Pub. No. : TI- 1691
Date : June. 1998

FURUNO®

TECHNICAL INFORMATION

TEST REPORT ON THE PERFORMANCE OF MARINE RADAR

MODEL: FR-2115

FURUNO ELECTRIC CO., LTD.
NISHINOMIYA CITY, JAPAN

Pub. No. : TI-1691
Date : June. 1998

June 15, 1998

All data herein contained is true and correct to my best knowledge.

T. Yoshihara

T. Yoshihara
Manager
Radio Navigation & Communication Section 2
Research & Development Department
Marine Product Division
FURUNO ELECTRIC CO., LTD.

Personal History

Born:	January 29, 1944
Graduated:	Osaka University Electric Engineering Faculty
Occupation:	Joined FURUNO ELECTRIC CO., LTD. in April 1967, since then engaged in the development of radar equipment.

Pub. No. : TI-1691

Date : June, 1998

****** CONTENTS ******

(e) Pulse Characteristics:

Pulse Type:	Short 1	Short 2	Middle 1	Middle 2	Middle 3	Long
Range Scale (nm):	0.125	3	6	12	24	96
Output pulselength (μs):	0.07	0.15	0.30	0.50	0.70	1.20
P.R.R. (Hz):	3000	3000	1500	1000	1000	600
Duty cycle:	2.10E-4	4.50E-4	4.50E-4	5.00E-4	7.00E-4	7.20E-4
Guard Band (MHz):	21.43	10.00	5.00	3.00	2.14	1.25

1.3 Modulator

(a) FET Type: 2SK1450

1.4 Receiver

(a) Passband

IF Stage: Pulse Type:	Short 1	Short 2	Middle 1	Middle 2	Middle 3	Long
(MHz)	27	27	27	3	3	3

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

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

(d) Video Output Voltage (V): 0.7 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)

1.5 Display

(a) Type: 21 (in.) multi-color, 1280X1024 pixels Rasterscan, non-interlace

(b) Size of Indicator Tube: 21 in. diagonal CRT effective dia. 275 mm

(h) Scanning (rotating or oscillating):	Rotating over 360° continuously clockwise
(i) Antenna Rotation Rate (rpm):	24 rpm (for RSB-0074) 42 rpm (for RSB-0075)
(j) Number of Degrees Scanned:	360°
(k) Sector Scan:	Not provided. Sector blanking available.
(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.

1.7 Line Power Supply Requirements

(a) Input Voltage:	24/32 VDC 100/110/115/220/230 VAC, 50/60 Hz
(b) Power Drain:	230 W 360 VA

1.8 Functional Controls

Range selector	Tune (manual)	EBL offset
INDEX LINE	Anti-clutter auto	Power Switch
A/C Sea control	Gain control	Panel dimmer
Heading line off	Echo stretch	MENU
Guard zone set/Audio alarm off	Range ring brilliance	Noise rejector on/off
Interference rejector	STBY/TX	Trackball (VRM,EBL,GUARD)
VRM on/off	Off-center (SHIFT)	A/C Rain control
Range set	Zoom	EBL on/off
Target trail	Brilliance (screen)	TRU/REL
Navigation on/off	Mark Brilliance	Function #1- #4
Range ring on/off	Text Brilliance	
ARPA function (option)		

1.9 Construction Features

(a) Does equipment embody replacement units with chassis type assembly:	Yes
(b) Are fuse alarms provided:	Fuses are provided.
(c) State units which are weatherproof:	Scanner Unit (IEC IPX6)

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

1 x Display Unit (Optional)	Type:	RDP-124	
1 × Scanner Unit	Type:	RSB-0074	(24 V, 24 rpm)
		RSB-0075	(24 V, 42 rpm)
Tranceiver	Type:	RTR-062	(contained in the Scanner unit)

(e) Approximate Weight of Complete Installation:

Display Unit:	55 kg	
Scanner Unit:	31 kg	(XN12AF-RSB-0074/75)
	34 kg	(XN20AF-RSB-0074/75)
	36 kg	(XN24AF-RSB-0074/75)

(f) Approximate space required for installation excluding scanner

Display Unit: 588 mm (W) X 573 mm (H) X 720 mm (D)

1.10 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:

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)

2 IDENTIFICATION OF EQUIPMENT (FCC Rule § 2.925)

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

FCC ID: ADB9ZWFR2115

Material of nameplate: Aluminium, 0.5 mm thick

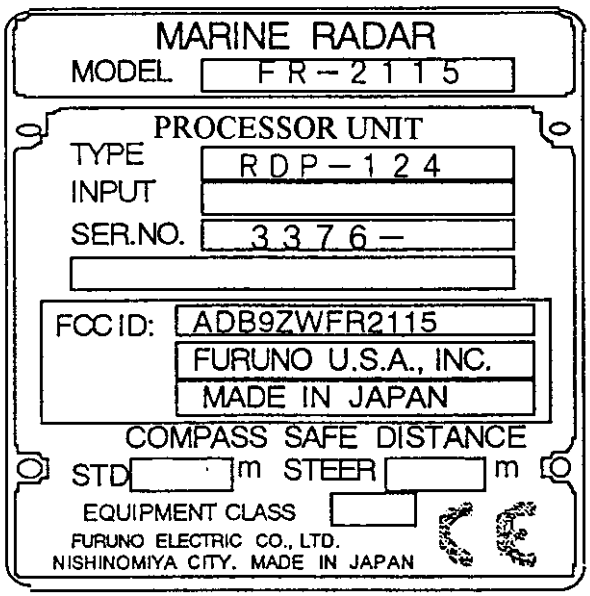


Fig.2.1
Nameplate for Processor unit
(RDP-0124)

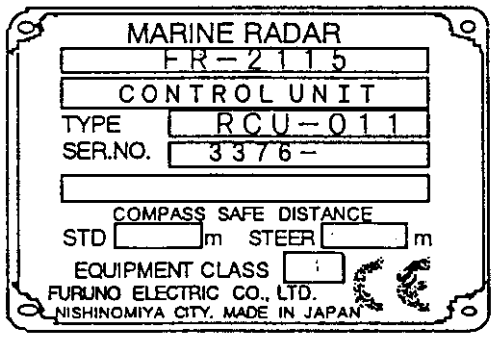


Fig.2.2
Nameplate for Control unit
(RCU-011)
(Display unit consists of
Control and Processor units.)

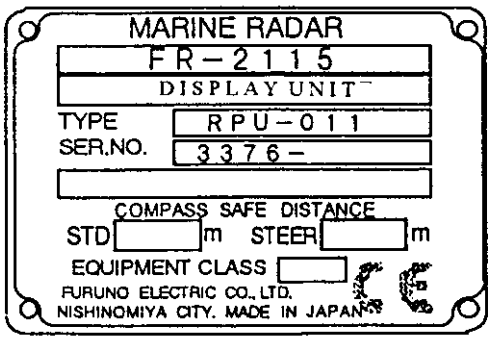


Fig.2.3
Nameplate for Display unit
(RPU-011)

3 RF POWER OUTPUT (FCC Rule §2.985)

3.1 Microwave characteristics

The peak voltage was determined using the Tektronix Divider having a ratio of 1000 to 1 and the Tektronix TDS 680B oscilloscope. Current pulse was viewed across the Pearson Electronics wideband current transformer model 2100, output voltage per ampere 1.00.

Nominal values

Pulselength	Short 1	Short 2	Middle 1	Middle 2	Middle 3	Long
Range scale (nm)	0.125	3	6	12	24	96
Output P/L (µs)	0.07	0.15	0.30	0.50	0.70	1.20
PRR (Hz)	3000	3000	1500	1000	1000	600
Duty cycle	0.00021	0.00045	0.00045	0.0005	0.0007	0.00072
Guard band (MHz)	21.43	10.00	5.00	3.00	2.14	1.25

Measured values

Magnetron input pulse voltage was measured at its cathode using the Tektronix TDS 680B oscilloscope and Tektronix Divider, ratio 1000 to 1.

Pulselength	Short 1	Short 2	Middle 1	Middle 2	Middle 3	Long
Directional coupler attenuation (dB)	40.54	40.54	40.54	40.54	40.54	40.54
Magnetron input voltage (kV)	6.30	6.30	6.10	6.00	6.00	6.00
Pulselength (µs) (50 % amplitude)	0.280	0.380	0.720	0.805	0.915	1.335
Rise time (µs) (10-90 % amplitude)	0.085	0.085	0.085	0.085	0.085	0.085
Decay time (µs) (90-10 % amplitude)	0.320	1.430	1.450	1.200	0.815	0.260

Magnetron input pulse current

Magnetron input pulse current was observed across the Pearson Electronics wideband current transformer model 2100, output volts per amp 1.00.

Pulselength	Short 1	Short 2	Middle 1	Middle 2	Middle 3	Long
Magnetron input current (A)	3.5	3.5	4.5	5.5	6.0	6.0
Pulselength (µs) (50 % amplitude)	0.098	0.155	0.302	0.488	0.685	1.120

Pub. No. : TI-1691
Date : June, 1998

Peak Power Input to RF Generator : 28110 W
Estimated Efficiency of RF Generator : 27.4 %

Pub. No. : TI-1691
Date : June. 1998

4 MODULATION CHARACTERISTICS (FCC Rule §2.987)

4.1 FET Trigger Pulse

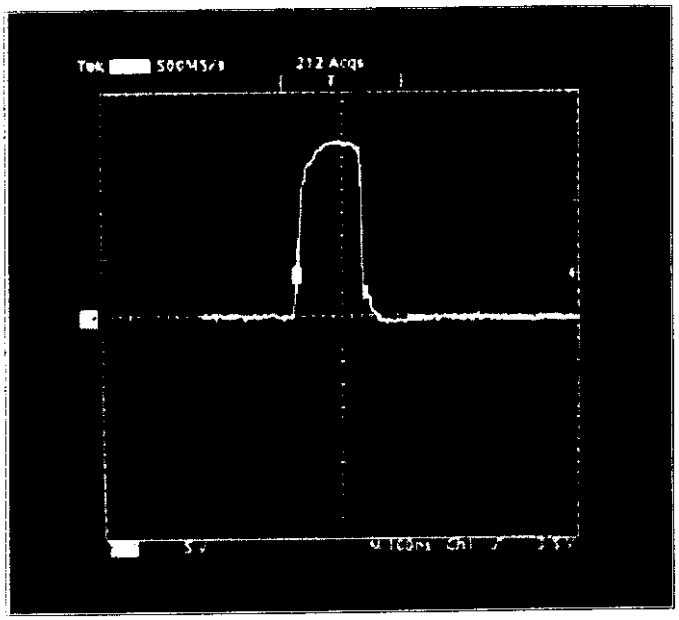
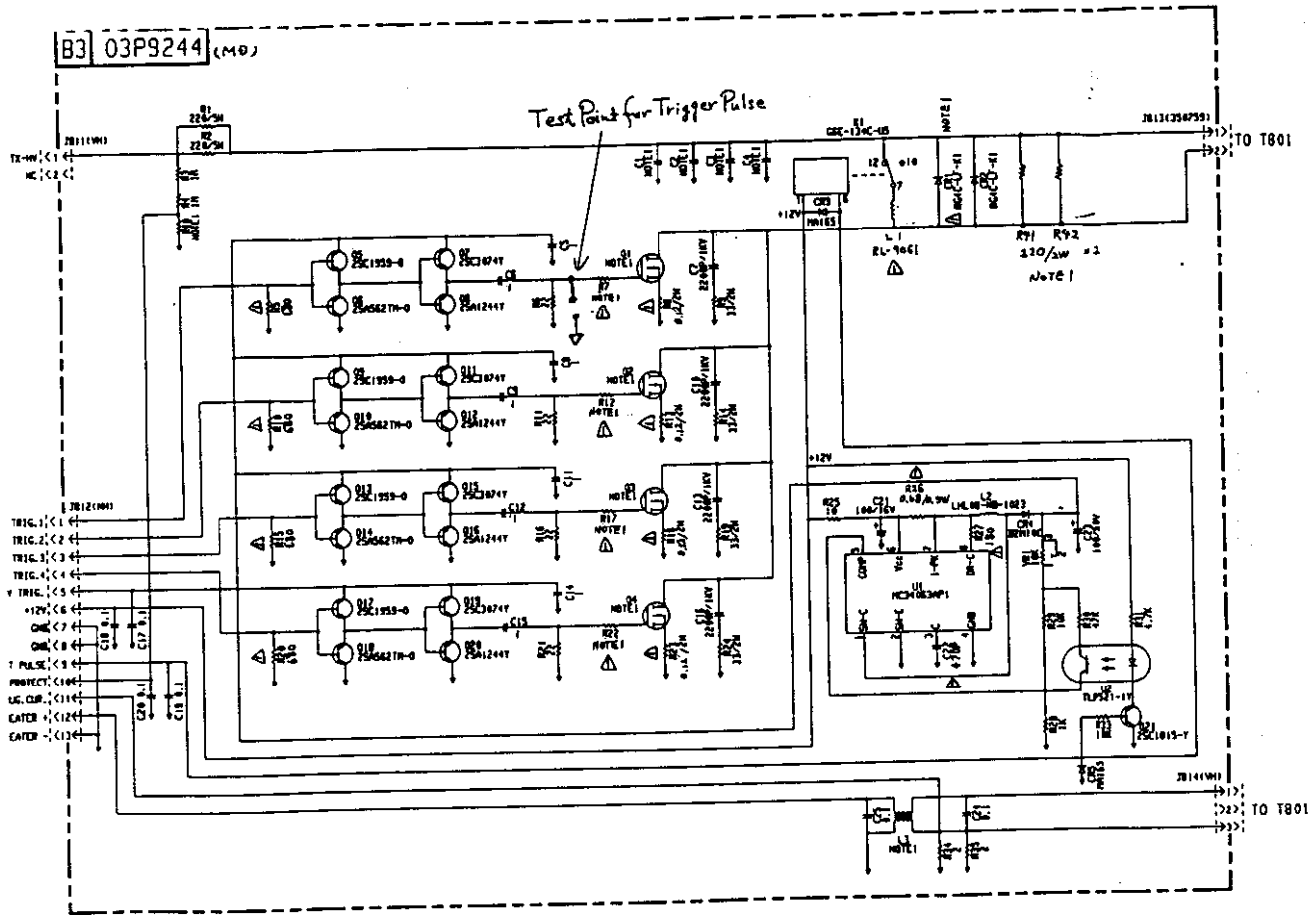


Fig. 4.1 (Typical wave form of Trigger Pulse) Scale: 5 V/div.
Short 1 Pulse (0.125 nm Range) 100 ns/div.



4.2 Trigger Pulse at Magnetron Cathode

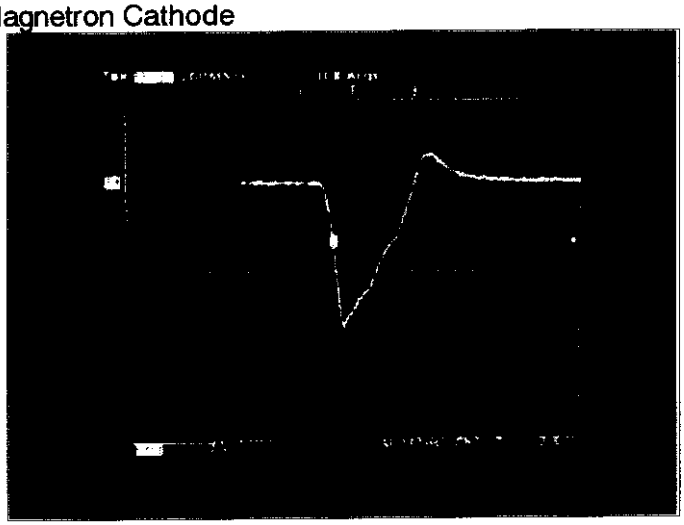


Fig. 4.2.1 Short 1 Pulse (0.125 nm Range) Scale: 2 kV/div. 250 ns/div.

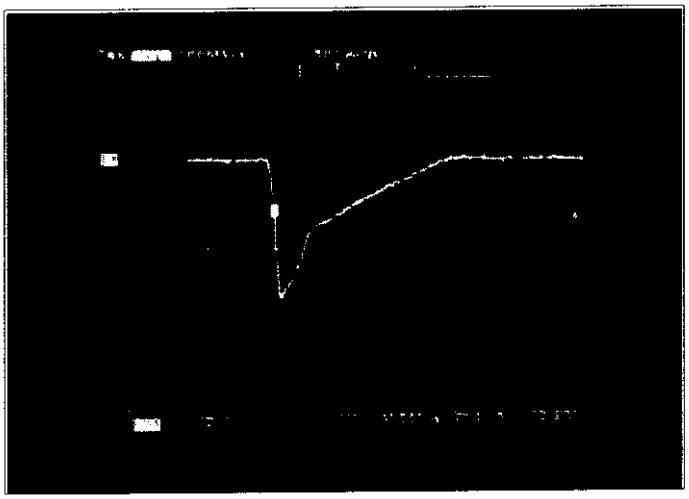


Fig. 4.2.2 Short 2 Pulse (3 nm Range) Scale: 2 kV/div. 500 ns/div.

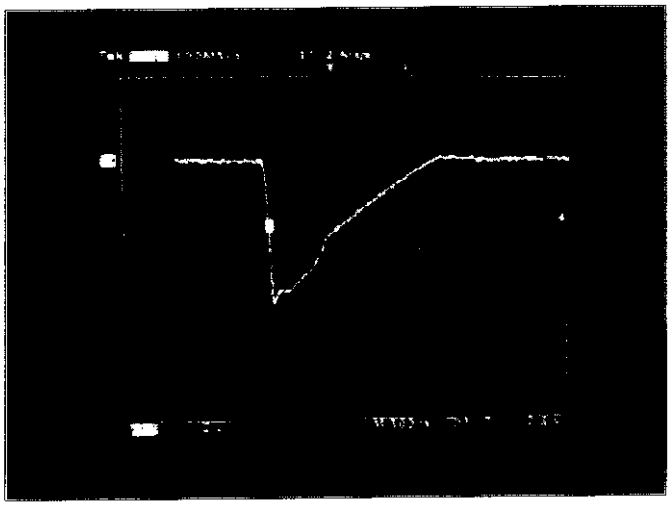


Fig. 4.2.3 Middle 1 Pulse (6 nm Range) Scale: 2 kV/div. 500 ns/div.

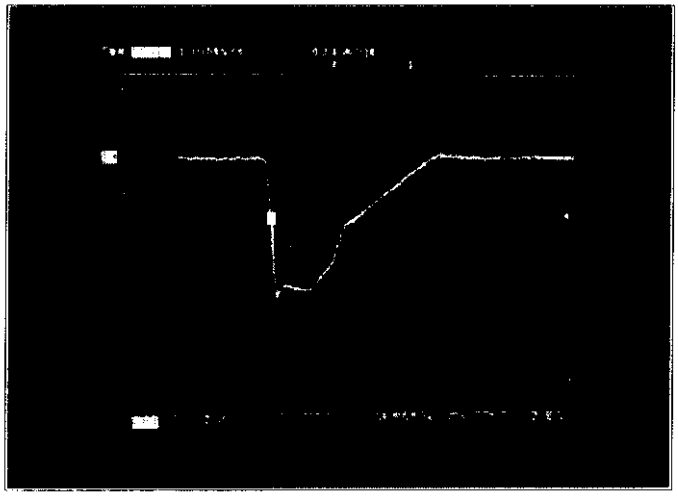


Fig. 4.2.4 Middle 2 Pulse (12 nm Range) Scale: 2 kV/div. 500 ns/div.

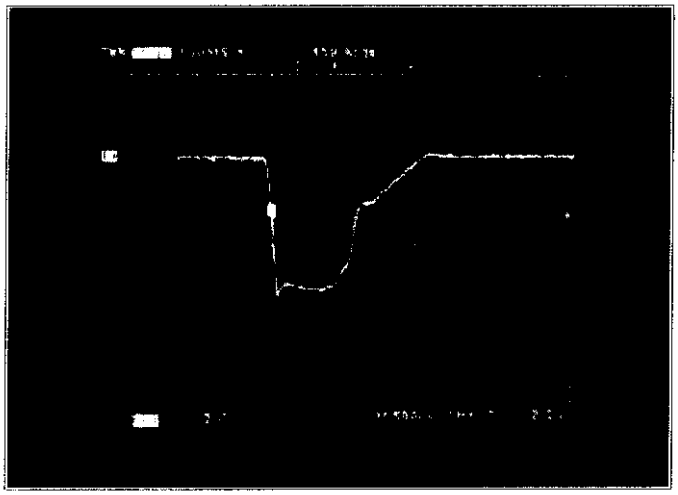


Fig. 4.2.5 Middle 3 Pulse (24 nm Range) Scale: 2 kV/div. 500 ns/div.

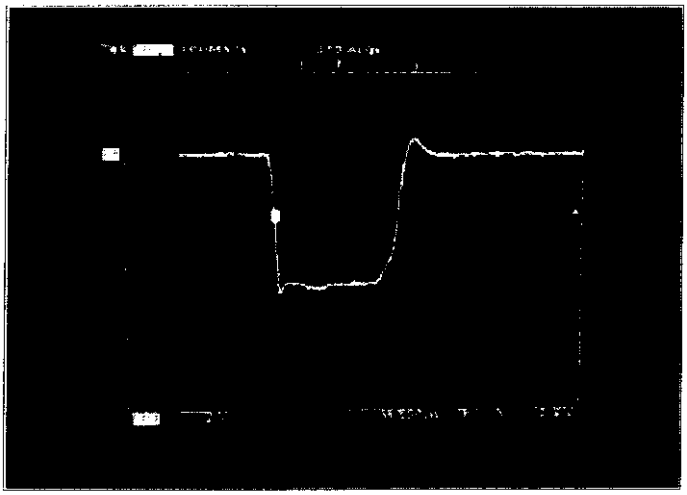


Fig. 4.2.6 Long Pulse (72 nm Range) Scale: 2 kV/div. 500 ns/div.

4.3 Magnetron Output (detected):

4.3.1 Setup for Measurement:

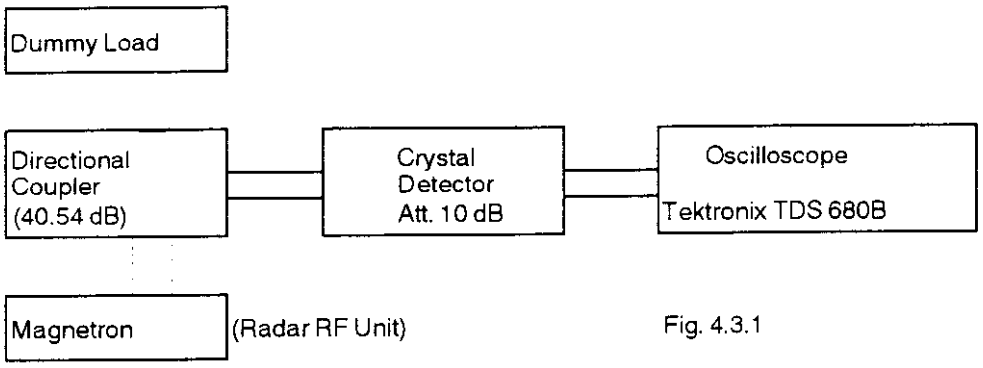


Fig. 4.3.1

4.3.2 Measuring Equipment List:

See ATTACHMENT 4 [LIST OF TEST/MEASURING EQUIPMENT].

4.3.3 Measured Data:

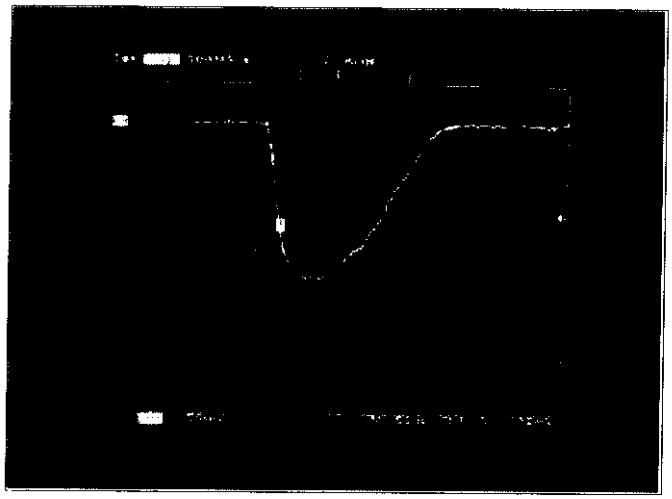


Fig. 4.3.2 Short 1 Pulse (0.125 nm Range) Scale: 50 mV/div. 50 ns/div.

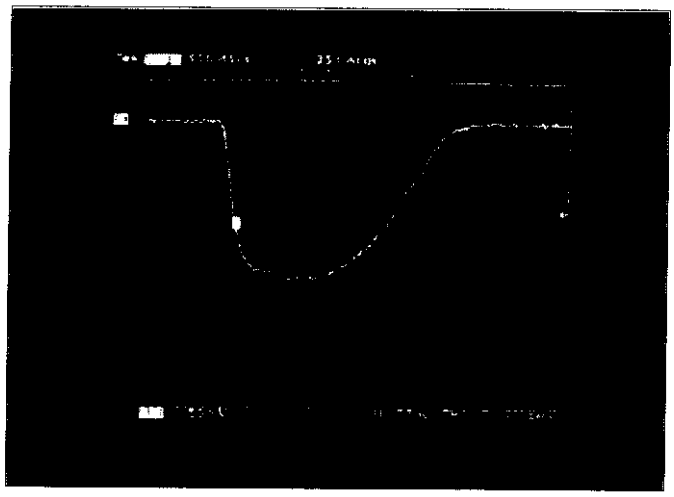


Fig. 4.3.3 Short 2 Pulse (3 nm Range) Scale: 50 mV/div. 50 ns/div.

