LABOTECH

TECHNICAL INFORMATION

TEST REPORT ON THE PERFORMANCE OF MARINE RADAR

Trade Name : FURUNO

Transceiver Type : RTR-060

Report no.: FLI 12-02-002

Date of issue: February 12, 2002

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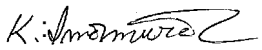
All tests were performed in Furuno Labotech International Co., Ltd.
All data herein contained is true and correct to our best knowledge.

All tests were performed by:

Name : Katsumi Imamura

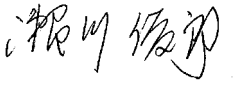
Function : Test Engineer

Signature 

Review and report by:

Name : Toshiro Segawa

Function : Manager, QA

Signature 

This report has been verified and approved by:

Date : February 12, 2002

Name : Mitsuyoshi Komori

Function : 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: MODEL 1953C

	Type	Serial Number
Display unit	RDP-139	4309-0020
Antenna unit	RSB-0072	R089-0005
Transceiver:	RTR-060	(contained in Antenna unit)
Radiator:	XN12A	
Power supply unit	PSU-005	R126-0001

(c) Primary Function: Search, Navigation and anticollison

(d) Discrimination

Range Discrimination: 20 meters on a range scale of 0.25 nm

Bearing Discrimination:

Radiator type	XN12A	XN13A
	1.9˚	1.4˚

on a range scale of 0.25 nm

(e) Minimum Range:25 meters on a range scale of 0.25 nm

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

Type of Emission: P0N

(g) Power Supply: 12 - 24 VDC

1.2 Antenna Unit

1.2.1 Transceiver

Type: RTR-060

(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: MG5241 E3566

Peak Output Power: 12 kW nominal

(c) Magnetron Ratings

Center frequency of Magnetron: 9410 MHz

Tolerances

	MG5241	E3566
Manufacturing:	± 30 MHz	± 30 MHz
Pulling:	23 MHz	18 MHz

Tolerance for 20˚C temperature variation: -5 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)	(Long 1)	(Long 2)	(Long 3)
	0.125				
	0.25				
	0.5				
	0.75				
	1				
	1.5	1.5			
		2			
		3	3		
			4		
			6		
			8		
			12		
			16		
			24		
			36		
				48	
				64	
					72
Pulselength (µs)	0.08	0.30	0.80	0.80	0.80
P.R.R.(Hz)	2100	1200	600	550	500
Duty cycle	$1.68X10^{-4}$	$3.60X10^{-4}$	$4.80X10^{-4}$	$4.40X10^{-4}$	$4.00X10^{-4}$
Guard Band (MHz)	18.75	5.00	1.88	1.88	1.88

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

(2) Modulator

(a) FET Type: 2SK1450

Trigger Voltage: Approx. +20 VDC positive

(3) Receiver

(a) Passband (MHz)

RF Stage: 100 MHz

IF Stage:

Pulselength	Short	Middle	Long 1	Long 2	Long 3
(MHz)	25	25	3	3	3

Video Amp.:

Pulselength	Short	Middle	Long 1	Long 2	Long 3
(MHz)	7	7	7	7	7

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

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

(d) Video Output Voltage (V): 0.7 V positive across 75 ohms

(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:

Not Provided.

(b) Reflector: Microstrip antenna

	XN12A	XN13A
Length (cm)	120	180

(c) Type of Beam: Vertical fan

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

	XN12A	XN13A
Horizontal (˚)	1.9	1.2
Vertical (˚)	22	22

(e) Polarization: Horizontal

(f) Antenna Gain:

	XN12A	XN13A
Gain (dB)	28	30

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

	XN12A	XN13A
Within ±10˚ (*)	-24 dB or less	-24 dB or less

Outside ±10° (*)	-30 dB or less	-30 dB or less

Note: (*) - ± 20° for Radiator type XN12A.

(h) Scanning (rotating or oscillating):

Rotating over 360° continuously clockwise

(i) Antenna Rotation Rate:

Scanner/Radiator	XN12A	XN13A
RSB-0072	24 rpm	24 rpm
RSB-0073	48 rpm	----

(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: 10.4 (in.) Color LCD,
640 X 480 pixels

(b) Size of Indicator: 10.4 in. diagonal
effective dia. 152 mm

(c) Sweep Linearity: 2 % on all ranges

(d) Range Scales:

Range (nm)	Number of Range Rings	Range Ring Interval (nm)
0.125	2	0.0625
0.25	2	0.125
0.5	4	0.125
0.75	3	0.25
1	4	0.25
1.5	3	0.5
2	4	0.5
3	3	1
4	4	1
6	3	2
8	4	2
12	4	3
16	4	4
24	4	6

Range (nm)	Number of Range Rings	Range Ring Interval (nm)
36	3	12
48	4	12
64	4	16
72	4	18

(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: Not provided

1.4 Functional Controls

Range selector	Power Switch	A/C Rain control [2)]
STC control [2)]	Gain control [2)]	Panel dimmer [2)]
Heading line off	Echo stretch [2)]	MENU
Guard zone [2)]	Range ring on/off [2)]	Interference rejecter [2)]
ST-BY/TX [2)]	Trackball (VRM/EBL/GUARD)	
VRM on/off [2)]	SHIFT (Offcenter)	Range set [2)]
Zoom [2)]	EBL on/off [2)]	Echo Trail [2)]
PLOT color [2)]	Navigation on/off [1), 2)]	Anchor watch [2)]
Display brilliance [2)]	TRU/REL [2), 3)]	Mode [2), 3)]
TLL [1), 2), 3)]	Chart display [2)]	Waypoint [2)]
Date box [1), 2)]		

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

(a) Input Voltage: 12 - 24 VDC

(b) Power Drain: 66.0 W (Power Supply Unit with Antenna Unit (RSB-0072))
38.4 W (Display Unit)

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 × Display Unit	Type:	RDP-139
1 × Antenna Unit	Type:	RSB-0072 (24 rpm)
		or RSB-0073 (48 rpm)
Transceiver	Type:	RTR-060 (contained in the Antenna unit)
1 × Power Supply Unit	Type:	PSU-005

(e) Approximate Weight of Complete Installation:

Display Unit:	6.0 kg
Antenna Unit:	23 kg (with XN12A)
	25 kg (with XN13A)
Power Supply Unit:	1.9 kg

(f) Approximate space required for installation excluding scanner

Display Unit:	383 mm (W) X 262 mm (H) X 180 mm (D)
Power Supply Unit:	200 mm (W) X 106 mm (H) X 290 mm (D)

2 Identification of Equipment (FCC Rule § 2.925)

The following nameplates are permanently fixed on the corresponding equipment units.

FCC ID: **ADB9ZWRTR060**

Material of nameplate: Polyester film, 0.1 mm thick

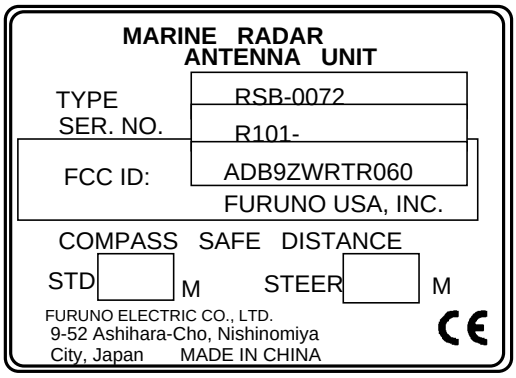


Fig. 2.1
Nameplate for
Antenna Unit

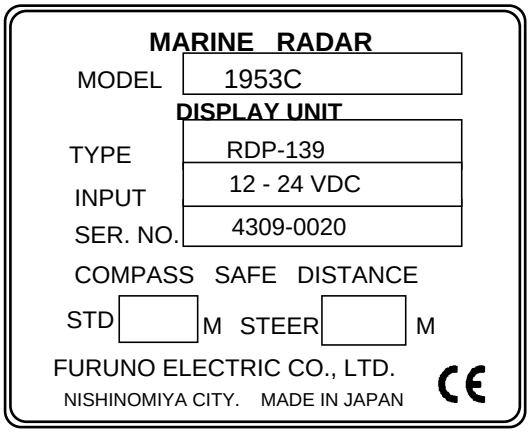


Fig. 2.2
Nameplate for
Display Unit

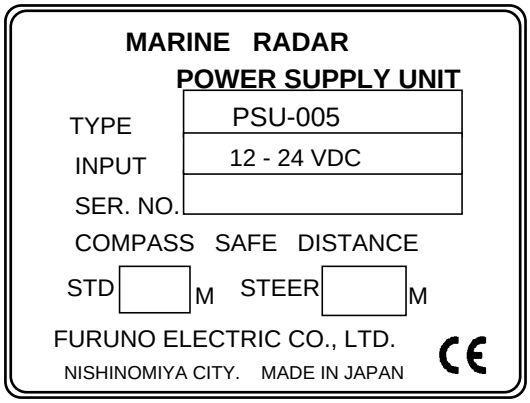


Fig. 2.3
Nameplate for
Power Supply Unit

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	Long 1	Long 2	Long 3
Range scale (nm)	0.125	2	36	48	72
Pulselength (µs)	0.08	0.30	0.80	0.80	0.80
PRR (Hz)	2100	1200	600	550	500
Duty cycle	2.52×10^{-4}	3.60×10^{-4}	4.80×10^{-4}	4.40×10^{-4}	4.00×10^{-4}
Guard band (MHz)	18.75	5.00	1.88	1.88	1.88

