Elliott

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Electromagnetic Emissions Test Report and Application for Grant of Equipment Authorization pursuant to FCC Part 15, Subpart C Specifications for an Intentional Radiator on the OTC Telecom, Inc. Model: Air EZY éLAN II

FCC ID: MKZAEZY2411BRG

GRANTEE: OTC Telecom, Inc.
2036 Bering Drive
San Jose, CA 95131

TEST SITE: Elliott Laboratories, Inc.
684 W. MaudeAvenue
Sunnyvale, CA 94086

REPORT DATE: May 11, 1998

FINAL TEST DATE: March 4 and April 16, 1998

TEST ENGINEER: Rudy Suy and Mehran M Birgani

AUTHORIZED SIGNATORY: David W Bare
David W. Bare
Principal Engineer

NVLAP

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SCOPE

An electromagnetic emissions test has been performed on the OTC Telecom Spread Spectrum radio system model Air EZY éLAN II pursuant to Subpart C of Part 15 of FCC Rules for intentional radiators. Conducted and radiated emissions data has been collected, reduced, and analyzed within this report in accordance with measurement guidelines set forth in ANSI C63.4-1992.

The intentional radiator above has been tested in a simulated typical installation to demonstrate compliance with the relevant FCC performance and procedural standards.

Final system data was gathered in a mode that tended to maximize emissions by varying orientation of EUT, orientation of power and I/O cabling, antenna search height, and antenna polarization.

Every practical effort was made to perform an impartial test using appropriate test equipment of known calibration. All pertinent factors have been applied to reach the determination of compliance.

The test results recorded herein are based on a single type test of the OTC Telecom model Air EZY éLAN II and therefore apply only to the tested sample. The sample was selected and prepared by Weiming Ou of OTC Telecom, Inc..

OBJECTIVE

The primary objective of the manufacturer is compliance with Subpart C of Part 15 of FCC Rules for the radiated and conducted emissions of intentional radiators. Certification of these devices is required as a prerequisite to marketing as defined in Part 2 the FCC Rules.

Certification is a procedure where the manufacturer or a contracted laboratory makes measurements and submits the test data and technical information to the FCC. The FCC issues a grant of equipment authorization upon successful completion of their review of the submitted documents. Once the equipment authorization has been obtained, the label indicating compliance must be attached to all identical units which are subsequently manufactured.

Maintenance of FCC compliance is the responsibility of the manufacturer. Any modification of the product which may result in increased emissions should be checked to ensure compliance has been maintained (i.e., printed circuit board layout changes, different line filter, different power supply, harnessing or I/O cable changes, etc.).

TEST SITE

GENERAL INFORMATION

Final test measurements were taken on March 4 and April 16, 1998 at the Elliott Laboratories Open Area Test Site located at 684 West Maude Avenue, Sunnyvale, California. Pursuant to section 2.948 of the Rules, construction, calibration, and equipment data has been filed with the Commission.

The FCC recommends that ambient noise at the test site be at least 6 dB below the allowable limits. Ambient levels are below this requirement with the exception of predictable local TV, radio, and mobile communications traffic. The test site contains separate areas for radiated and conducted emissions testing. Considerable engineering effort has been expended to ensure that the facilities conform to all pertinent FCC requirements.

CONDUCTED EMISSIONS CONSIDERATIONS

Conducted emissions testing is performed in conformance with ANSI C63.4-1992. Measurements are made with the EUT connected to the public power network through a nominal, standardized RF impedance, which is provided by a line impedance stabilization network, known as a LISN. A LISN is inserted in series with each current-carrying conductor in the EUT power cord.

RADIATED EMISSIONS CONSIDERATIONS

The FCC has determined that radiation measurements made in a shielded enclosure are not suitable for determining levels of radiated emissions. Radiated measurements are performed in an open field environment. The test site is maintained free of conductive objects within the CISPR defined elliptical area incorporated in ANSI C63.4 guidelines.

MEASUREMENT INSTRUMENTATION

RECEIVER SYSTEM

AN EMI receiver as specified in CISPR 16 is used for emissions measurements. The ESH3 receiver can measure over the frequency range of 9 kHz up to 2000 MHz. These receivers, allow both ease of measurement and high accuracy to be achieved. The receivers have Peak, Average, and CISPR (Quasi-peak) detectors built into their design so no external adapters are necessary. The receiver automatically sets the required bandwidth for the particular detector used during measurements.