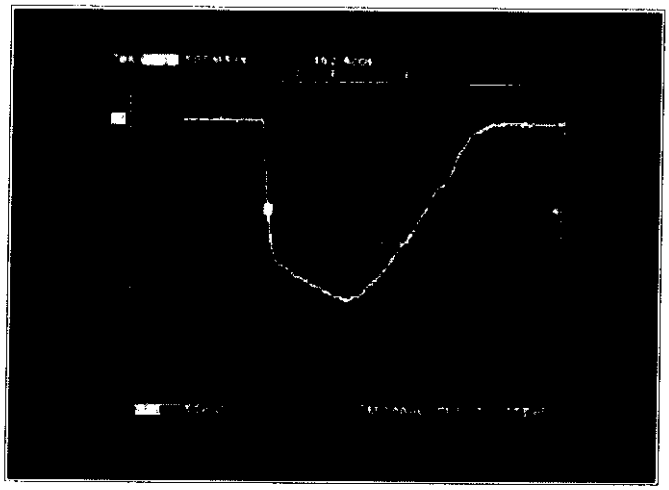


Fig. 4.3.4 Middle 1 Pulse (6 nm Range) Scale: 50 mV/div. 100 ns/div.

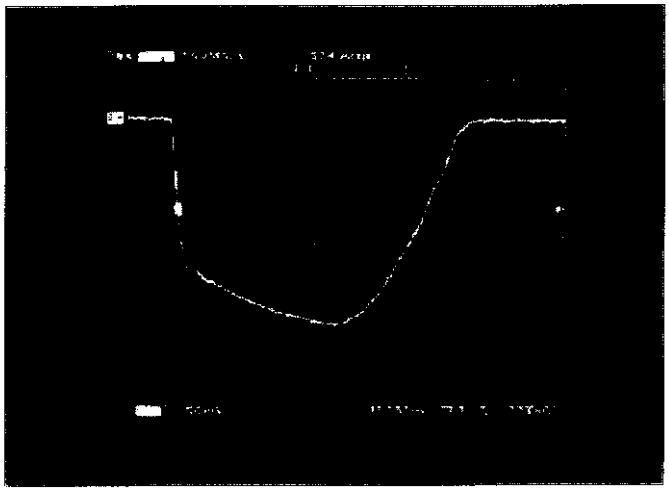


Fig. 4.3.5 Middle 2 Pulse (12 nm Range) Scale: 50 mV/div. 100 ns/div.

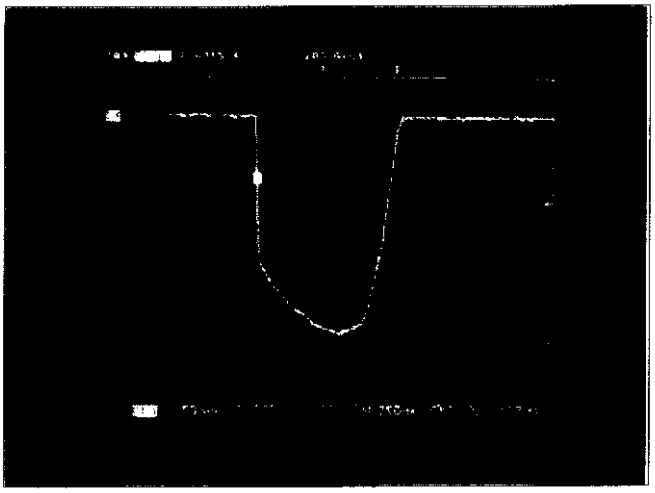


Fig. 4.3.6 Middle 3 Pulse (24 nm Range) Scale: 50 mV/div. 250 ns/div.

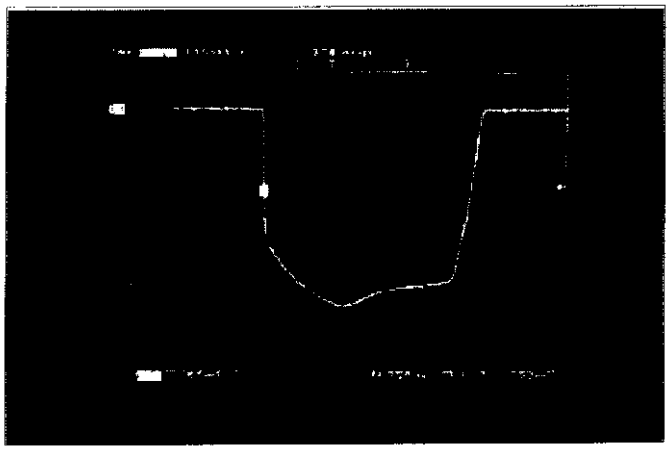


Fig. 4.3.7 Long Pulse (72 nm Range) Scale: 50 mV/div. 250 ns/div.

4.4 Radar Pulse Spectrum :

Measured by the HEWLETT-PACKARD Spectrum Analyzer Model 71210C.
(Test Equipment Setup and Measuring Equipment List are same as Clause 6.1 and 6.2.)

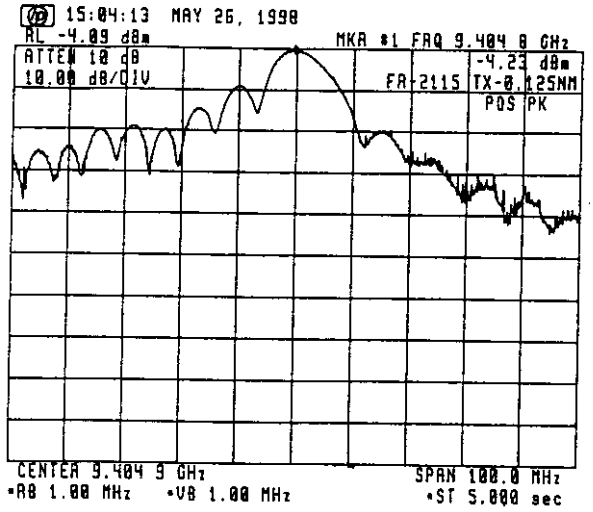


Fig. 4.4.1

Short 1 Pulse (0.125 nm Range)

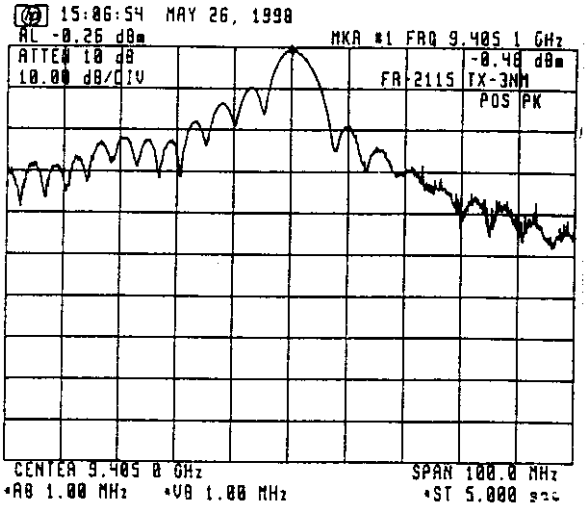


Fig. 4.4.2

Short 2 Pulse (3 nm Range)

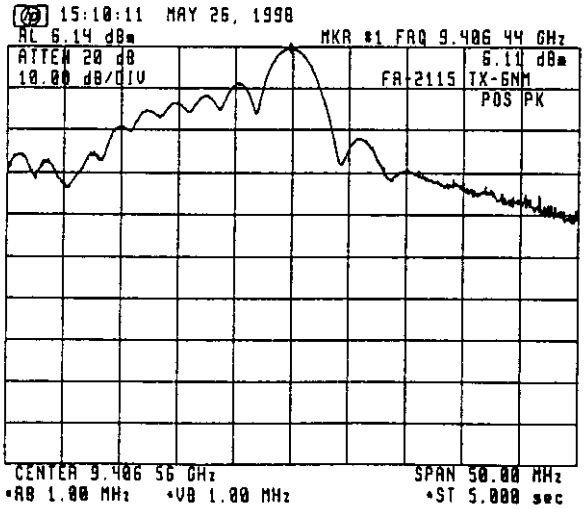


Fig. 4.4.3

Middle 1 Pulse (6 nm Range)

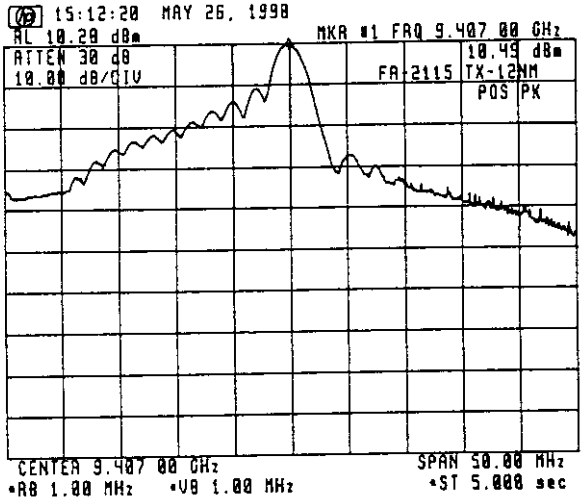


Fig. 4.4.4

Middle 2 Pulse (12 nm Range)

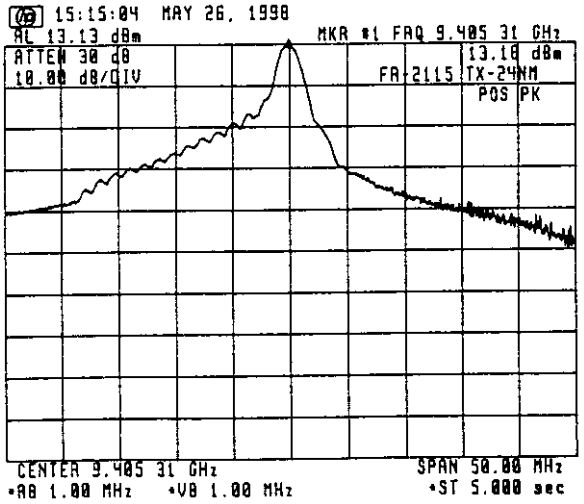


Fig. 4.4.5

Middle 3 Pulse (24 nm Range)

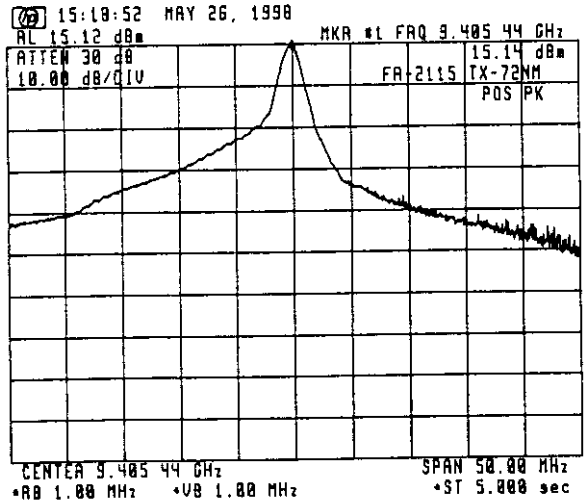


Fig. 4.4.6

Long Pulse (72 nm Range)

5 OCCUPIED BANDWIDTH (FCC Rule §2.989)

5.1 Measuring Method

FCC rule 47 CFR 2.989 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 HP 71210C 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;" 1,%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,14;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 I;";
620  OUTPUT  @Sa;"PD;PA 700,743;";
630  OUTPUT  @Sa;"PU;PA 701,654;";
640  OUTPUT  @Sa;"LINET I;";
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. 5.1 Program for Calculation of Occupied Bandwidth

5.2 Test Equipment Setup:

Same as Clause 6.1.

5.3 Measuring Equipment List:

Same as Clause 6.2.

5.4 Test Result:

The test result is shown below.

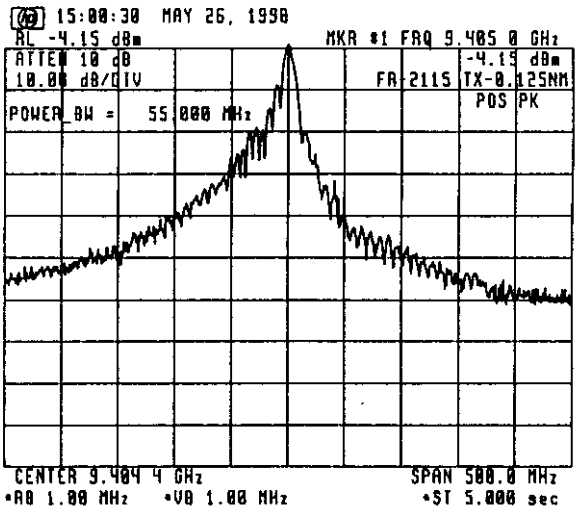


Fig. 5.2 Measurement of Occupied Bandwidth

Occupied bandwidth = 55.000 MHz

6 SPURIOUS EMISSIONS AT ANTENNA TERMINAL (FCC Rule § 2.991)

6.1 Test Equipment Setup :

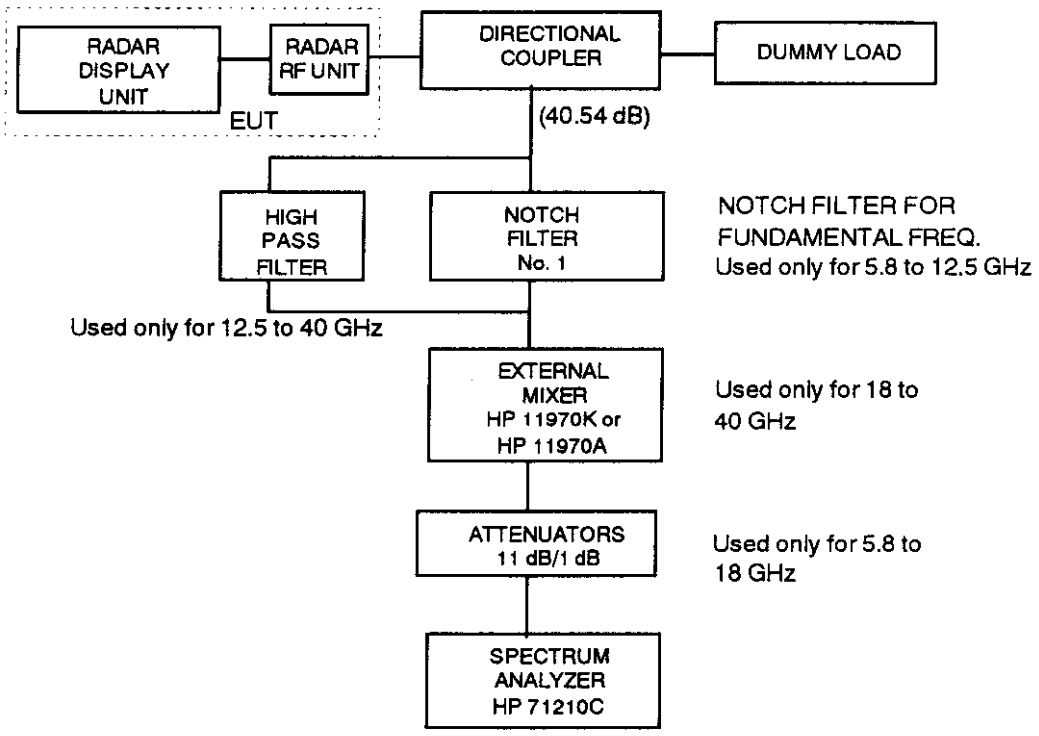


Fig. 6.1

6.2 Measuring Equipment List:

See ATTACHMENT 4 [LIST OF TEST/MEASURING EQUIPMENT].

Note : (1) The characteristics of Notch Filter (No. 1) are described in Fig. 6.2 to Fig. 6.5.
(2) The characteristic of High Pass Filter (No. 2) is described in Fig. 6.6.

6.3 Test Conditions :
Radar Range Settings: 0.125 nm (Short1)/3 nm (Short2)/6 nm (Middle1)/
12 nm (Middle2)/24 nm (Middle3)/96 nm (Long)

6.4 Emission Limits:

(a) Frequency Range (FCC Rule § 2.997) : 10 kHz - 40 GHz

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

Frequency removed from the assigned frequency	Frequency (kHz)	Emission attenuation (mean power ,dB)
50 - 100 % (of the authorized bandwidth)	9310 - 9360 9460 - 9510	At least 25
100 - 250 %	9160 - 9310 9510 - 9660	At least 35
more than 250 %	10 - 9160 9660 - 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

6.5 Test Results:

As shown in ATTACHMENT 1 , 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 (wave guide tube)).

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

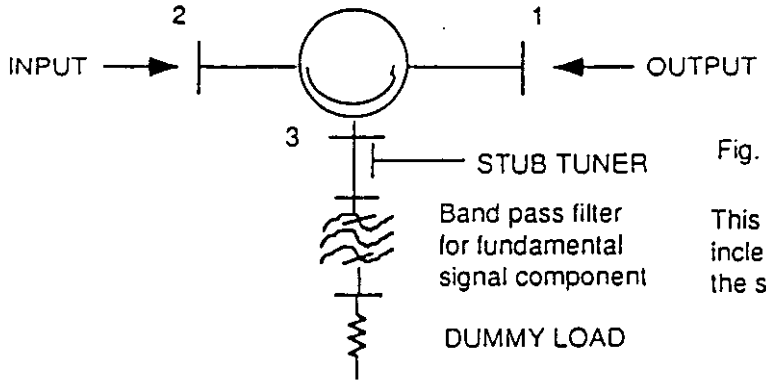


Fig. 6.2 Setup of Notch Filter No.1

This notch filter is used to inclease the dynamic range of the spectrum analyzer

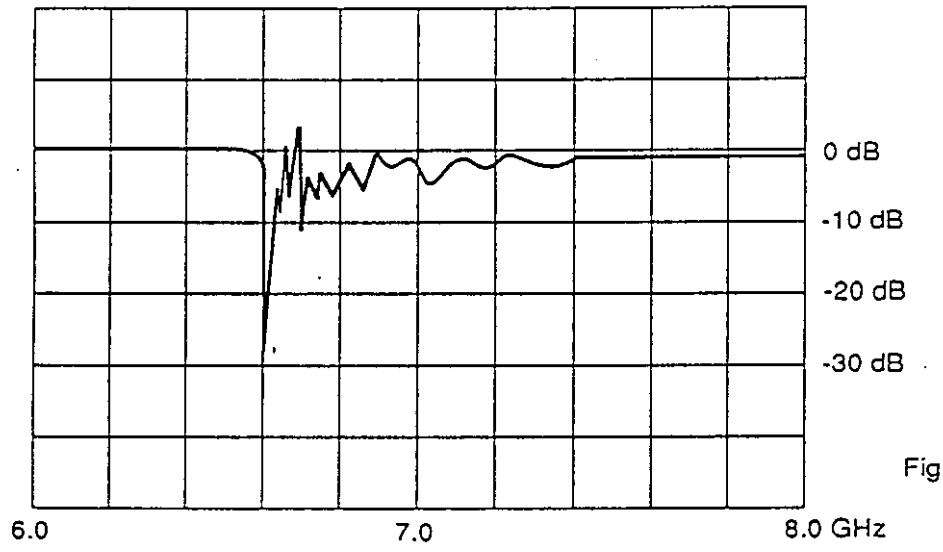


Fig. 6.3

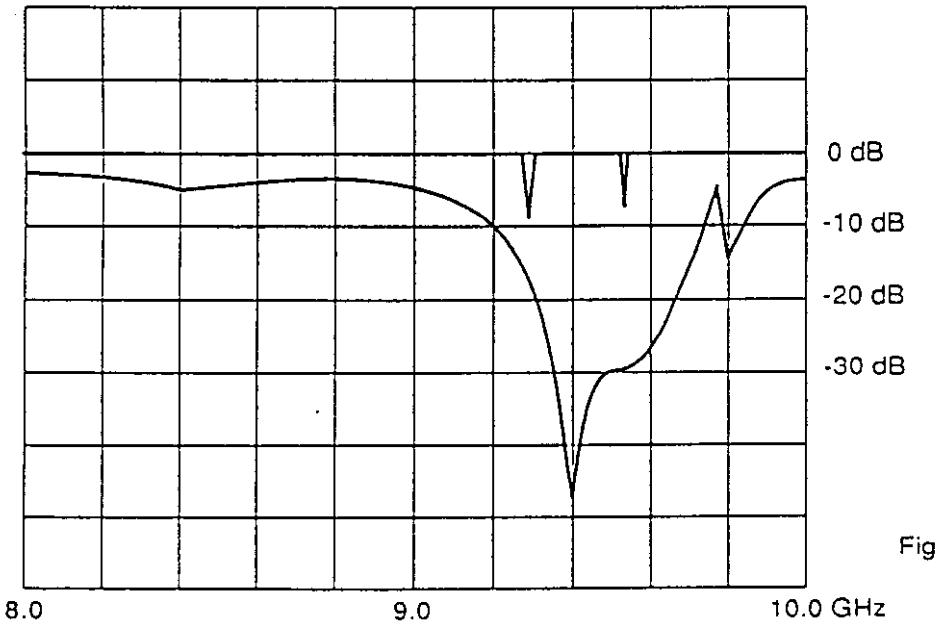


Fig. 6.4

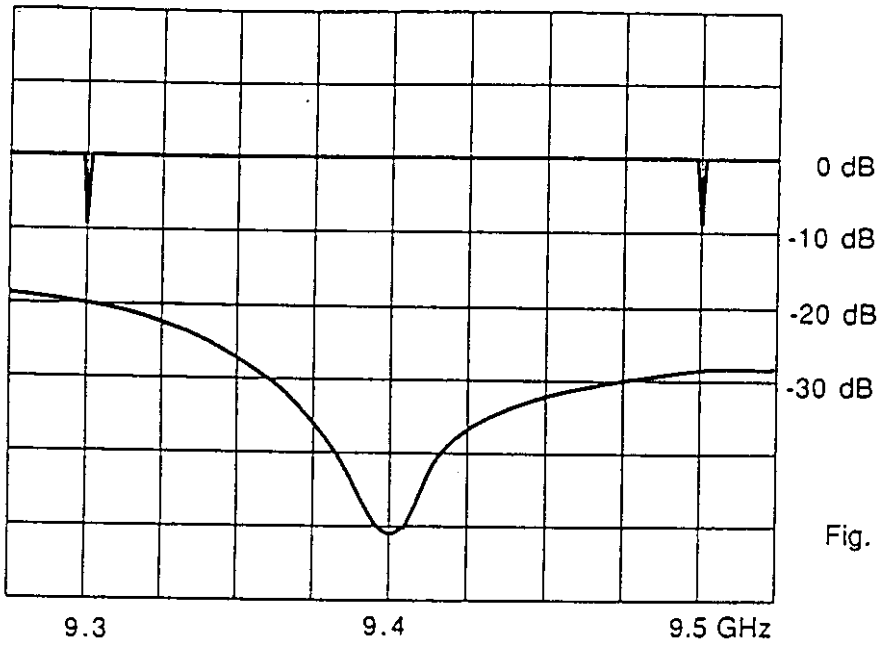
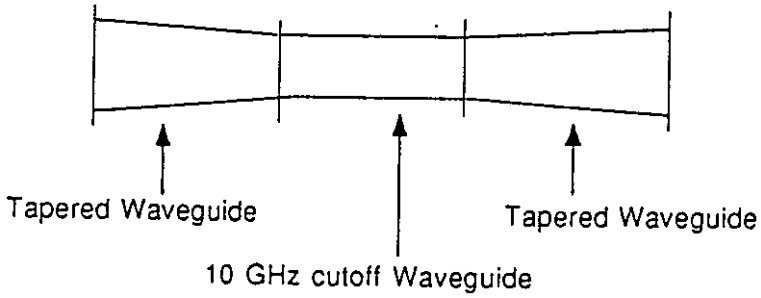


Fig. 6.5

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

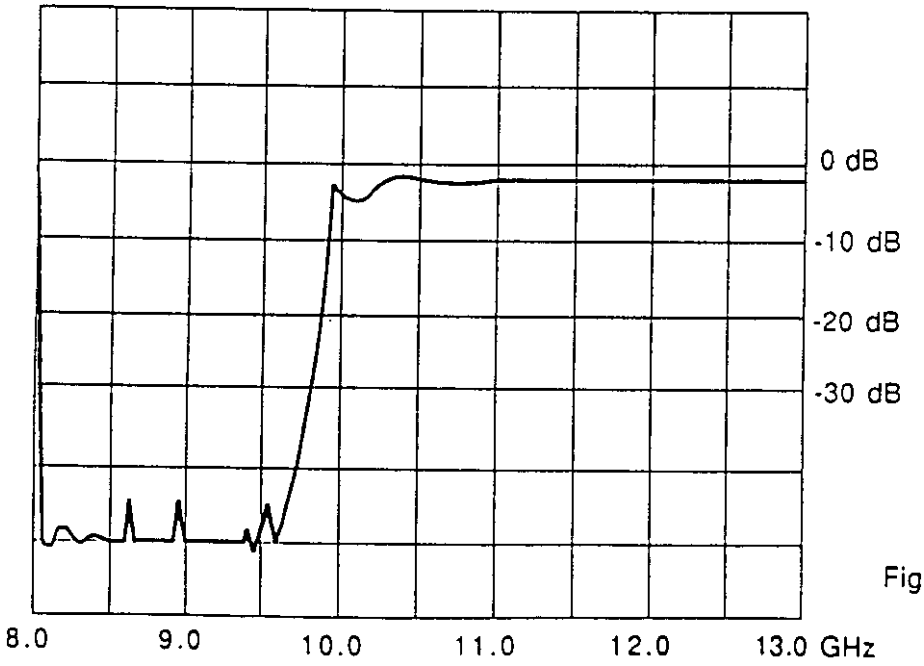


Fig.6.6

Pub. No. : TI-1691
Date : June, 1998

7 FIELD STRENGTH OF SPURIOUS RADIATION (FCC Rule § 2.993)

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

7.2 Date: May, 1998

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

7.4 Radar Range settings: 0.125 nm (Short1)/3 nm (Short2)/6 nm (Middle1)/
12 nm (Middle2)/24 nm (Middle3)/96 nm (Long)

7.5 Measuring Equipment List:

See ATTACHMENT 4 [LIST OF TEST/MEASURING EQUIPMENT].