(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	Long 1	Long 2	Long 3
Directional coupler attenuation (dB)	40.44	40.44	40.44	40.46	40.46
Magnetron input voltage (kV)	5.6	5.7	5.7	2.35	2.35
Pulselength (µs) (50 % amplitude)	0.340	0.560	1.096	1.096	1.096
Rise time (µs) (10 - 90 % amplitude)	0.100	0.104	0.080	0.080	0.080
Decay time (µs) (90 - 10 % amplitude)	0.740	0.620	0.460	0.460	0.460

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	Long 1	Long 2	Long 3
Magnetron input current (A)	4.3	4.9	4.9	4.9	4.9
Pulselength (µs) (50 % amplitude)	0.086	0.318	0.868	0.868	0.868
Rise time (µs) (10 - 90 % amplitude)	0.092	0.096	0.098	0.868	0.098
Decay time (µs) (90 - 10 % amplitude)	0.061	0.116	0.116	0.116	0.116

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	Long 1	Long 2	Long 3
Pulselength (µs) (-3 dB points)	0.087	0.325	0.870	0.870	0.870
Rise time (µs) (10 - 90 % amplitude)	0.040	0.045	0.048	0.048	0.048
Decay time (µs) (90 - 10 % amplitude)	0.100	0.110	0.110	0.110	0.110

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	Long 1	Long 2	Long 3
Range scale (nm)	0.125	2	36	48	72
P.R.R (Hz)	2130.7	1209.3	621.4	552.4	508.5
Duty cycle	1.85×10^{-4}	3.93×10^{-4}	5.40×10^{-4}	4.80×10^{-4}	4.42×10^{-4}
Magnetron input, av. (W)	4.46	10.98	15.10	13.42	12.36
Magnetron input, peak (kW)	24.08	27.93	27.93	27.93	27.93
Power meter reading (mW)	0.1430	0.3160	0.4470	0.3950	0.3640

Pulselength	Short	Middle	Long 1	Long 2	Long 3
Magnetron output, av. (W)	1.582	3.497	4.947	4.371	4.028
Spurious response limits (dB)	44.99	48.44	49.94	49.41	49.05
Magnetron Output, peak (kW):	8.54	8.90	9.15	9.10	9.11
Magnetron efficiency (%):	35.5	31.9	32.8	32.6	32.6

Peak Power Input to RF Generator : 26.6 kW
Estimated Efficiency of RF Generator : 36.4 %

3.2 Modulation Characteristics (FCC Rule § 2.1047)

3.2.1 FET Trigger Pulse

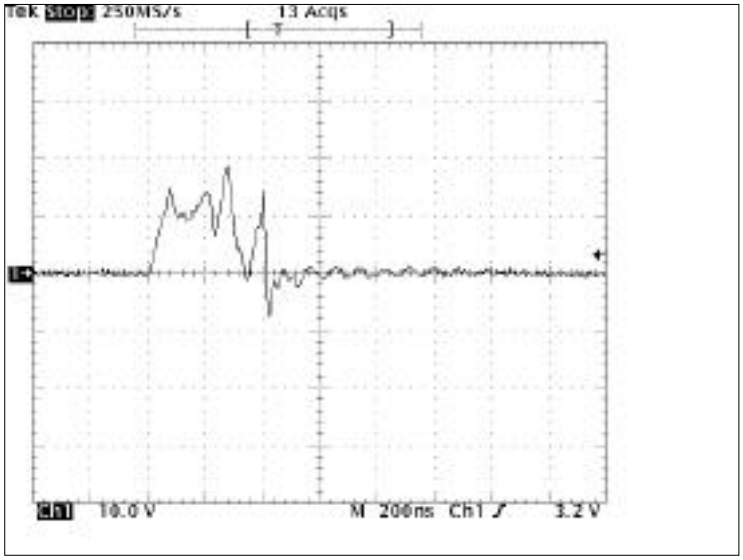


Fig. 3.2.1.1 Typical waveform of Trigger Pulse Scale: 10 V/div., 200 ns/div.

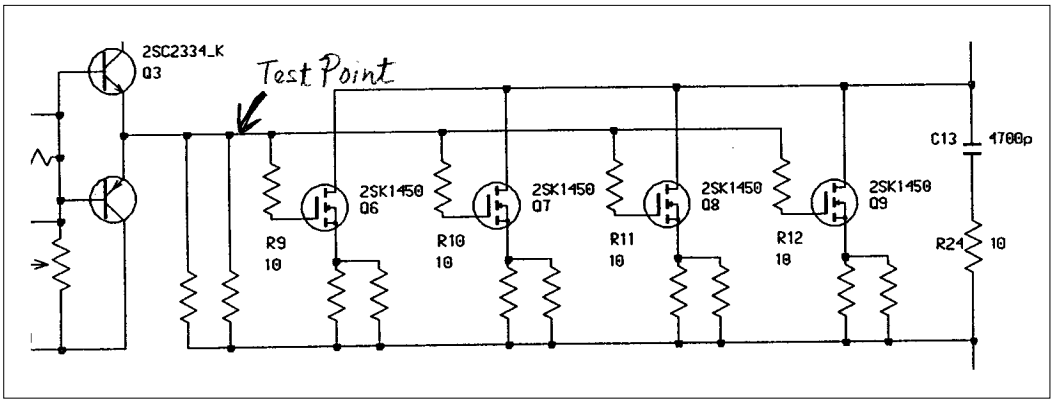


Fig. 3.2.1.2 Test Point for Trigger Pulse
(in MD Board (03P9237) of Radar Antenna Unit)

3.2.2 Trigger Pulse at Magnetron Cathode

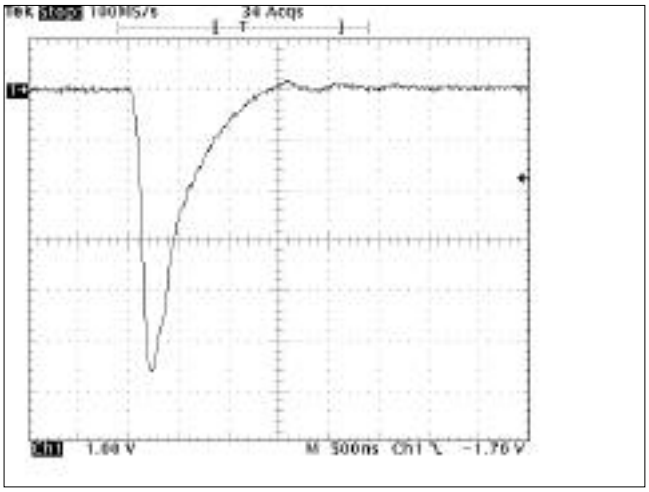


Fig. 3.2.2.1 Short Pulse (0.125 nm Rnge) Scale: 1 kV/div. 500 ns/div.