For measurements above the frequency range of the receivers, a spectrum analyzer is utilized because it provides visibility of the entire spectrum along with the precision and versatility required to support engineering analysis. Average measurements above 1000MHz are performed on the spectrum analyzer using the linear-average method with a resolution bandwidth of 1 MHz and a video bandwidth of 10 Hz.

INSTRUMENT CONTROL COMPUTER

A Rohde and Schwarz EZM Spectrum Monitor/Controller is utilized to convert the receiver measurements to the field strength at the antenna, which is then compared directly with the appropriate specification limit. This provides faster, more accurate readings by performing the conversions described under Sample Calculations within the Test Procedures section of this report. Results are printed in a graphic and/or tabular format, as appropriate.

The EZM provides a visual display of the signal being measured. In addition, the EZM Spectrum Monitor runs the automated data collection programs which control both receivers. This provides added accuracy since all site correction factors, such as cable loss and antenna factors, are added automatically.

LINE IMPEDANCE STABILIZATION NETWORK (LISN)

Line conducted measurements utilize a fifty microhenry Line Impedance Stabilization Network as the monitoring point. The 50 uH LISNs used were manufactured by Fischer Custom Communications, model LISN-3 in combination with a 250 uH Fischer Custom Communications LISN-3 CISPR adapter. This network provides for calibrated radio frequency noise measurements by the design of the internal low pass and high pass filters on the EUT and measurement ports, respectively.

POWER METER

A power meter and thermister mount are used for all output power measurements from transmitters as they provides a broadband indication of the power output. The power meter used was the Hewlett Packard model 432A, S/N 992-05509 and the thermister mount was the Hewlett Packard model 478A, S/N 46397.

FILTERS/ATTENUATORS

External filters and precision attenuators are often connected between the receiving antenna or LISN and the receiver. This eliminates saturation effects and non-linear operation due to high amplitude transient events.

ANTENNAS

A biconical antenna is used to cover the range from 30 MHz to 300 MHz and a log periodic antenna is utilized from 300 MHz to 1000 MHz. Narrowband tuned dipole antennas are used over the 30 to 1000 MHz range for precision measurements of field strength. Above 1000 MHz, a horn antenna is used.

The antenna calibration factors are included in site factors which are programmed into the test receivers

ANTENNA MAST AND EQUIPMENT TURNTABLE

The antennas used to measure the radiated electric field strength are mounted on a non-conductive antenna mast equipped with a motor-drive to vary the antenna height.

ANSI C63.4 specifies that the test height above ground for table mounted devices shall be 80 centimeters. Floor mounted equipment shall be placed on the ground plane if the device is normally used on a conductive floor or separated from the ground plane by insulating material from 3 to 12 mm if the device is normally used on a non-conductive floor. During radiated measurements, the EUT is positioned on a motorized turntable in conformance with this requirement.

INSTRUMENT CALIBRATION

All test equipment is regularly checked to ensure that performance is maintained in accordance with the manufacturer's specifications. All antennas are calibrated at regular intervals with respect to tuned half-wave dipoles. An appendix of this report contains the list of test equipment used and calibration information.

TEST PROCEDURES

EUT AND CABLE PLACEMENT

The FCC requires that interconnecting cables be connected to the available ports of the unit and that the placement of the unit and the attached cables simulate the worst case orientation that can be expected from a typical installation, so far as practicable. To this end, the position of the unit and associated cabling is varied within the guidelines of ANSI C63.4, and the worst case orientation is used for final measurements.

CONDUCTED EMISSIONS

Conducted emissions are measured at the plug end of the power cord supplied with the EUT. Excess power cord length is wrapped in a bundle between 30 and 40 centimeters in length near the center of the cord. Preliminary measurements are made to determine the highest amplitude emission relative to the specification limit for all the modes of operation. Placement of system components and varying of cable positions are performed in each mode. A final peak mode scan is then performed in the position and mode for which the highest emission was noted on all current carrying conductors of the power cord.

RADIATED EMISSIONS

Radiated emissions measurements are performed in two phases as well. A preliminary scan of emissions is conducted in which all significant EUT frequencies are identified with the system in a nominal configuration. At least two scans are performed from 30 to 1000 MHz. One or more of these is with the antenna polarized vertically while the one or more of these is with the antenna polarized horizontally. During the preliminary scans, the EUT is rotated through 360°, the antenna height is varied and cable positions are varied to determine the highest emission relative to the limit.