7.6 Test settings:

See Fig. 7.1 - Fig. 7.5.

7.7 Field Strength Limits:
(a) Frequency Range (FCC Rule § 2.997) : 10 kHz - 40 GHz
(b) Emission Limits (FCC Rule § 80.211) :

Frequency removed from the assigned frequency	Frequency (kHz)	Emission attenuation (mean power ,dB)
50 - 100 % (of the authorized bandwidth)	9310 - 9360 9460 - 9510	At least 25
100 - 250 %	9160 - 9310 9510 - 9660	At least 35
more than 250 %	10 - 9160 9660 - 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

7.8 Test Results:

As shown in ATTACHMENT 2 , the field strengths of spurious radiation generated by EUT are found lower than the specified limits.

8 FREQUENCY STABILITY (FCC Rule § 2.995)

8.1 Setup for Measurement

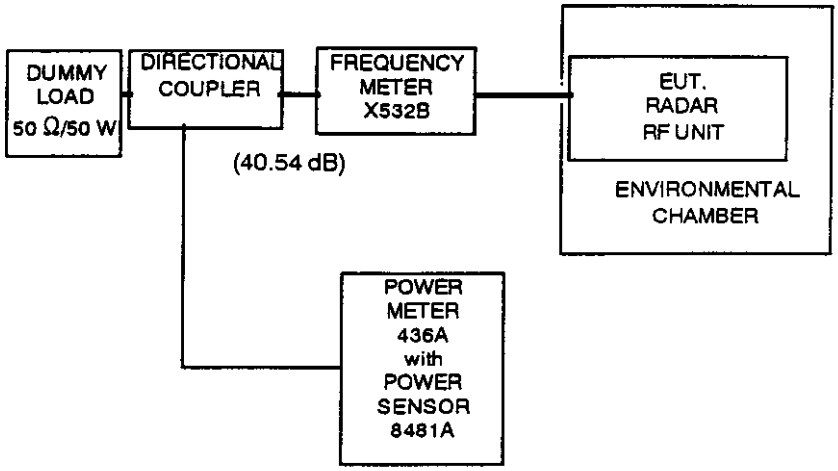


Fig. 8.1

8.2 Test Conditions:

1) Radar Range settings : 0.125 nm (Short1)/3 nm (Short2)/6 nm (Middle1)/ 12 nm (Middle2)/24 nm (Middle3)/72 nm (Long)
2) Ambient Temperature settings: - 20 to + 50 °C (10 °C step)
3) Power Supply Voltage settings: 85 /115 % of nominal voltage (187 to 253 VAC)

8.3 Measuring Equipment List:

See ATTACHMENT 4 [LIST OF TEST/MEASURING EQUIPMENT].

8.4 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)

1) Center frequency (f0): 9410 MHz
2) Authorized bandwidth (f(AUBW)): 100 MHz

"Upper limit frequency of the authorized band", f(UAUBW) = f0 + f(AUBW)/2 = 9460 MHz

"Lower limiti frequency of the authorized band", f(LAUBW) = f0 - f(AUBW)/2 = 9360 MHz

3) Assignanble 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)) :

Range setting	Pulse duration (μ sec)	f(1.5/T) (MHz)
0.25 nm (Short)	0.08	18.75
2 nm (Middle)	0.3	5.00
36 nm (Long 1)	0.8	1.88
48 nm (Long 2)	0.8	1.88
96 nm (Long 3)	0.8	1.88

8.5 Test Results:

Shown on Fig. 8.2.

(1) "Upper Tolerance Frequency measured (at - 20℃)", f(U) = 9414.5 MHz

(2) "Lower Tolerance Frequency measured (at + 50 ℃)", f(L) = 9401.63 MHz

(3) (a) f(U) + max. f(1.5/T) = 9433.25 MHz < f(UAUBW) = 9460 MHz < f(UASB) = 9500 MHz

(b) f(L) - max. f(1.5/T) = 9382.875 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 (187 to 253 VAC for nominal 220 VAC).

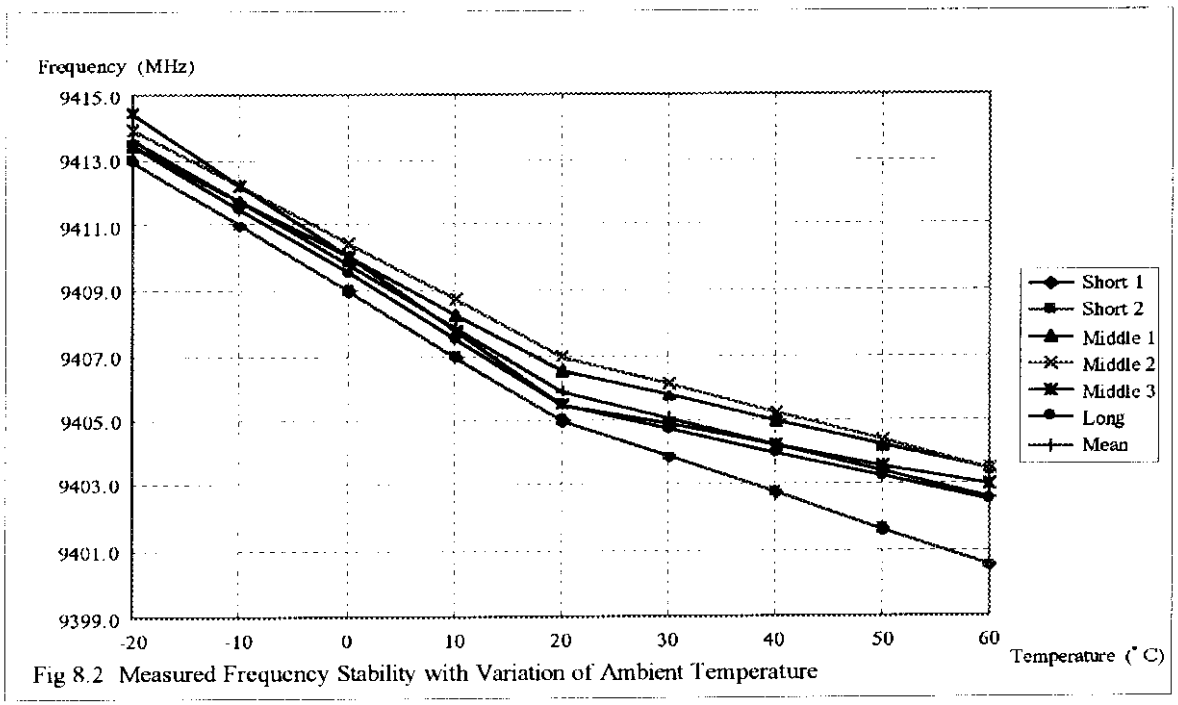


Fig 8.2 Measured Frequency Stability with Variation of Ambient Temperature

9 SUPPRESSION OF INTERFERENCE ABOARD SHIPS

(FCC Rule § 80.217)

9.1 Measuring Antenna Characteristics at Repersentative Frequencies:

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

Length	Test Frequency (Hz)	Impedence (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

9.2 Test Site: Rooftop of 6-story buiding,
Furuno Electric Company, Ltd.
Ashihara-cho 9-52, Nishinomiya-city, 662-8580 JAPAN

9.3 Measuring Instruments:

(1) RF Vector Impedence Meter, HP 4815A
(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

9.4 Test Results:

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

9.4.1 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 3)

9.4.2 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 3)

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

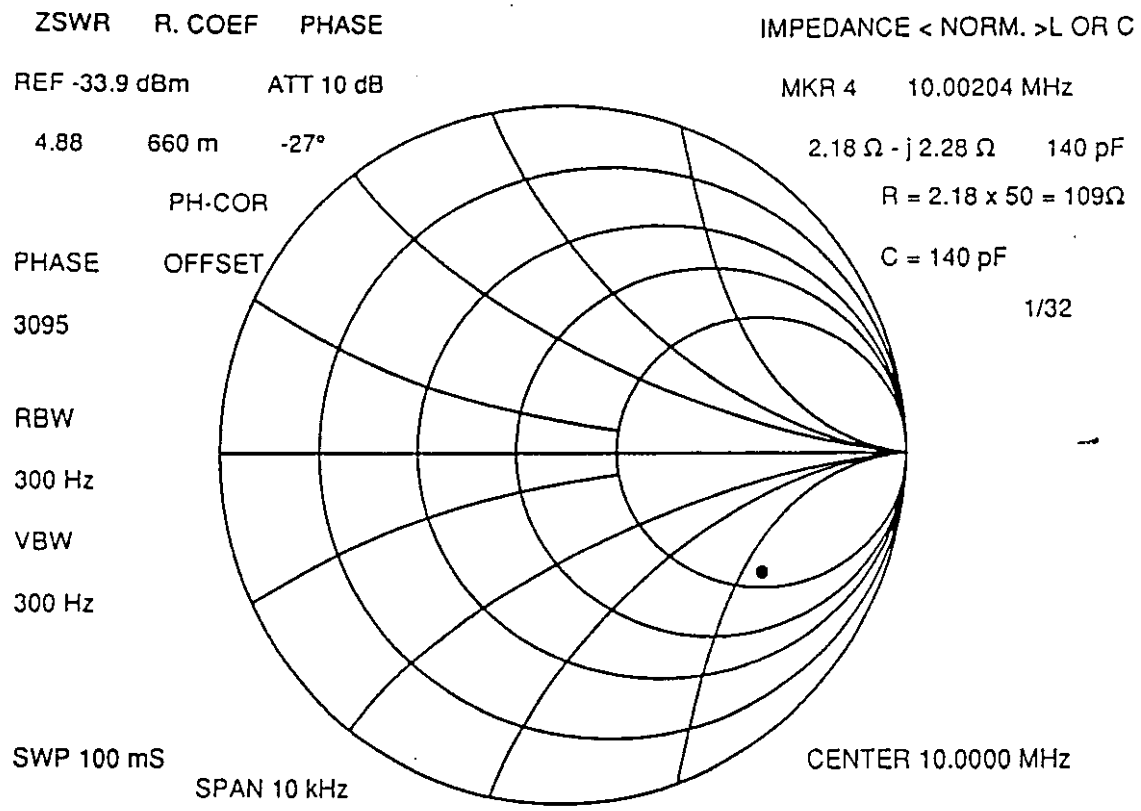
Limits:	for below 30 MHz,	400 μW
	for 30 to 100 MHz,	4,000 μW
	for 100 to 300 MHz	40,000 μW
	for over 300 MHz,	400,000 μW

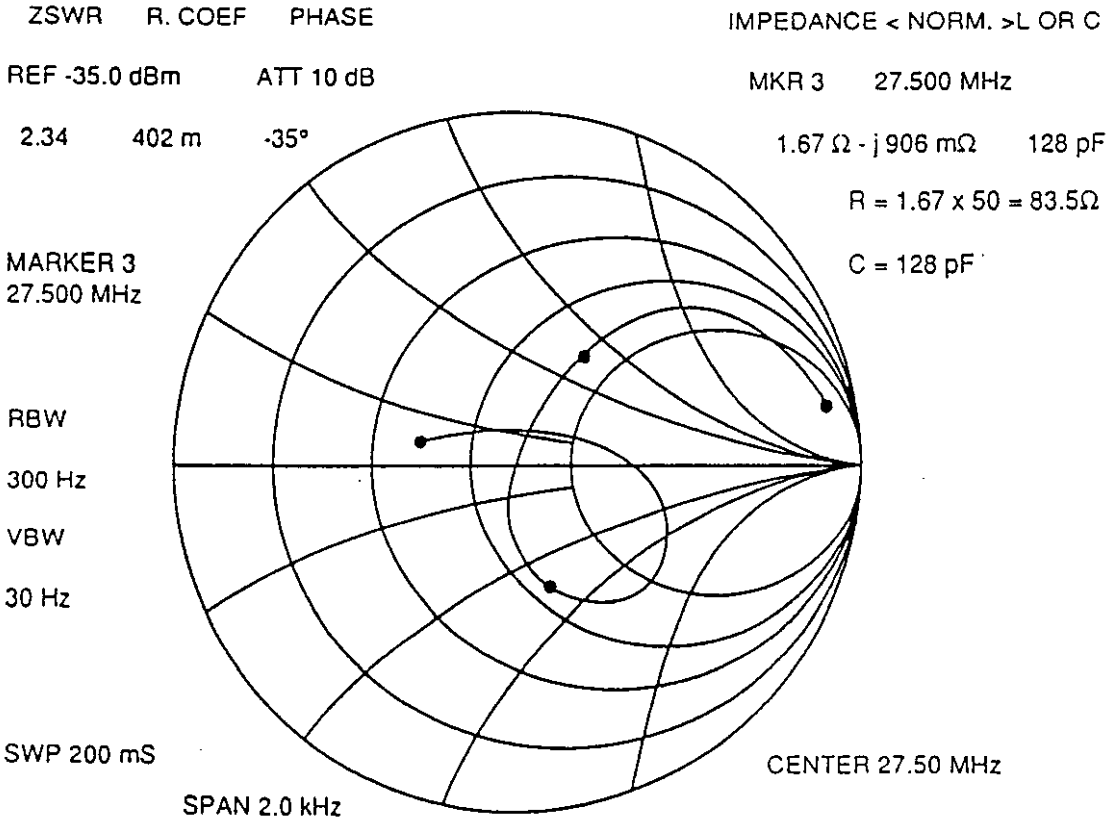
Results: There is no spurious component exceeding the limits. (Test data are shown in ATTACHMENT 3)

Pub. No. : TI- 1691

Date : June. 1998

MEASUREMENT OF IMPEDANCE OF TEST ANTENNAS





Pub. No. : TI-1691

Date : June. 1998

MEASUREMENT OF IMPEDANCE OF TEST ANTENNAS

ZSWR R. COEF PHASE

REF -33.7 dBm ATT 10 dB

2.69 458 m -24°

MG-COR PH-COR

MARKER 7

150.00 MHz

RBW

100 Hz

VBW

30 Hz

SWP 500 mS

SPAN 10 kHz

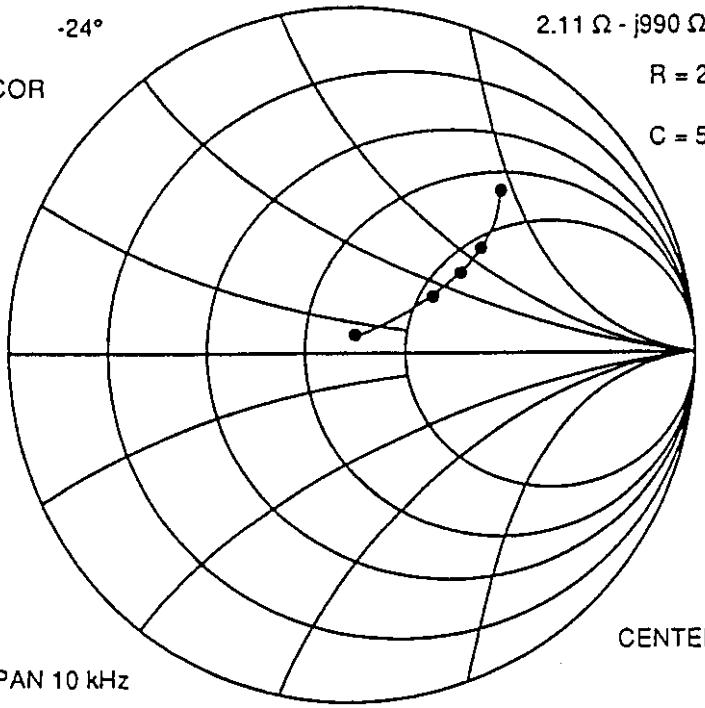
IMPEDANCE < NORM. >L OR C

MKR 7 150.00 MHz

2.11 Ω - j990 Ω 52.5 nH

R = 2.11 x 50 = 105.5 Ω

C = 52.5 nH



CENTER 150.0 MHz

ZSWR R. COEF PHASE

REF -35.1 dBm ATT 10 dB

4.16 612 m -68°

MARKER 1
450.00 MHz

RBW

100 Hz

VBW

30 Hz

SWP 500 mS

SPAN 10 kHz

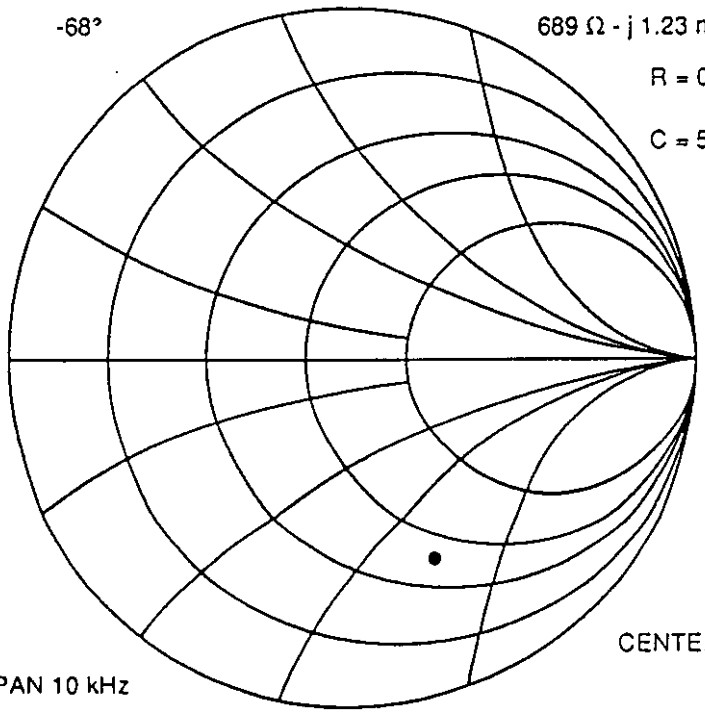
IMPEDANCE < NORM. >L OR C

MKR 1 450.00 MHz

689 Ω - j 1.23 mΩ 5.68 pF

R = 0.689 x 50 = 34.5Ω

C = 5.68 pF



CENTER 450.0 MHz

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

(FCC Rule § 2.983 (d) (11))

ANTENNA UNIT
TRANSCEIVER MODULE (RTR-062)

Modulator Trigger Circuit 03P9243 (RFC)

The modulator trigger generates the pulses that fire the modulator FETs.

The pulse forming circuit formed by U2 to U6 produces four trigger pulses TRIG1 to TRIG4, the pulselengths of which vary depending on the setting of pulselength (P/L A, P/L B and P/L C). For short pulse 1 (SP1), TRIG1 to TRIG4 have the same pulselength (0.12 μs). For short pulse 2 (SP2), middle pulse 1 (MP1), middle pulse 2 (MP2) and middle pulse 3 (MP3), TRIG1 to TRIG4 have the different lengths (between 0.10 to 1.04 μs). For long pulse (LP), TRIG1 to TRIG4 have the same pulselength (1.2 μs). These pulses are sent to the modulator board.

U4 also produces the bandwidth selection signals (BW:S, BW:L), which are sent to the IF ampliffier for bandwidth selection.

The circuit composed of U7, U8 and Q15 is provided to regulate the magnetron heater voltage.

The U10 is a current amplifier to detect the average magnetron current.

Modulator Board 03P9244 (MD)

The function of the modulator board is to produce a high tention pulse that drives the magnetron.

The high voltage (TX-HV) is charged into C1 to C4 through R1/R2 while the magnetron is inactive. This high voltage is discharged through the pulse transformer T801 whe FETs Q1 - Q4 are conductive. T801 boosts the voltage and makes the magnetron oscillate.

Because the magnetron oscillates only when the FET is conductive, transmission pulselength can be changed by the pulselength fed to the gates of FETs. Also the magnetron current is proportional to the discharging current via the FETs, thus the transmission power can be changed by the number of FETs conductive.

The four pulses TRIG1 to TRIG4 are produced on the modulator board and applied to the gates of Q1/Q2/Q3/Q4 via the current amplifier Q7/Q11/Q15/Q19.

The relay K1 and coil L1 are provided to eliminate the ringing at the trailing edge of the transmission pulse across the primary winding of T801. This relay is active when the short pulse 1 (SP1) is selected.

Duplexer and Mixer

Since the radar system uses a single antenna for transmission and reception, and efficient device is required for switching the transmitter and the receiver, this radar employs a circulator HY801. The circulator HY801 is a passive directional coupler with three ports. The incoming signal is bent in the specific direction and emerges from another port with little loss, the other port being isolated. In the same manner, the received signal entering into another port is tranferred to the other port, isolating one port. This operation of the circulator protects the receiver during transmission and minimizes loss of the received signal during reception.

The diode limiter is a self-activating switch made of two PIN diodes. Its function is to attenuate the strong transmission signals from the magnetron and other boat radars through the antenna and to protect the MIC (microwave IC) U801. The PIN diode conducts at a certain level of microwave power. When the diode is the cut-off state, the input impedance of the diode limiter matches the impedance of the waveguide, and the microwave energy is delivered to the MIC. When the diode is put into a conductive state, the waveguide is short-circuited and most of the input energy is reflected back to the transmitter side. The strong signal is thus weakened down to about 50 mW by the diode limiter.

U801 is a microwave IC (MIC) incorporating a local oscillator and mixer diodes. The received microwave signal of 9410 MHz coming from the diode limiter is mixed with the local oscillation signal in the mixer diodes and converted to IF signal of 60 MHz.

IF Amplifier 03P9232 (IF)

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/Q609/Q610), Logarithmic Amplifier(U601/U602/U603/U610), Video Amplifier (Q625/Q626/Q627/Q628), Bandwidth Selector (U604, CR601 to CR607), Tuning Indicator Circuit (Q614 to Q620) and Main Bang Suppression Circuit (Q630, Q631,Q603, CR631, CR626, CR608, CR609, U611, U612).

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

The IF amplifier operates in narrow or wide bandwidth mode depending on the settings of the RANGE switch and TX touchpad. For short ranges, a wide bandwidth (27 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/T604, selecting a narrow bandwidth (3 MHz) on medium and long ranges.

The signal through the bandwidth selector is coupled to the logarithmic amplifier, amplified and detected by U601/U602/U610. Thus, the detected signals are fed to Q625/Q626 to be amplified further, and then sent to the display unit via buffers Q627, Q628.

The IF signal at 60 MHz is amplified by Q609/Q610, U603, Q614/Q615 and detected by 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.

The purpose of the main bang suppression circuit is to minimize transmission leakage into the receiver, which represents the center spot on the screen.

When the magnetron current pulse generated in the Modulator board 03P9244 is fed to inverter U612, pulse generator U611 produces a modified rectangular pulse.

This pulse is fed to the emitter of Q603 through Q630 as a main bang suppression waveform, then Q602 turns off during transmission to eliminate direct reception of the strong TX energy (main bang).

Bearing Signal Generator MP-3795

The bearing signal generator produces a square wave signal that is used to synchronize the sweep rotation with that of the antenna.

U901 is a photo interrupter composed of a light emitting diode and a photo transistor. It has a configuration in the shape of "U" shape. The light emitting diode is mounted on one wall of the "U" shape and the photo transistor on the other wall. A rotating timing disc is arranged between the two walls.

The timing disc is provided with 60 silts at regular intervals along its circumference. It is fitted on the scanner motor shaft and rotated at a speed of 144 rpm by the 24 rpm scanner motor.

The photo transistor receives the light emitted by the light emitting diode through each slit of the timing disc and converts it into elctric current. The output of the photo transistor across

R903 is a half-rectified sine wave at a frequency of 144 Hz. This signal is amplified, reshaped and sent to the display unit for display echo synchronization.