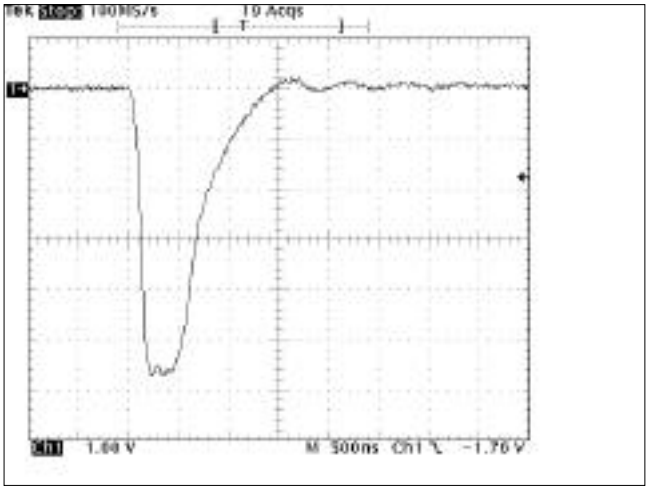


Fig. 3.2.2.2 Middle Pulse (2 nm Range) Scale: 1 kV/div. 500 ns/div.

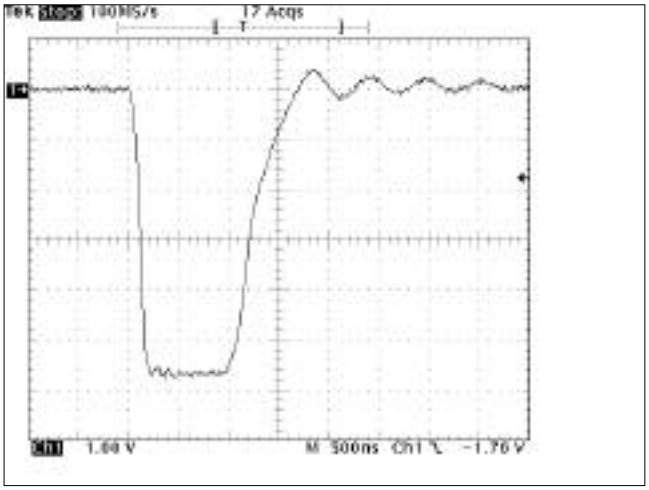


Fig. 3.2.2.3 Long1 Pulse (36 nm Range) Scale: 1 kV/div. 500 ns/div.

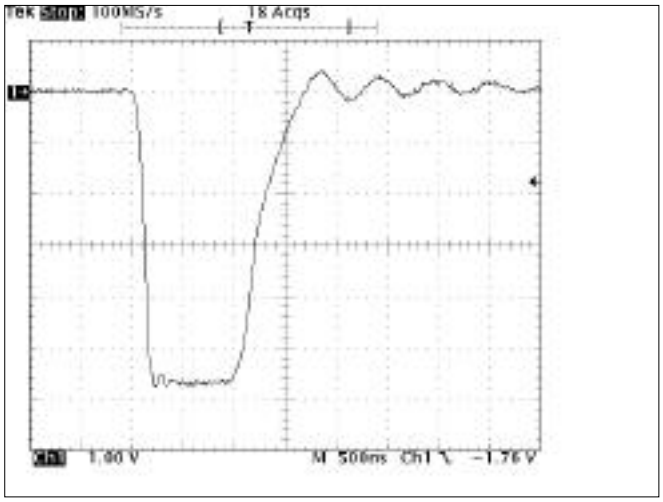


Fig. 3.2.2.4 Long2 Pulse (48 nm Range) Scale: 1 kV/div. 500 ns/div.

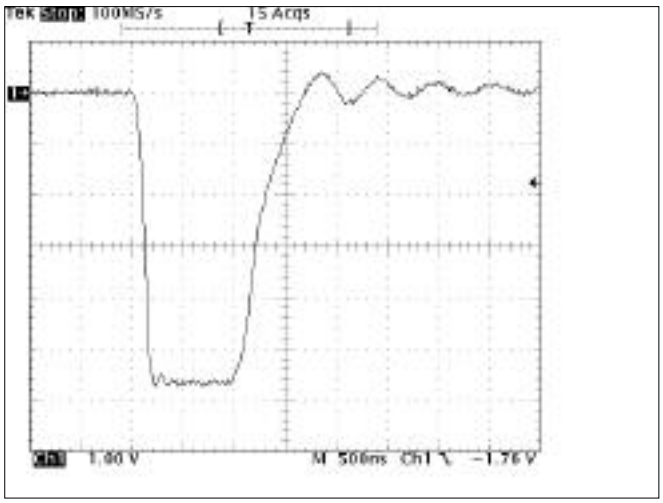


Fig. 3.2.2.5 Long3 Pulse (72 nm Range) Scale: 1 kV/div. 500 ns/div.

3.2.3 **Magnetron Output** (detected):

3.2.3.1 Setup for Measurement:

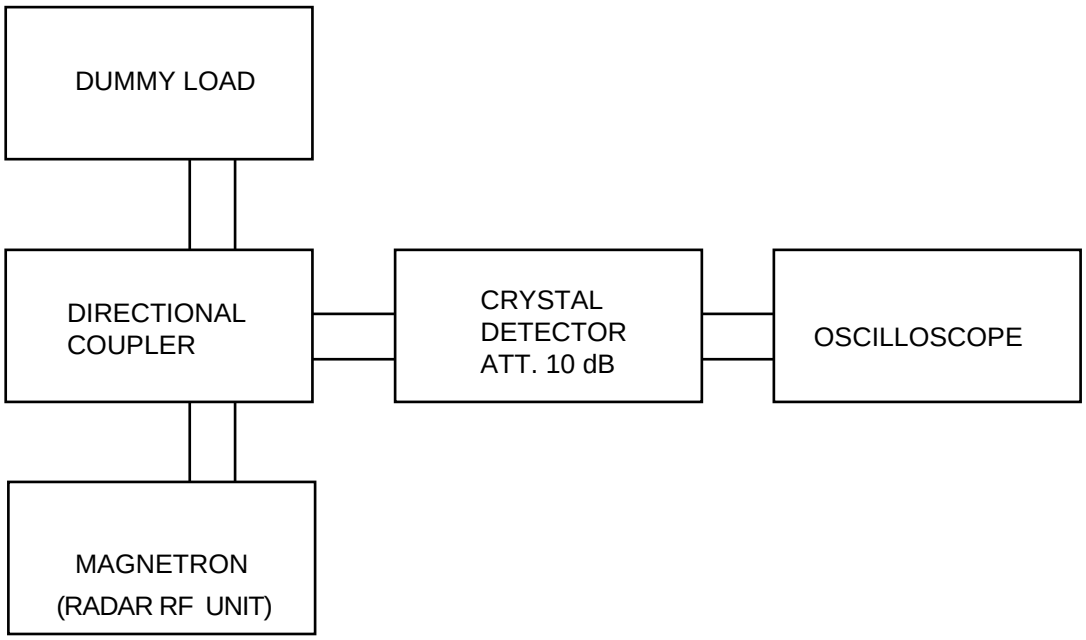


Fig. 3.2.3.1

3.2.3.2 Measuring Equipment List:

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

3.2.3.3 Measured Data:

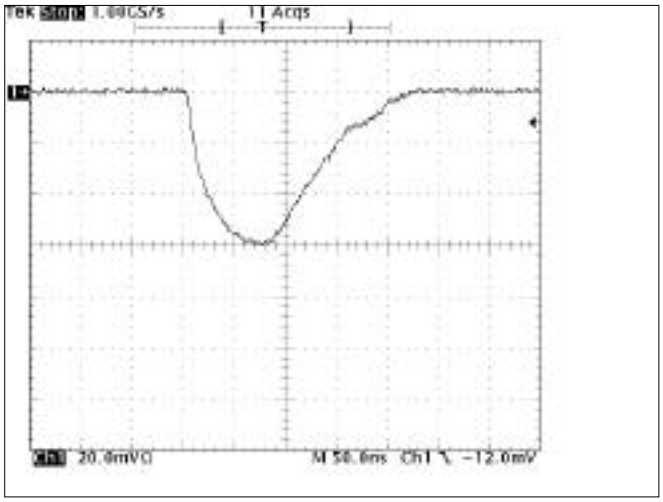


Fig. 3.2.3.2 Short Pulse (0.125 nm Range) Scale: 20 mV/div. 50 ns/div.