A speaker is provided in the receiver to aid in discriminating between EUT and ambient emissions. Other methods used during the preliminary scan for EUT emissions involve scanning with near field magnetic loops, monitoring I/O cables with RF current clamps, and cycling power to the EUT.

Final maximization is a phase in which the highest amplitude emissions identified in the spectral search are viewed while the EUT azimuth angle is varied from 0 to 360 degrees relative to the receiving antenna. The azimuth which results in the highest emission is then maintained while varying the antenna height from one to four meters. The result is the identification of the highest amplitude for each of the highest peaks. Each recorded level is corrected in the receiver using appropriate factors for cables, connectors, antennas, and preamplifier gain. Emissions which have values close to the specification limit may also be measured with a tuned dipole antenna to determine compliance.

DIRECT MEASUREMENTS OF EMISSIONS FROM THE ANTENNA PORT

Direct measurements are performed with the antenna port of the EUT connected to either the power meter or spectrum analyzer via a suitable attenuator and/or filter. These are used to ensure that the front end of the measurement instrument is not overloaded by the fundamental transmission.

SPECIFICATION LIMITS AND SAMPLE CALCULATIONS

The limits for conducted emissions are given in units of microvolts, and the limits for radiated emissions are given in units of microvolts per meter at a specified test distance. Data is measured in the logarithmic form of decibels relative to one microvolt, or dB microvolts (dBuV). For radiated emissions, the measured data is converted to the field strength at the antenna in dB microvolts per meter (dBuV/m). The results are then converted to the linear forms of uV and uV/m for comparison to published specifications.

For reference, converting the specification limits from linear to decibel form is accomplished by taking the base ten logarithm, then multiplying by 20. These limits in both linear and logarithmic form are as follows:

CONDUCTED EMISSIONS SPECIFICATION LIMITS

Frequency Range (MHz)	Limit (uV)	Limit (dBuV)
0.450 to 30.000	250	48

RADIATED EMISSIONS SPECIFICATION LIMITS

Frequency Range (MHz)	Limit (uV/m @ 3m)	Limit (dBuV/m @ 3m)
0.009-0.490	$2400/F_{KHz}$ @ 300m	$67.6-20*\log_{10}(F_{KHz})$ @ 300m
0.490-1.705	$24000/F_{KHz}$ @ 30m	$87.6-20*\log_{10}(F_{KHz})$ @ 30m
1.705 to 30	30 @ 30m	29.5 @ 30m
30 to 88	100	40
88 to 216	150	43.5
216 to 960	200	46.0
Above 960	500	54.0

SAMPLE CALCULATIONS - CONDUCTED EMISSIONS

Receiver readings are compared directly to the conducted emissions specification limit (decibel form) as follows:

$$R_r - B = C$$

and

$$C - S = M$$

where:

R_r = Receiver Reading in dBuV

B = Broadband Correction Factor*

C = Corrected Reading in dBuV

S = Specification Limit in dBuV

M = Margin to Specification in +/- dB

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* Broadband Level - Per ANSI C63.4, 13 dB may be subtracted from the quasi-peak level if it is determined that the emission is broadband in nature. If the signal level in the average mode is six dB or more below the signal level in the peak mode, the emission is classified as broadband.

SAMPLE CALCULATIONS - RADIATED EMISSIONS

Receiver readings are compared directly to the specification limit (decibel form). The receiver internally corrects for cable loss, preamplifier gain, and antenna factor. The calculations are in the reverse direction of the actual signal flow, thus cable loss is added and the amplifier gain is subtracted. The Antenna Factor converts the voltage at the antenna coaxial connector to the field strength at the antenna elements. A distance factor, when used for electric field measurements, is calculated by using the following formula:

$$F_d = 20*LOG_{10}(D_m/D_s)$$

where:

F_d = Distance Factor in dB

D_m = Measurement Distance in meters

D_s = Specification Distance in meters

Measurement Distance is the distance at which the measurements were taken and Specification Distance is the distance at which the specification limits are based. The antenna factor converts the voltage at the antenna coaxial connector to the field strength at the antenna elements.

