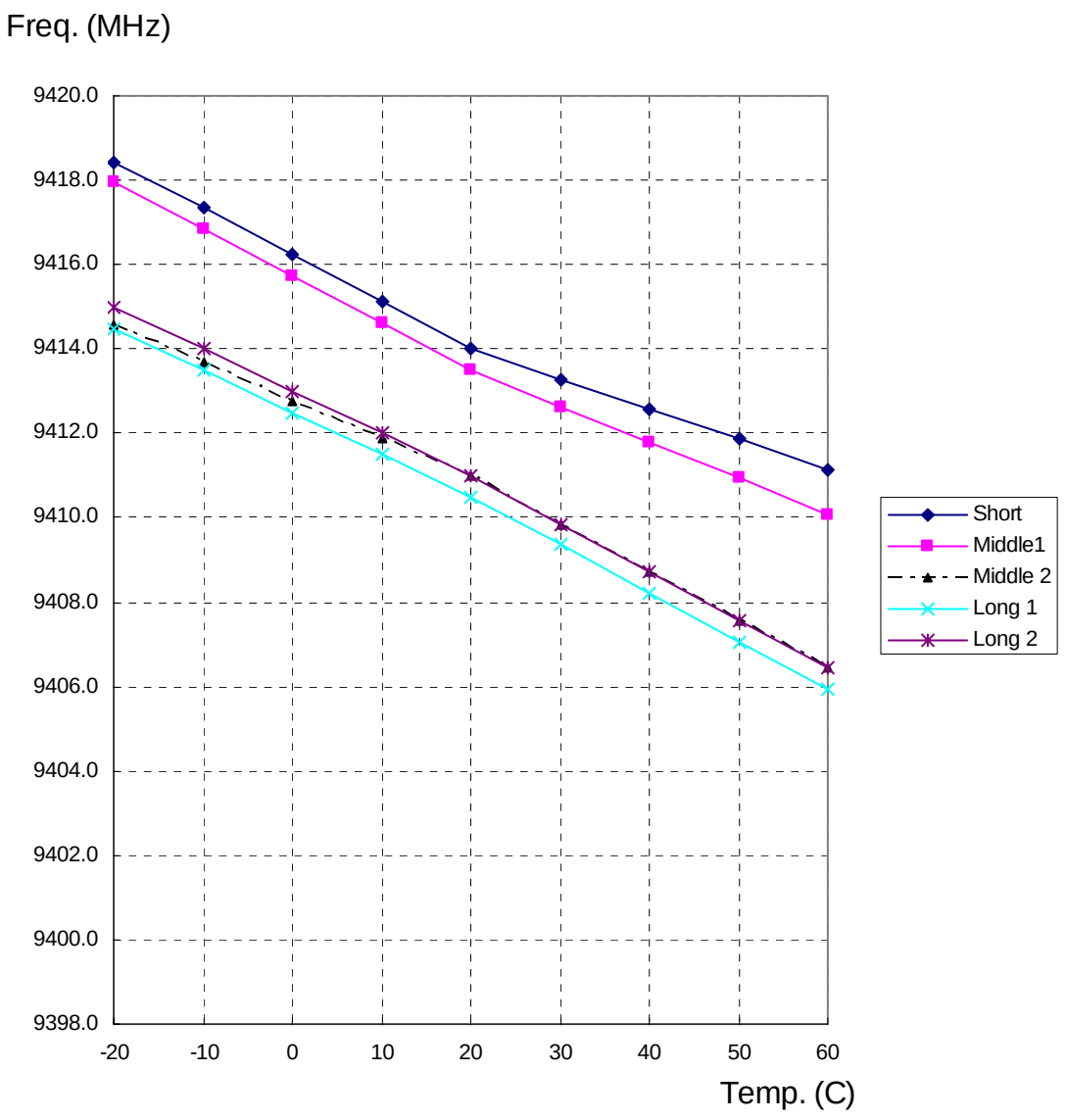


Fig. 3.6.2 Frequency Stability with Variation of Ambient Temperature

3.7 Suppression of Interference Aboard Ships (FCC Rule, 80.217)

3.7.1 Measuring Antenna Characteristics at Representative Frequencies:

Whip antennas are used to determine the level of interference caused by the radar to shipboard receivers. These antennas have the following characteristics (refer to impedance charts attached):

Length	Test Frequency (Hz)	Impedance (Ω)	θ	R (Ω)	C or L
6 m	500.5 k	1 k	-90°	0	80 pF
6 m	1.992 M	1.25 k	-86°	87.2	64 pF
6 m	10.00204 M	158		109	140 pF
4 m	27.5 M	95		83.5	128 pF
5/8 λ	150 M	116.5		105.5	52.5 nH
1/4 λ	450 M	70.5		34.5	5.68 pF

3.7.2 Test Site:

Rooftop of 6-story building,
Furuno Electric Company, Ltd.
Ashihara-cho 9-52, Nishinomiya-city, 662-8580 JAPAN

3.7.3 Measuring Instrument List:

See Attachment D [List of Test/Measuring Equipment].
(Instruments for measuring antenna characteristics are listed below.)

(1) RF Vector Impedence Meter, HP4815A
(2) Spectrum Analyzer, ADVANTEST TR4172
(3) Spectrum Analyzer, HP 8566B
(4) Antennas,
for 14 k - 10 MHz, 6 m whip
for 10 - 30 MHz, 4 m whip
for 30 - 300 MHz, VHF whip
for 300 - 1000 MHz, UHF whip

3.7.4 Test Results:

Interference levels to the respective antenna were measured at 2 m from the radar which was put in OFF and TRANSMIT conditions, and found within the specified limits.

3.7.4.1 **Harmful Interference to Receiver** (FCC Rule, 80.217 (a))

Limits: for 14 - 490 kHz, 5 μV/m
for 490 kHz - 1 GHz, 1 μV/m

Results: There is no spurious component which is deemed harmful interference. (Test data are shown in Attachment C.)

3.7.4.2 **Electromagnetic Field** (FCC Rule, 80.217 (b) - 1)

Limits: for below 30 MHz, 0.1 μV/m at 1 nm (-20 dBμV/m)
for 30 to 100 MHz, 0.3 μV/m at 1 nm (-10.5 dBμV/m)
for 100 to 300 MHz, 1.0 μV/m at 1 nm (0 dBμV/m)
for over 300 MHz, 3.0 μV/m at 1 nm (9.5 dBμV/m)

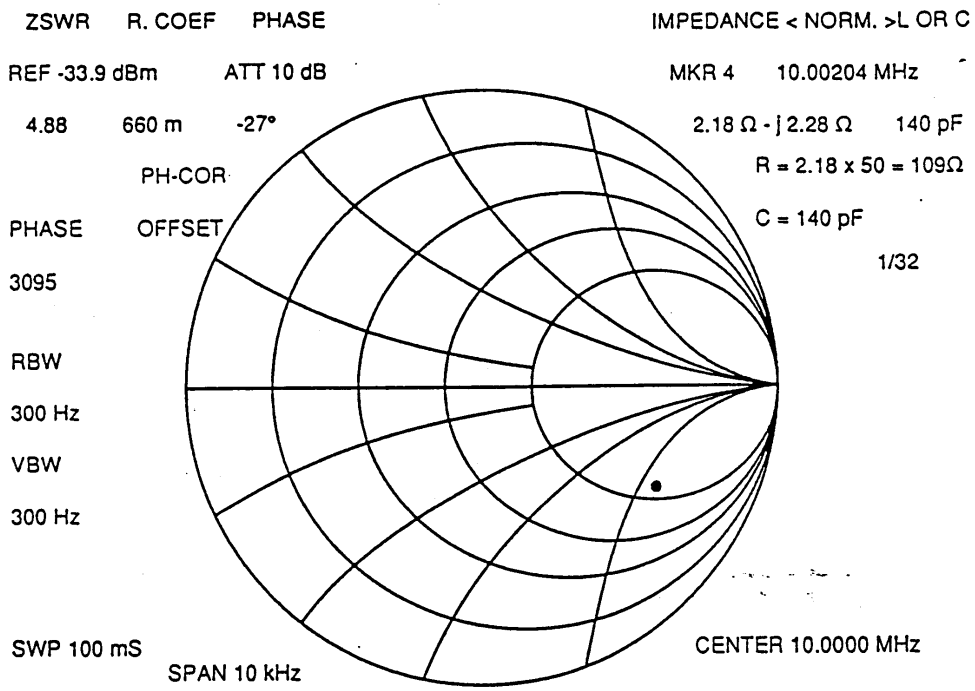
Results: Interference was measured with the antenna located 2 m from the radar and converted to levels at 1 nm. There is no spurious component exceeding the limits.
(Test data are shown in Attachment C.)

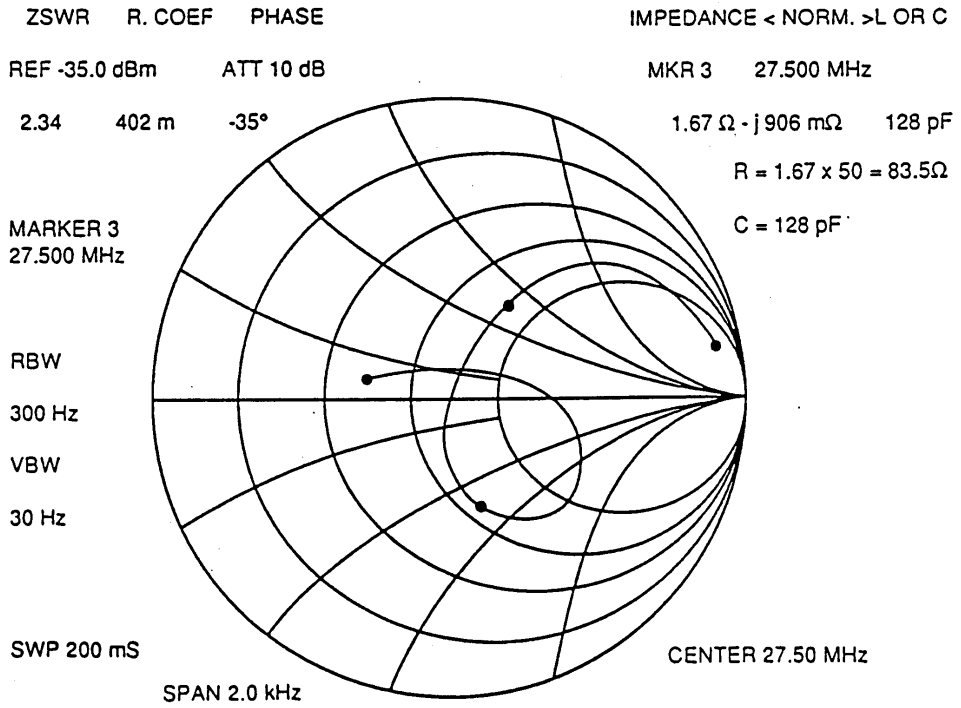
3.7.4.3 **Power Input to an Artificial Antenna** (FCC Rule, 80.217 (b) - 2)

Limits: for below 30 MHz, 400 μW
for 30 to 100 MHz, 4,000 μW
for 100 to 300 MHz, 40,000 μW
for over 300 MHz, 400,000 μW

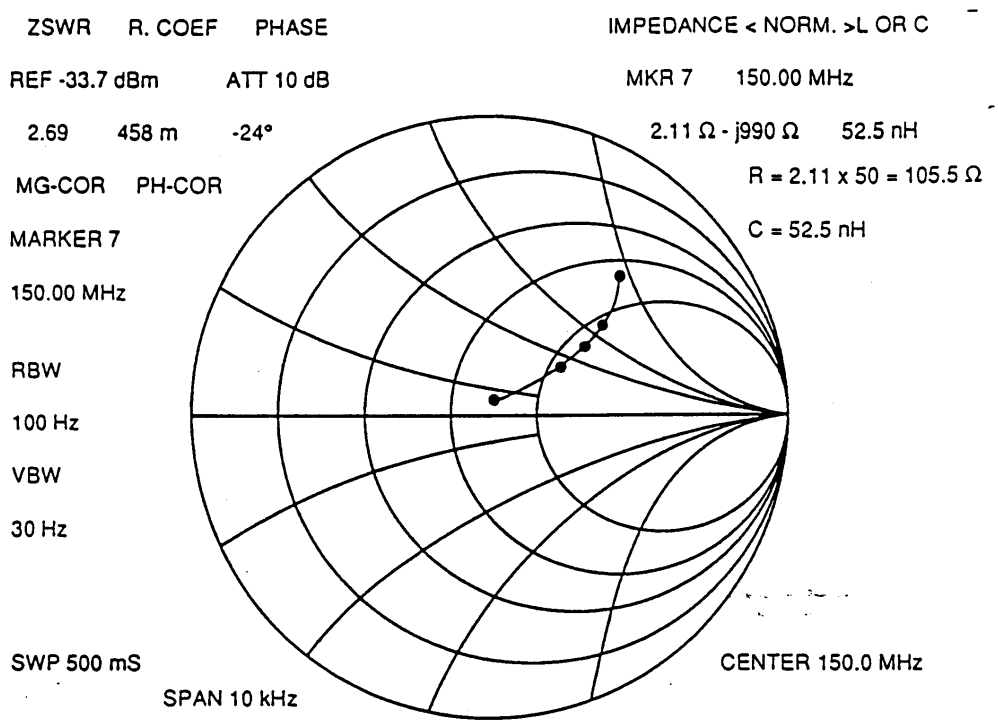
Results: There is no spurious component exceeding the limits.
(Test data are shown in Attachment C.)