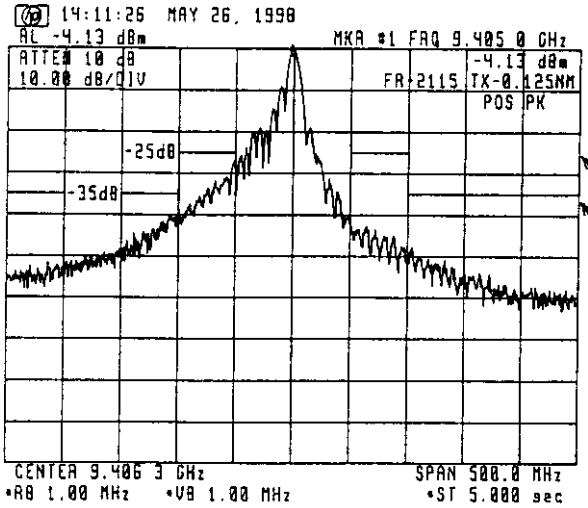
12 OPERATOR'S MANUAL INCL. CIRCUIT DIAGRAMS (FCC Rule §2.983)

(See separate covers)

ATTACHMENT 1

[TEST DATA FOR 6. SPURIOUS EMISSIONS AT ANTENNA TERMINALS]

1. Spurious emissions for 0.125 nm Range:

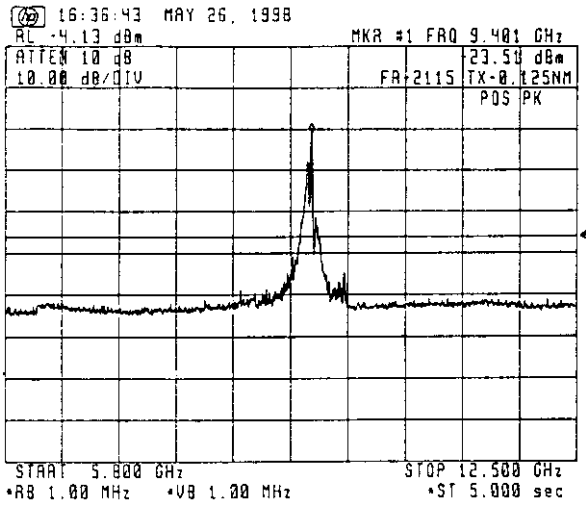


Emission limitations:

(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)

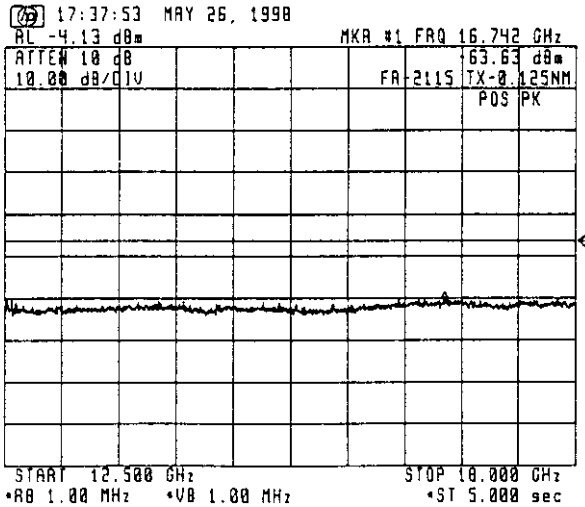
Fig. 1.1 Without Filter



Emission limitations:

(c) 43 + 10 log Pm = 46.07 dB for more than 250 % of the authorized BW (100 MHz)

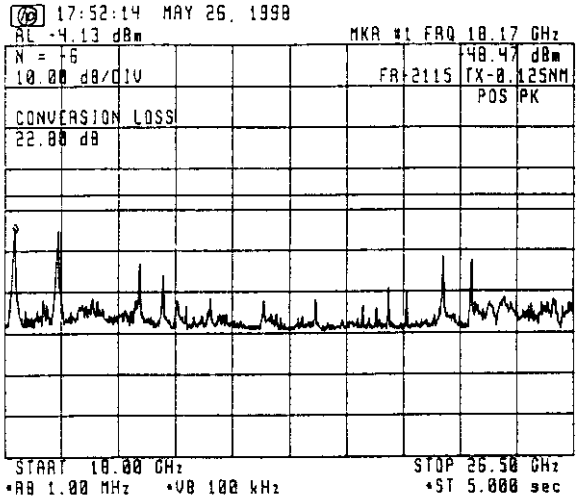
Fig. 1.2 With Filter No.1



Emission limitations:

(c) 43 + 10 log Pm = 46.07 dB for more than 250 % of the authorized BW (100 MHz)

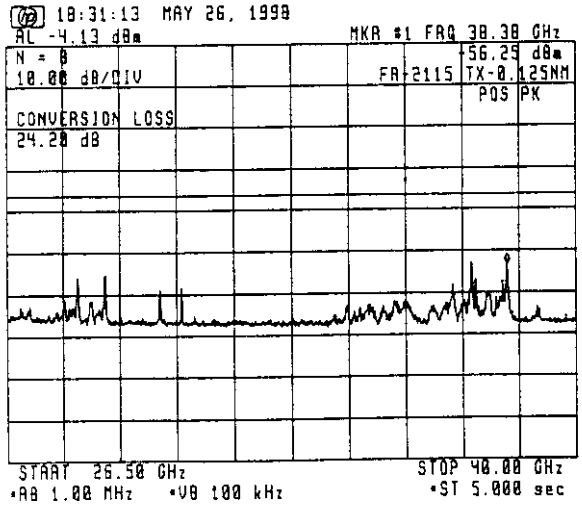
Fig. 1.3 With Filter No. 2



Emission limitations:

(c) 43 + 10 log Pm = 46.07 dB
for more than 250 % of
the authorized BW (100 MHz)

Fig. 1.4 With Filter No. 2

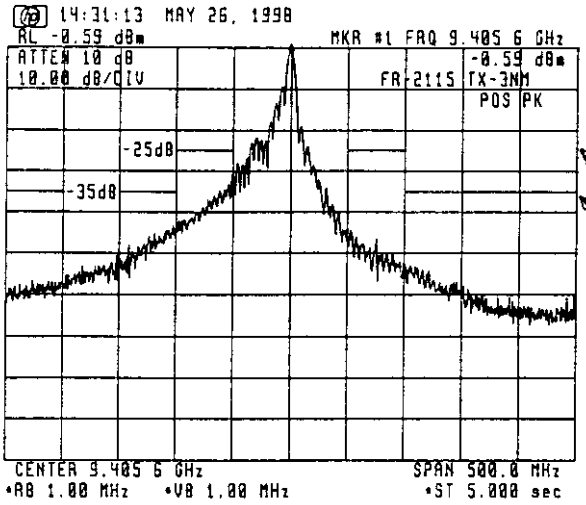


Emission limitations:

(c) 43 + 10 log Pm = 46.07 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:

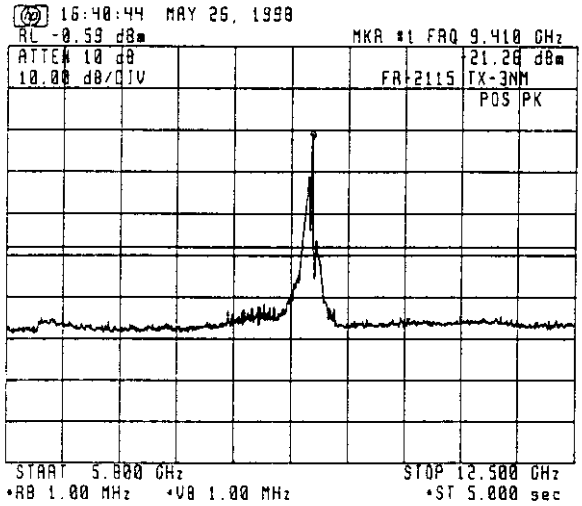


Emission limitations:

(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)

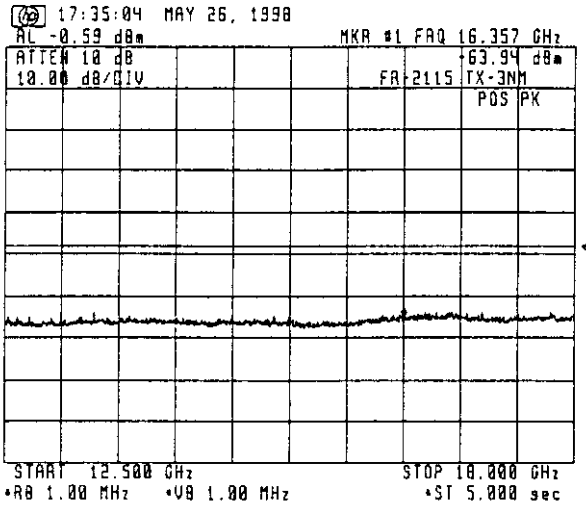
Fig. 2.1 Without Filter



Emission limitations:

(c) 43 + 10 log Pm = 47.77 dB for more than 250 % of the authorized BW (100 MHz)

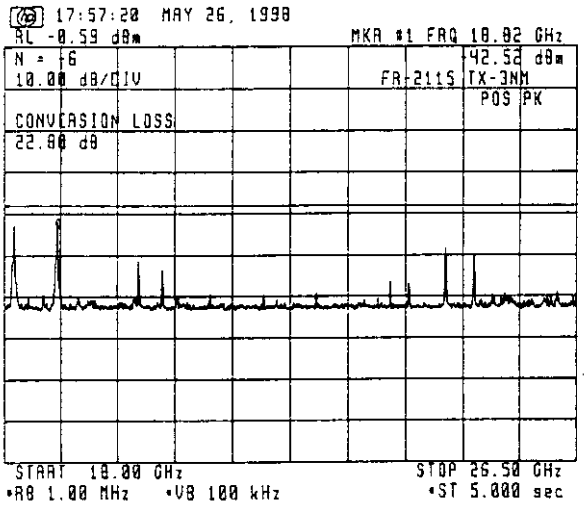
Fig. 2.2 With Filter No.1



Emission limitations:

(c) 43 + 10 log Pm = 47.77 dB for more than 250 % of the authorized BW (100 MHz)

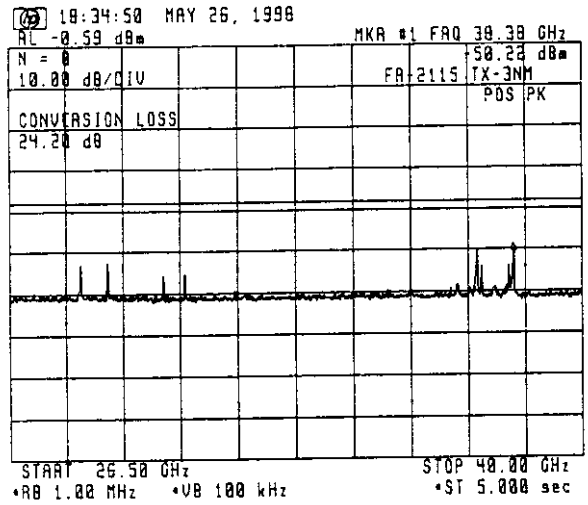
Fig. 2.3 With Filter No. 2



Emission limitations:

(c) 43 + 10 log Pm = 47.77 dB
for more than 250 % of
the authorized BW (100 MHz)

Fig. 2.4 With Filter No. 2

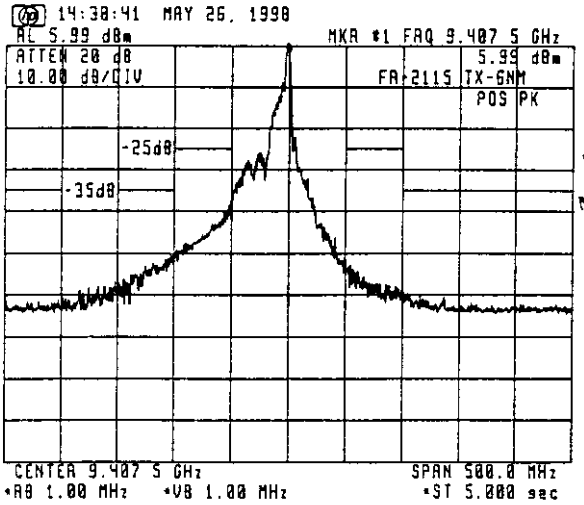


Emission limitations:

(c) 43 + 10 log Pm = 47.77 dB
for more than 250 % of
the authorized BW (100 MHz)

Fig. 2.5 With Filter No. 2

3. Spurious emissions for 6 nm Range:

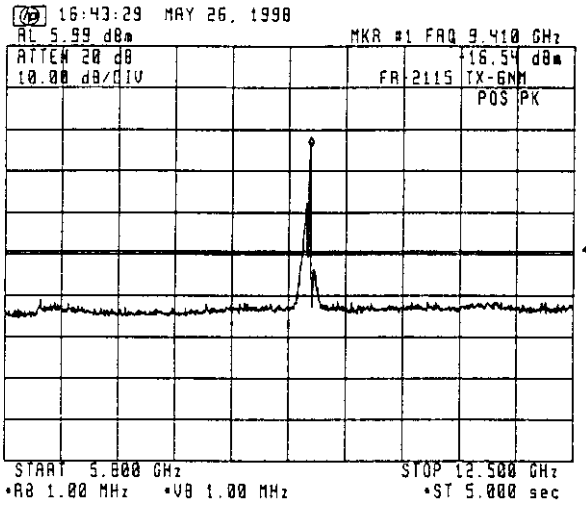


Emission limitations:

(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)

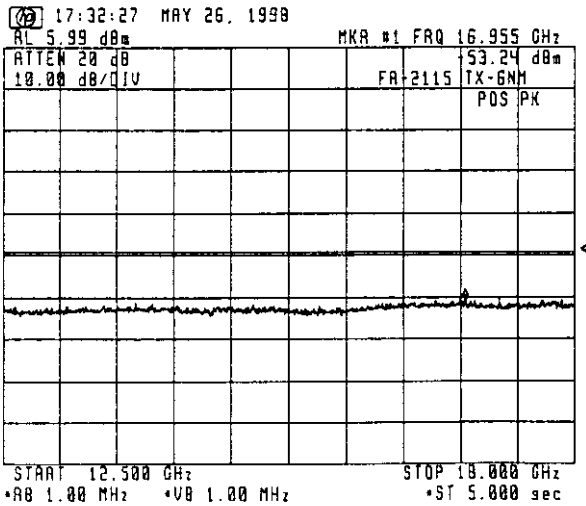
Fig. 3.1 Without Filter



Emission limitations:

(c) 43 + 10 log Pm = 48.92 dB for more than 250 % of the authorized BW (100 MHz)

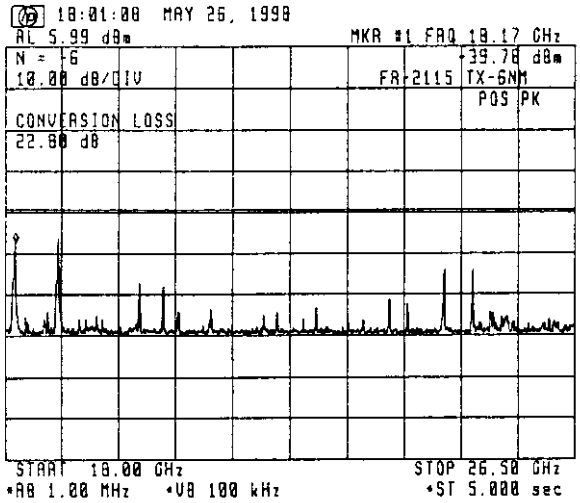
Fig. 3.2 With Filter No.1



Emission limitations:

(c) 43 + 10 log Pm = 48.92 dB for more than 250 % of the authorized BW (100 MHz)

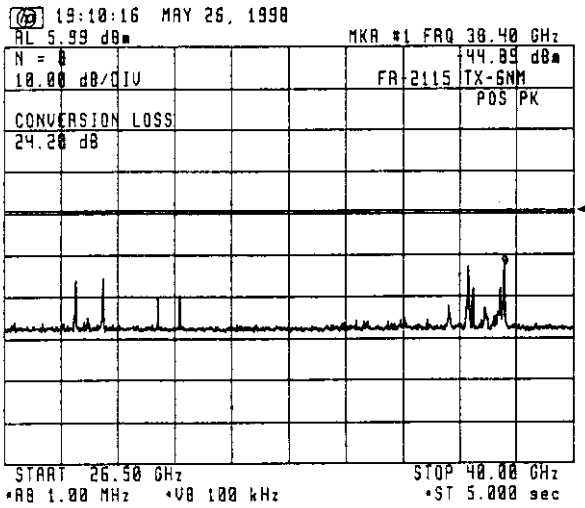
Fig. 3.3 With Filter No. 2



Emission limitations:

(c) 43 + 10 log Pm = 48.92 dB
for more than 250 % of
the authorized BW (100 MHz)

Fig. 3.4 With Filter No. 2

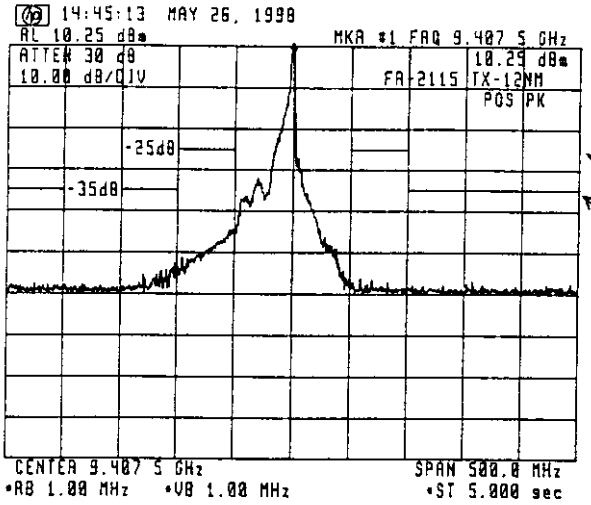


Emission limitations:

(c) 43 + 10 log Pm = 48.92 dB
for more than 250 % of
the authorized BW (100 MHz)

Fig. 3.5 With Filter No. 2

4. Spurious emissions for 12 nm Range:

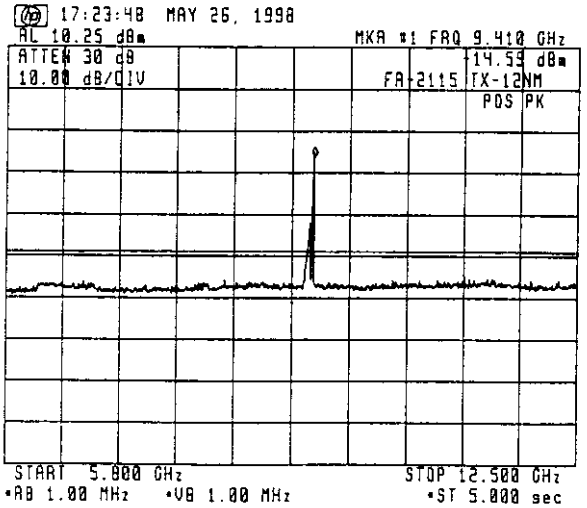


Emission limitations:

(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)

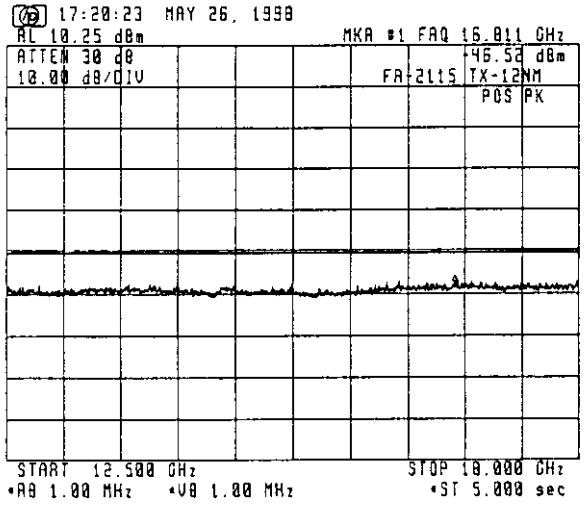
Fig. 4.1 Without Filter



Emission limitations:

(c) 43 + 10 log Pm = 49.66 dB for more than 250 % of the authorized BW (100 MHz)

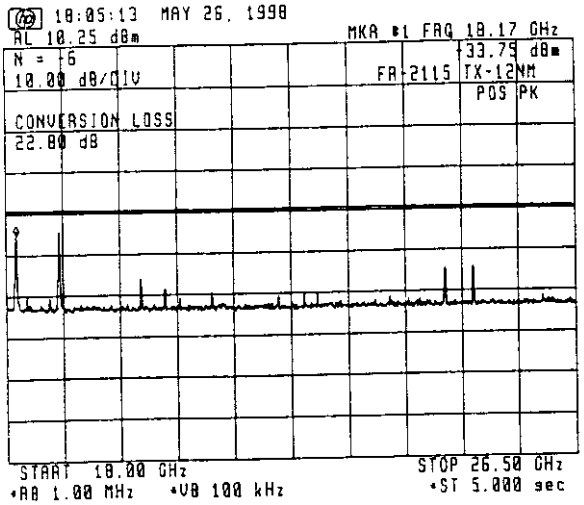
Fig. 4.2 With Filter No.1



Emission limitations:

(c) 43 + 10 log Pm = 49.66 dB for more than 250 % of the authorized BW (100 MHz)

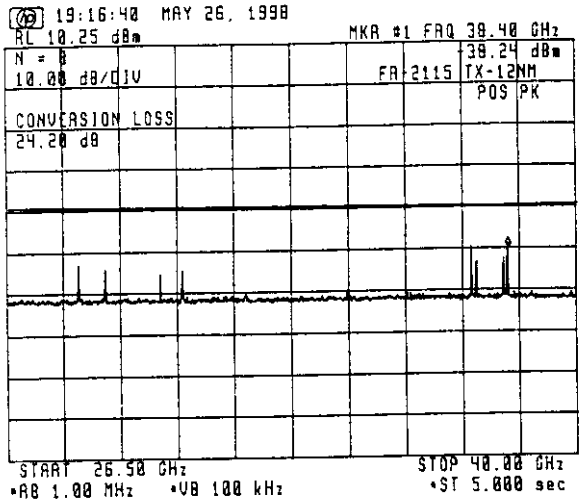
Fig. 4.3 With Filter No. 2



Emission limitations:

(c) 43 + 10 log Pm = 49.66 dB
for more than 250 % of
the authorized BW (100 MHz)

Fig. 4.4 With Filter No. 2

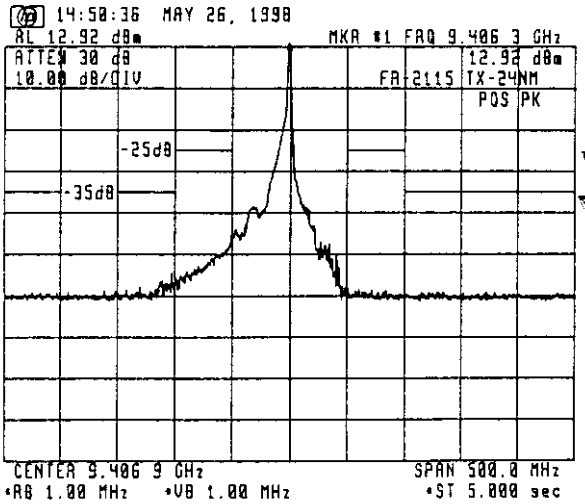


Emission limitations:

(c) 43 + 10 log Pm = 49.66 dB
for more than 250 % of
the authorized BW (100 MHz)

Fig. 4.5 With Filter No. 2

5. Spurious emissions for 24 nm Range:

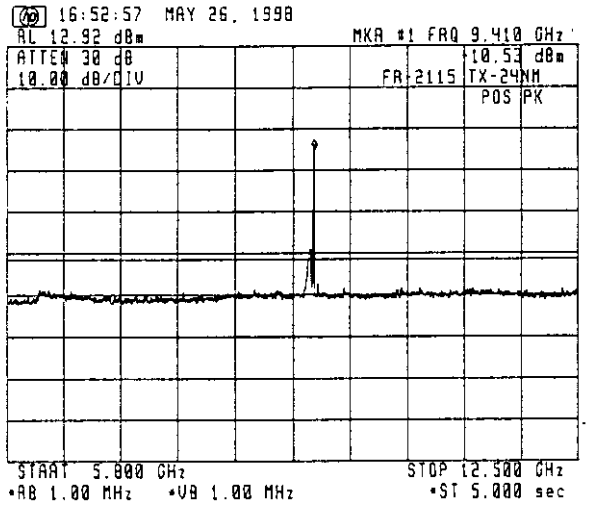


Emission limitations:

(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)

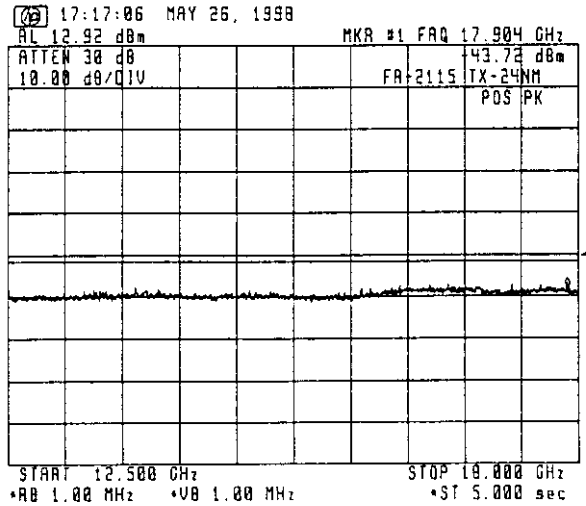
Fig. 5.1 Without Filter



Emission limitations:

(c) 43 + 10 log Pm = 51.41 dB for more than 250 % of the authorized BW (100 MHz)

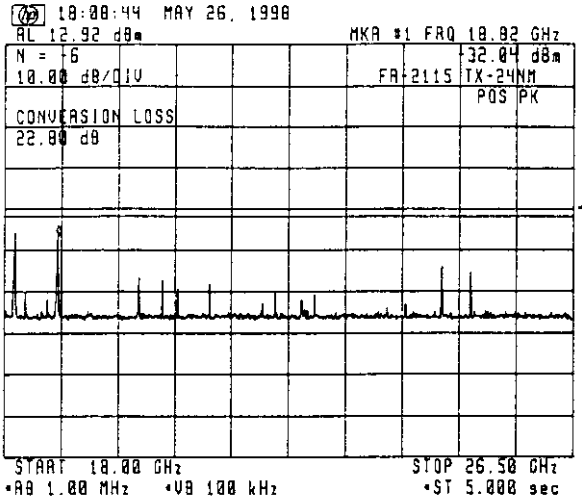
Fig. 5.2 With Filter No.1



Emission limitations:

(c) 43 + 10 log Pm = 51.41 dB for more than 250 % of the authorized BW (100 MHz)

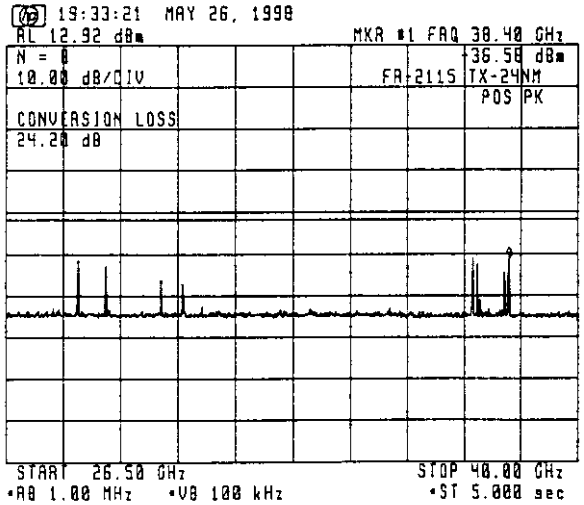
Fig. 5.3 With Filter No. 2



Emission limitations:

(c) 43 + 10 log Pm = 51.41 dB
for more than 250 % of
the authorized BW (100 MHz)