The margin of a given emission peak relative to the limit is calculated as follows:

$$R_c = R_r + F_d$$

and

$$M = R_c - L_s$$

where:

R_r = Receiver Reading in dBuV/m

F_d = Distance Factor in dB

R_c = Corrected Reading in dBuV/m

L_s = Specification Limit in dBuV/m

M = Margin in dB Relative to Spec

EQUIPMENT UNDER TEST (EUT) DETAILS

GENERAL

The OTC Telecom model Air EZY éLAN II is a Spread Spectrum radio system which utilises direct sequence and is designed to use the 1 channel at 2443 MHz in the allocated frequency band of 2400-2483.5 MHz. Normally, the EUT would attach to a personal computer ethernet port. The sample was received on March 4, 1998 and tested on March 4 and April 16, 1998. The EUT consisted of the following component(s):

Manufacturer/Model/Description	Serial #	FCC ID #
OTC Telecom AirEzy 2400 éLAN Bridge	241650	MKZAEZY2411BRG

ENCLOSURE

The EUT enclosure is primarily constructed of fabricated sheet steel. It measures approximately 9.8 cm wide by 15.3 cm deep by 3.8 cm high.

INPUT POWER

The EUT input is rated at 120/240, 50/60 Hz. The EUT contained the following input power components during emissions testing:

Description	Manufacturer	Model
AC / DC Converter	AKII	A10D1-05MP

PRINTED WIRING BOARDS

The OTC Telecom model Air EZY éLAN II contained the following printed wiring boards during emissions testing:

Manufacturer/Description	Assembly #	Rev.	Serial #	Crystals (MHz)
OTC/ Telecom/ RF Board	1710-2410BT-00	-	None	10
OTC/ Telecom/ Digital Board	1700-2410BT-0A	-	None	44

SUPPORT EQUIPMENT

The following equipment was used as local support equipment for emissions testing:

Manufacturer/Model/Description	Serial Number	FCC ID Number
HP / Multimedia 6170 S	US52120866	EJMMORRISON
AMAX/Impression3 Plus3428N / Monitor	59252636	H79DCM-1458
HP / Mouse	LCA51105563	DZL210472
HP / Keyboard	30250393	AQ6MTN4XZ15
Ethernet Adapter NIC	-	-
HP 2225C Parallel Thinkjet Printer	2714S40166	DSI6XU2225

The following equipment was used as remote support equipment for emissions testing:

Manufacturer/Model/Description	Serial Number	FCC ID Number
CompuStar/ AT	01F23NP	-
AMAX/ Zmpersion3 Plus / Monitor	E134786	-
AMAX/ Keyboard	D00100608	-
OTC Telecom/ AEZY 2400 éLAN Bridge	24166561	-
Scepter/ Power Supply	LR67888	-

EXTERNAL I/O CABLING

The I/O cabling configuration during emissions testing was as follows:

Cable Description	Length (m)	From Unit/Port	To Unit/Port
RJ45	2.5	EUT	PC NIC
Shielded Serial	2	Host PC Serial	Modem
Shielded Parallel	2	Host PC Parallel	Printer
Shielded Keyboard	2	Host PC Keyboard	Keyboard
Shielded Mouse	2	Host PC Mouse	Mouse
Coax	20'	EUT	Lighting Arrester
Coax	20'	Lighting Arrester	Antenna

TEST SOFTWARE

During emissions testing the EUT transmitter was set to continuous transmit and recieve mode, using OTC Telecom test program OTCFCC.

ANTENNA SYSTEM

The antenna system used with the OTC Telecom model Air EZY éLAN II consists of either a 2, 8 or 11 dBi rod antennas or a 24 dBi Parabolic antenna either directly to the EUT or through 40' of coaxial cable and a lighting arrester.

TEST RESULTS

TEST DATA ANALYSIS - CONDUCTED

The following measurements were extracted from the data recorded during the conducted emissions scan and represent the highest amplitude peaks relative to the specification limit. The actual test data and correction factors are contained in the appendices of this report.