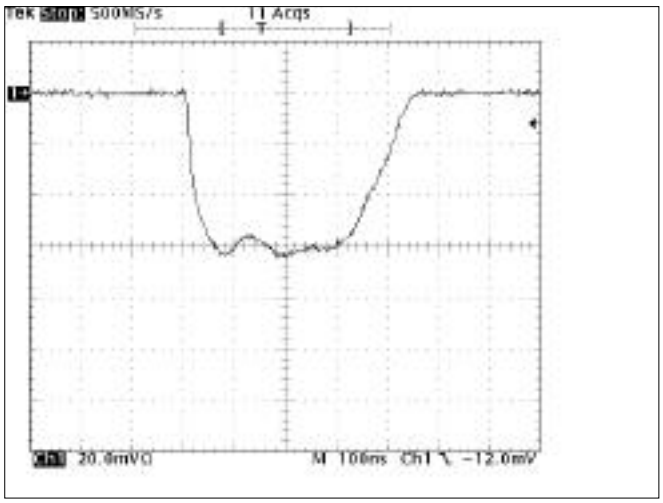


Fig. 3.2.3.3 Middle Pulse (2 nm Range) Scale: 20 mV/div. 100 ns/div.

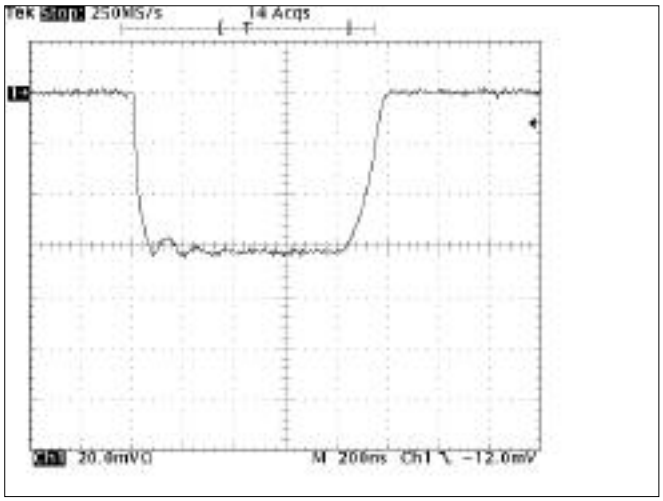


Fig. 3.2.3.4 Long1 Pulse (36 nm Range) Scale: 20 mV/div. 200 ns/div.

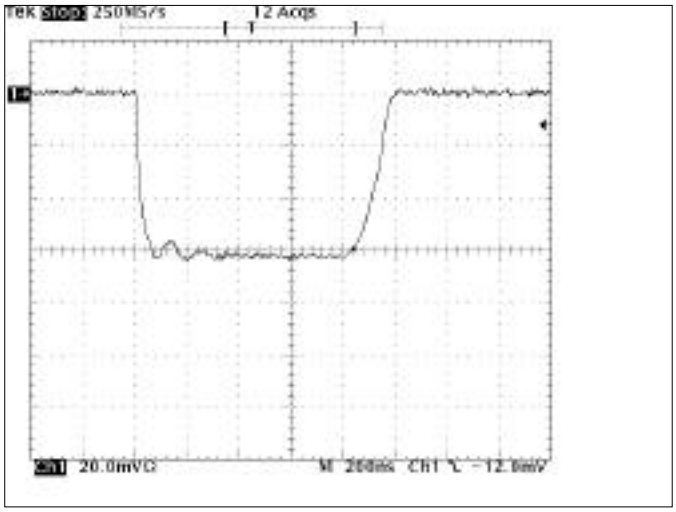


Fig. 3.2.3.5 Long2 Pulse (48 nm Range) Scale: 20 mV/div. 200 ns/div.

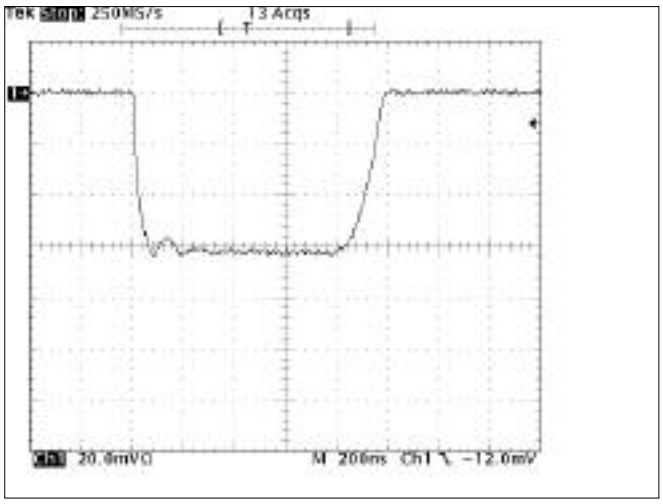


Fig. 3.2.3.6 Long3 Pulse (72 nm Range) Scale: 20 mV/div. 200 ns/div.

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.)

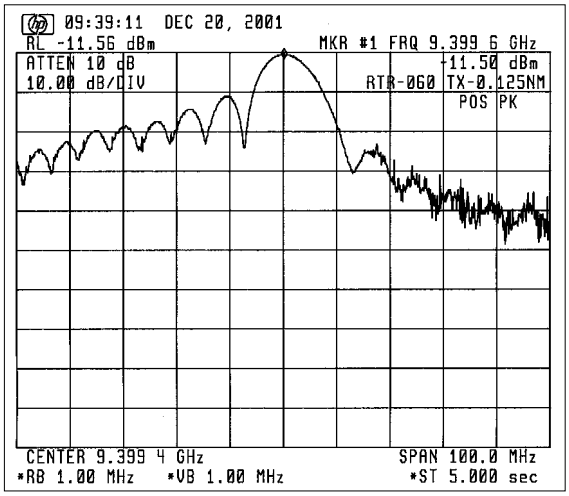


Fig. 3.2.4.1 For Short Pulse (0.125 nm Range)

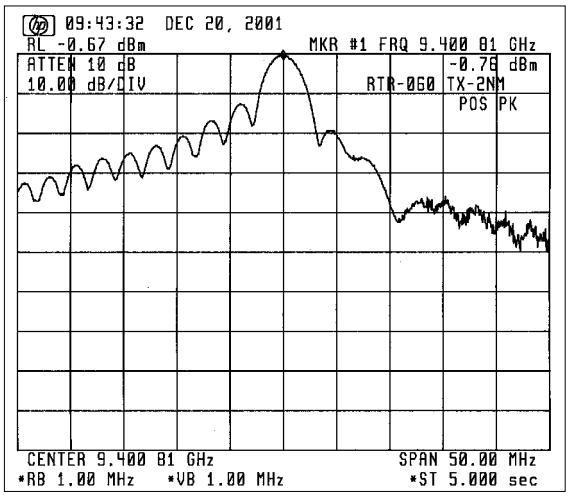


Fig. 3.2.4.2 For Middle Pulse (2 nm Range)

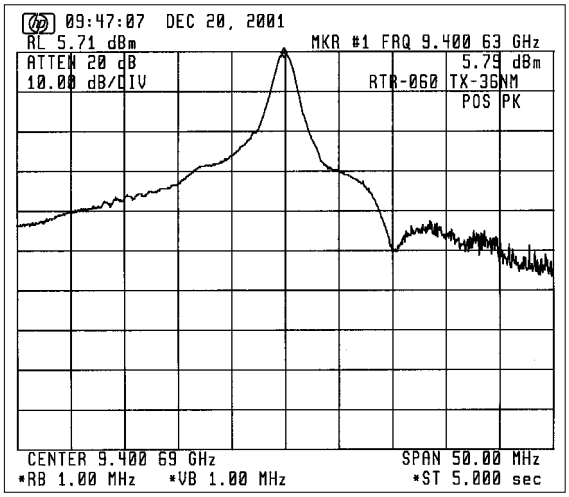


Fig. 3.2.4.3 For Long1 Pulse (36 nm Range)

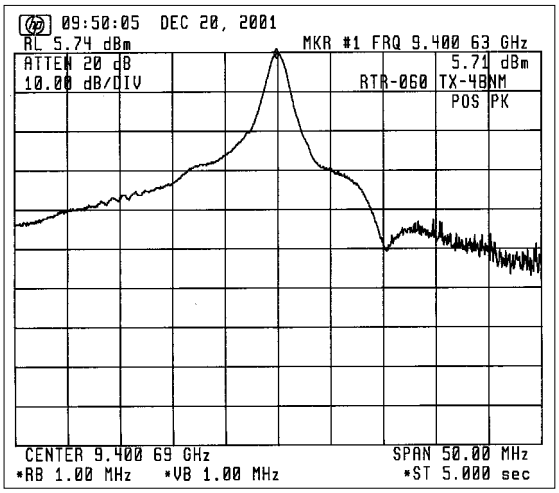


Fig. 3.2.4.4 For Long2 Pulse (48 nm Range)

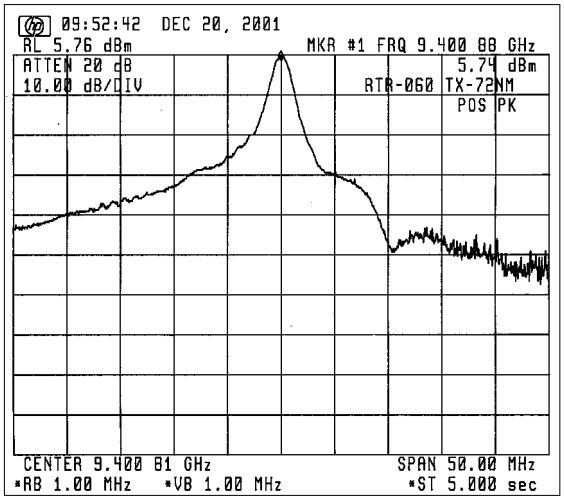


Fig. 3.2.4.5 For Long3 Pulse (72 nm Range)

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.