Fig. 5.4 With Filter No. 2

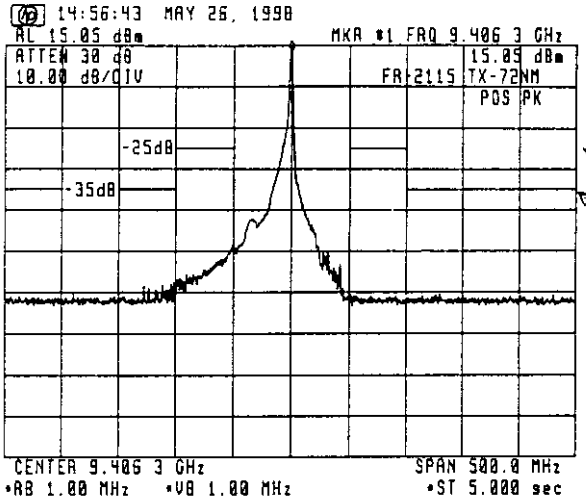


Emission limitations:

(c) 43 + 10 log Pm = 51.41 dB
for more than 250 % of
the authorized BW (100 MHz)

Fig. 5.5 With Filter No. 2

6. Spurious emissions for 72 nm Range:

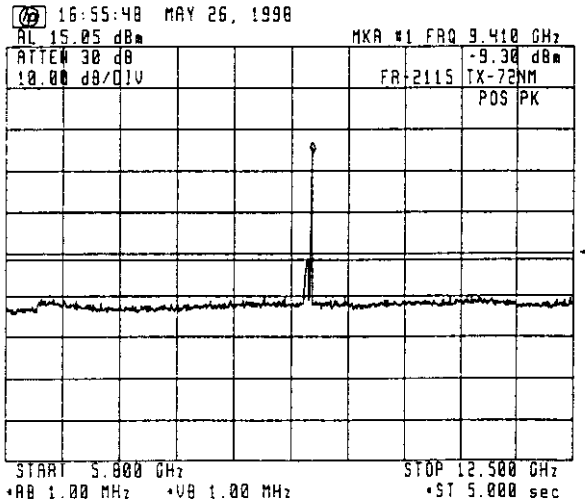


Emission limitations:

(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)

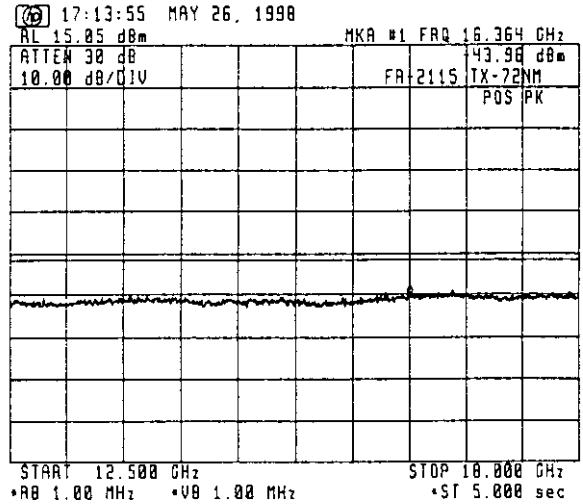
Fig. 6.1 Without Filter



Emission limitations:

(c) 43 + 10 log Pm = 51.23 dB for more than 250 % of the authorized BW (100 MHz)

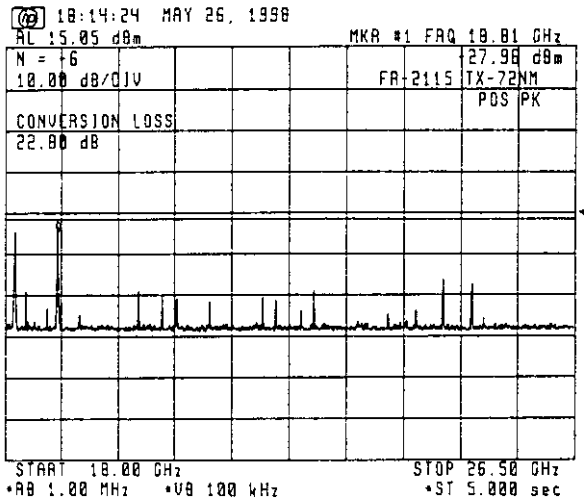
Fig. 6.2 With Filter No.1



Emission limitations:

(c) 43 + 10 log Pm = 51.23 dB for more than 250 % of the authorized BW (100 MHz)

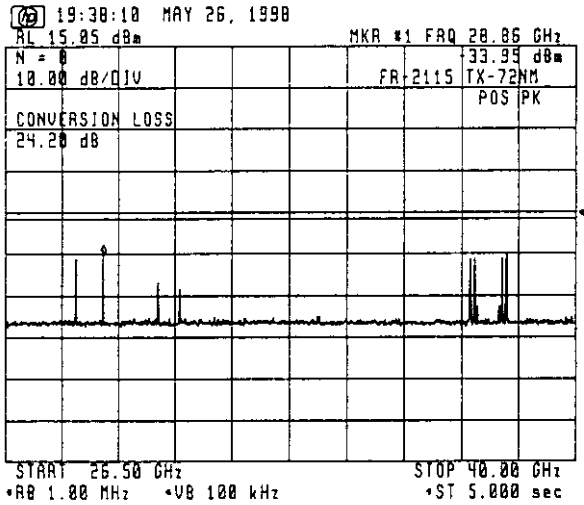
Fig. 6.3 With Filter No. 2



Emission limitations:

(c) 43 + 10 log Pm = 51.23 dB
for more than 250 % of
the authorized BW (100 MHz)

Fig. 6.4 With Filter No. 2



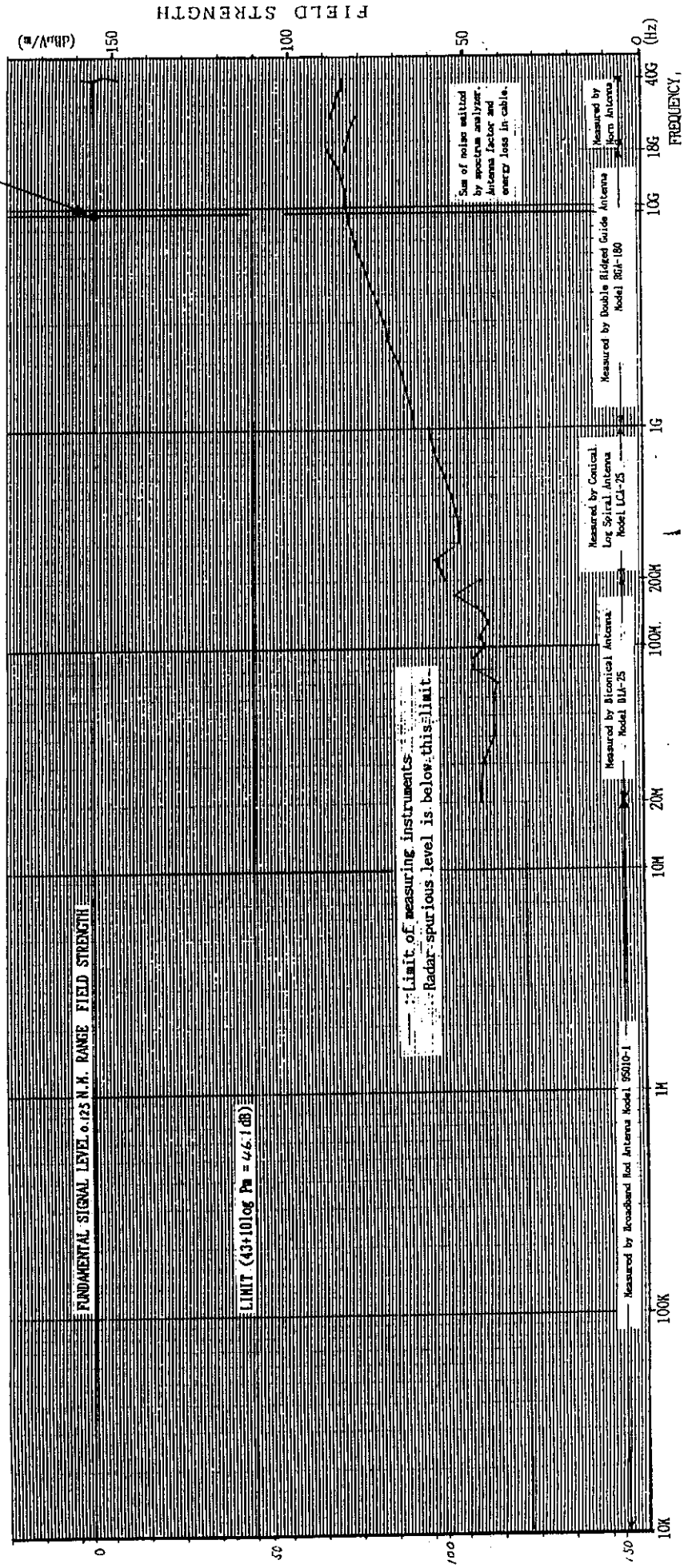
Emission limitations:

(c) 43 + 10 log Pm = 51.23 dB
for more than 250 % of
the authorized BW (100 MHz)

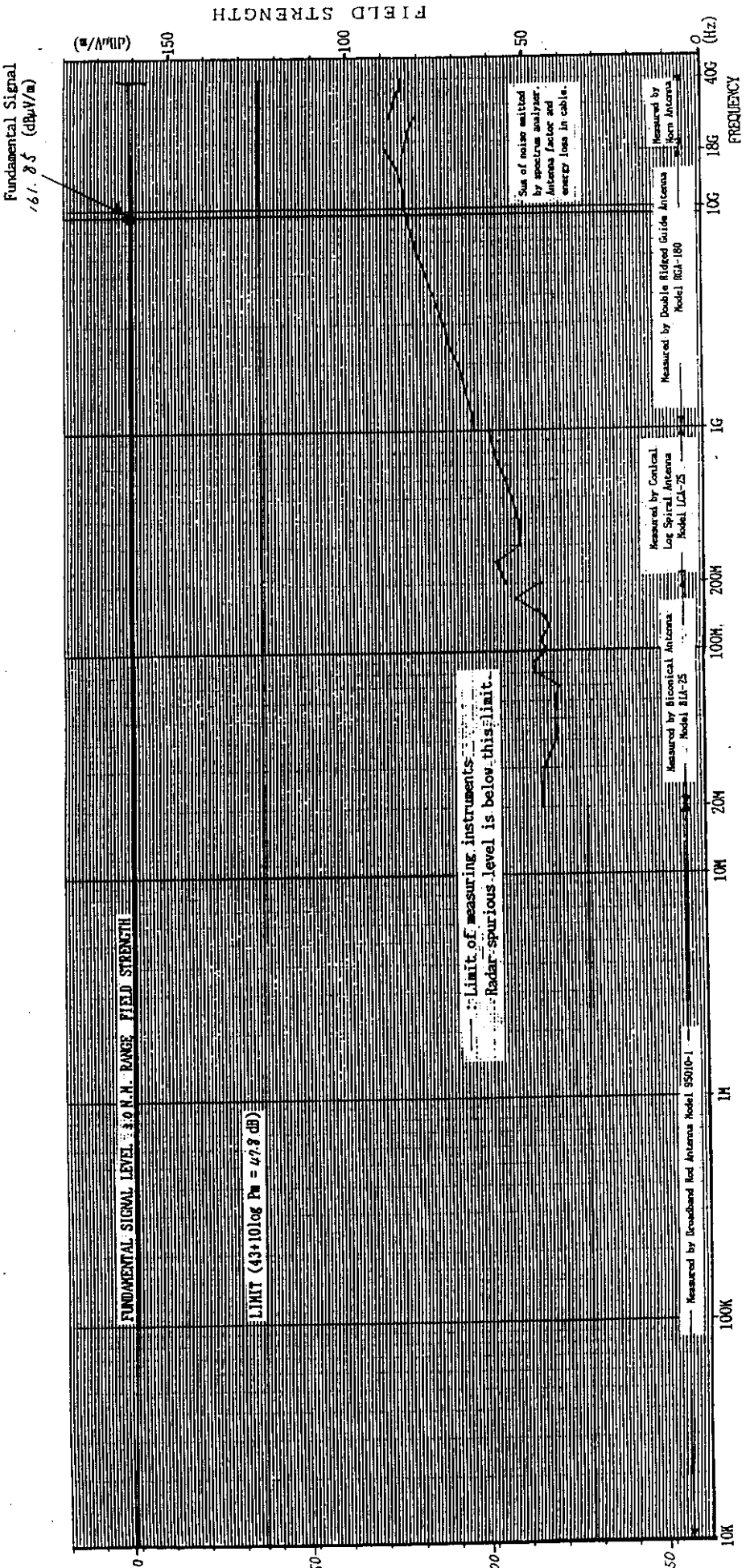
Fig. 6.5 With Filter No. 2

ATTACHMENT 2

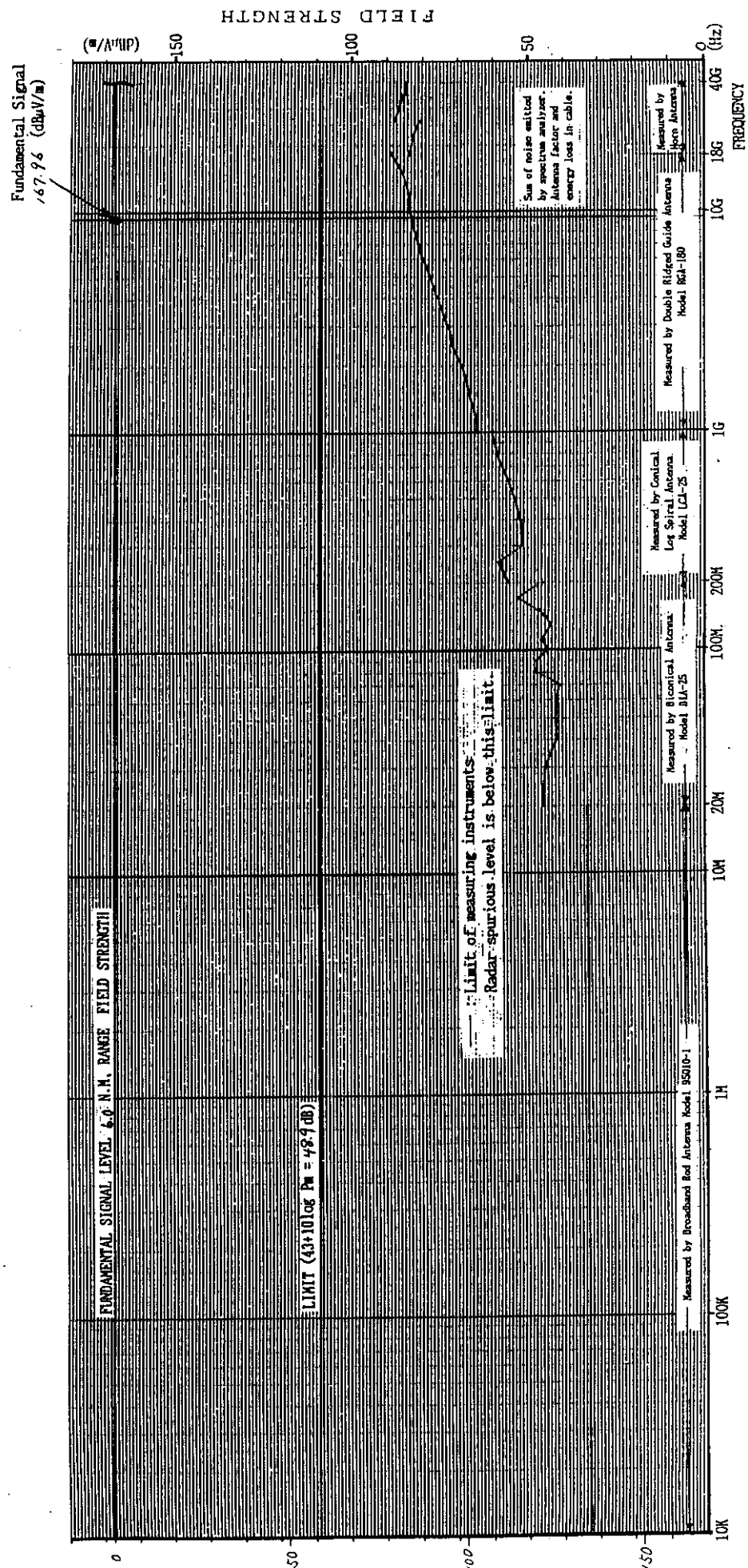
[TEST DATA FOR 7. FIELD STRENGTH OF SPURIOUS RADIATION]



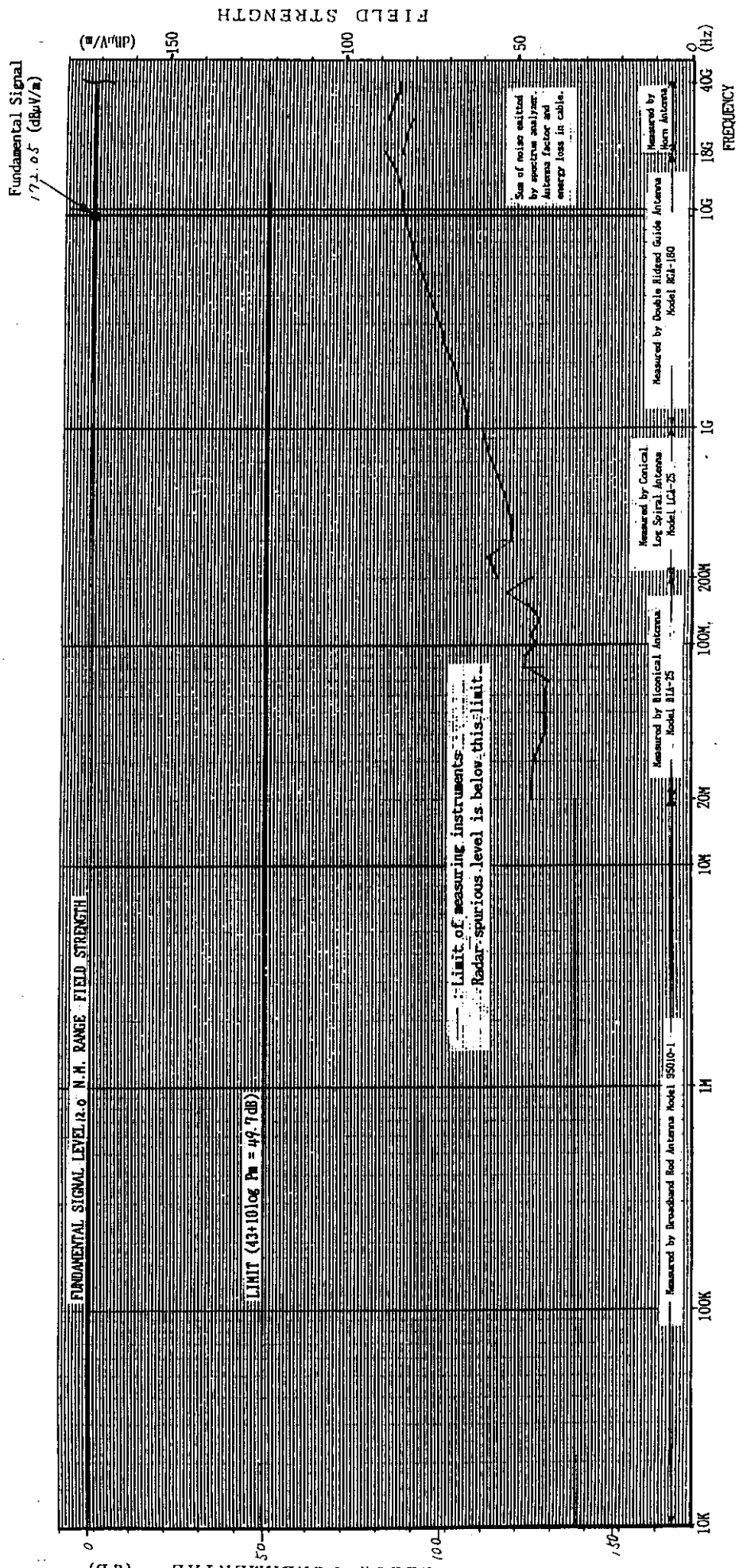
Graph 7 - 1 Field strength of spurious radiation measured with pick-up antenna (*short* range)



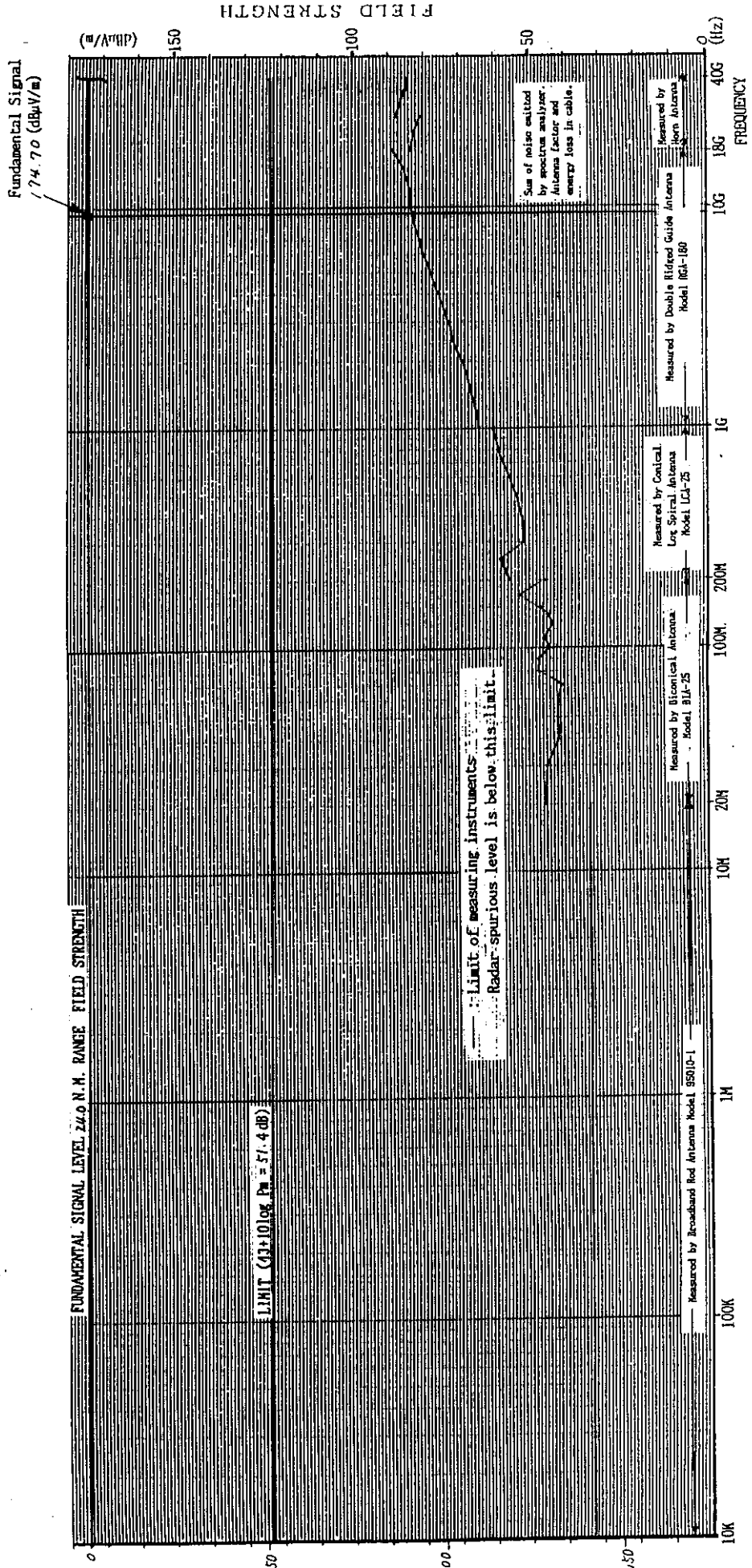
Graph 7 - 2 Field strength of spurious radiation measured with pick-up antenna (*short* ↓ range)



Graph 7 - 3 Field strength of spurious radiation measured with pick-up antenna (*Middle* range)