Conducted Emissions, 0.45-30.0 MHz, Sorted by Margin, 120 V, 60 Hz

Frequency MHz	Level dBuV	Power Lead	FCC B Limit	FCC B Margin	Detector Function	Comments
0.6500	37.1	line	48.0	-10.9	QP	
0.6500	36.6	neutral	48.0	-11.4	QP	
0.8700	34.9	line	48.0	-13.1	QP	
0.8700	33.4	neutral	48.0	-14.6	QP	
1.0800	32.4	line	48.0	-15.6	QP	
1.0800	29.2	neutral	48.0	-18.8	QP	
0.1500	51.0	line	N/A	N/A	QP	
0.1500	49.9	neutral	N/A	N/A	QP	

TEST DATA ANALYSIS - ANTENNA CONDUCTED

The highest out-of-band (Un-restricted) emission recorded was 41.8 dB below the in-band level at 7367 MHz.

TEST DATA ANALYSIS - POWER AND BANDWIDTH

The maximum power output was 14.2 dBm on channel 1. The maximum power density in any 3 kHz band was -14.7 dBm on channel 1. The 6 dB bandwidth was 11.32 Megahertz. The actual test data and any correction factors are contained in the appendices of this report.

TEST DATA ANALYSIS - RADIATED

The following measurements were extracted from the data recorded during the radiated electric field emissions scan and represent the highest amplitude peaks relative to the specification limit. The actual test data and correction factors are contained in the appendices of this report.

Maximized Radiated Emissions, 30-1000 MHz, Quasi-Peak Readings, Sorted by Margin

Frequency MHz	Level dBuV/m	Pol v/h	FCC B Limit	FCC B Margin	Azimuth degrees	Height meters	Comments
600.093	43.4	v	46.0	-2.6	91	1.0	Borad Band
55.400	37.1	v	40.0	-2.9	254	1.0	
600.093	43.0	h	46.0	-3.0	183	1.9	Borad Band
60.003	36.5	v	40.0	-3.5	236	1.0	
330.000	41.3	h	46.0	-4.7	64	3.4	
44.000	31.7	v	40.0	-8.3	0	1.0	

TEST DATA ANALYSIS - RADIATED HARMONIC AND SPURIOUS

The following measurements were extracted from the data recorded during the radiated electric field emissions scan and represent the highest amplitude peaks relative to the specification limit. The actual test data and correction factors are contained in the appendices of this report.

Maximized radiated emissions 1-25 GHz, 2dBi antenna

Frequency MHz	Level dBuV/m	Pol v/h	FCC B Limit	FCC B Margin	Detector Pk/QP/Avg	Azimuth degrees	Height meters	Comments
7327.630	69.9	v	74.0	-4.1	Peak	100	1.5	Restricted Band
7327.630	48.3	v	54.0	-5.7	Average	100	1.5	Restricted Band
7327.630	46.1	h	54.0	-7.9	Average	60	1.3	Restricted Band
7327.630	65.2	h	74.0	-8.8	Peak	60	1.3	Restricted Band
2488.800	64.6	v	74.0	-9.4	Peak	200	1.3	Restricted Band
2488.800	63.8	h	74.0	-10.2	Peak	200	1.3	Restricted Band
4885.000	39.8	h	54.0	-14.2	Average	220	1.3	Restricted Band
4885.000	39.5	v	54.0	-14.5	Average	200	1.5	Restricted Band
4885.000	57.7	h	74.0	-16.3	Peak	220	1.3	Restricted Band
2488.800	35.0	h	54.0	-19.0	Average	200	1.3	Restricted Band
2488.800	34.7	v	54.0	-19.3	Average	200	1.3	Restricted Band
4885.000	53.8	v	74.0	-20.2	Peak	200	1.5	Restricted Band

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EMC Test Log

Client:	OTC Telecom	Date:	8/12/98	Test Engr:	Mark Briggs
Product:	AirEzy éLan II	File:	T27776	Proj. Eng:	David Bare
Objective:	Final Qualification	Site:	SV EMC Lab	Contact:	Wei Ming
Spec:	FCC §15.247	Page:	1 of 2	Approved:	

Test Objective

The objective of this test session is to perform final qualification testing the EUT defined below relative to the specification(s) defined above.

Test Summary

Run #1 - Output Power

PASS Results: Output Power from the EUT was measured directly using a HP 432A Power Meter. the output power was 16 dBm (39.8 mW).

Equipment Under Test (EUT) General Description

The EUT is a spread spectrum radio which is designed to operate in the 2.4 GHz ISM band using direct sequence spreading techniques. Normally, the EUT would be placed on a table top during operation. The EUT was, therefore, placed in this position during emissions testing to simulate the end user environment.