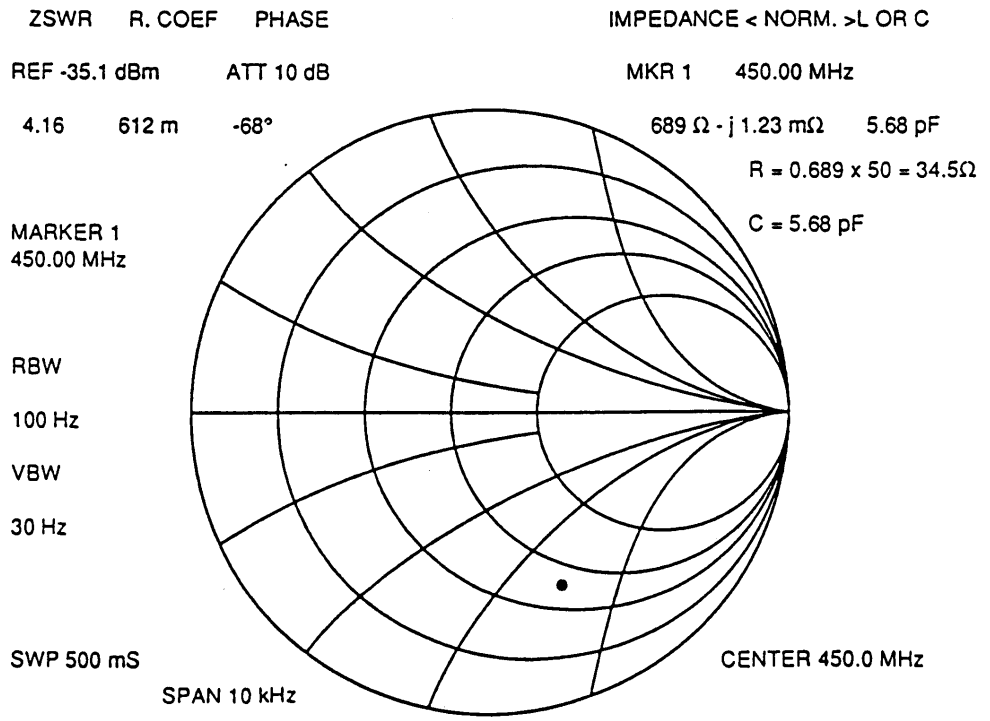
MEASUREMENT OF IMPEDANCE OF TEST ANTENNAS





MEASUREMENT OF IMPEDANCE OF TEST ANTENNAS





4 Photographs to Reveal Equipment Construction and Layout (FCC Rule, 2.1033)

(See separate covers.)

5 Description of Circuitry and Devices (FCC Rules, 2.1033)

(See separate covers.)

6 Operator's Manual Incl. Circuit Diagrams (FCC Rule, 2.1033)

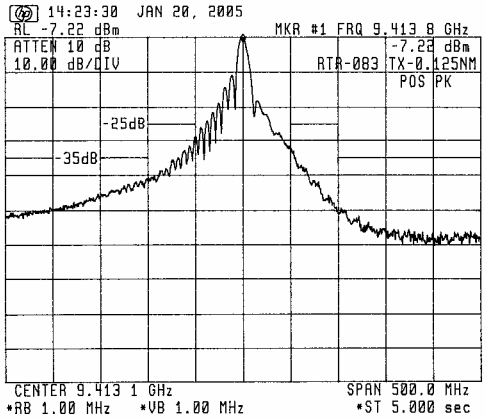
(See separate covers)

Attachment A

[TEST DATA for Clause 3.4. SPURIOUS EMISSIONS AT ANTENNA TERMINALS]

1. Spurious emissions for 0.125 nm Range:

Ref. level: -7.22 dBm

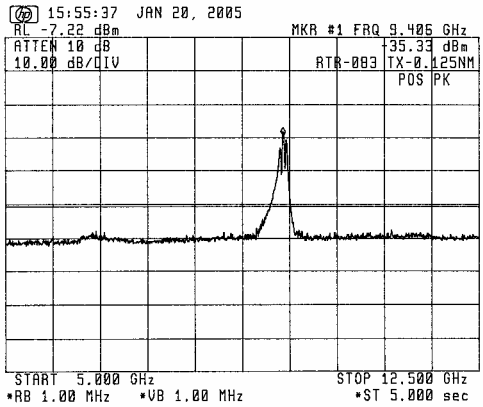


Emission limitations:

(a) 25 dB for 50 to 100 % of the authorized BW (100 MHz)

(b) 35 dB for 100 to 250 % of the authorized BW (100 MHz)

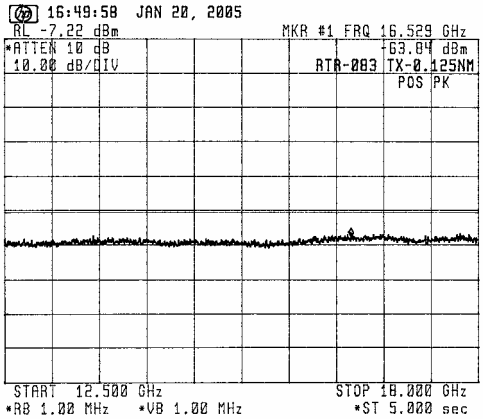
Fig. 1.1 Without Filter



Emission limitations:

(c) 43 + 10 log Pm = -50.32 dB for more than 250 % of the authorized BW (100 MHz)

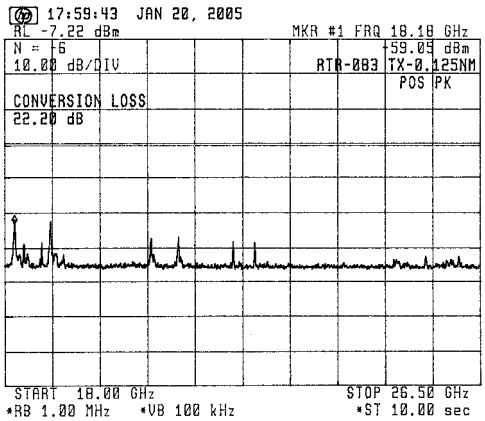
Fig. 1.2 With Filter No.1



Emission limitations:

(c) 43 + 10 log Pm = -50.32 dB for more than 250 % of the authorized BW (100 MHz)

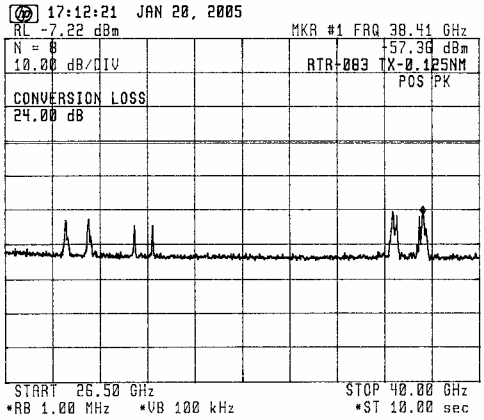
Fig. 1.3 With Filter No. 2



Emission limitations:

(c) 43 + 10 log Pm = -50.32 dB
for more than 250 % of
the authorized BW (100 MHz)

Fig. 1.4 With Filter No. 2



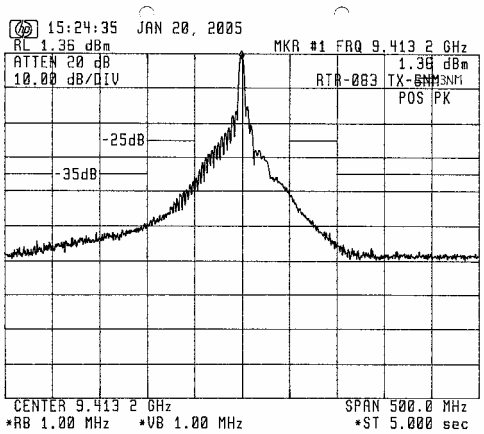
Emission limitations:

(c) 43 + 10 log Pm = -50.32 dB
for more than 250 % of
the authorized BW (100 MHz)

Fig. 1.5 With Filter No. 2

2. Spurious emissions for 3 nm Range:

Ref. level: 1.36 dBm

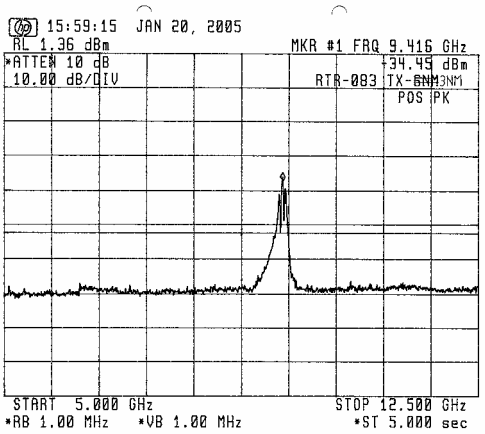


Emission limitations:

(a) 25 dB for 50 to 100 % of the authorized BW (100 MHz)

(b) 35 dB for 100 to 250 % of the authorized BW (100 MHz)

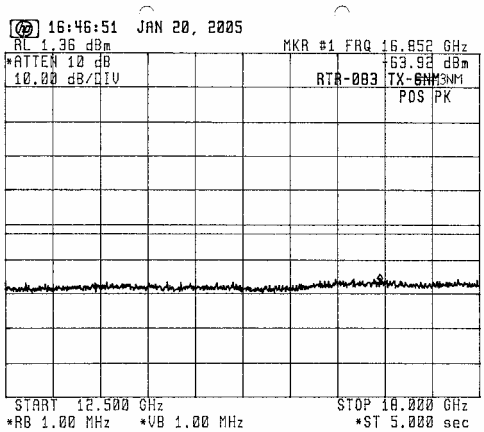
Fig. 2.1 Without Filter



Emission limitations:

(c) 43 + 10 log Pm = -52.2 dB for more than 250 % of the authorized BW (100 MHz)

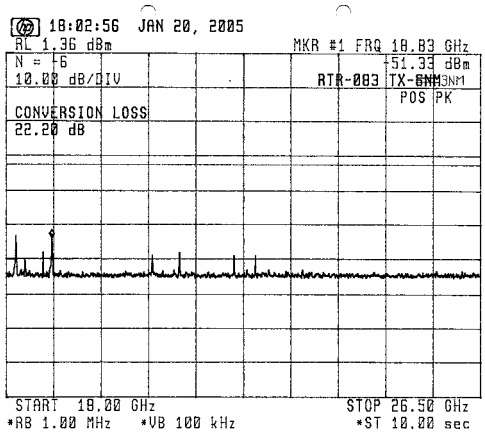
Fig. 2.2 With Filter No.1



Emission limitations:

(c) 43 + 10 log Pm = -52.2 dB for more than 250 % of the authorized BW (100 MHz)

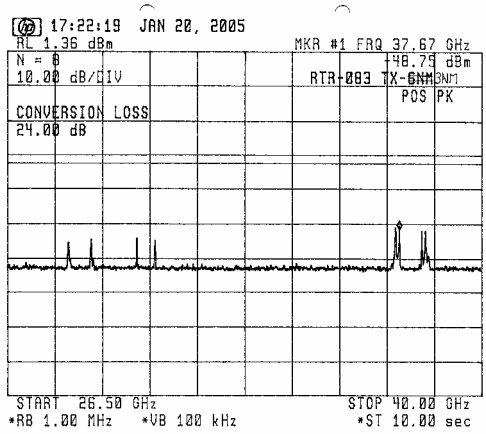
Fig. 2.3 With Filter No. 2



Emission limitations:

(c) 43 + 10 log Pm = -52.2 dB
for more than 250 % of
the authorized BW (100 MHz)

Fig. 2.4 With Filter No. 2



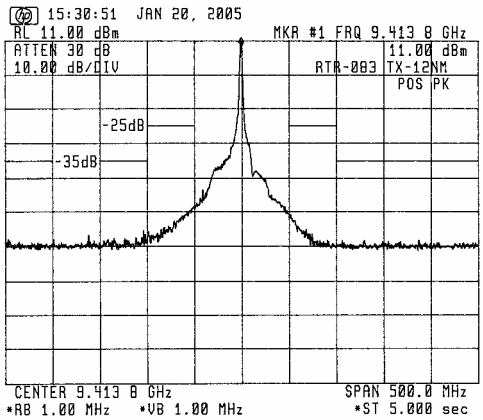
Emission limitations:

(c) 43 + 10 log Pm = -52.2 dB
for more than 250 % of
the authorized BW (100 MHz)

Fig. 2.5 With Filter No. 2

3. Spurious emissions for 12 nm Range:

Ref. level: 11.00 dBm

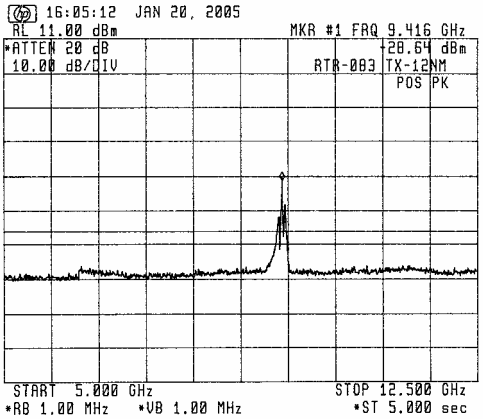


Emission limitations:

(a) 25 dB for 50 to 100 % of the authorized BW (100 MHz)

(b) 35 dB for 100 to 250 % of the authorized BW (100 MHz)

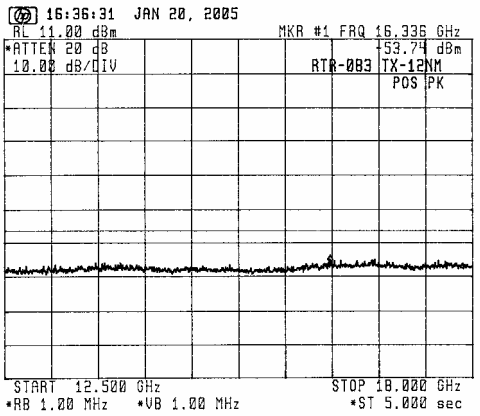
Fig. 3.1 Without Filter



Emission limitations:

(c) 43 + 10 log Pm = -56.06 dB for more than 250 % of the authorized BW (100 MHz)