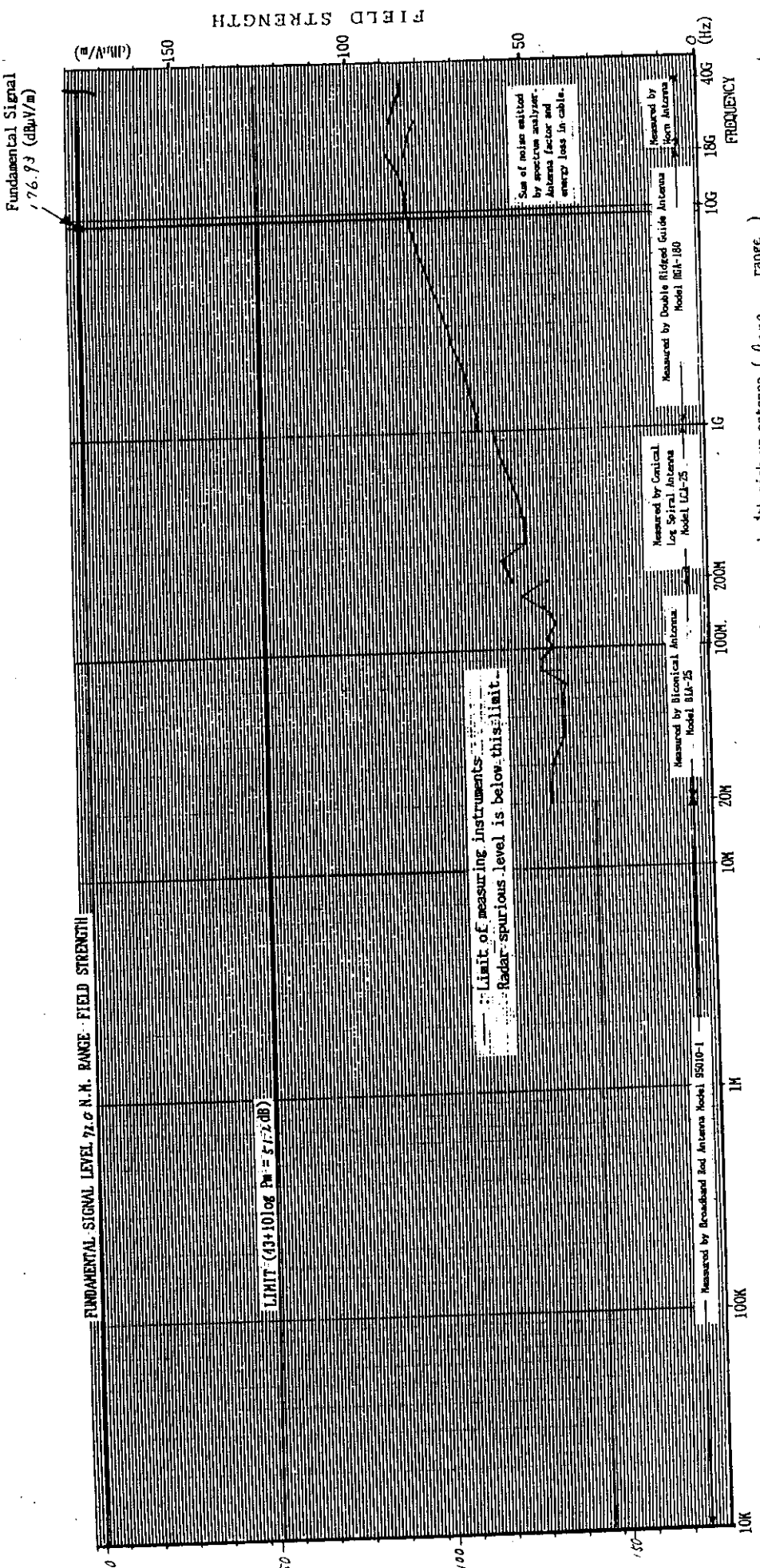


Graph 7 - 4 Field strength of spurious radiation measured with pick-up antenna (*Middle 2 range*)



Graph 7 - 3 Field strength of spurious radiation measured with pick-up antenna (*Middle* 3 range)

Pub. No. : TI-1691
Date : June, 1998



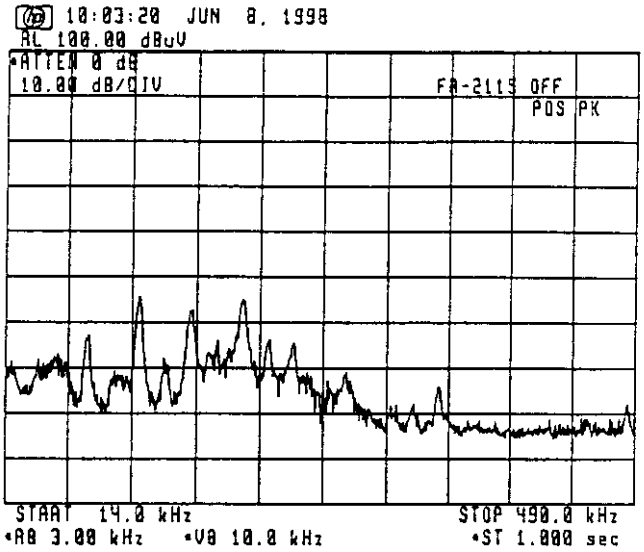
Graph 7 - 6 Field strength of spurious radiation measured with pick-up antenna (*Long* range)

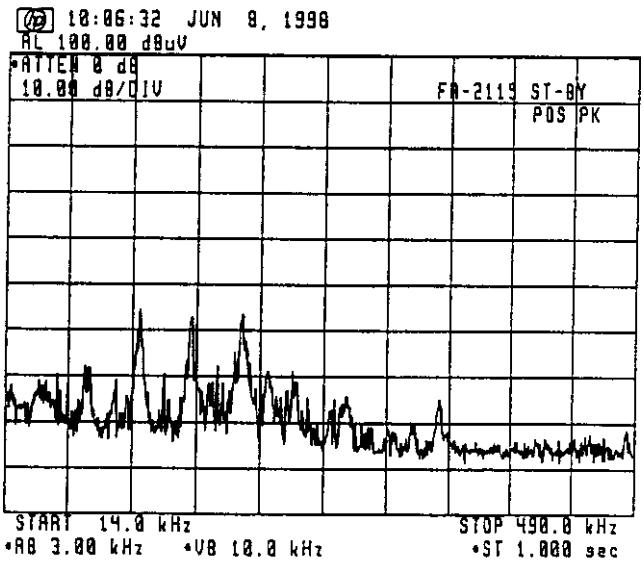
ATTACHMENT 3

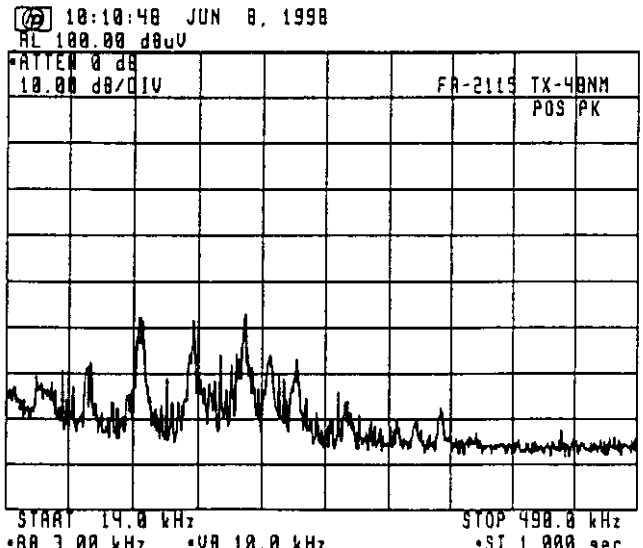
[TEST DATA FOR 9. SUPPRESSION OF INTERFERENCE ABOARD SHIP]