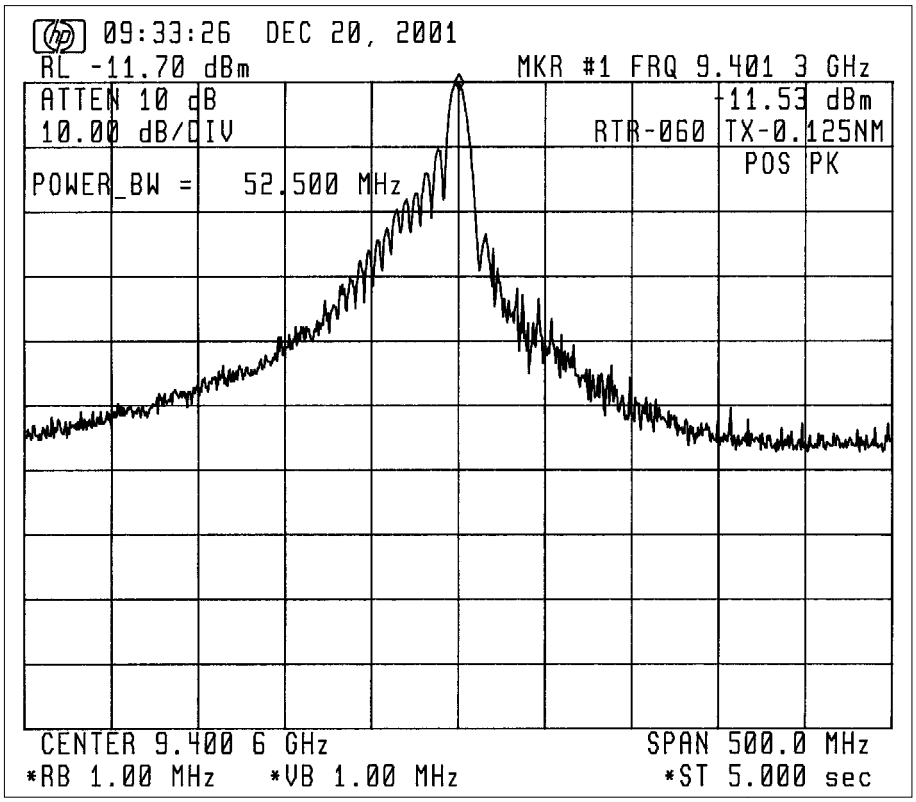


Fig. 3.3.2 Measurement of Occupied Bandwidth

Occupied bandwidth = 52.500 MHz

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

3.4.1 Test Equipment Setup:

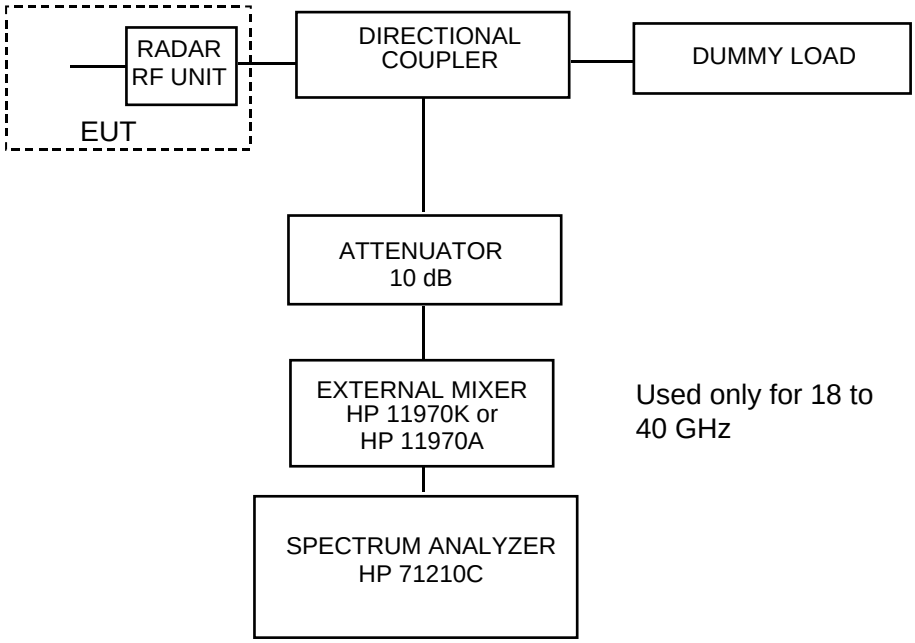


Fig. 3.4.1

3.4.2 Measuring Equipment List:

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

3.4.3 Test Conditions:

Radar Range Settings: 0.125 nm (Short)/2 nm (Middle)/ 36 nm (Long 1)
48 nm (Long 2)/72 nm (Long 3)

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 - 9660M	At least 35
more than 250 %	10 k - 9160M 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)).

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

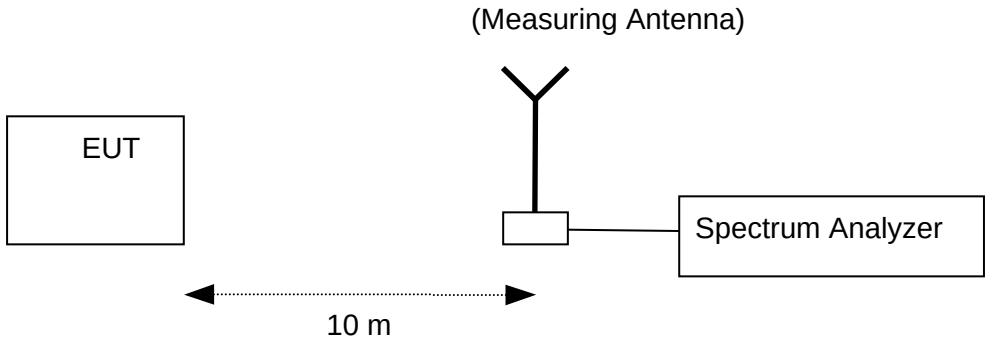
3.5.1 Test Site: Rooftop of 6-story building,
FURUNO ELECTRIC CO., LTD.
Ashihara-cho 9-52, Nishinomiya-city, 662-8580 Japan

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

3.5.3 Radar Range settings: 0.125 nm (Short)/2 nm (Middle)/ 36 nm (Long 1)/
48 nm (Long 2)/72 nm (Long 3)

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 - 4GHz

(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

Frequency removed from the assigned frequency	Frequency (MHz)	Emission attenuation (mean power, dB)
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