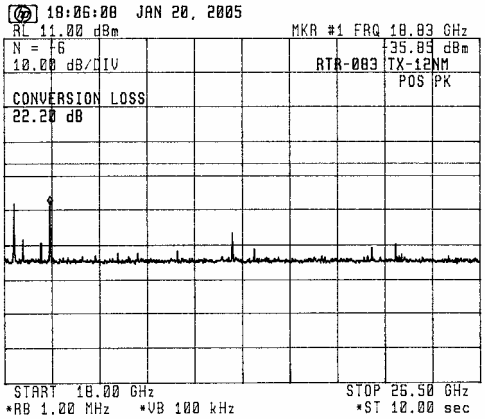
Fig. 3.2 With Filter No.1



Emission limitations:

(c) 43 + 10 log Pm = -56.06 dB for more than 250 % of the authorized BW (100 MHz)

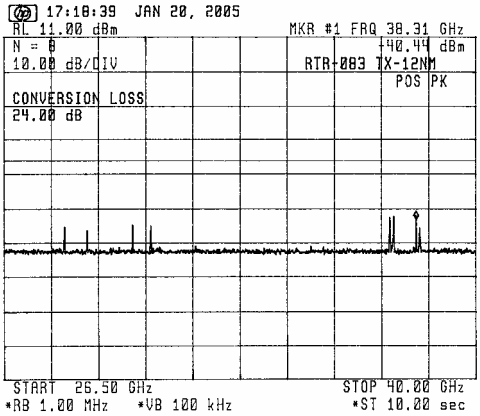
Fig. 3.3 With Filter No. 2



Emission limitations:

(c) 43 + 10 log Pm = -56.06 dB
for more than 250 % of
the authorized BW (100 MHz)

Fig. 3.4 With Filter No. 2



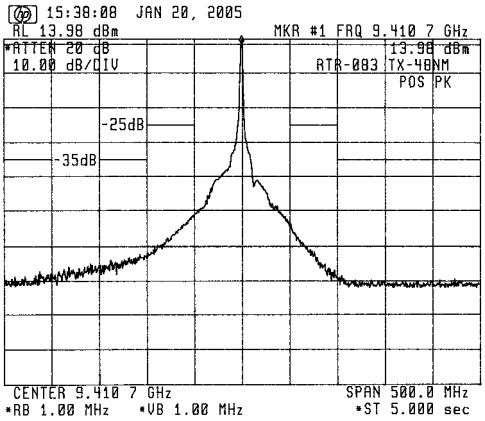
Emission limitations:

(c) 43 + 10 log Pm = -56.06 dB
for more than 250 % of
the authorized BW (100 MHz)

Fig. 3.5 With Filter No. 2

4. Spurious emissions for 48 nm Range:

Ref. level: 13.98 dBm

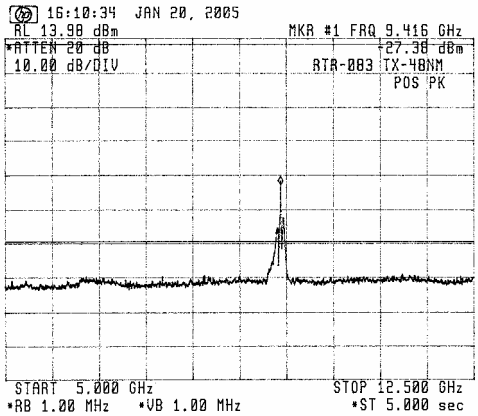


Emission limitations:

(a) 25 dB for 50 to 100 % of the authorized BW (100 MHz)

(b) 35 dB for 100 to 250 % of the authorized BW (100 MHz)

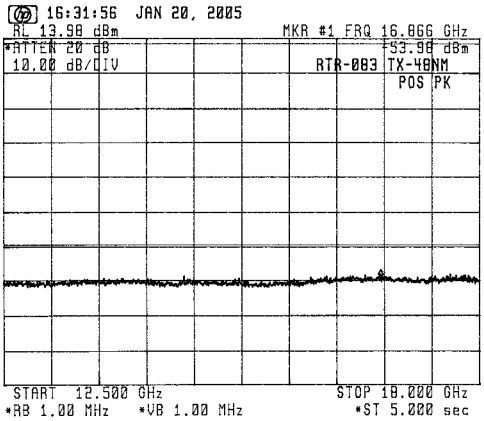
Fig. 4.1 Without Filter



Emission limitations:

(c) 43 + 10 log Pm = -59.22 dB for more than 250 % of the authorized BW (100 MHz)

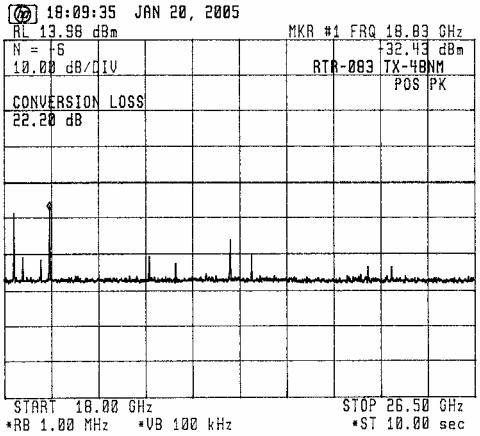
Fig. 4.2 With Filter No.1



Emission limitations:

(c) 43 + 10 log Pm = -59.22 dB for more than 250 % of the authorized BW (100 MHz)

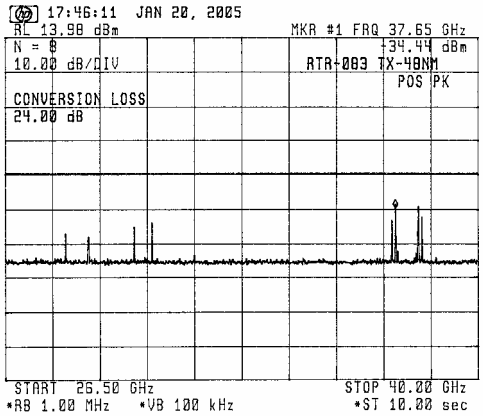
Fig. 4.3 With Filter No. 2



Emission limitations:

(c) 43 + 10 log Pm = -59.22 dB
for more than 250 % of
the authorized BW (100 MHz)

Fig. 4.4 With Filter No. 2



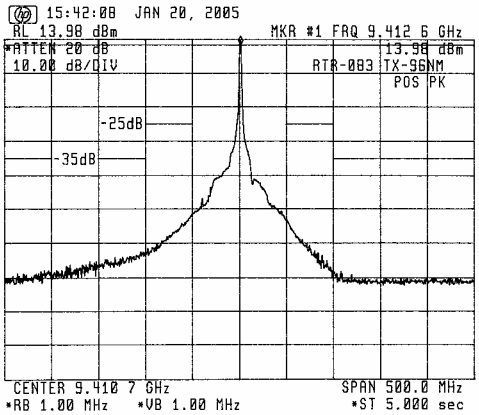
Emission limitations:

(c) 43 + 10 log Pm = -59.22 dB
for more than 250 % of
the authorized BW (100 MHz)

Fig. 4.5 With Filter No. 2

5. Spurious emissions for 96 nm Range:

Ref. level: 13.98 dBm

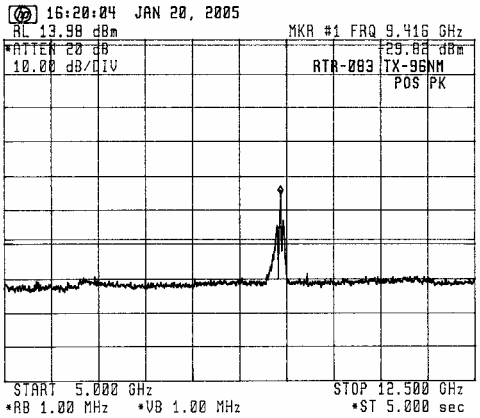


Emission limitations:

(a) 25 dB for 50 to 100 % of the authorized BW (100 MHz)

(b) 35 dB for 100 to 250 % of the authorized BW (100 MHz)

Fig. 5.1 Without Filter

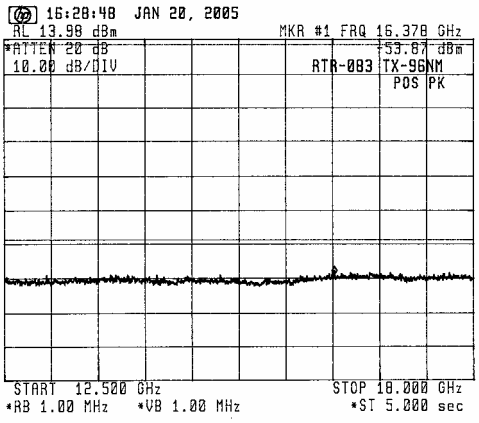


Emission limitations:

(c) 43 + 10 log Pm = -58.4 dB for more than 250 % of the authorized BW (100 MHz)

Fig. 5.2 With Filter No.1

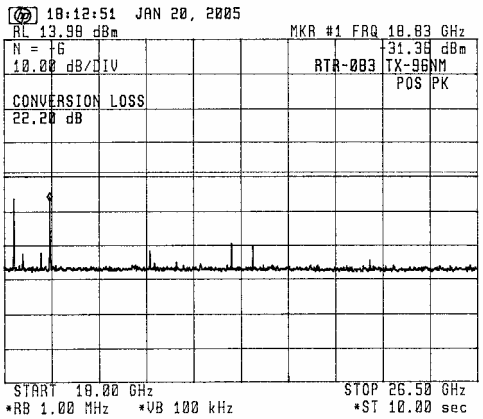
Note: 3rd-order harmonics detected.
Spurious emission level corrected: -80.27 dB
Margin for Spurious emission limit: 24.52 dB.



Emission limitations:

(c) 43 + 10 log Pm = -58.4 dB for more than 250 % of the authorized BW (100 MHz)

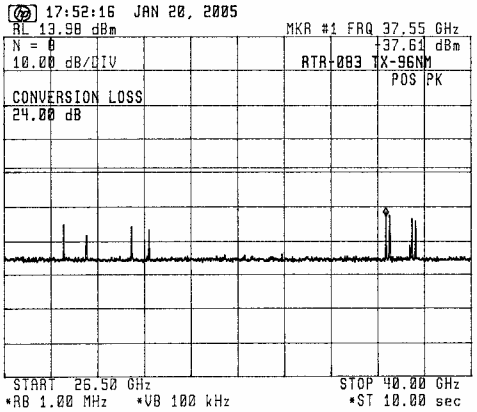
Fig. 5.3 With Filter No. 2



Emission limitations:

(c) 43 + 10 log Pm = -58.4 dB
for more than 250 % of
the authorized BW (100 MHz)

Fig. 5.4 With Filter No. 2

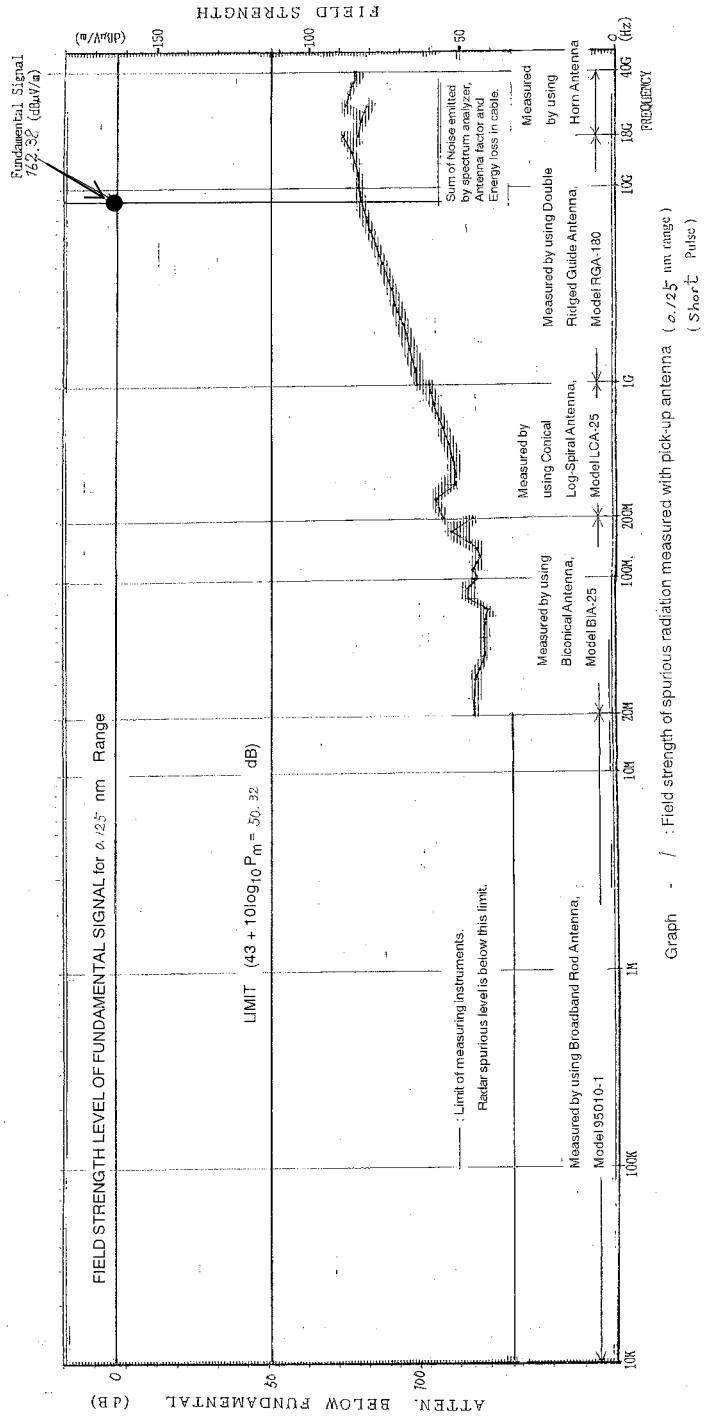


Emission limitations:

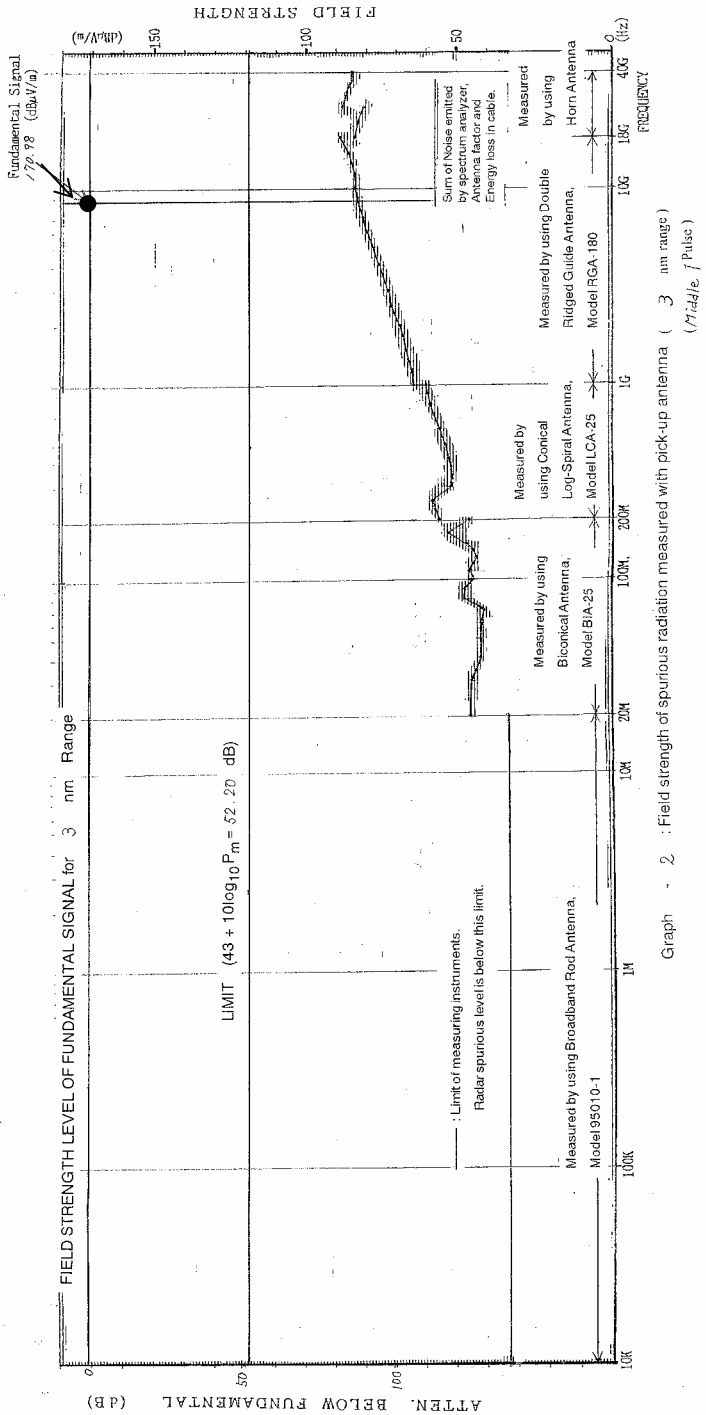
(c) 43 + 10 log Pm = -58.4 dB
for more than 250 % of
the authorized BW (100 MHz)

Fig. 5.5 With Filter No. 2

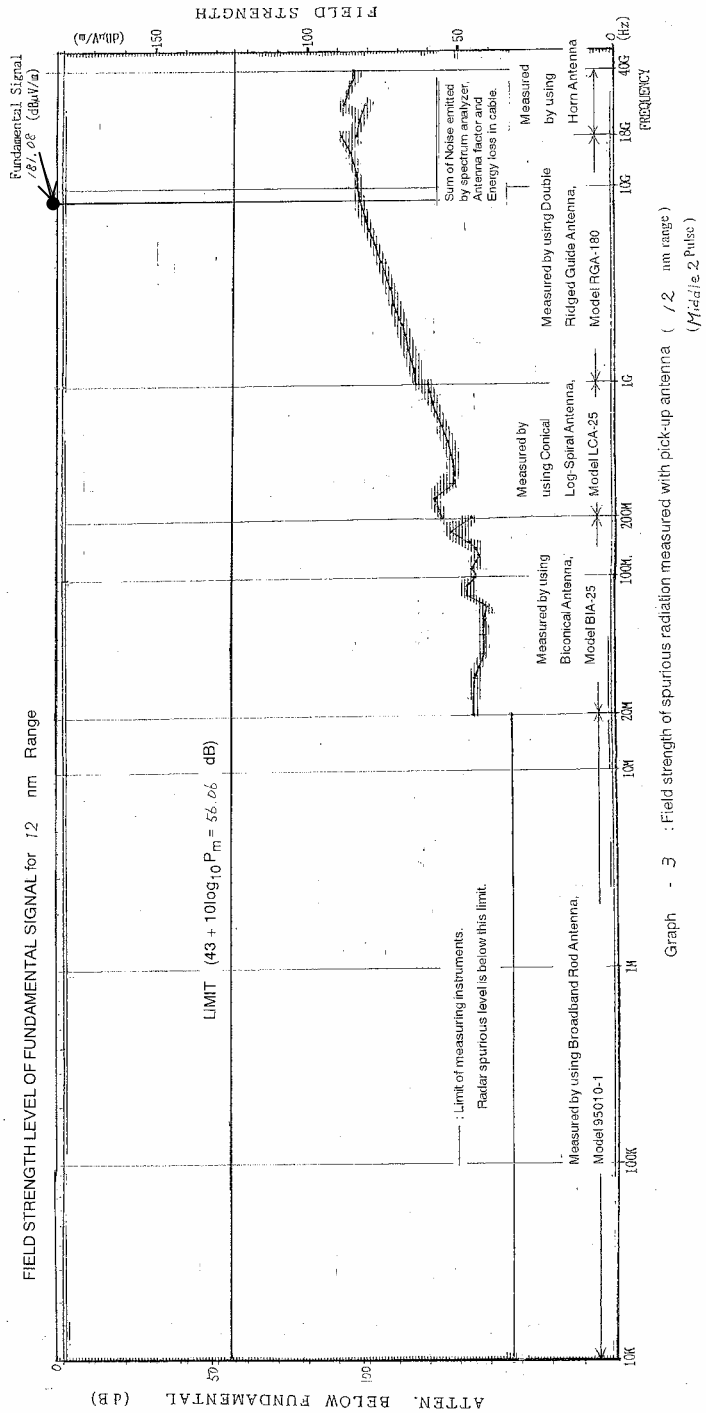
Attachment B TEST DATA for Clause 3.5 FIELD STRENGTH OF SPURIOUS RADIATION



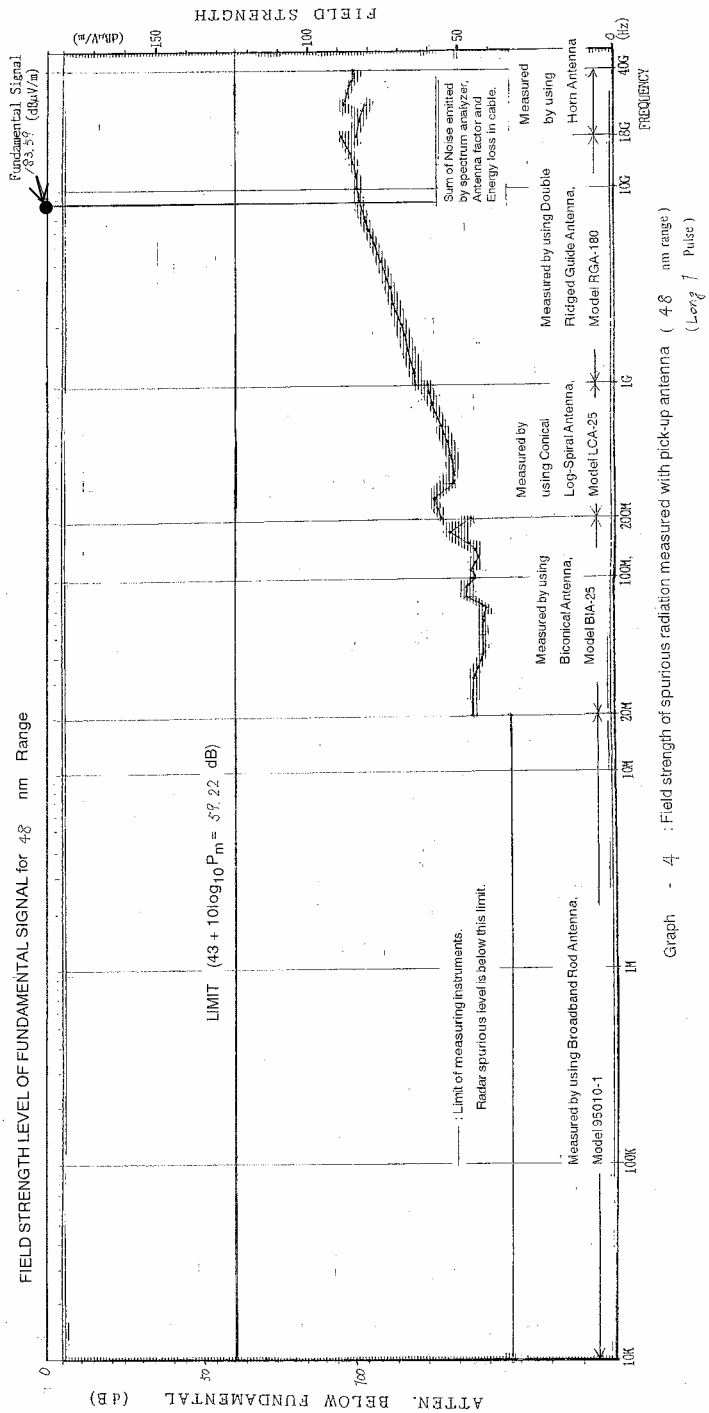
Graph - 1 : Field strength of spurious radiation measured with pick-up antenna (0.125 nm range) (Short Pulse)



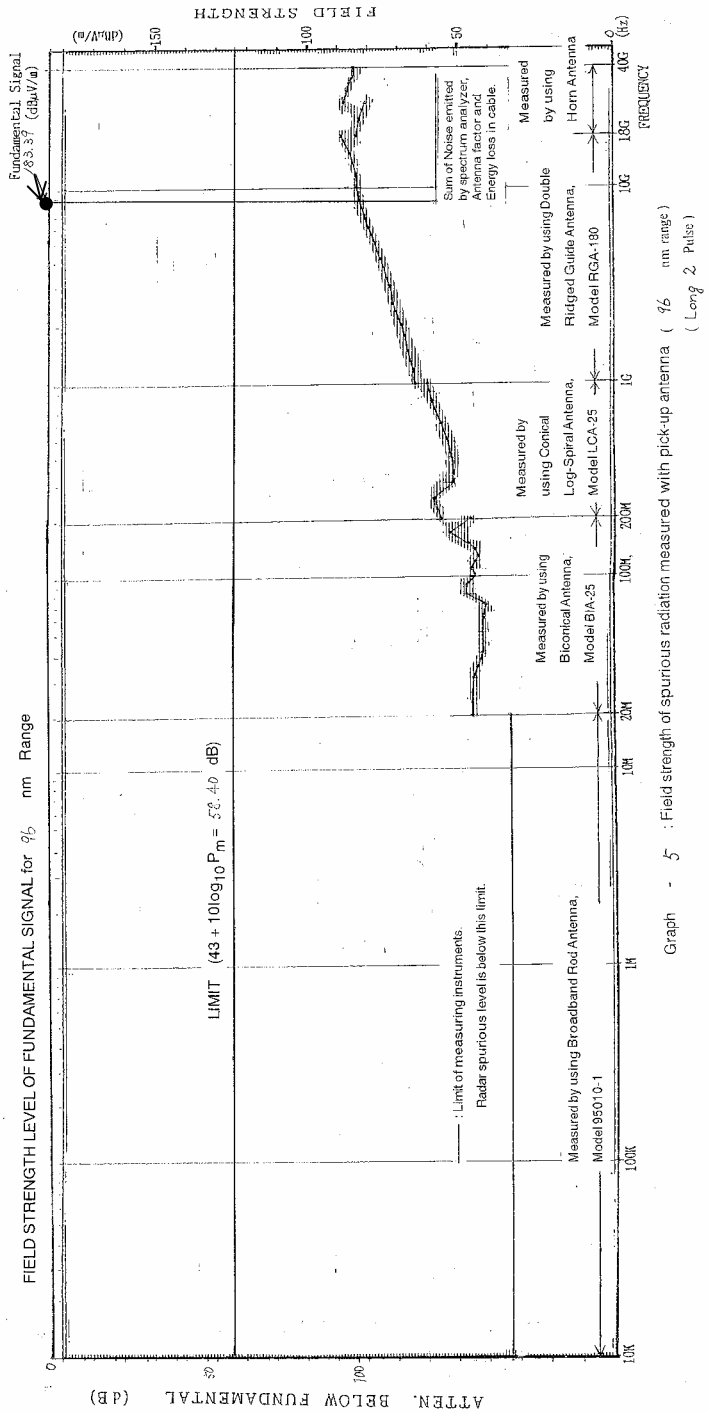
Graph - 2 : Field strength of spurious radiation measured with pick-up antenna (3 nm range)
(Middle / Pulse)



Graph - 3 : Field strength of spurious radiation measured with pick-up antenna (12 nm range)
(Middle 2 Pulse)



Graph - 4 : Field strength of spurious radiation measured with pick-up antenna (48 nm range)
(Long / Pulse)



Graph - 5 : Field strength of spurious radiation measured with pick-up antenna (96 nm range)
(Long 2 Pulse)