1. Harmful Interference to Receiver

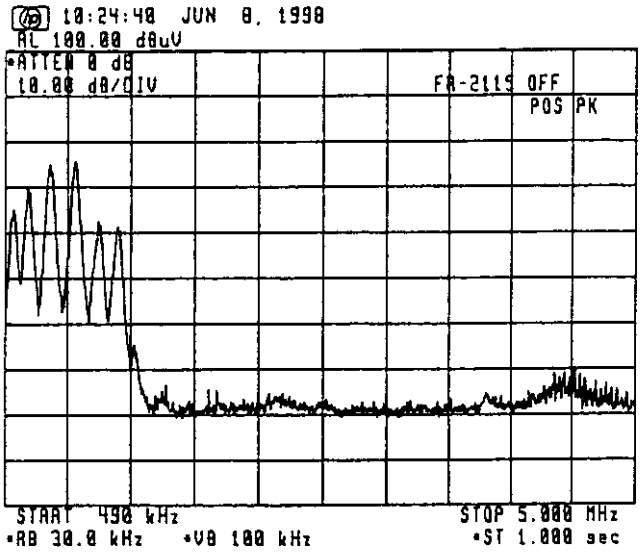
Band : 14 kHz ~ 490 kHz

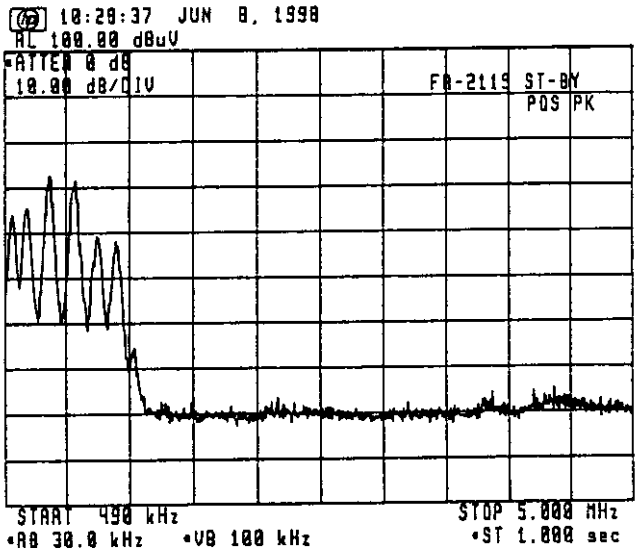


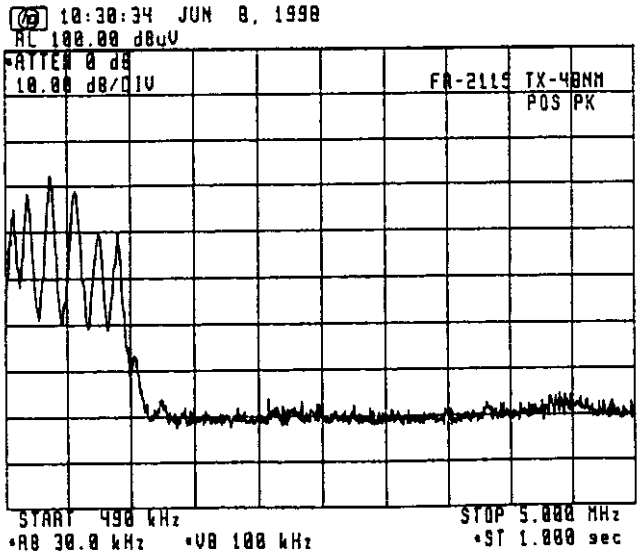




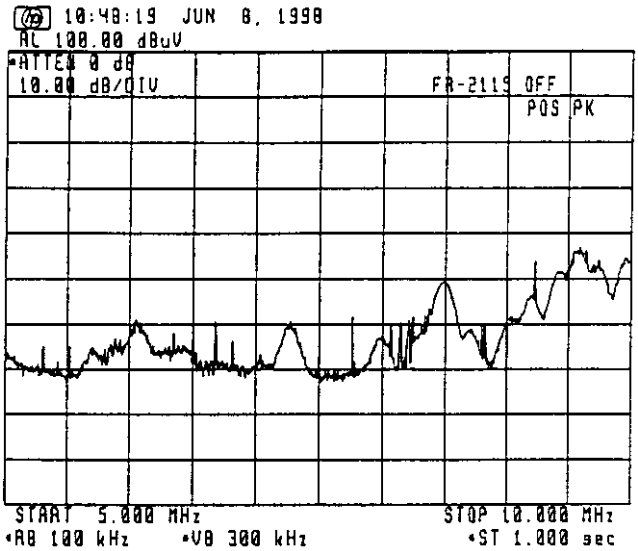
Band: 490kHz ~ 5MHz

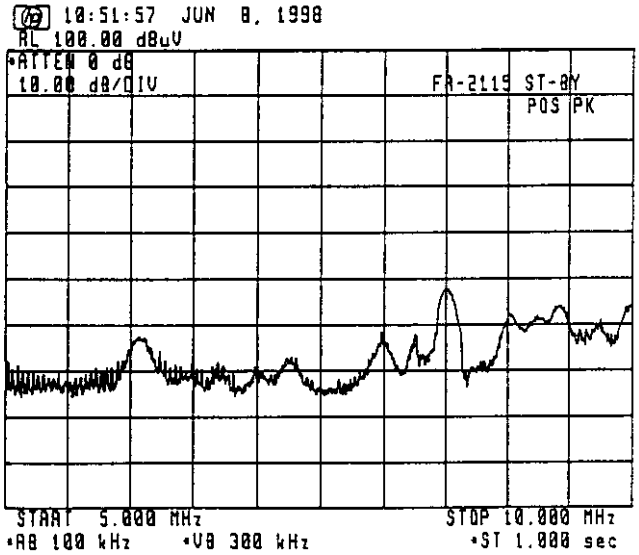


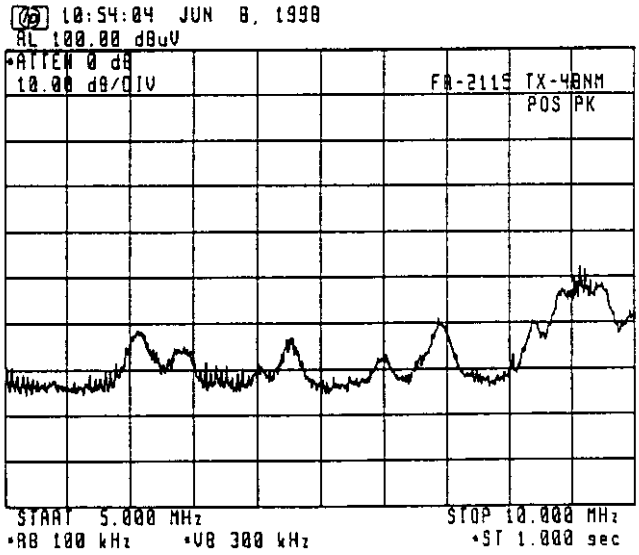




Band: 5MHz ~ 10MHz

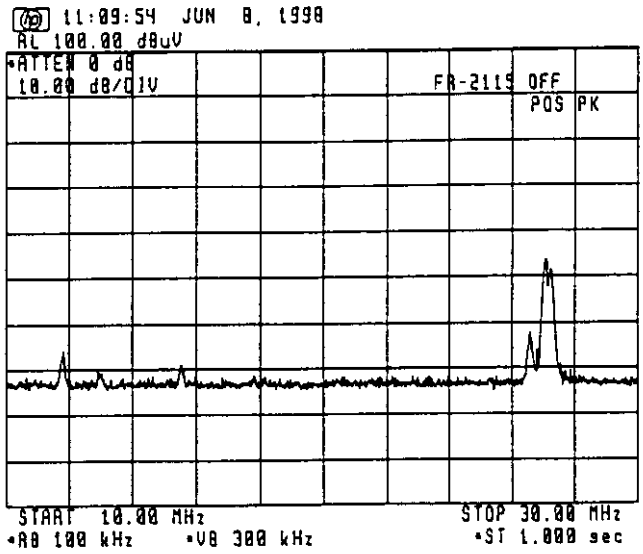


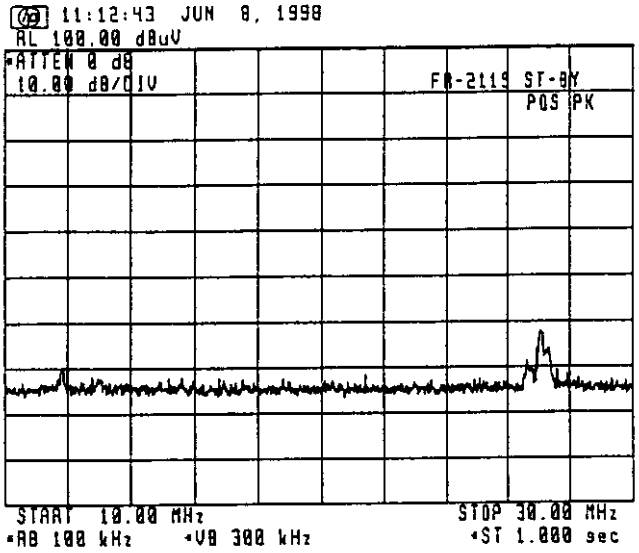


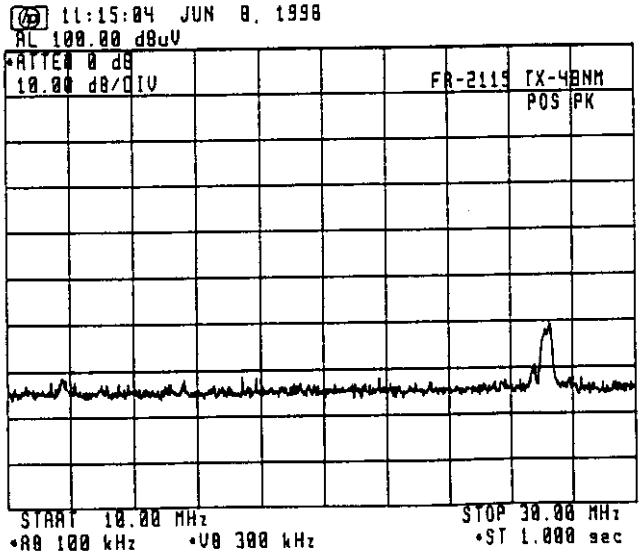


Pub. No. : TI-1691
Date : June, 1998

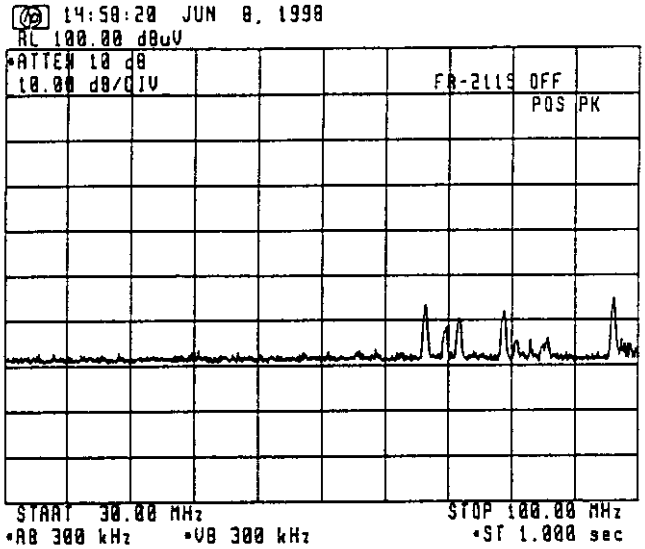
Band: 10MHz ~ 30MHz

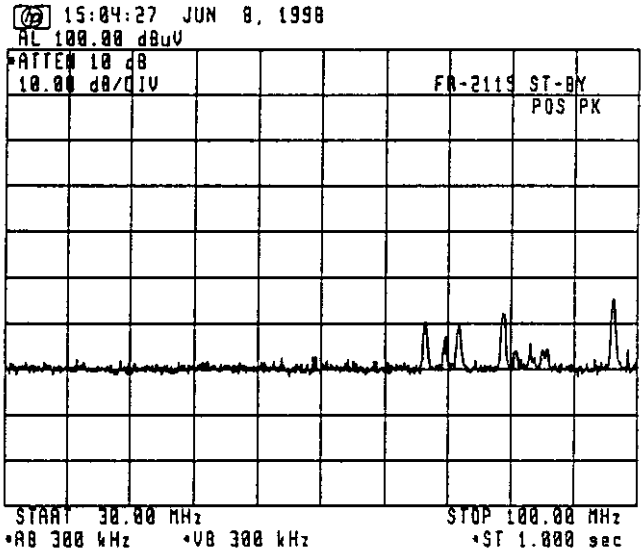


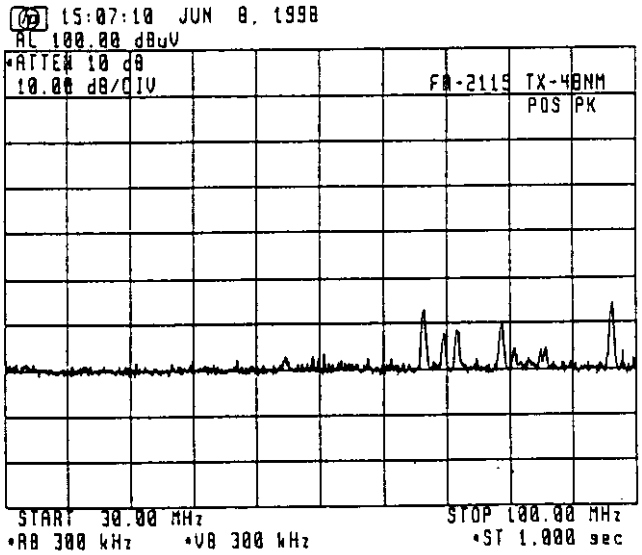




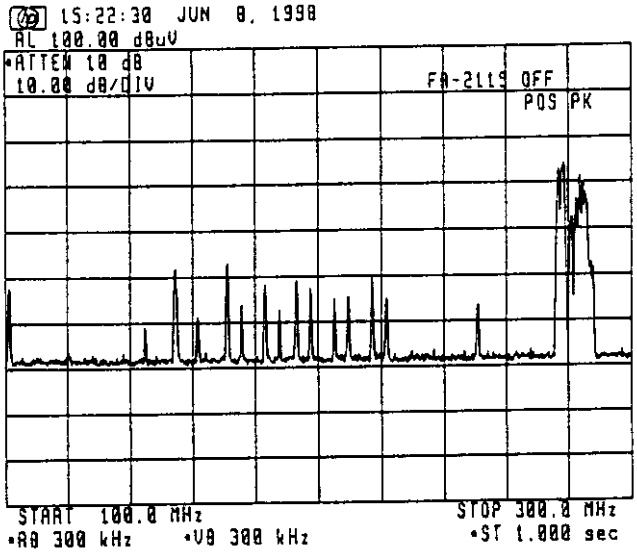
Band: 30MHz ~ 100MHz

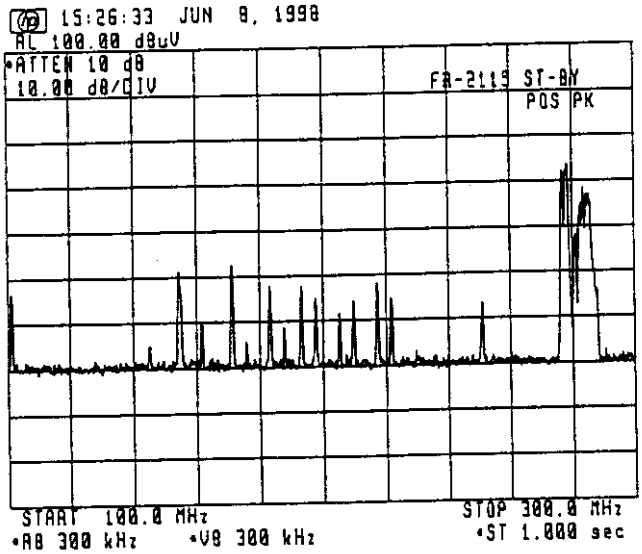


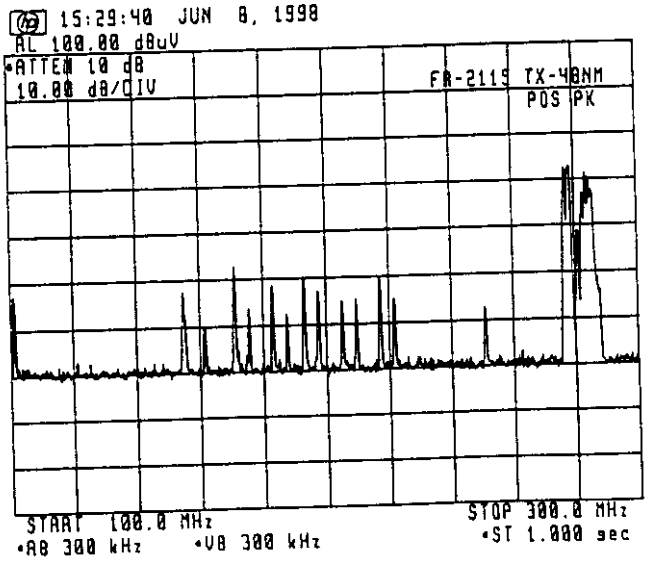




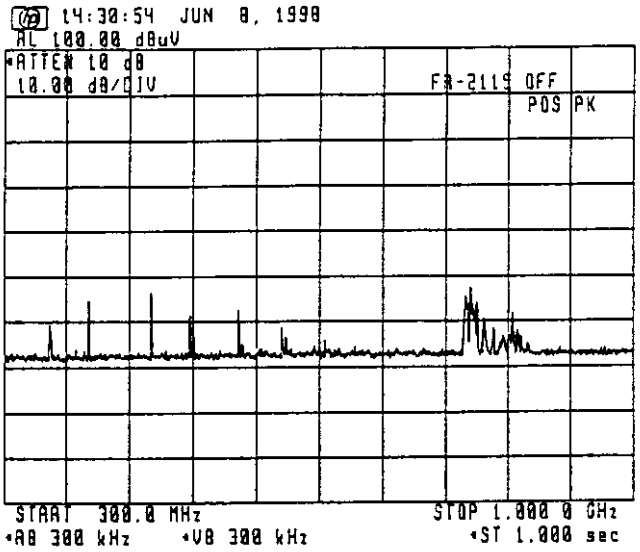
Band: 100MHz ~ 300MHz

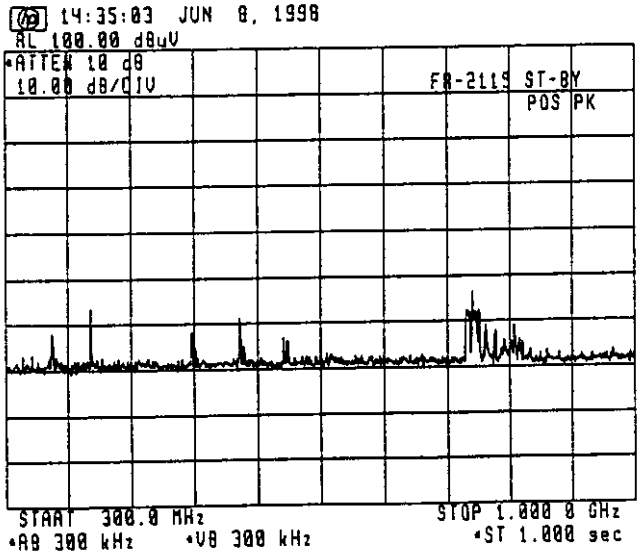


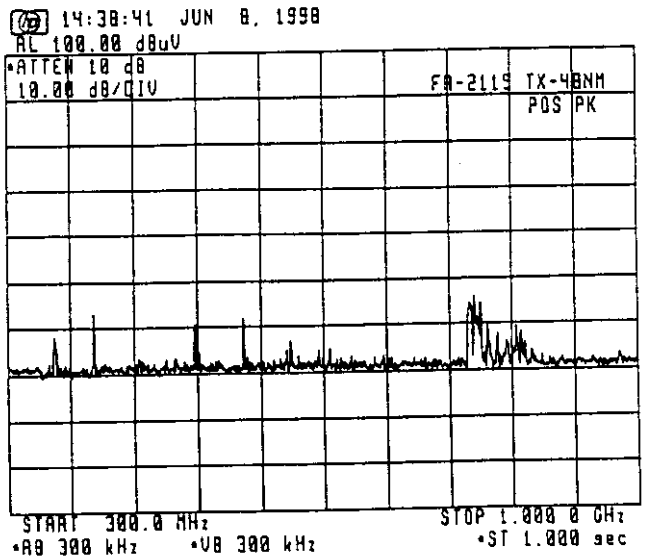




Band: 300MHz ~ 1GHz

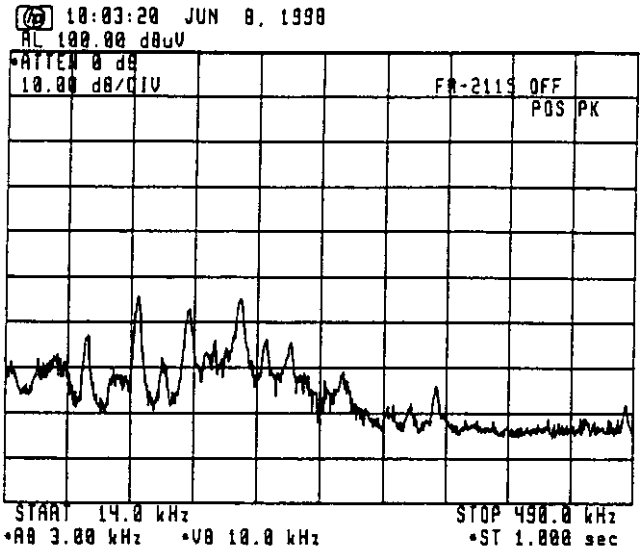


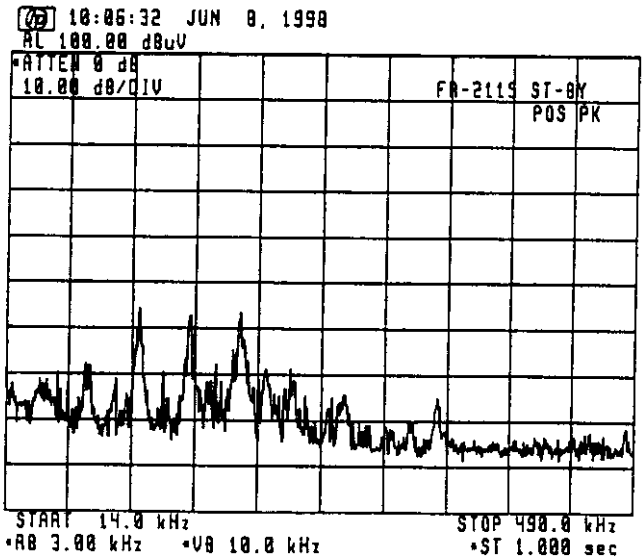




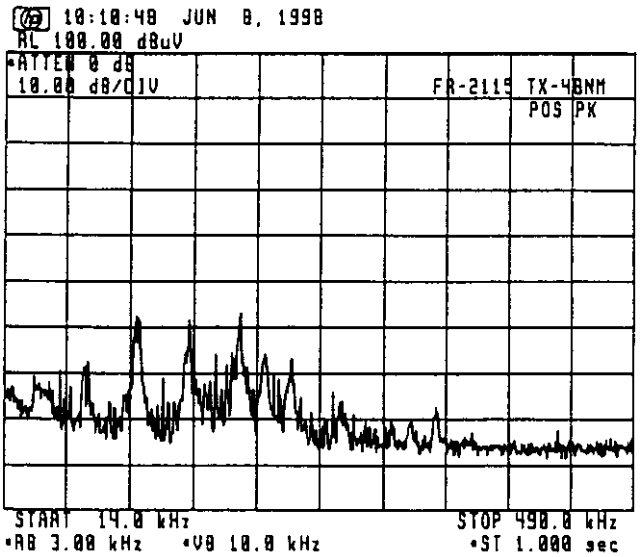
2. Electromagnetic Field

Band: 14kHz ~ 490kHz (Limit at 1 N.M. = 0.1μV/m = -20dBμV/m)



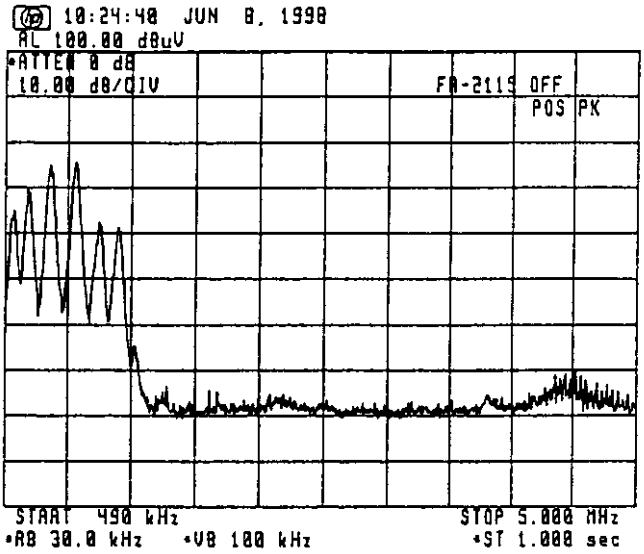


R.E.F
-26dBμV/m

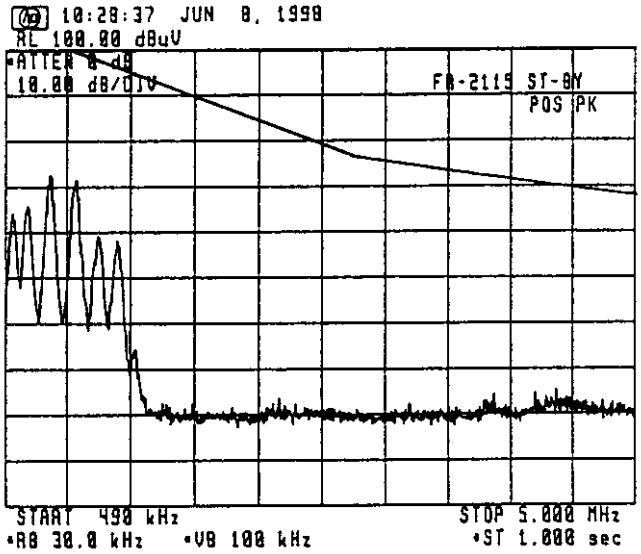


-26dBμV/m

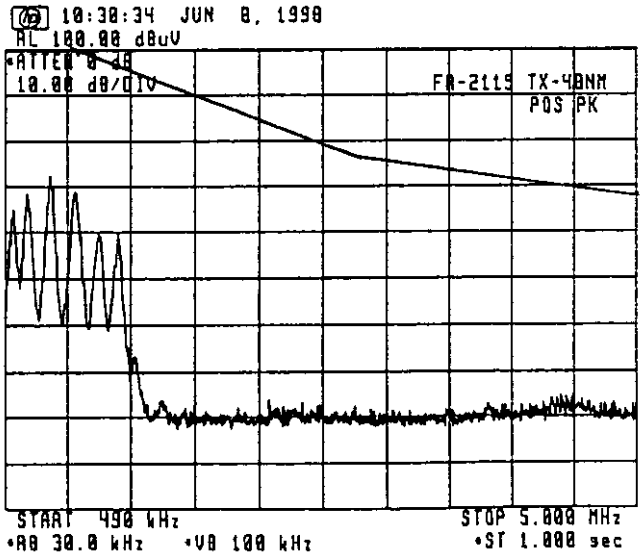
Band: 490kHz ~ 5MHz (Limit at 1 N.M. = 0.1μV/m = -20dBμV/m)



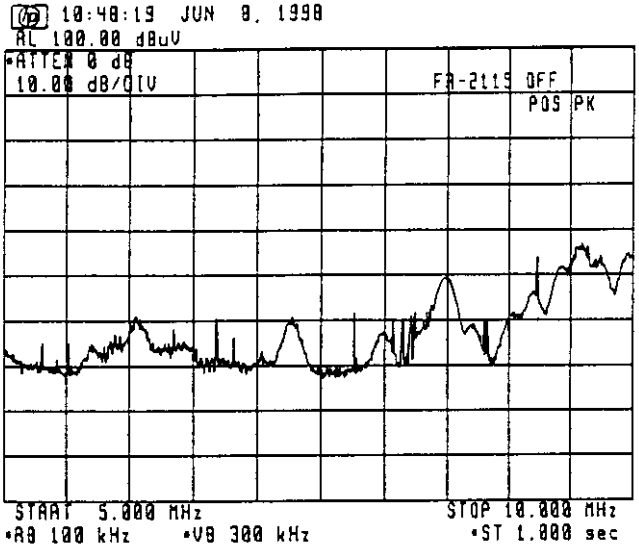
REF. (dBμV/m)
100 - 126 = -26 (0.5MHz)
100 - 96 = 4 (3MHz)
100 - 88 = 12 (5MHz)

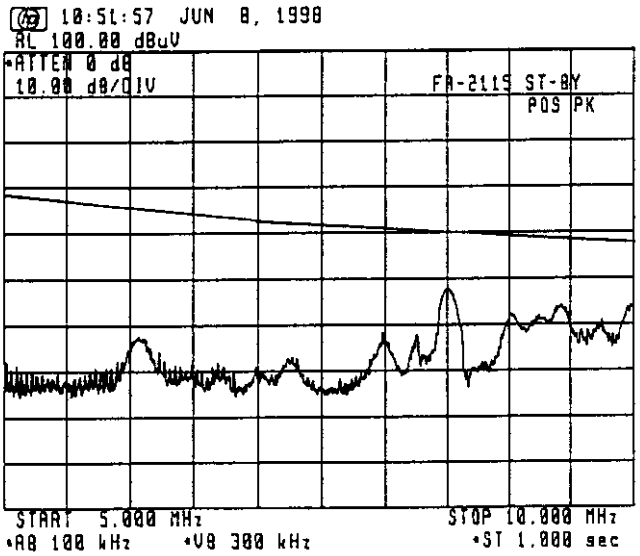


100 - 126 = -26 (0.5MHz)
100 - 96 = 4 (3MHz)
100 - 88 = 12 (5MHz)



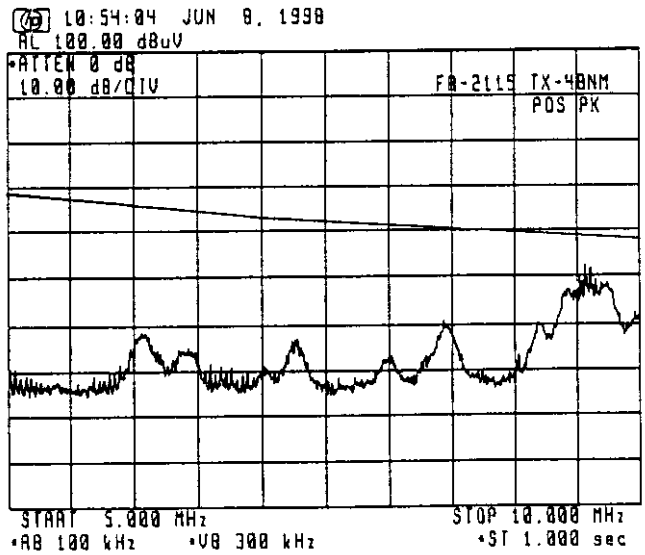
Band: 5MHz ~ 10MHz (Limit at 1N.M. = 0.1μV/m = -20dBμV/m)





REF. (dBμV/m)
100 - 88 = 12 (5MHz)
100 - 88 = 17 (7MHz)
100 - 78 = 22 (10MHz)

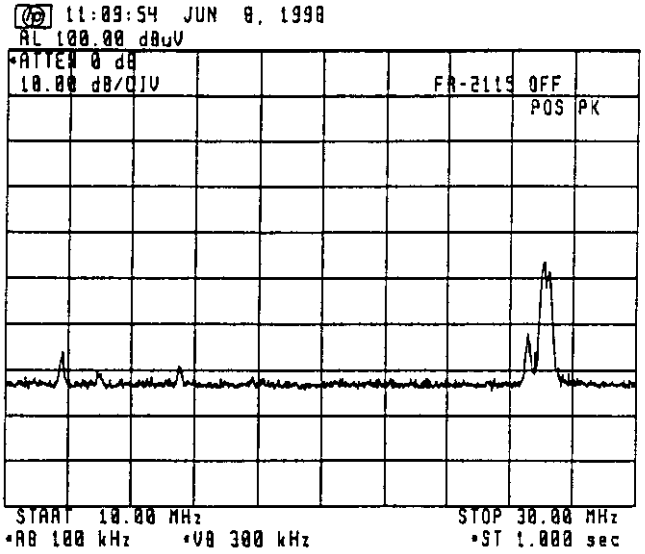
-20dBμV/m

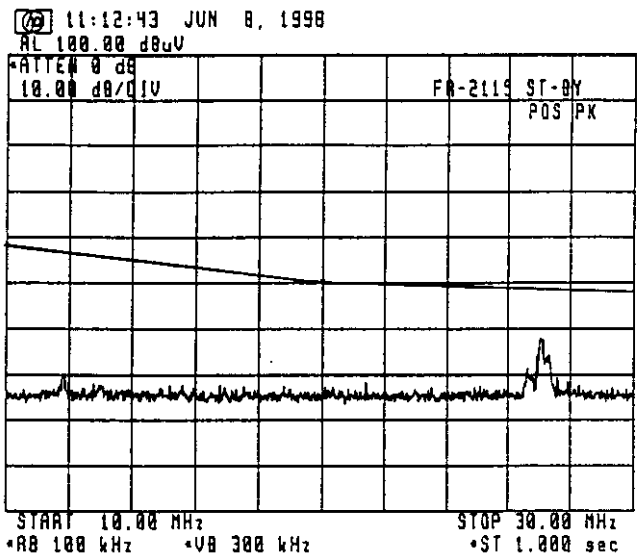


REF. (dBμV/m)
100 - 88 = 12 (5MHz)
100 - 88 = 17 (7MHz)
100 - 78 = 22 (10MHz)

-20dBμV/m

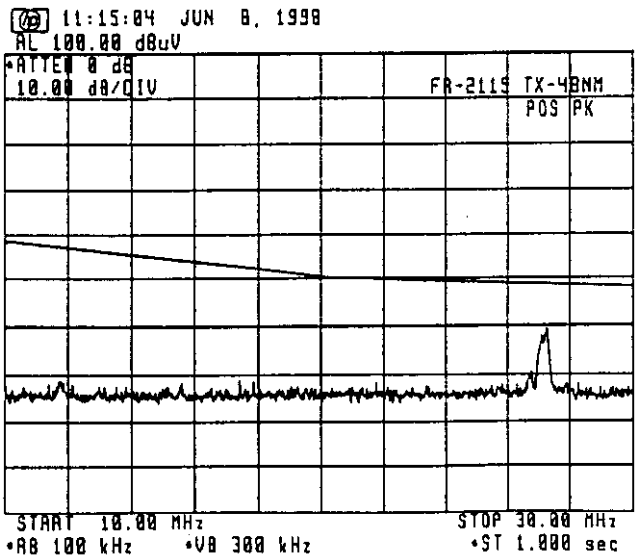
Band: 10MHz ~ 30MHz (Limit at 1N.M. = 0.1μV/m = -20 dBμV/m)





REF. (dBμV/m)
100 - 78 = 22 (10MHz)
100 - 70 = 30 (20MHz)
100 - 67 = 33 (30MHz)

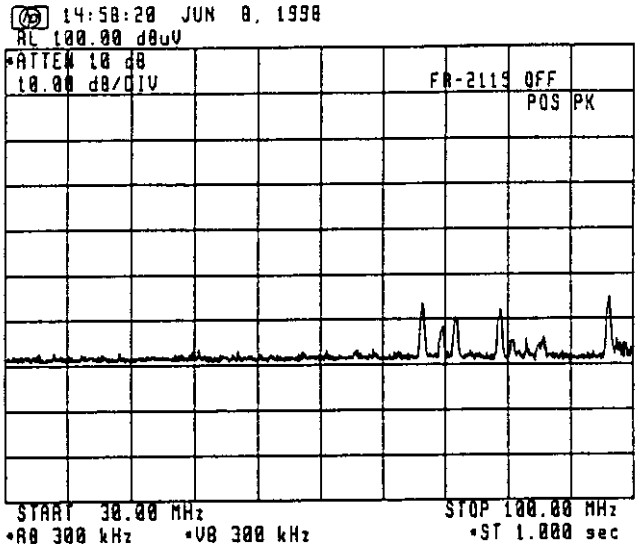
-20dBμV/m



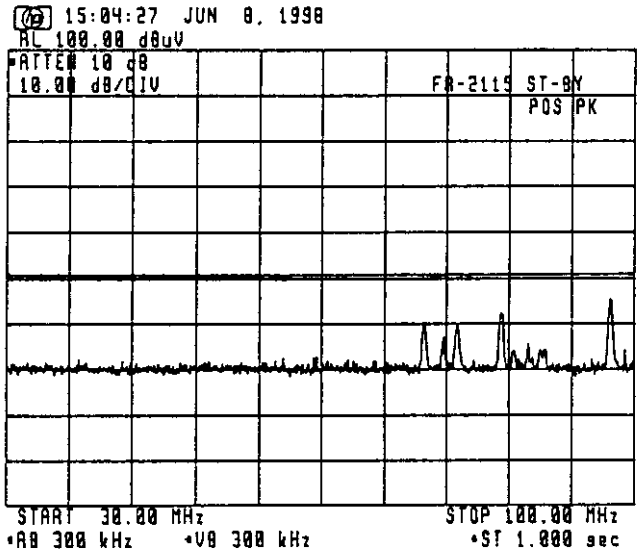
REF. (dBμV/m)
100 - 78 = 22 (10MHz)
100 - 70 = 30 (20MHz)
100 - 67 = 33 (30MHz)

-20dBμV/m

Band = 30MHz ~ 100MHz (Limit at 1N.M. = 0.3μV/m = -10.5dBμV/m)

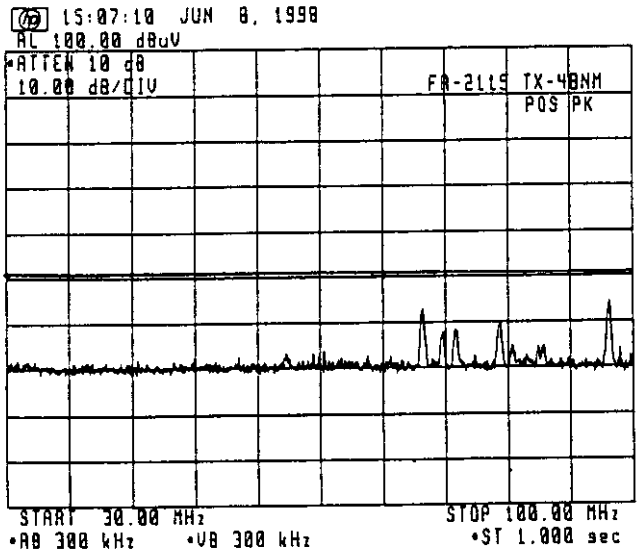


REF. (dBμV/m)
100 - 61 = 39



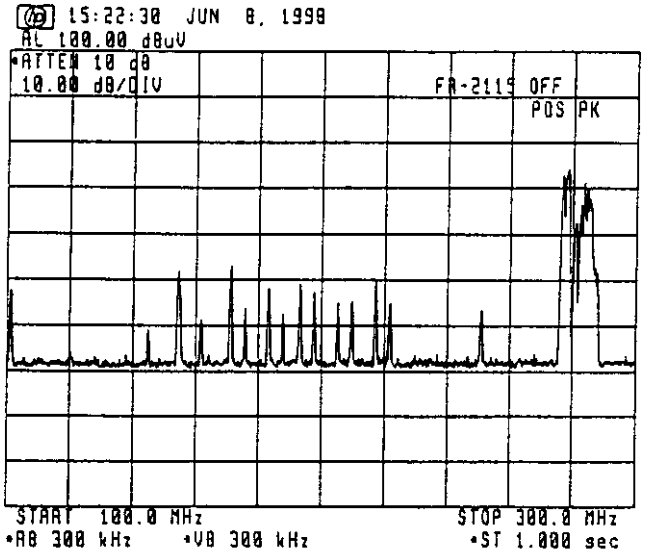
-10.5dBμV/m

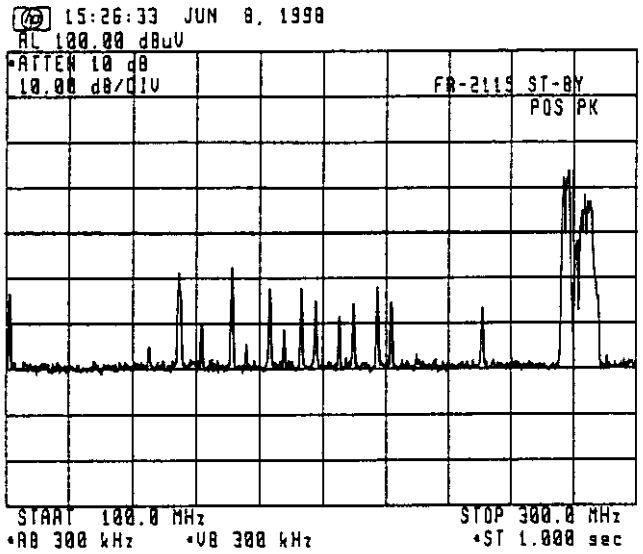
REF. (dBμV/m)
100 - 61 = 39



-10.5dBμV/m

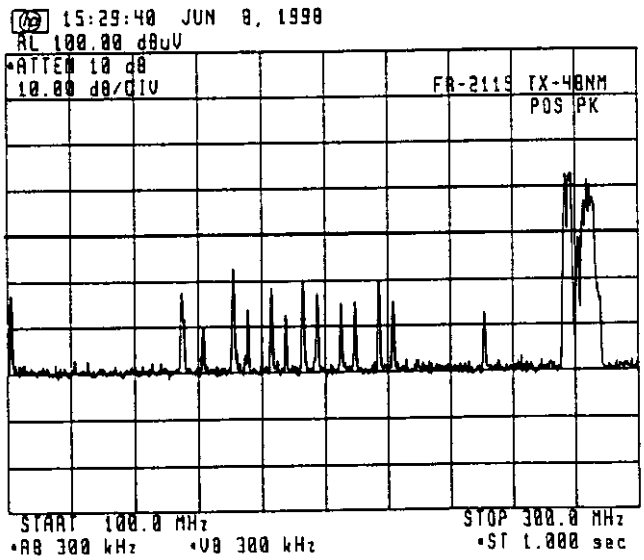
Band : 100MHz ~ 300MHz (Limit at 1N.M. = 1μV/m = 0dBμV/m)





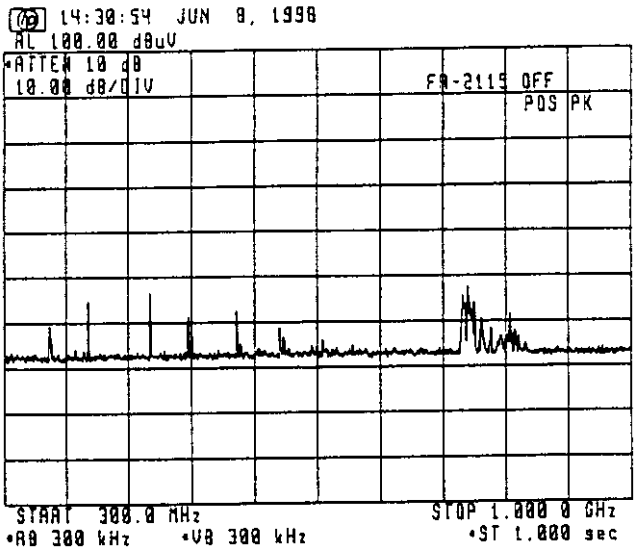
REF. (dBμV/m)
100-60=40

0dBμV/m
ALL COMPONENTS ABOVE THE LIMIT ARE FROM EXTERNAL NOISE OR SIGNALS, NOT FROM RADAR.