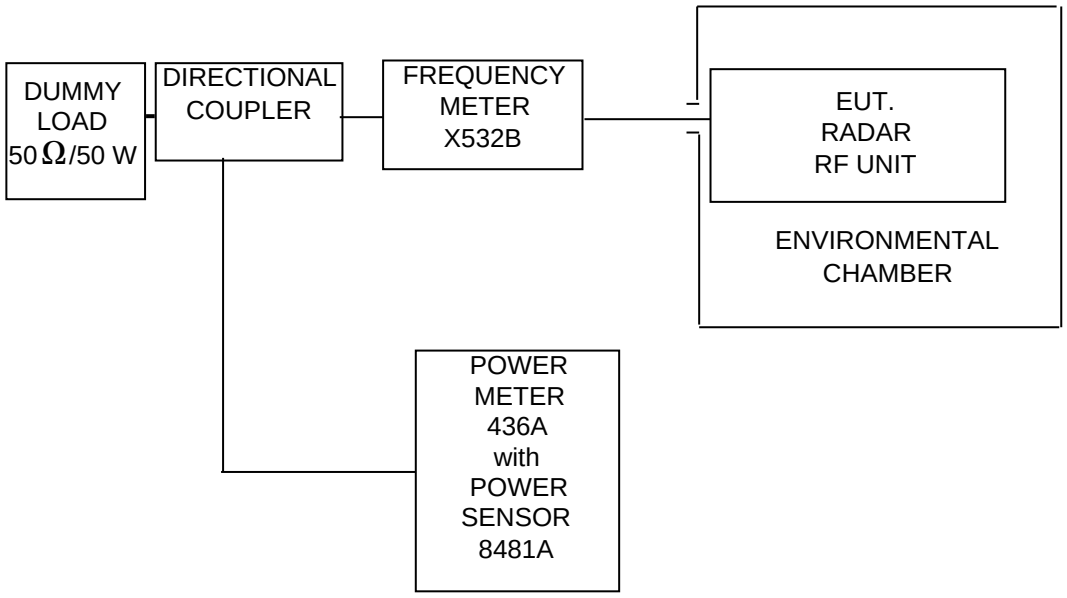


Fig. 3.6.1

3.6.2 Test Conditions:

1) Radar Range settings : 0.125 nm (Short)/2 nm (Middle)/ 36 nm (Long 1)/ 48 nm (Long 2)/72 nm (Long 3)
2) Ambient Temperature settings: - 20 to + 50° C (10 °C step)
3) Power Supply Voltage settings: 85 /115 % of nominal voltage (20.4 to 27.6 VDC)

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	Long 1	Long 2	Long 3
Range Scale (nm)	0.125	2	36	48	72
Pulselength (µsec)	0.08	0.30	0.80	0.80	0.80
Guard Band f(1.5/T) (MHz)	18.75	5.00	1.88	1.88	1.88

3.6.5 Test Results:

Shown on Fig. 3.6.2.
(1) "Upper Tolerance Frequency measured (at - 20 ˚C)", f(U) = 9405.6 MHz
(2) "Lower Tolerance Frequency measured (at + 50 ˚C)", f(L) = 9395.5 MHz
(3)-(a)
f(U) + max. f(1.5/T) = 9424.32 MHz < f(UAUBW) = 9460 MHz $\leqq$ f(UASB) = 9500 MHz
(3) - (b)
f(L) - max. f(1.5/T) = 9376.75 MHz > f(LAUBW) = 9360 MHz $\geqq$ 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 (20.4 to 27.6 VDC for nominal 24 VDC).

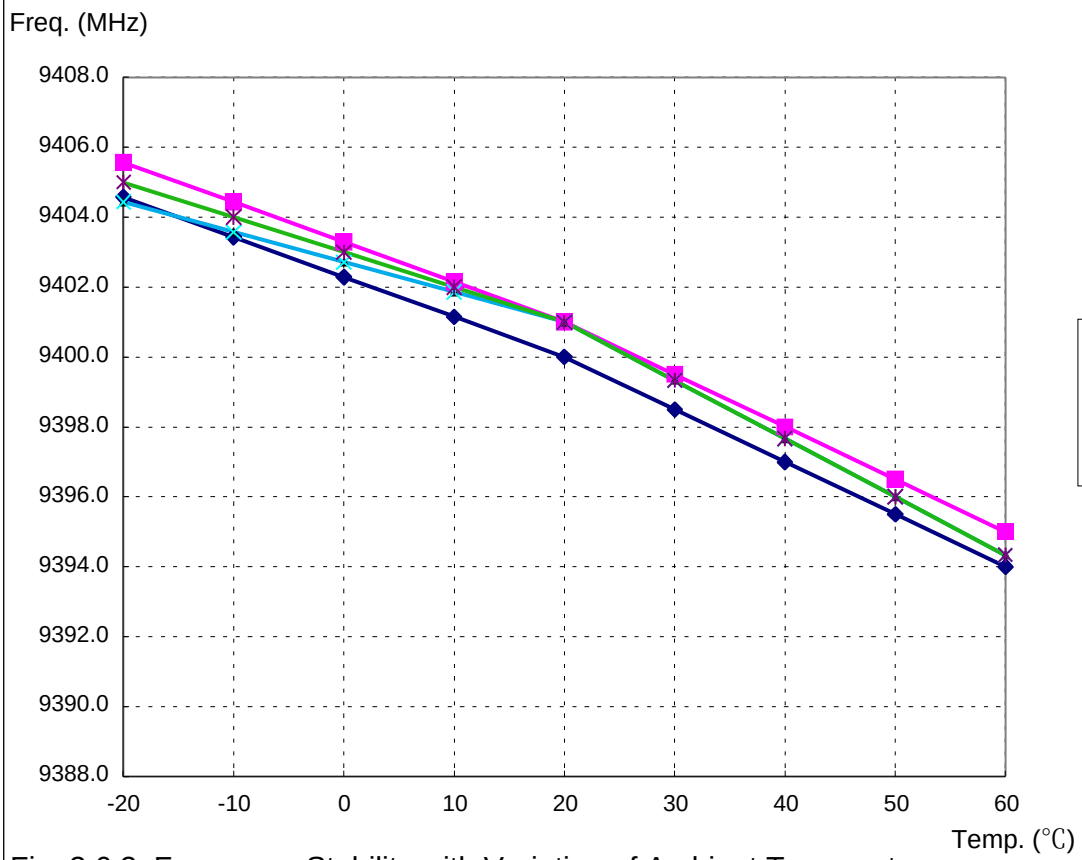


Fig. 3.6.2 Frequency Stability with Variation of Ambient Temperature

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 (W)	q	R (W)	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) Network Analyzer, HP 8753C
(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 mV/m
for 490 kHz - 1 GHz, 1 mV/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 mV/m at 1 nm (-20 dBmV/m)
for 30 to 100 MHz, 0.3 mV/m at 1 nm (-10.5 dBmV/m)
for 100 to 300 MHz, 1.0 mV/m at 1 nm (0 dBmV/m)
for over 300 MHz, 3.0 mV/m at 1 nm (9.5 dBmV/m)

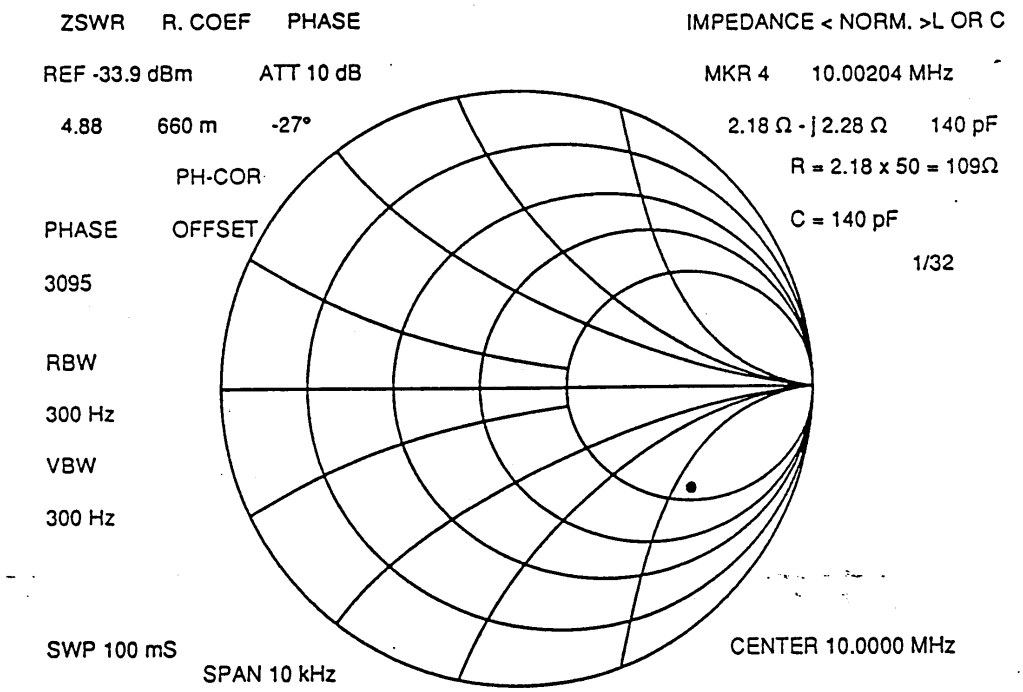
Results: Interference was measured with the antenna located 2 m from the radar and converted to levels at 1 nm. There is no spurious component exceeding the limits.
(Test data are shown in Attachment C.)