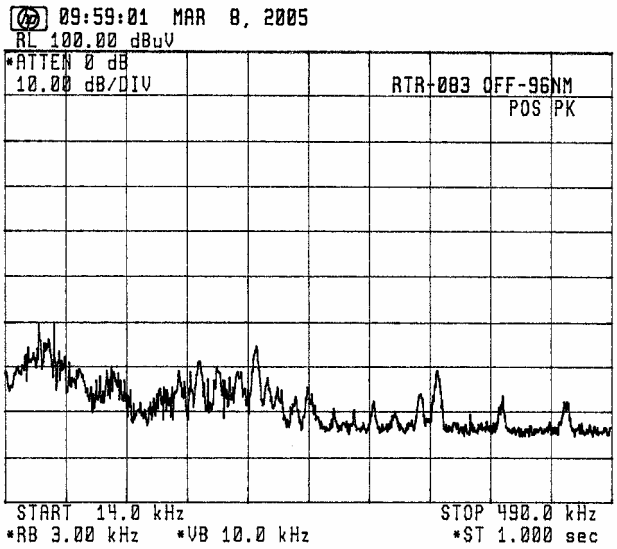
Attachment C

[TEST DATA for Clause 3.7 SUPPRESSION OF INTERFERENCE ABOARD SHIPS]

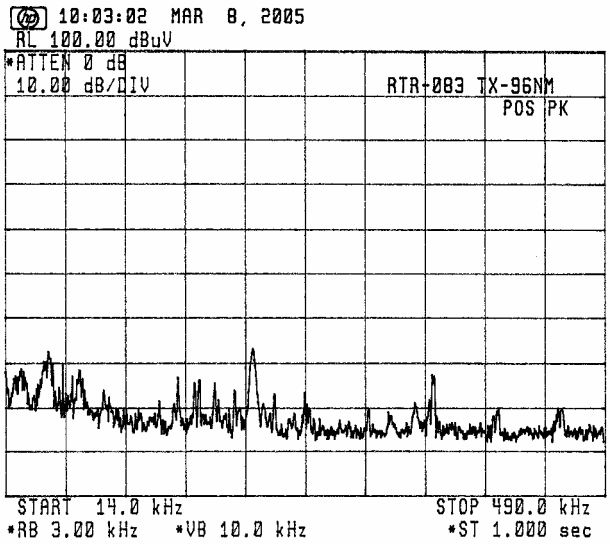
1 Harmful Interference to Receiver

(Band: 14 kHz - 490 kHz)

a) Radar Power: OFF

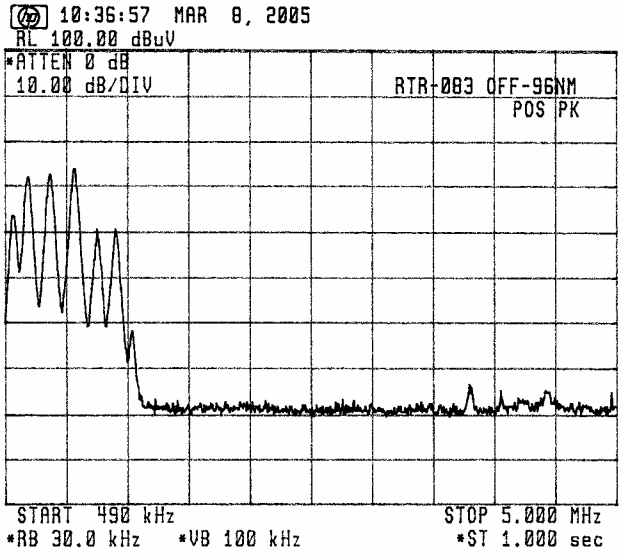


b) Radar TX: ON

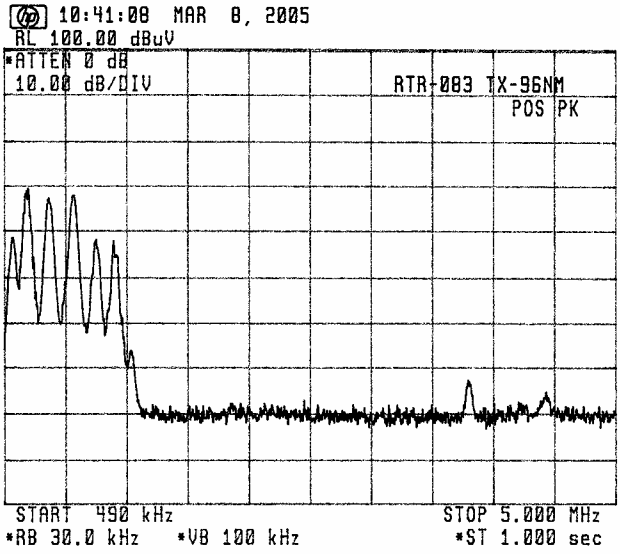


(Band: 490 kHz - 5 MHz)

a) Radar Power: OFF

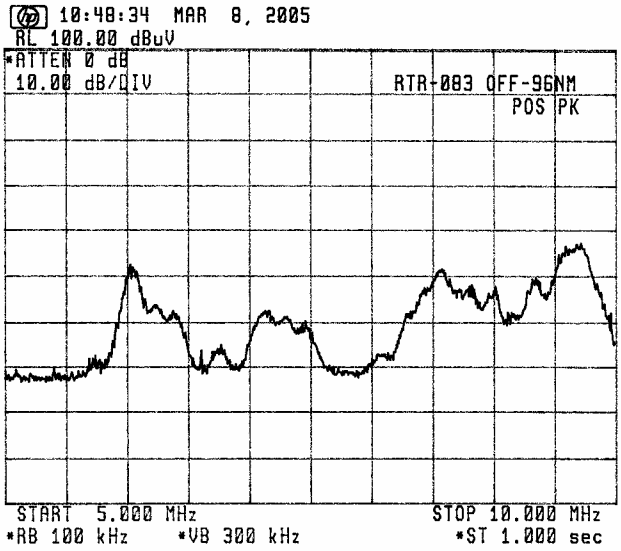


b) Radar TX: ON

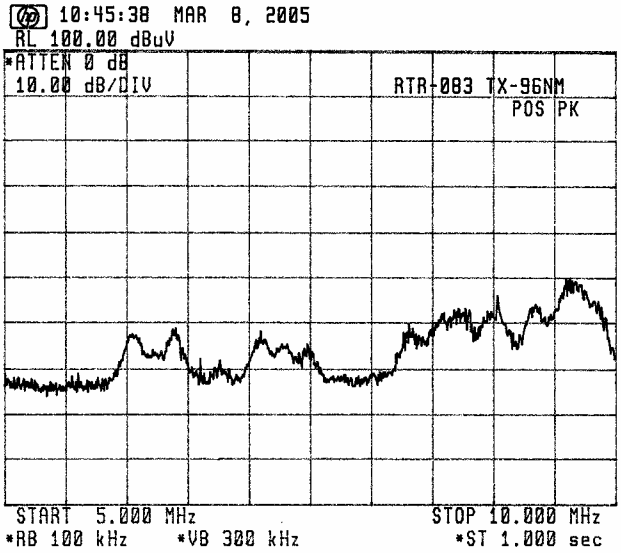


(Band: 5 MHz - 10 MHz)

a) Radar Power: OFF

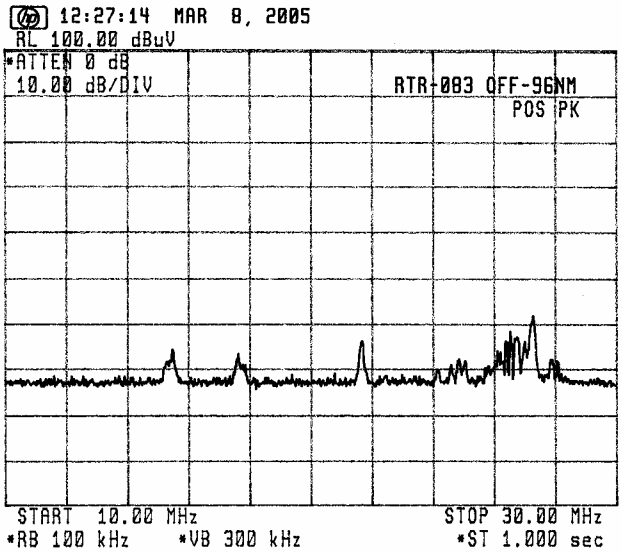


b) Radar TX: ON

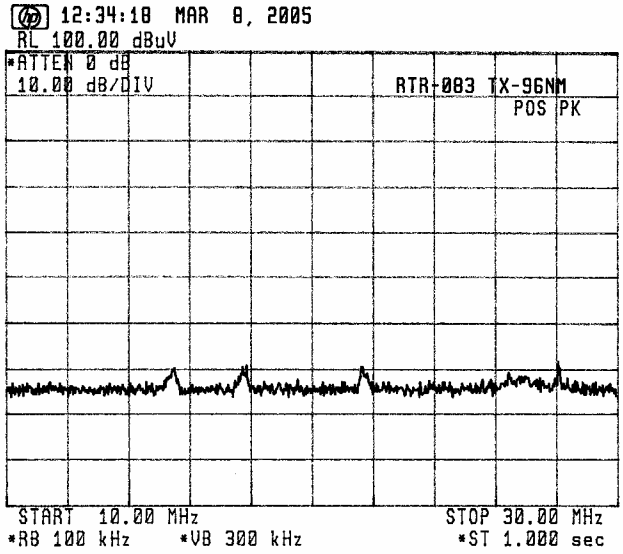


(Band: 10 MHz - 30 MHz)

a) Radar Power: OFF

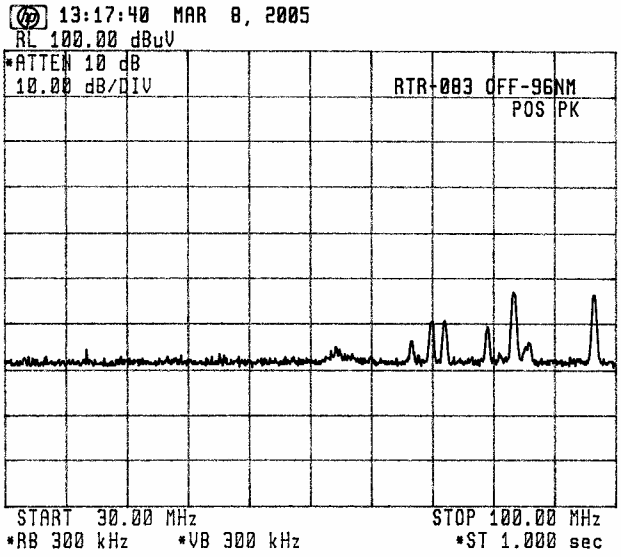


b) Radar TX: ON

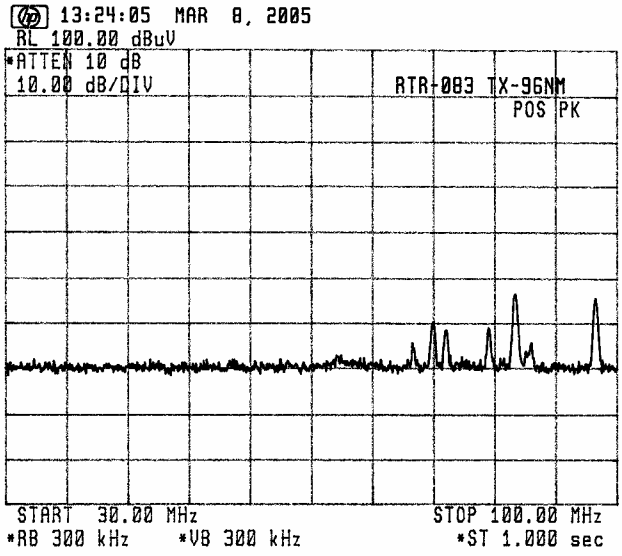


(Band: 30 MHz - 100 MHz)

a) Radar Power: OFF

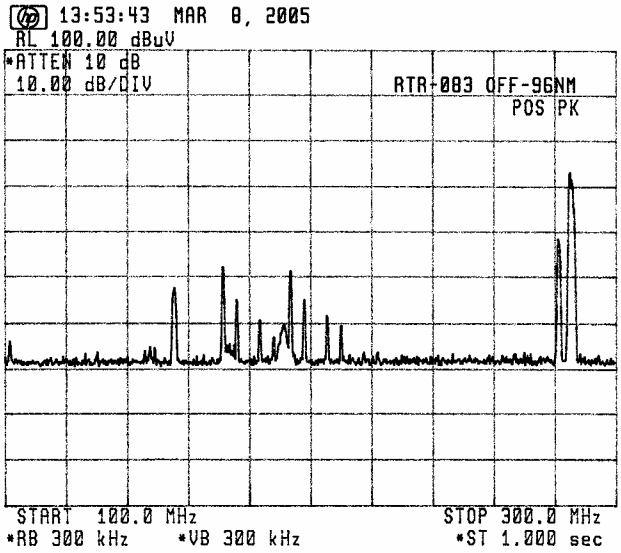


b) Radar TX: ON

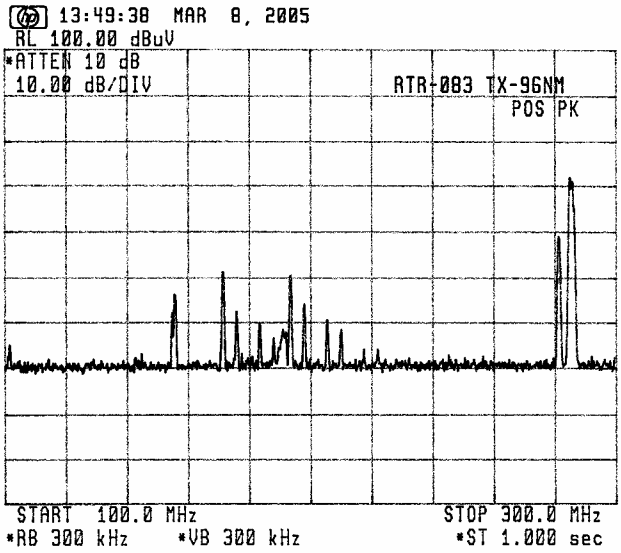


(Band: 100 MHz - 300 MHz)