Equipment Under Test (EUT)

Manufacturer/Model/Description	Serial Number	FCC ID Number
OTC Telecom AirEzy 2400 e'LAN Bridge	None	MKZAEZY 2411BRG

Power Supply and Line Filters

The EUT used the following external AC-DC adapter:

Description	Manufacturer	Model
125Vac - 5Vdc AC-DC adapter	AKI Power Supply	A10D1-05MP

Printed Wiring Boards in EUT

Manufacturer/Description	Assembly #	Rev.	Serial Number	Crystals (MHz)
OTC/ Telecom/ RF Board	1710-2410BT-00	-	None	10
OTC/ Telecom/ Digital Board	1700-2410BT-0A	-	None	44

Subassemblies in EUT

Manufacturer/Description	Assembly Number	Rev.	Serial Number
None	-	-	-

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EUT Enclosure(s)

The EUT enclosure is primarily constructed of fabricated sheet steel. It measures approximately 9.8 cm wide by 15.3 cm deep by 3.8 cm high.

EMI Suppression Devices (filters, gaskets, etc.)

Description	Manufacturer	Part Number
None		

Support Equipment

Manufacturer/Model/Description	Serial Number	FCC ID Number
None	-	-

Interface Cabling

Cable Description	Length (m)	From Unit/Port	To Unit/Port
50Ω coaxial cable adapter	0.1	EUT antenna	Power Meter

Test Software

The EUT was transmitting on 2.44 GHz using direct sequence modulation.

General Test Conditions

The EUT's AC-DC adapter was connected to 120V, 60Hz power input.

Test Equipment List - SVOATS#1

Manufacturer/Description		Model	Asset #	Interval	Last Cal	Cal Due
☐ Elliott Laboratories	FCC / CISPR LISN	LISN-3, OATS	304	12	6/24/98	6/24/99
☐ EMCO	Double Ridge Horn Antenna, 1-18	3115	487	12	6/18/98	6/18/99
☐ EMCO	Biconical Antenna, 30-300 MHz	3110B	363	12	4/8/98	4/8/99
☐ EMCO	Log Periodic Antenna, 0.3-1 GHz	3146A	364	12	4/8/98	4/8/99
☐ EMCO	Double Ridge Horn Antenna, 1-18	3115	786	12	11/13/97	5/13/99
☒ Hewlett Packard	Power Meter	432A	259, (F304)	12	3/10/98	3/10/99
☐ Hewlett Packard	Spectrum Analyzer, RF Section	85680B	BN1724	12	5/11/98	5/11/99
☐ Hewlett Packard	Spectrum Analyzer, Display Section	85662A	BN110605	12	5/11/98	5/11/99
☐ Hewlett Packard	RF Preselector	85685A	BN1725	12	5/11/98	5/11/99
☐ Hewlett Packard	Quasi Peak Adapter	85650A	BN281	12	5/11/98	5/11/99
☐ Hewlett Packard	Spectrum Analyzer	8563E	284, (F194)	24	1/14/98	1/14/2000
☐ Hewlett Packard	Microwave Preamplifier, 1-26.5	8449B	263, (F303)	12	6/8/98	6/8/99
☐ Hewlett Packard	Thermistor Mount	478A	652	12	3/10/98	3/10/99
☐ Hewlett Packard	EMC Receiver /Analyzer	8595EM	780	24	10/24/97	10/24/99
☐ Hewlett Packard	Microwave Preamplifier, 1-26.5GHz	8449B	785	12	11/10/97	11/10/98
☐ Hewlett Packard	EMC Receiver /Analyzer	8595EM	787	12	10/27/97	10/27/98
☐ Narda West	High Pass Filter	HPF 180	821	12	2/20/98	2/20/99
☐ Narda-West	EMI Filter 5.6 GHz, High Pass	60583 HXF370	247	12	4/27/98	4/27/99
☐ Narda-West	EMI Filter 2.4 GHz, High Pass	60583 HPF-161	248	12	4/27/98	4/27/99
☐ Rohde & Schwarz	10 dB Pad / Pulse Limiter	ESH3 Z2	372	12	6/22/98	6/22/99
☐ Rohde & Schwarz	Test Receiver	ESN	775	12	6/22/98	6/22/99
☐ Solar Electronics	High Pass Filter, fc = 8 kHz	7930-8.0	277	12	7/1/98	7/18/99

File Number: T27776

Date: 8-12-98

Engr: MB.