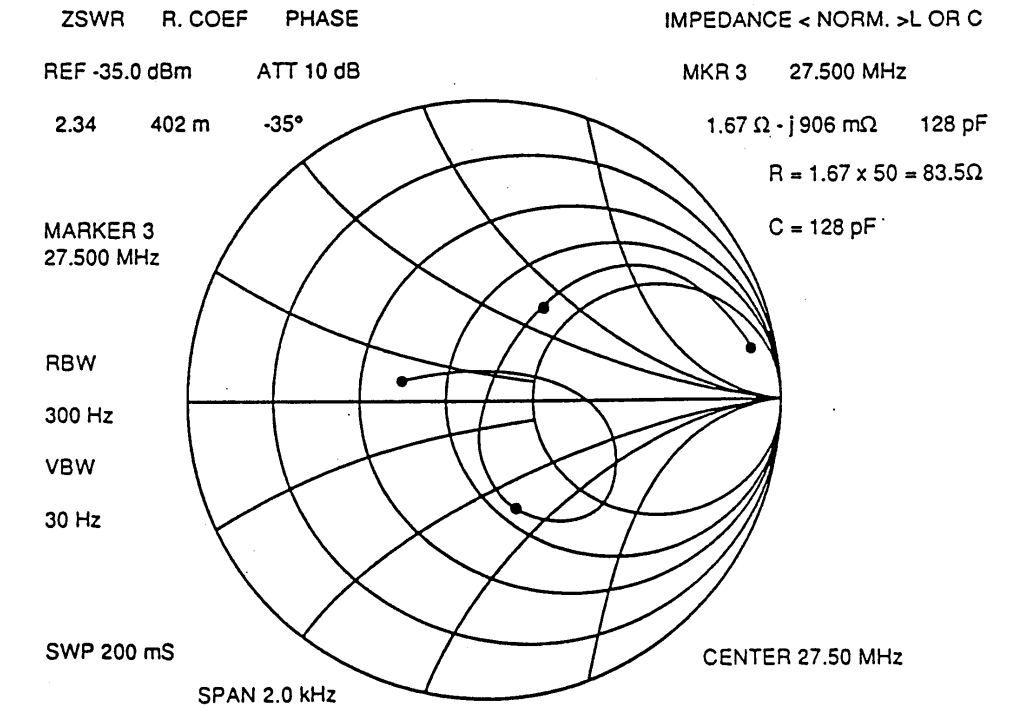
3.7.4.3 Power Input to an Artificial Antenna (FCC Rule §80.217 (b) - 2)

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

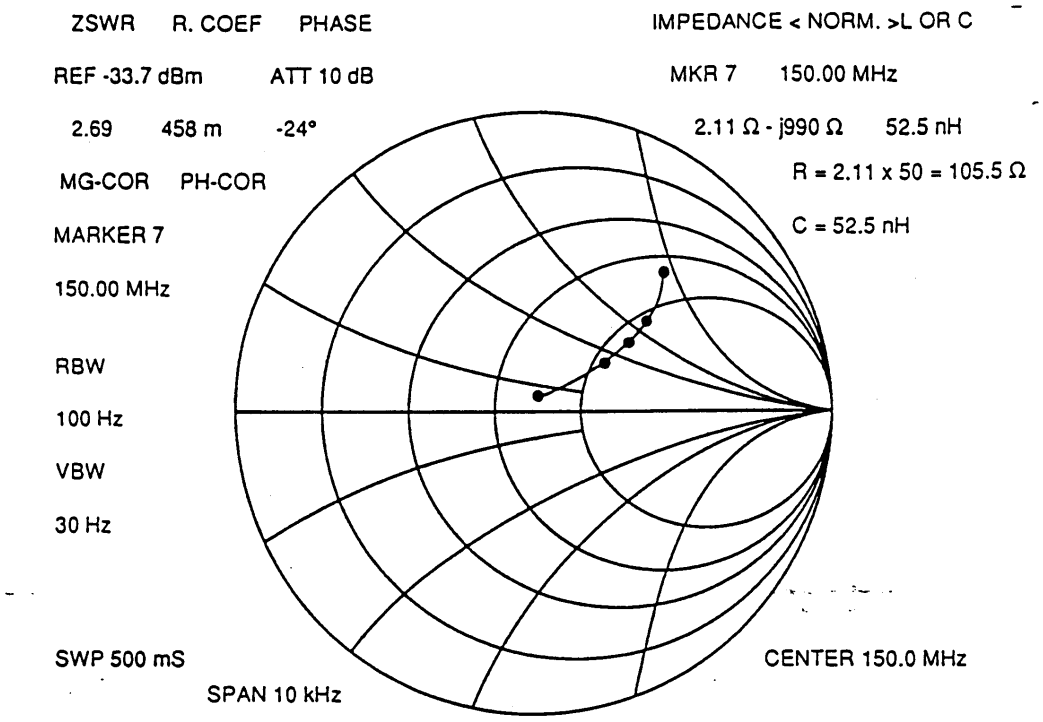
Results: There is no spurious component exceeding the limits.
(Test data are shown in Attachment C.)

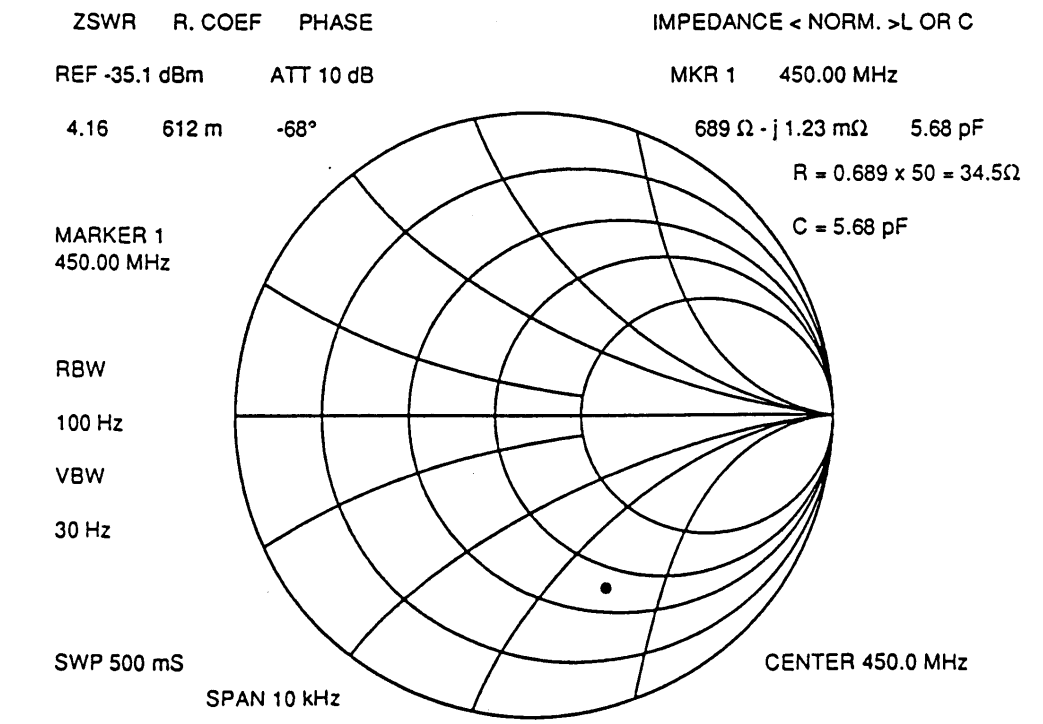
MEASUREMENT OF IMPEDANCE OF TEST ANTENNAS





MEASUREMENT OF IMPEDANCE OF TEST ANTENNAS





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

(See Attachment E Photos of the Equipment Under Test (EUT))

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

5.1 Function of Each Semiconductor or Active Device

ANTENNA UNIT

TRANSCEIVER MODULE (RTR-060)