a) Radar Power: OFF

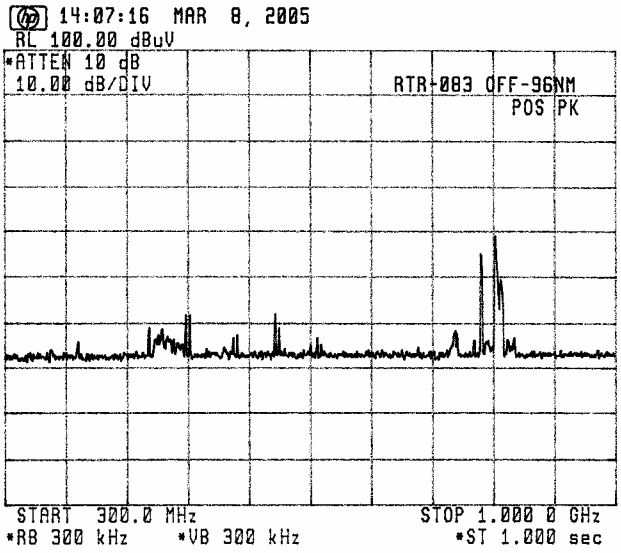


b) Radar TX: ON

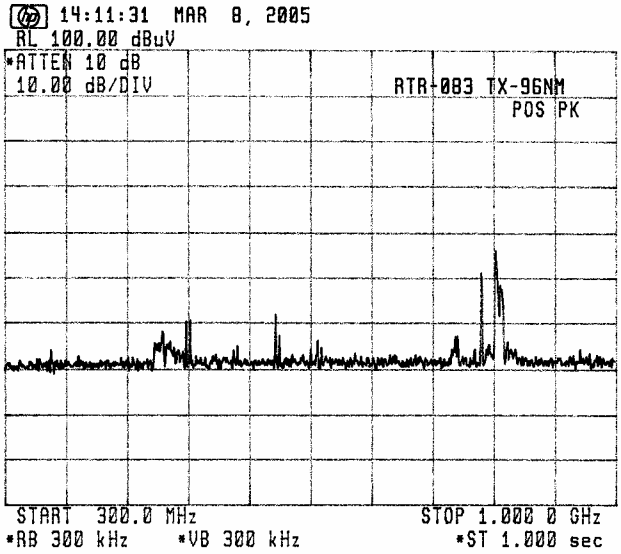


(Band: 300 MHz - 1 GHz)

a) Radar Power: OFF



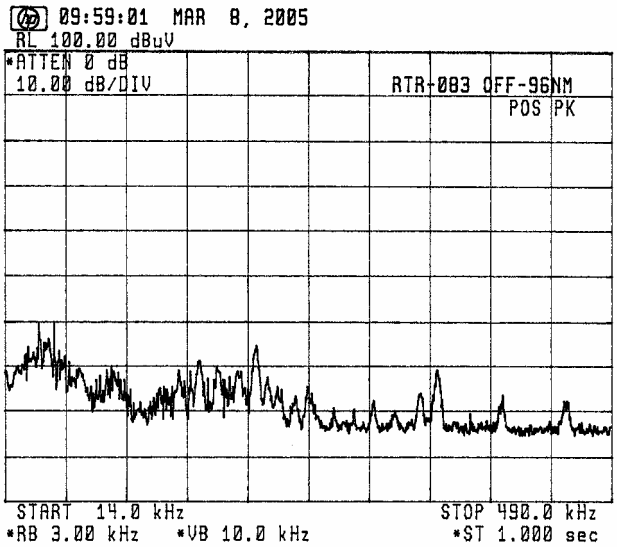
b) Radar TX: ON



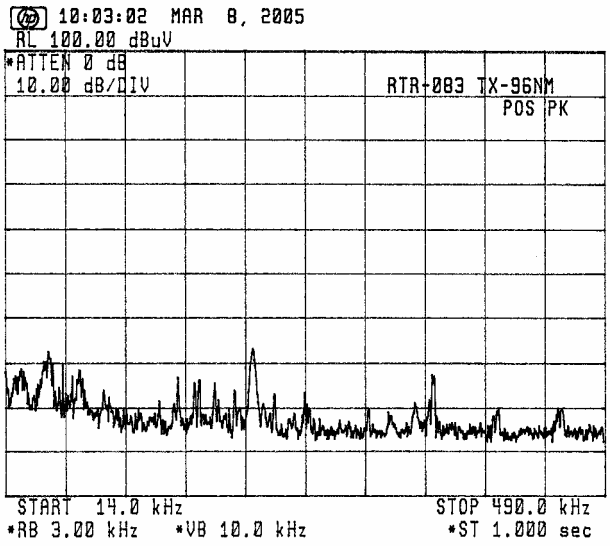
2 Electromagnetic Field

(Band: 14 kHz - 490 kHz, Limit at 1 nm = 0.1 µV/m = -20 dBµV/m)

a) Radar Power: OFF



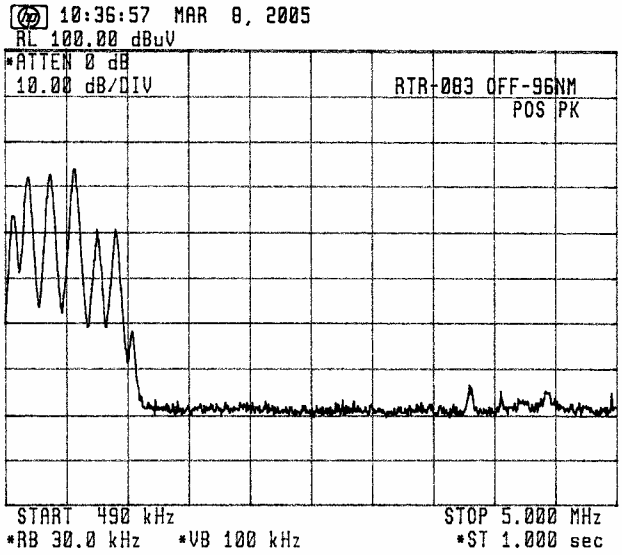
b) Radar TX: ON



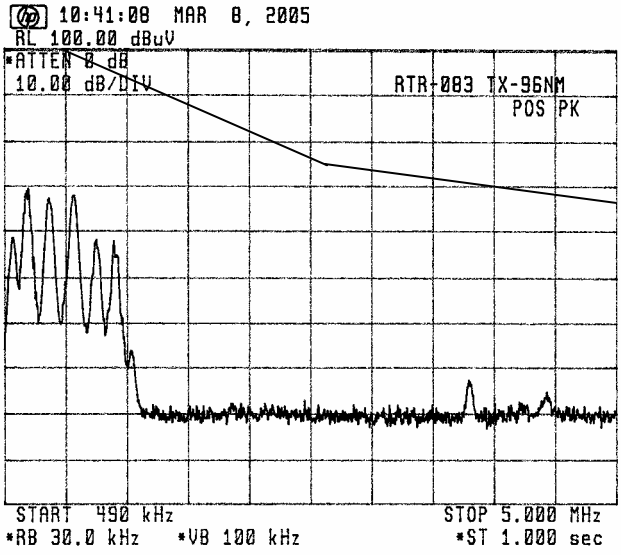
Ref. Level: -26 dBµV/m

(Band: 490 kHz - 5 MHz, Limit at 1 nm = 0.1 µV/m = -20 dBµV/m)

a) Radar Power: OFF



b) Radar TX: ON



Ref. level (dBµV/m)

= 100 - 126 = -26 (at 0.5 MHz)

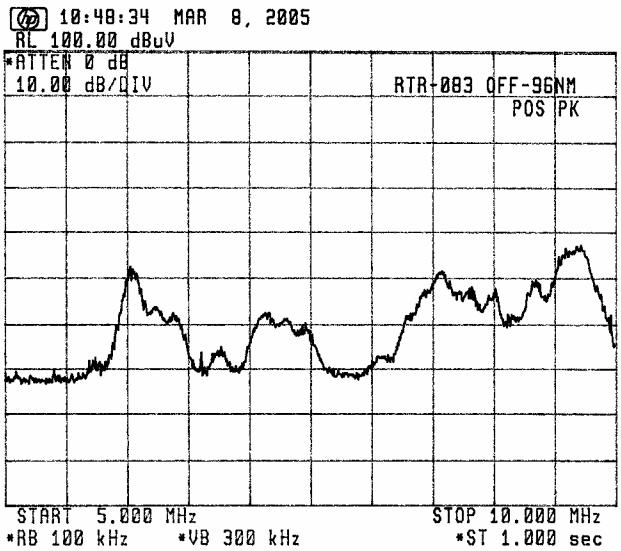
= 100 - 96 = 4 (at 3 MHz)

= 100 - 88 = 12 (at 5 MHz)

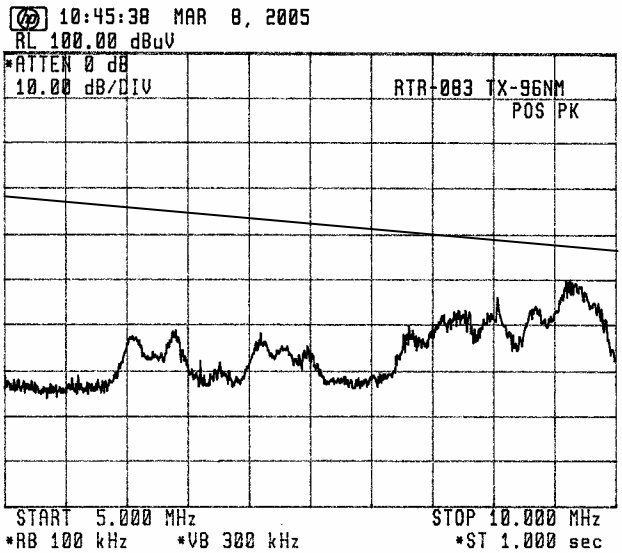
-20 dBµV/m limit line

(Band: 5 MHz - 10 MHz, Limit at 1 nm = 0.1 µV/m = -20 dBµV/m)

a) Radar Power: OFF



b) Radar TX: ON



Ref. level (dBµV/m)

= 100 - 88 = 12 (at 5 MHz)

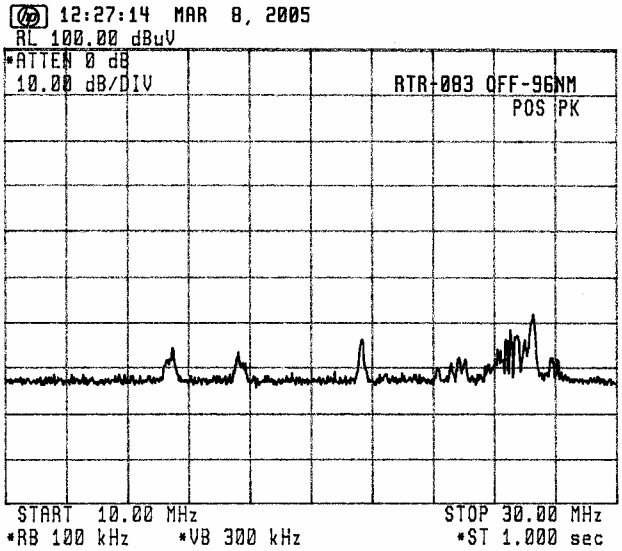
= 100 - 83 = 17 (at 7 MHz)

= 100 - 78 = 22 (at 10 MHz)

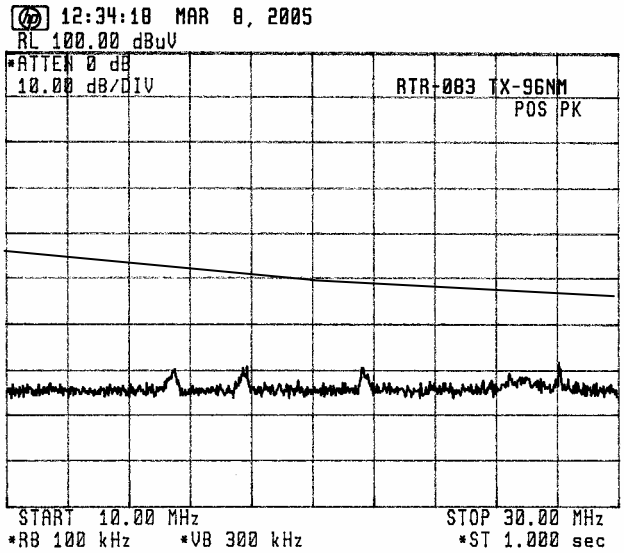
-20 dBµV/m limit line

(Band: 10 MHz - 30 MHz, Limit at 1 nm = 0.1 µV/m = -20 dBµV/m)

a) Radar Power: OFF



b) Radar TX: ON



Ref. level (dBµV/m)

= 100 - 78 = 22 (at 10 MHz)

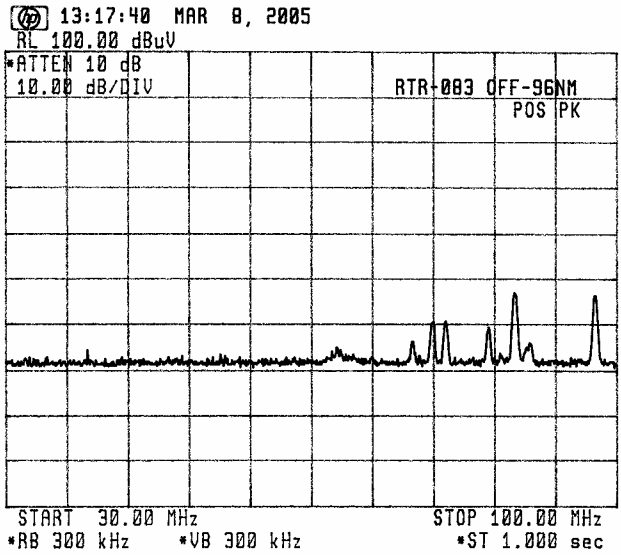
= 100 - 70 = 30 (at 20 MHz)

= 100 - 67 = 33 (at 30 MHz)