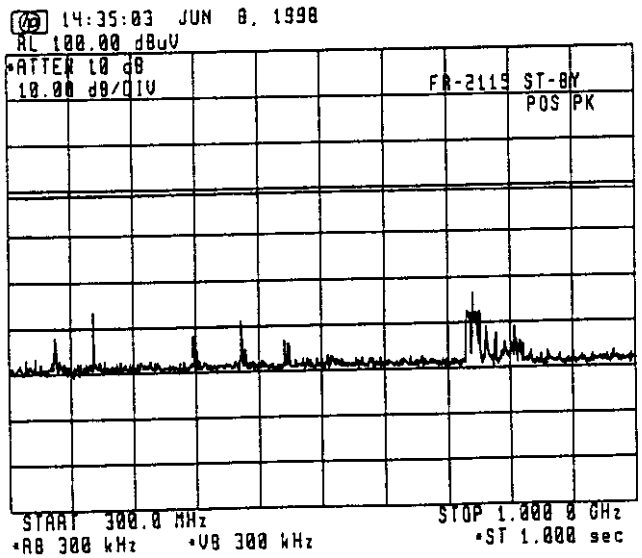


REF. (dBμV/m)
100-60=40

Band: 300MHz ~ 1GHz (Limit at 1N.M. = 3μV/m = 9.5 dBμV/m)

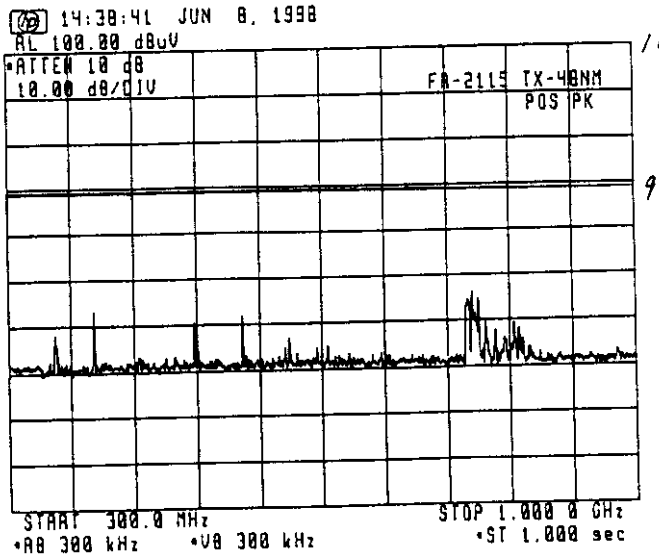


REF. (dBμV/m)
100 - 59.5 = 40.5



9.5 dBμV/m

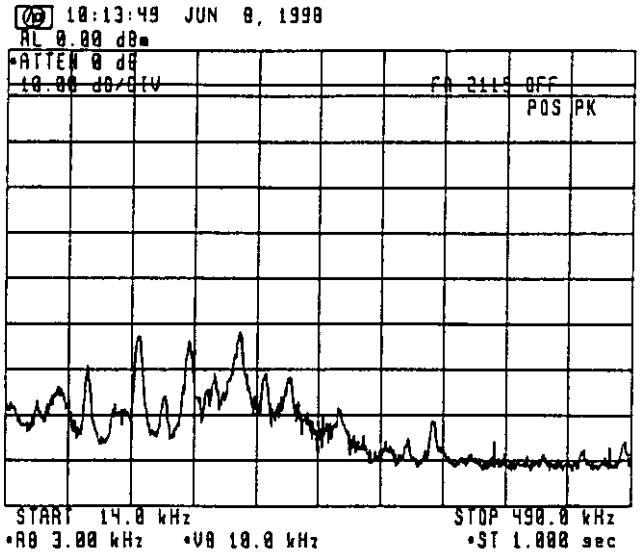
REF. (dBμV/m)
100 - 59.5 = 40.5

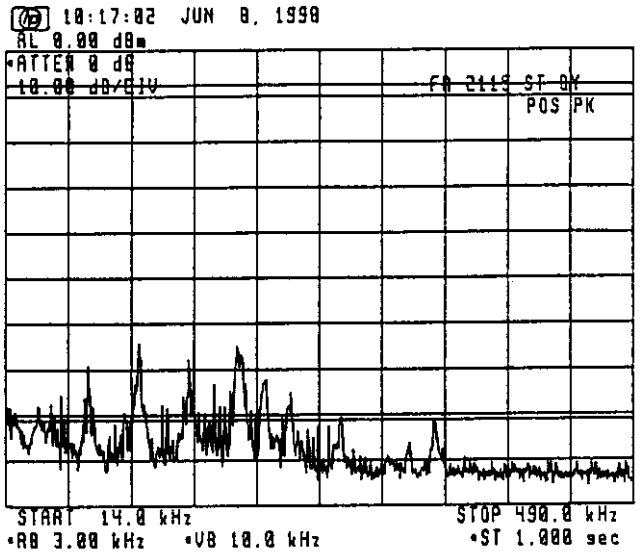


9.5 dBμV/m

3. Power Input to an Artificial Antenna

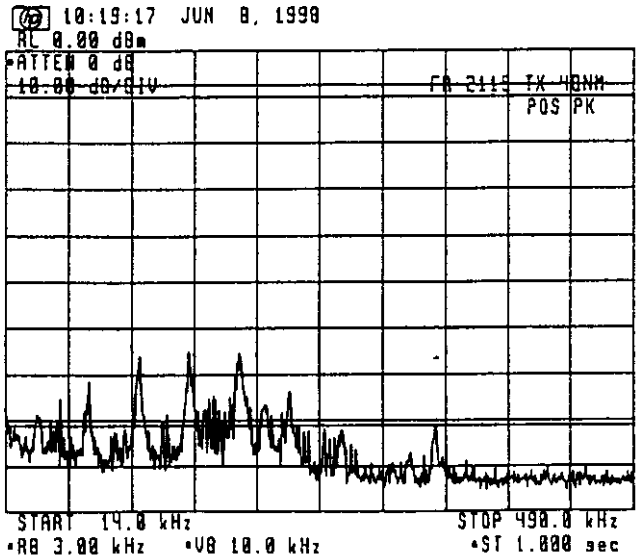
Band : 14kHz ~ 490kHz (Limit at 2 meter = -81dBm)





-81dBm

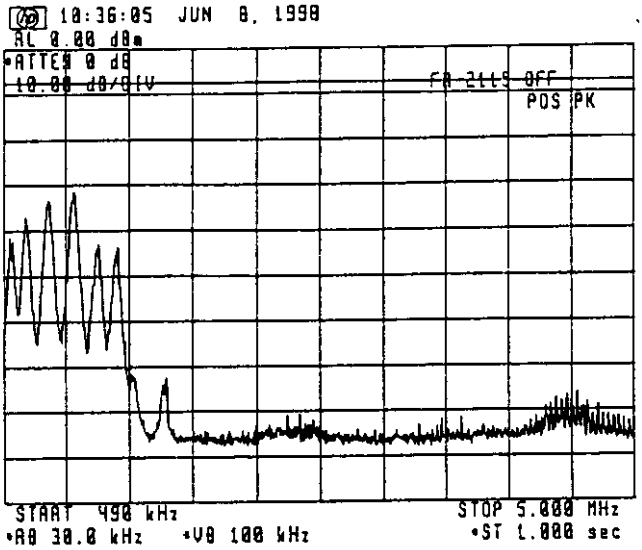
All components above the limit are from external noise or signals, not from Radar.

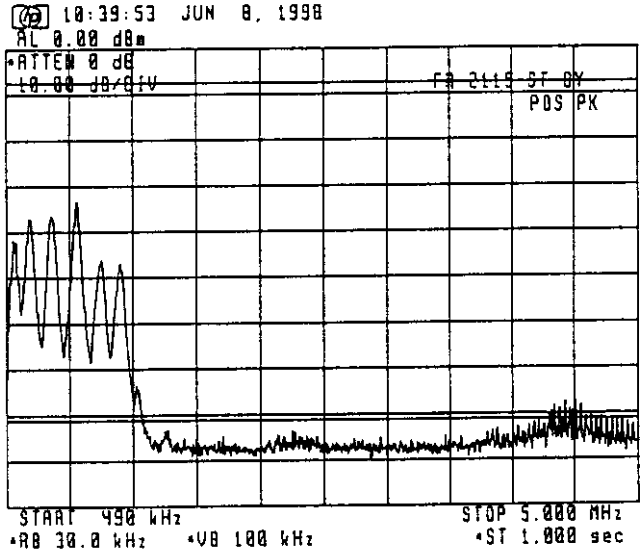


-81dBm

Pub. No. : TI-1691
Date : June, 1998

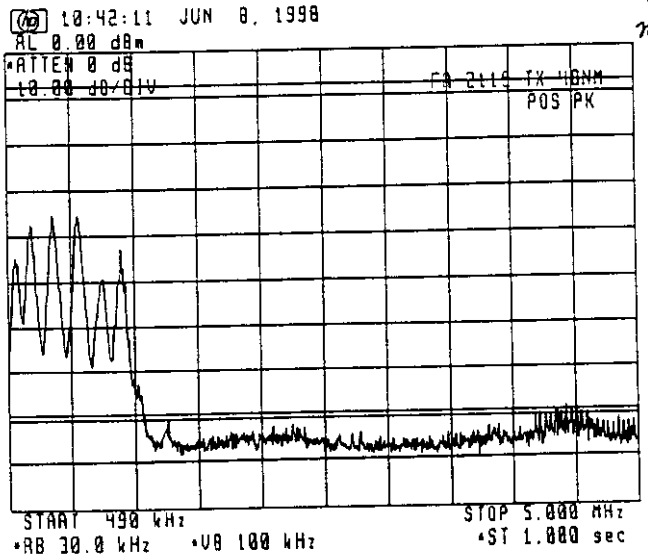
Band: 490kHz ~ 5MHz (Limit at 2meter = -81dBm)





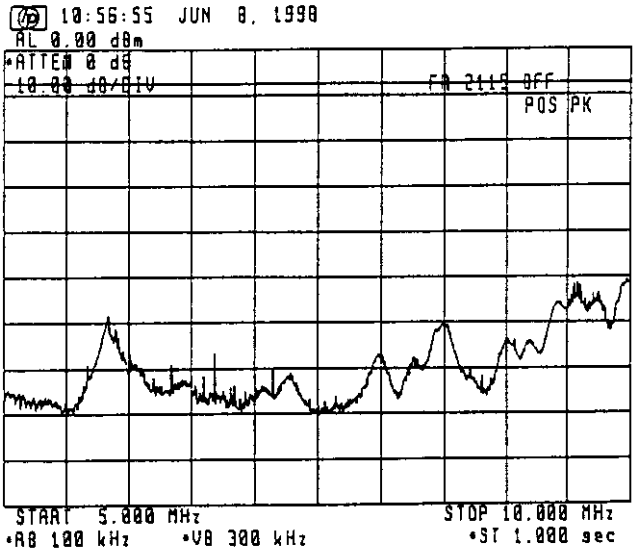
-81dBm

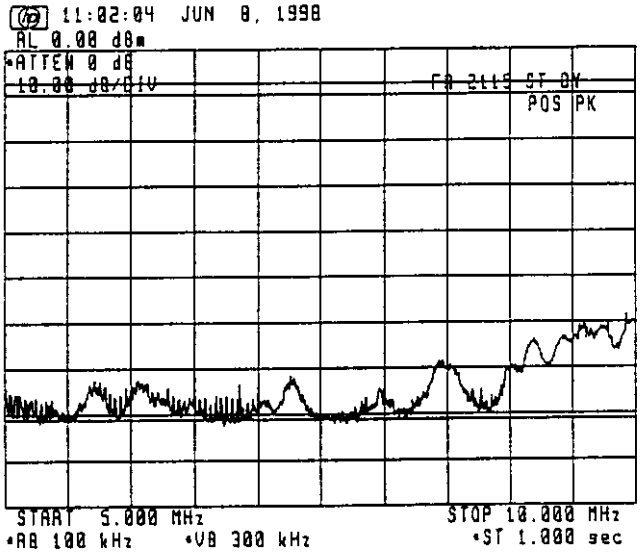
All components above the limit are from external noise or signals, not from Radar.



-81dBm

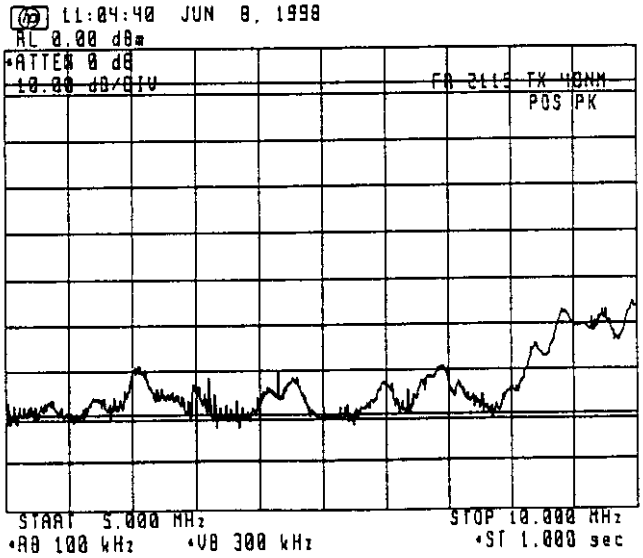
Band: 5MHz ~ 10MHz (Limit at 2meter = -81dBm)





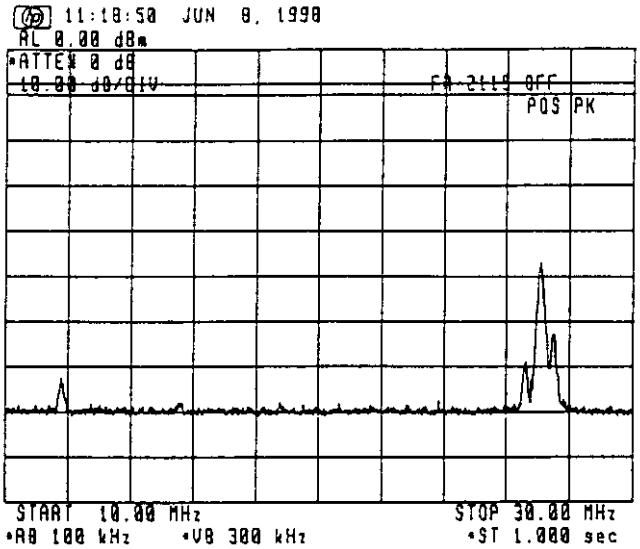
-81dBm

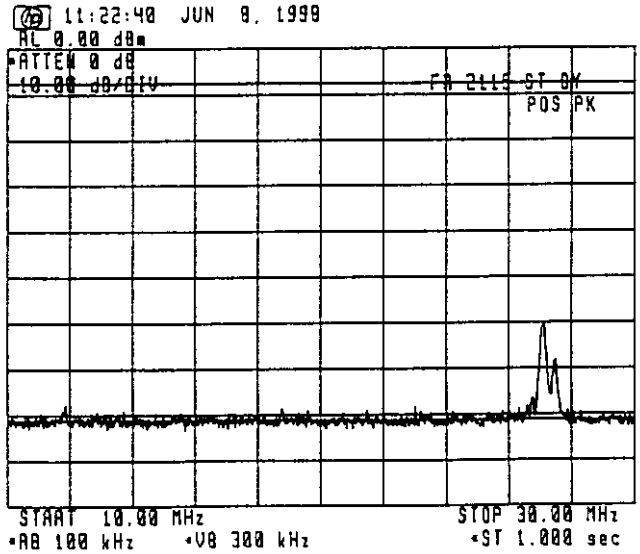
All components above the limit are from external noise or signals, not from Radar.



-81dBm

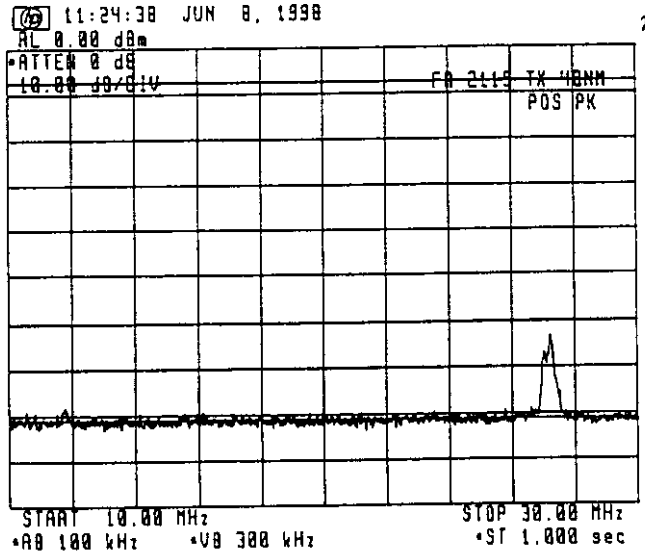
Band = 10MHz ~ 30MHz (Limit at 2meter = -81dBm)





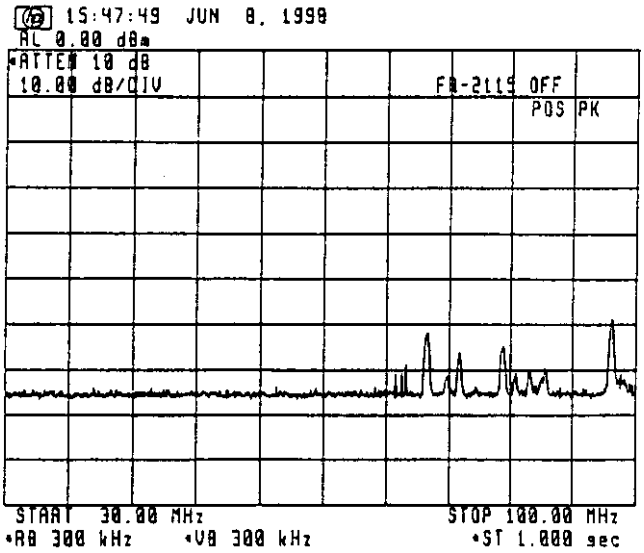
-81dBm

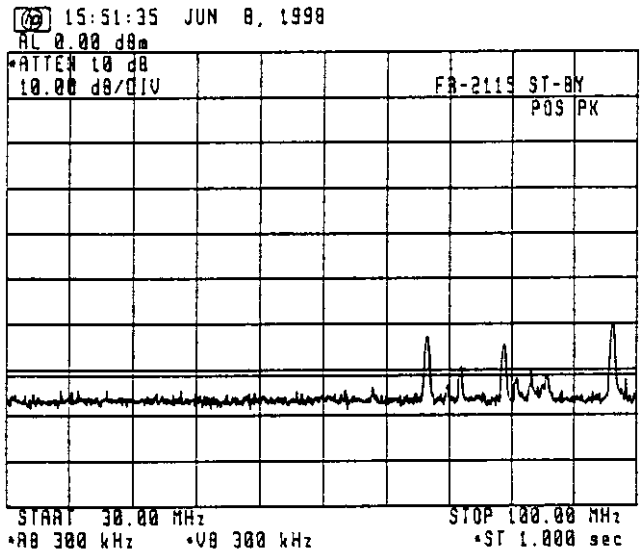
All components above the limit are from external noise or signals, not from Radar.



-81dBm

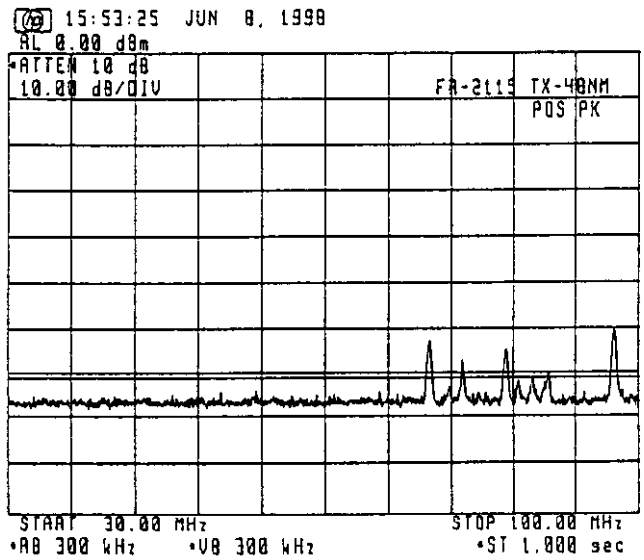
Band: 30MHz ~ 100MHz (Limit at 3meter = -71dBm)





-71dBm

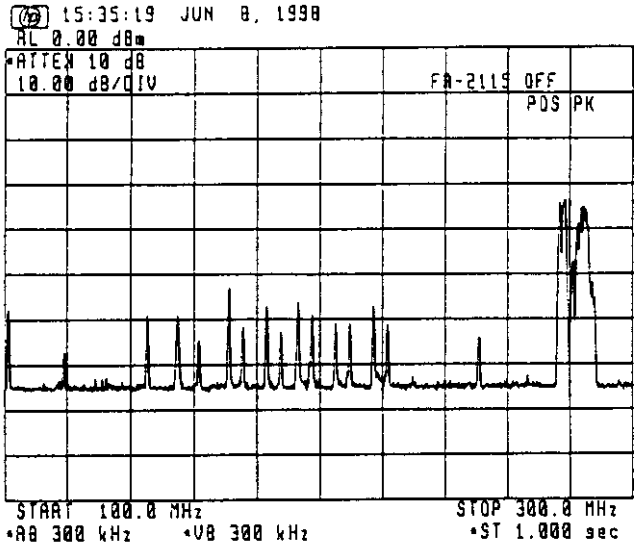
All components above the limit are from external noise or signals, not from Radar.

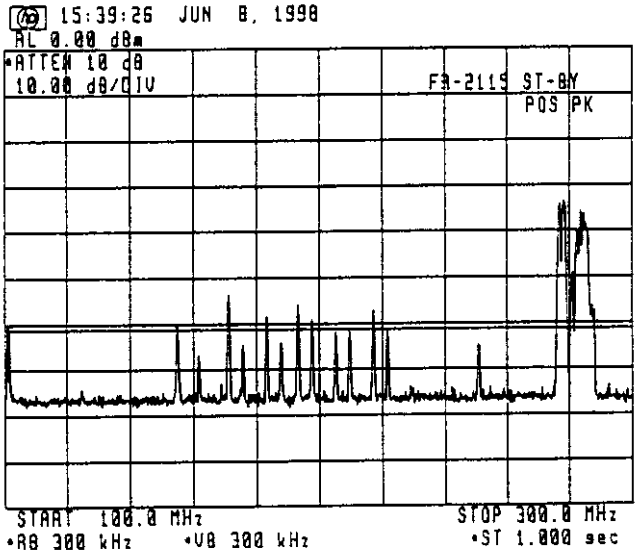


-71dBm

Pub. No. : TI-1691
Date : June, 1998

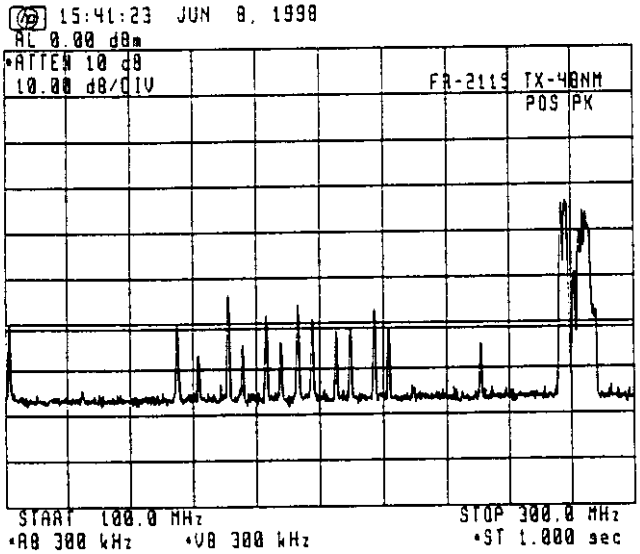
Band: 100MHz ~ 300MHz (Limit at 3meter = -61dBm)





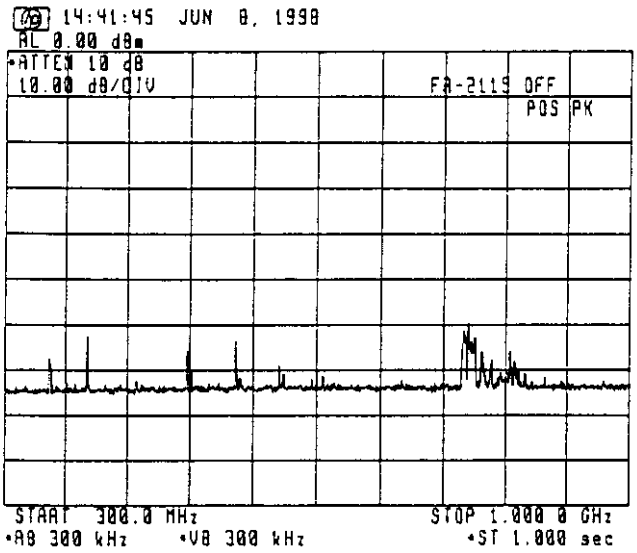
-61dBm

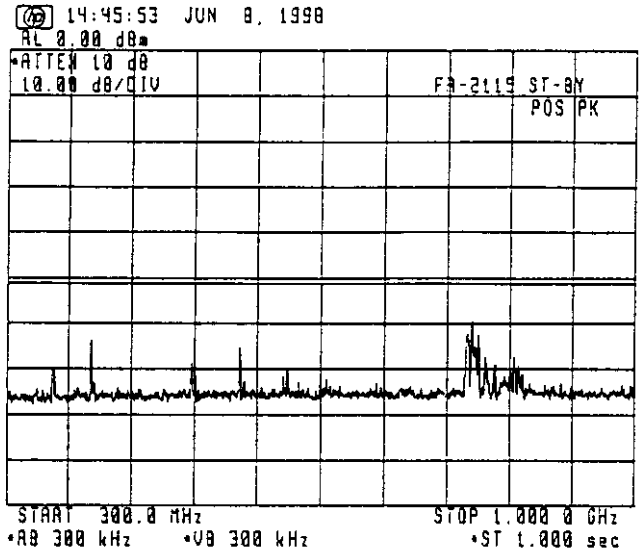
All components above the limit are from external noise or signals, not from Radar.



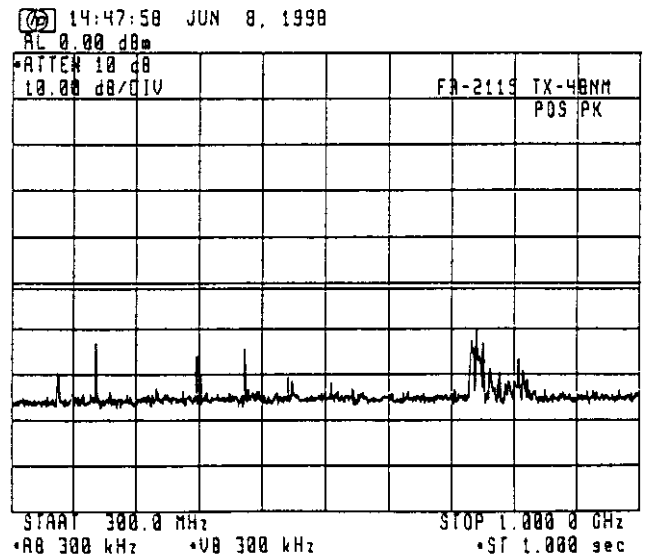
-61dBm

Band : 300MHz ~ 1GHz (Limit at 3meter = -51dBm)





-51dBm



-51dBm