Modulator (MD) PCB 03P9237

CR1:	Voltage Shifter
CR2:	Transient Suppression
CR3:	Transient Suppression
CR4:	Voltage Shifter
CR6:	Rectifier
CR7:	Rectifier
CR8:	Voltage Shifter
L1:	Noise Rejection
Q1:	Transistor Amplifier
Q2:	Pulse Amplifier
Q3:	Pulse Amplifier
Q4:	Pulse Amplifier
Q5:	Pulse Amplifier
Q6:	Pulse Amplifier
Q7:	Pulse Amplifier
Q8:	Pulse Amplifier
Q9:	Pulse Amplifier
Q10:	Magnetron Current Detector
U1:	Pulse Forming Network

Chassis Mounted Parts

HY801:	3 Ports Circulator
U801:	MIC Frequency Converter with Limiter
V801:	Magnetron
CR810:	Limiter

I.F. PCB IF-9099

CR601:	Switching
CR602:	Switching
CR603:	Switching
CR604:	Switching
CR605:	Switching
CR606:	Switching
CR607:	Switching
CR608:	Over Voltage Protection
CR609:	Switching
CR616:	Reverse Voltage Protection
CR622:	Thermal sensor
CR625:	Over Voltage Protection
CR626:	Switching
CR629:	Over Voltage Protection
CR630:	Over Voltage Protection
CR633:	Over Voltage Protection
Q601:	I.F. Amplifier in Cascade Connection
Q602:	I.F. Amplifier in Cascade Connection
Q603:	Switching
Q609:	I.F. Amplifier in Cascade Connection
Q610:	I.F. Amplifier in Cascade Connection
Q614:	I.F. Amplifier in Cascade Connection
Q615:	I.F. Amplifier in Cascade Connection
Q616:	Detector
Q617:	Detector
Q618:	DC Amplifier
Q619:	DC Amplifier
Q620:	DC Amplifier
Q625:	Video Amplifier
Q626:	Video Amplifier
Q627:	Video Amplifier
Q628:	Video Amplifier
Q630:	Emitter-follower Amplifier
Q635:	Switching
Q636:	Switching
U601:	I.F. Amplifier
U602:	I.F. Amplifier

U603:	I.F. Amplifier
U604:	DC Amplifier
U605:	DC Regulator
U606:	DC Regulator
U607:	DC Regulator
U608:	DC Regulator
U609:	DC Regulator
U610:	Inverter

Interface/Motor Soft Starter (INT) PCB 03P9250

CR1:	Reverse Voltage Protection
CR2:	C3 discharger
CR3:	Level Shifter
CR4:	Soft starter switch
CR5:	Reverse Voltage Protection
Q1:	Buffer for bearing pulse
Q2:	Buffer for bearing pulse
Q3:	Trigger switch for CR4

Power Supply (PWR) PCB 03P9236

CR51:	Rectifier
CR52:	Rectifier
CR53:	Rectifier
CR54:	Rectifier
L51:	Noise Rejection
Q51:	45 kHz PWM Output MOS FET
Q52:	IF Bandwidth Select
Q56:	Power Supply Protection Thyristor
Q57:	Power Supply Protection Thyristor
U51:	45 kHz PWM Inverter
U52:	Over Current Detector
U53:	Voltage Detector
U54:	Voltage Detector

5.2 Description of the circuits employed for suppression of spurious radiation, for limiting or shaping the control pulse, and for limiting or controlling power

ANTENNA UNIT

TRANSCEIVER MODULE (RTR-060)

Modulator (MD) PCB 03P9237 (in Scanner unit)

The primary function of the modulator is to produce narrow high tension pulses to drive the magnetron. To produce such pulses, the modulator board incorporates a modulator trigger circuit, a modulating pulse generator and a booster pulse transformer.

The modulator trigger circuit is composed of U1 and associated components. It generates pulses that fire modulator FET Q6, Q7, Q8 and Q9. Normally, the circuit is stable with U1 on. The pulse to fire the modulator FET is produced when U1 turns off upon receiving the TX trigger pulse from the display unit. When U1 turns off at the positive-going edge of the TX trigger pulse, it produces a narrow pulse. This narrow pulse is boosted by pulse transformer T801 by the ratio 1:25. The resultant pulse, its level being 5.7 kV, is provided to limit the magnetron current.

C801 decouples the pulse energy that is liable to occur across the magnetron heater when T801's secondary windings are unbalanced or the load is asymmetric.

Power Supply (PWR) PCB 03P9236

The PCB 03P9236 contains power supply circuits including TX-HV circuit and magnetron heater power supply. The TX-HV circuit provides a high tension of about 310V to the pulse forming network through CR51 and CR52. A DC voltage of 7.5 V is supplied to the magnetron heater through CR54.

Duplexer and Frequency Converter (in Scanner unit))

The microwave energy produced by the magnetron enters the circulator from port 2. It is fed to port 3 with a negligible loss of energy; port 1 at this time is isolated. In the same manner, the received signal entering into port 3 is transferred to port 1, isolating port 2. This operation of the circulator protects the receiver during transmission and minimizes

the loss of the received signal. Thus, the circulator allows a single antenna radiator to be used for transmission and reception of radar signals.

During transmission cycles the receiver circuits are isolated from high-level RF energy by the diode limiter CR810 and second stage limiter built in MIC U801.
It is a passive switching device which allows the low-level RF signal to pass through and prohibits relatively strong microwave energy, such as the leak from the magnetron.
It also protects the sensitive amplifier from pulses received direct from other radars in the proximity.

When a low-level signal is received, the PIN diodes remain in the cutoff state, and the limiter's input impedance matches the characteristic impedance of the receiver allowing the signal to be delivered to the frequency converter of U801. When strong microwave energy is received, the PIN diodes are put in the conductive state (or short-circuited) causing the input energy to be attenuated. The strong input is further reduced to about 150 mW by the varacter diode.

The MIC converts 9 GHz RF signal into an intermediate frequency of 60 MHz. It is achieved by mixing the received signal with the local oscillator signal in the frequency converter of the MIC. The built-in local oscillator oscillates at a frequency 60 MHz higher than the magnetron frequency of 9410 MHz.

I.F. Amplifier PCB IF9099

The IF signal of 60 MHz coming from the MIC is amplified and converted into a video signal, which is delivered to the display unit.

The IF amplifier is composed of six major circuits; Linear Amplifier (Q601/Q602), Logarithmic Amplifier (U601/U602, Q625/Q626), Video Amplifier (Q627/Q628), Bandpass Selector (U604, CR601 to CR607), Tuning Indicator Circuit (Q609/Q610, Q614 to Q620, U603) and Main Bang Suppression Circuit (U610, Q630, Q635/Q636、CR626/CR633).

The signal applied to the base of Q601 is amplified in cascade by Q601 and Q602, and sent to the bandpass selector.

The IF amplifier operates in narrow or wide bandwidth mode depending on the settings of

the RANGE switch and TX touchpad. For short or middle ranges, a wide bandwidth (25 MHz) is selected, since the levels at pin #3 of U604 and pin #6 of U604 go high, thus CR602 to CR605 and CR607 are conductive and CR601/CR606 are cut off, causing the signal to pass through CR603/CR604. On the contrary, CR602 to CR605 and CR607 are cut off and CR601/CR606 are conductive, which causes the signal to pass through T603, selecting a narrow bandwidth (3 MHz) on long ranges.

The signal through the bandpass selector is coupled to the logarithmic amplifier and amplified by U601/U602 and Q625/Q626. Thus, the output signals of Q625/Q626 are fed to Q627/Q628 to be amplified further, and then sent to the display unit.

The IF signal of 60 MHz is amplified by Q609/Q610, U603, Q614/Q615 and detected by Q616/Q617. Then the detected signal (Tuning Indicator Signal) is sent to the display unit via Q618 to Q620.

On the other hand, Q609/Q610 and U603 are additional amplifier circuits to make the dynamic range of the IF signal wider, causing the discrimination of the target echoes to get better. The IF signal from the MIC is fed to Q609/Q610 as well as through resistor R651 which is employed to attenuate the signal level. Therefore, Q609/Q610 amplifies even a strong signal which may be saturated in Q601/Q602 and U601/U602, and then sent to logarithmic amplifier U603. This signal is added to the saturated signal in U601/U602, causing the saturation level of the IF signal to become high.

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

(See separate covers)