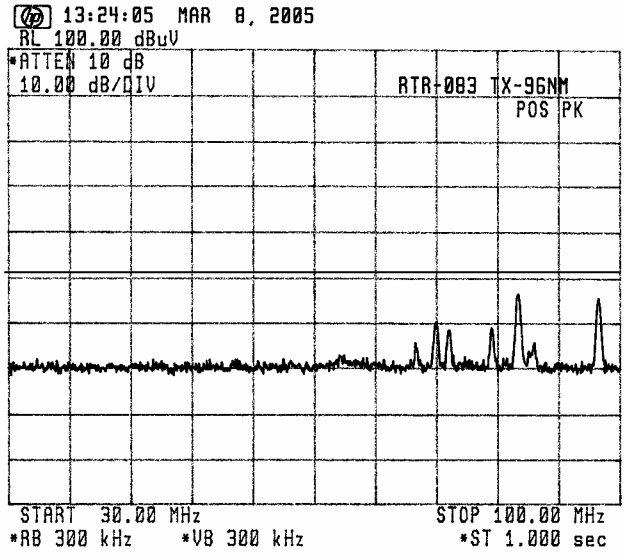
-20 dBµV/m limit line

(Band: 30 MHz - 100 MHz, Limit at 1 nm = 0.1 µV/m = -10.5 dBµV/m)

a) Radar Power: OFF



b) Radar TX: ON



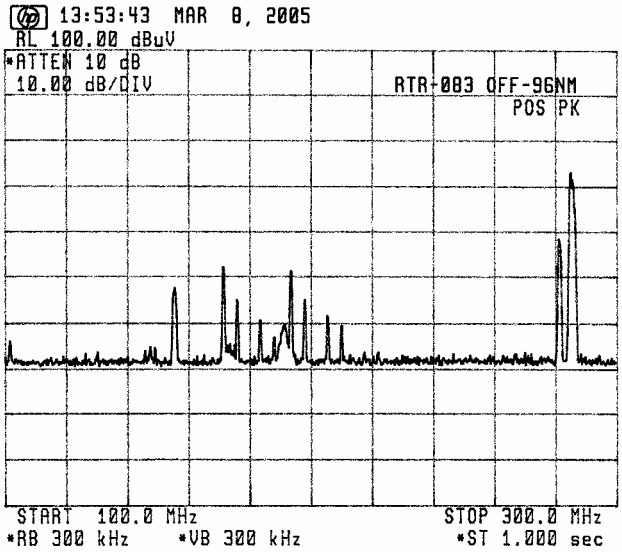
Ref. level (dBµV/m)

= 100 - 61 = 39

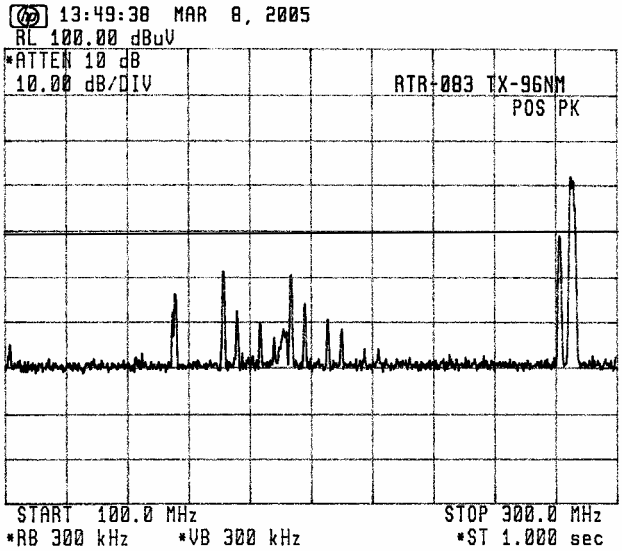
-10.5 dBµV/m limit line

(Band: 100 MHz - 300 MHz, Limit at 1 nm = 0.1 µV/m = -0 dBµV/m)

a) Radar Power: OFF



b) Radar TX: ON



Ref. level (dBµV/m)

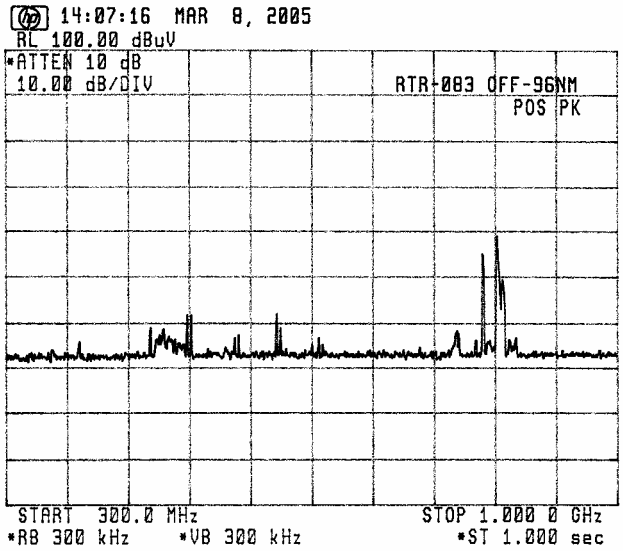
= 100 - 60 = 40

0 dBµV/m limit line

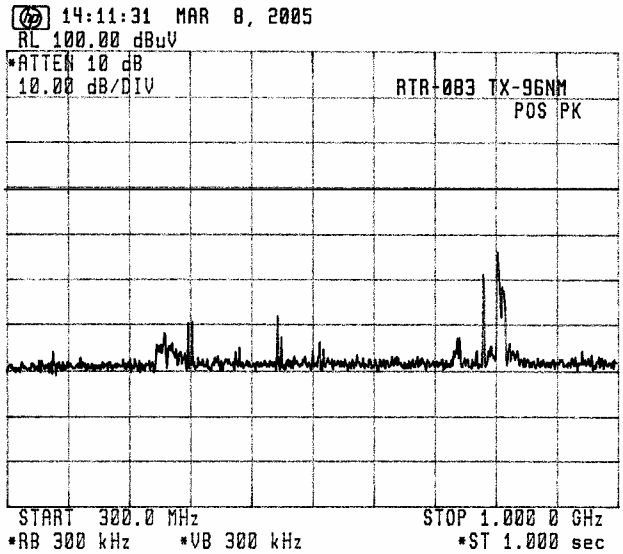
Note:
All components above the limit are from external noise or signals, not from Radar.

(Band: 300 MHz - 1 GHz, Limit at 1 nm = 3 µV/m = 9.5 dBµV/m)

a) Radar Power: OFF



b) Radar TX: ON



Ref. level (dBµV/m)

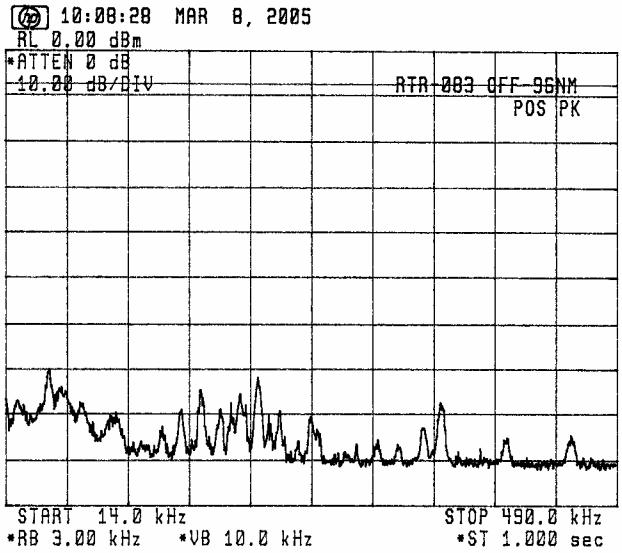
= 100 - 59.5 = 40.5

9.5 dBµV/m limit line

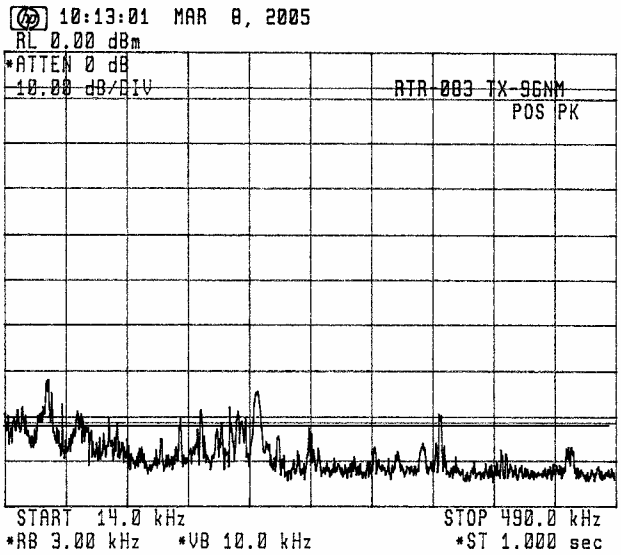
3 Power Input to an Artificial Antenna

(Band: 14 kHz - 490 kHz, Limit at 2 m = -81 dBm)

a) Radar Power: OFF



b) Radar TX: ON

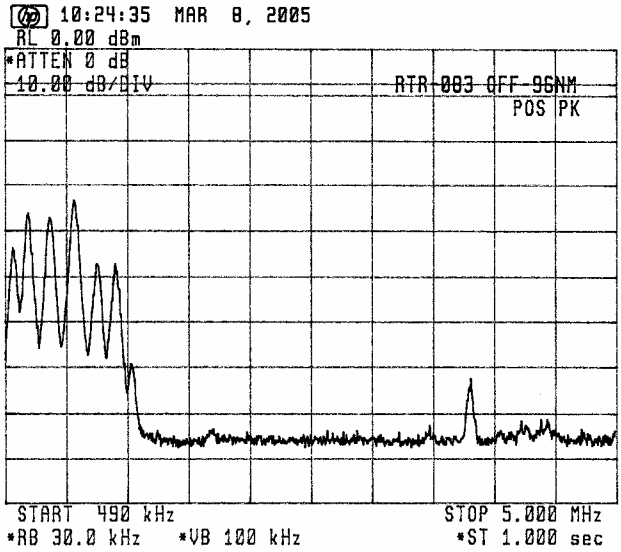


Note:
All components above the limit are from external noise or signals, not from Radar.

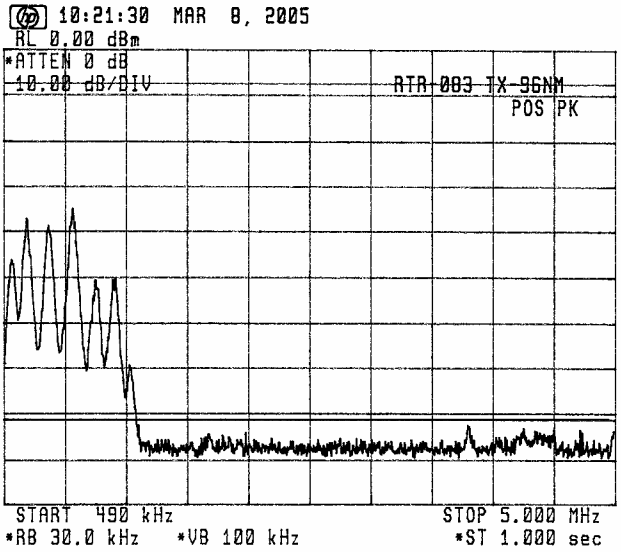
-81 dBm limit line

(Band: 490 kHz - 5 MHz, Limit at 2 m = -81 dBm)

a) Radar Power: OFF



b) Radar TX: ON

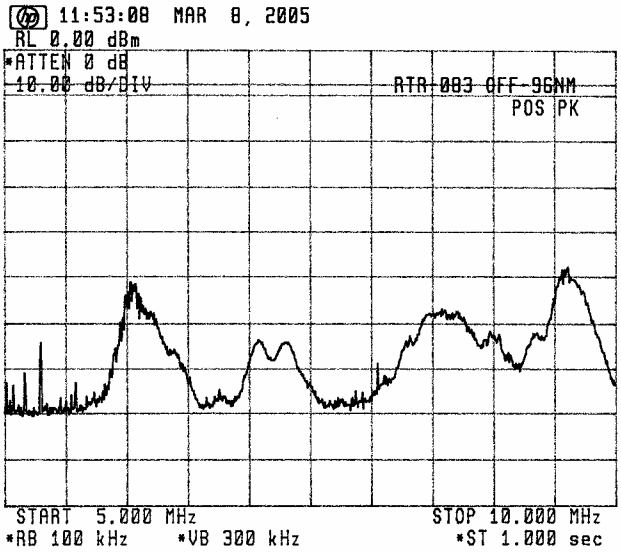


Note:
All components above the limit are from external noise or signals, not from Radar.

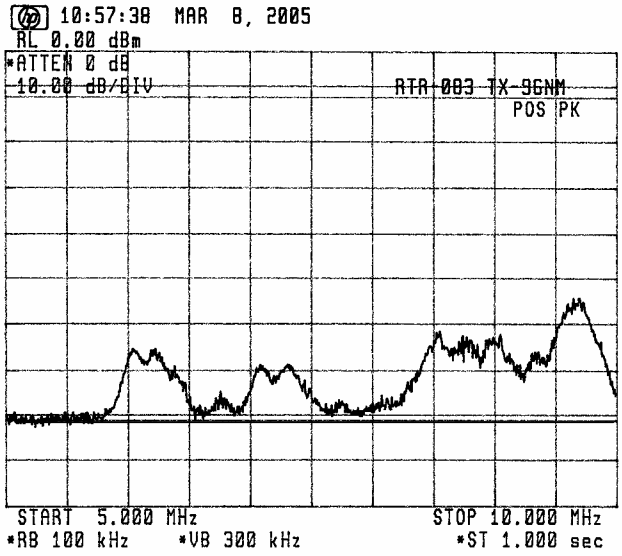
-81 dBm limit line

(Band: 5 MHz - 10 MHz, Limit at 2 m = -81 dBm)

a) Radar Power: OFF



b) Radar TX: ON

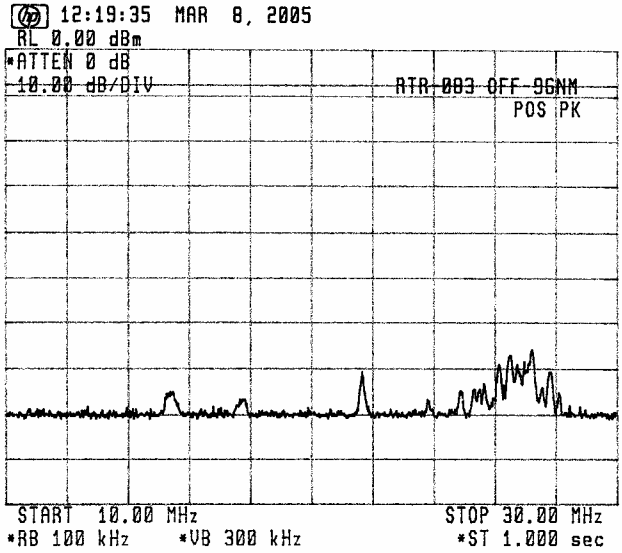


Note:
All components above the limit are from external noise or signals, not from Radar.

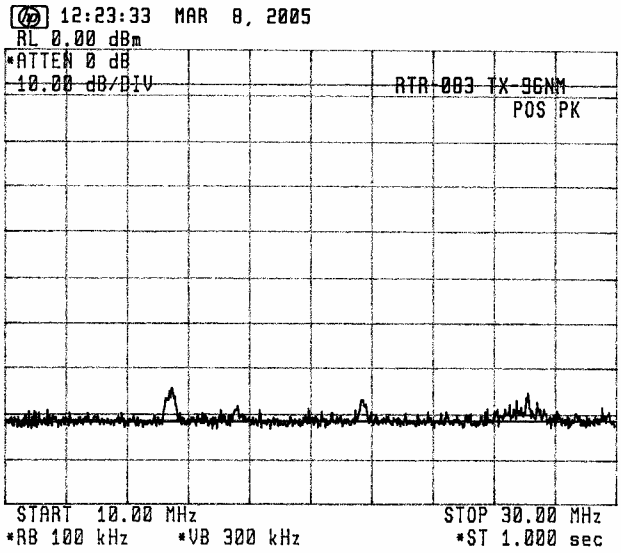
-81 dBm limit line

(Band: 10 MHz - 30 MHz, Limit at 2 m = -81 dBm)

a) Radar Power: OFF



b) Radar TX: ON

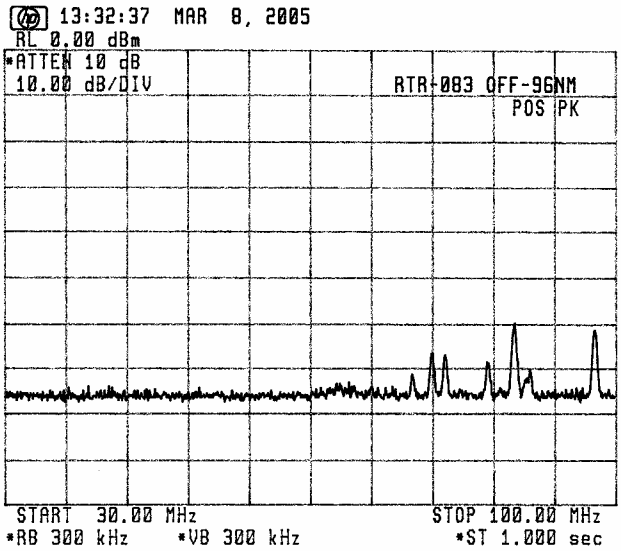


Note:
All components above the limit are from external noise or signals, not from Radar.

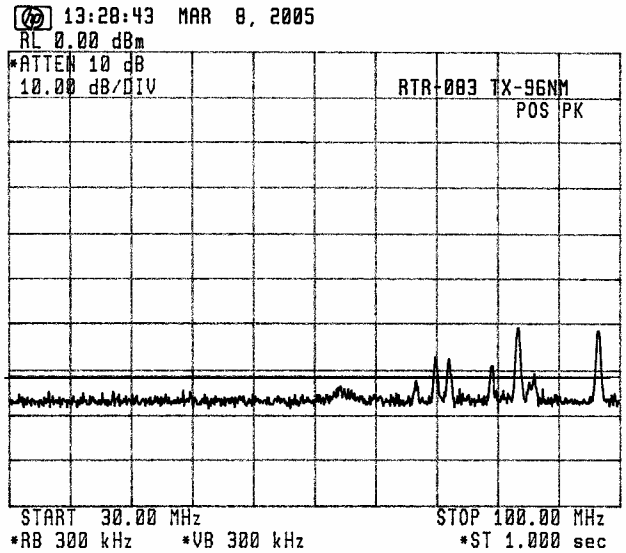
-81 dBm limit line

(Band: 30 MHz - 100 MHz, Limit at 2 m = -71 dBm)

a) Radar Power: OFF



b) Radar TX: ON

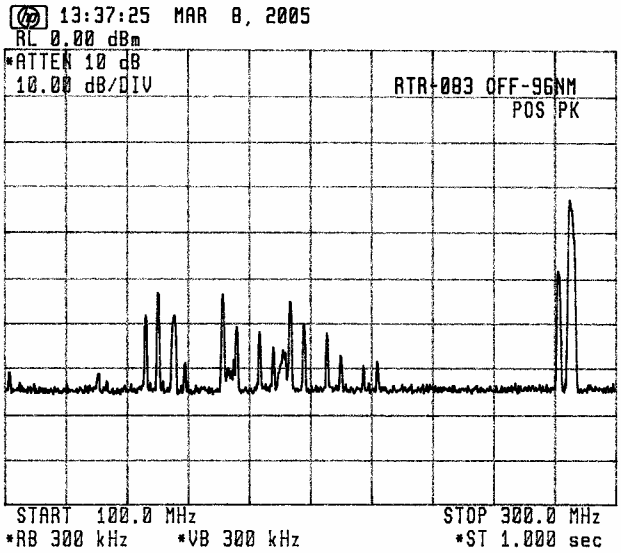


Note:
All components above the limit are from external noise or signals, not from Radar.

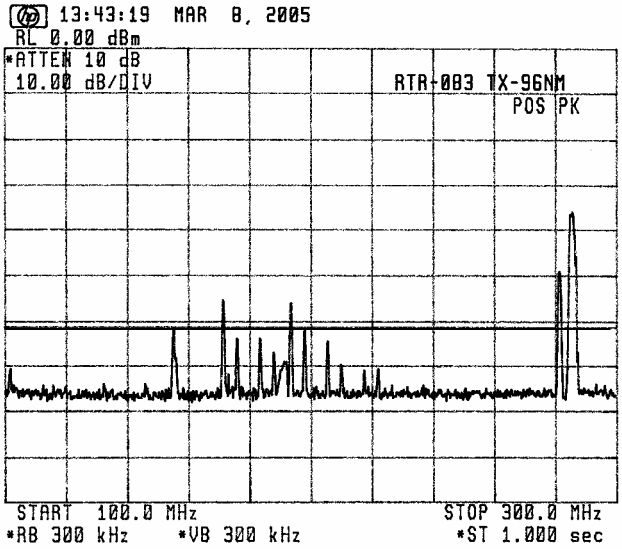
-71 dBm limit line

(Band: 100 MHz - 300 MHz, Limit at 2 m = -61 dBm)

a) Radar Power: OFF



b) Radar TX: ON

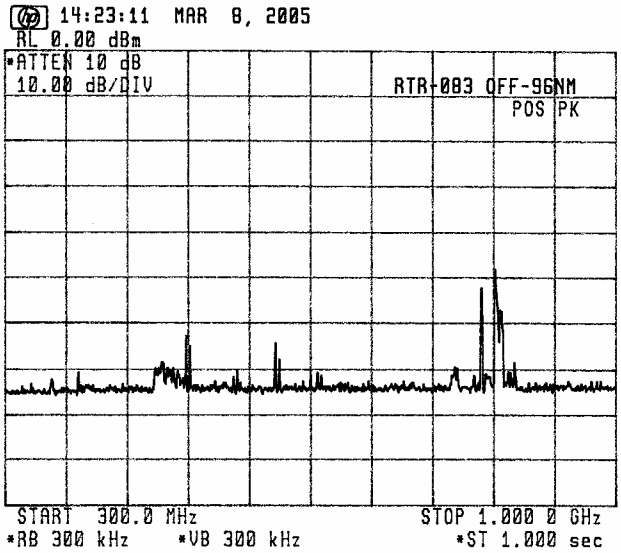


Note:
All components above the limit are from external noise or signals, not from Radar.

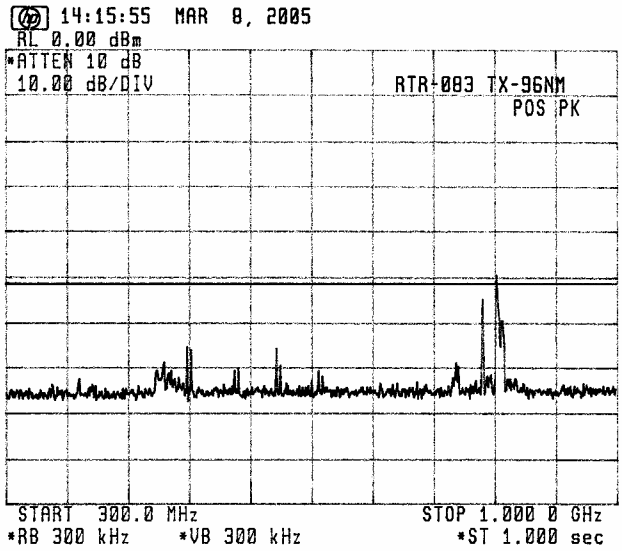
-61 dBm limit line

(Band: 300 MHz - 1 GHz, Limit at 2 m = -51 dBm)

a) Radar Power: OFF



b) Radar TX: ON



-51 dBm limit line

Note:
All components above the limit are from external noise or signals, not from Radar.

Attachment D [List of Test/Measuring Equipment] (for X-band radar)

For Clause 3.1 RF Power Output

Model	Type	Serial no.	Mfr.
Spectrum Analyzer	71210C	2927A02847	HP
Oscilloscope	TDS680B	B030202	Tektronix
Directional Coupler	5D364S	R05762	Shimada
Voltage Divider	HV-P30	2780	Iwatsu
Current Transformer	2100	----	Pearson Electronics
Power Meter	436A	2410A19137	HP
Power Sensor	8481A	2349A39603	HP
Frequency Counter	TR5824A	41940036	Advantest
Frequency Meter	X532B	1441A00523	HP
Crystal Detector	423B	1822A34735	HP
Dummy Load	4D376	R05763	Shimada
Attenuator (10 dB step, 70 dB)	8495B	3308A22026	Agilent
Attenuator (1 dB step, 11 dB)	8494B	US00430229	Agilent

For Clause 3.2 Modulation Characteristics

Model	Type	Serial no.	Mfr.
Oscilloscope	TDS680B	B030202	Tektronix
Crystal Detector	423B	1822A34735	HP
Directional Coupler	5D364S	R05762	Shimada
Dummy Load	4D376	R05763	Shimada
Voltage Divider	HV-P30	2780	Iwatsu
Spectrum Analyzer	71210C	2927A02847	HP
Attenuator (10 dB step, 70 dB)	8495B	3308A22026	Agilent
Attenuator (1 dB step, 11 dB)	8494B	US00430229	Agilent

For Clause 3.4 Spurious Emissions at Antenna Terminal

Model	Type	Serial no.	Mfr.
Spectrum Analyzer	71210C	2927A02847	HP
Attenuator (10 dB step, 70 dB)	8495B	3308A22026	Agilent
External Mixer:	11970K	2332A00589	HP
External Mixer:	11970A	2332A01187	HP
Directional Coupler	5D364S	R05762	Shimada
Dummy Load	4D376	R05763	Shimada
Notch Filter (X-band)			
Circulator	MA8L32#82	----	Microwave Associates
Bandpass filter	-----	R9904	Shimada
High Pass Filter (X-band)	-----	-----	Furuno

For Clause 3.5 Field Strength of Spurious Radiation

Model	Type	Serial no.	Mfr.
Broadband Rod Antenna	95010-1		Advanced Electronics
Biconical Antenna	BIA-25	2650	Electro Metrics
Conical Log-Spiral Antenna	LCA-25	2886	Electro Metrics
Double Ridged Guide Horn Antenna	:RGA-180	2248	Electro Metrics
Horn Antenna:	----	----	Toshiba
Spectrum Analyzer:	71210C	2927A02847	HP
External Mixer:	11970K	2332A00589	HP
External Mixer:	11970A	2332A01187	HP
Attenuator (10 dB step, 70 dB)	8495B	3308A22026	Agilent
Notch Filter (X-band)			
Circulator	MA8L32#82	----	Microwave Associates
Bandpass filter	-----	R9904	Shimada

For Clause 3.6 Frequency Stability

Model	Type	Serial no.	Mfr.
Power Meter:	436A	2410A19137	HP
Power Sensor:	8481A	2349A39603	HP
Frequency Meter:	X532B	1441A00523	HP
Directional Coupler:	5D364S	R5762	Shimada
Dummy Load:	4D376	R05763	Shimada
Environmental Chamber:	PL-4KP	14004204	Tabai Espec

For Clause 3.7 Suppression of Interference Aboard Ships

Model	Type	Serial no.	Mfr.
Spectrum Analyzer:	71210C	2927A02847	HP
6 m Whip Antenna	14 k - 10 MHz	----	Furuno
4 m Whip Antenna	10 - 30 MHz	----	Furuno
VHF Whip Antenna	30 - 300 MHz	150M-W2UM	Anten
UHF Whip Antenna	300 - 1000 MHz	----	Anten
Network analyzer:	8753C	3214J01067	HP
Spectrum Analyzer	TR4172	30690116	Advantest
Spectrum Analyzer	8566B	2637A03642	HP
Attenuator (10 dB step, 70 dB)	8495B	3308A22026	Agilent
Attenuator (1 dB step, 11 dB)	8494B	US00430229	Agilent