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Support Equipment

Manufacturer/Model/Description	Serial Number	FCC ID Number
None	-	-

Interface Cabling

Cable Description	Length (m)	From Unit/Port	To Unit/Port
50Ω coaxial cable adapter	0.1	EUT antenna	Power Meter

Test Software

The EUT was transmitting on 2.44 GHz using direct sequence modulation.

General Test Conditions

The EUT's AC-DC adapter was connected to 120V, 60Hz power input.

Test Equipment List - SVOATS#1

Manufacturer/Description		Model	Asset #	Interval	Last Cal	Cal Due
☐ Elliott Laboratories	FCC / CISPR LISN	LISN-3, OATS	304	12	6/24/98	6/24/99
☐ EMCO	Double Ridge Horn Antenna, 1-18	3115	487	12	6/18/98	6/18/99
☐ EMCO	Biconical Antenna, 30-300 MHz	3110B	363	12	4/8/98	4/8/99
☐ EMCO	Log Periodic Antenna, 0.3-1 GHz	3146A	364	12	4/8/98	4/8/99
☐ EMCO	Double Ridge Horn Antenna, 1-18	3115	786	12	11/13/97	5/13/99
☒ Hewlett Packard	Power Meter	432A	259, (F304)	12	3/10/98	3/10/99
☐ Hewlett Packard	Spectrum Analyzer, RF Section	85680B	BN1724	12	5/11/98	5/11/99
☐ Hewlett Packard	Spectrum Analyzer, Display Section	85662A	BN110605	12	5/11/98	5/11/99
☐ Hewlett Packard	RF Preselector	85685A	BN1725	12	5/11/98	5/11/99
☐ Hewlett Packard	Quasi Peak Adapter	85650A	BN281	12	5/11/98	5/11/99
☐ Hewlett Packard	Spectrum Analyzer	8563E	284, (F194)	24	1/14/98	1/14/2000
☐ Hewlett Packard	Microwave Preamplifier, 1-26.5	8449B	263, (F303)	12	6/8/98	6/8/99
☐ Hewlett Packard	Thermistor Mount	478A	652	12	3/10/98	3/10/99
☐ Hewlett Packard	EMC Receiver /Analyzer	8595EM	780	24	10/24/97	10/24/99
☐ Hewlett Packard	Microwave Preamplifier, 1-26.5GHz	8449B	785	12	11/10/97	11/10/98
☐ Hewlett Packard	EMC Receiver /Analyzer	8595EM	787	12	10/27/97	10/27/98
☐ Narda West	High Pass Filter	HPF 180	821	12	2/20/98	2/20/99
☐ Narda-West	EMI Filter 5.6 GHz, High Pass	60583 HXF370	247	12	4/27/98	4/27/99
☐ Narda-West	EMI Filter 2.4 GHz, High Pass	60583 HPF-161	248	12	4/27/98	4/27/99
☐ Rohde & Schwarz	10 dB Pad / Pulse Limiter	ESH3 Z2	372	12	6/22/98	6/22/99
☐ Rohde & Schwarz	Test Receiver	ESN	775	12	6/22/98	6/22/99
☐ Solar Electronics	High Pass Filter, fc = 8 kHz	7930-8.0	277	12	7/1/98	7/18/99

File Number: T27776

Date: 8·12·98
Engr: MB

EXHIBIT A

Test Equipment Calibration

Test Equipment List - SVOATS#1

Manufacturer/Description		Model	Asset #	Interval	Last Cal	Cal Due
☐ Elliott Laboratories	2 x (Solar 8028 LISN + 6512 Caps)	LISN-5, SV01	379	12	6/5/97	6/5/98
☒ Elliott Laboratories	300-1000 MHz Log Periodic	EL300.1000	297, (F113)	12	11/10/97	11/10/98
☒ Elliott Laboratories	Biconical Antenna, 30-300 MHz	EL30.300	382, (F201)	12	7/28/97	7/28/98
☐ Elliott Laboratories	FCC / CISPR LISN	LISN-3, OATS	304	12	6/5/97	6/5/98
☐ Elliott Laboratories	FCC / CISPR LISN	LISN-3, OATS	304	12	6/5/97	6/5/98
☐ EMCO	Double Ridge Horn Antenna, 1-18	3115	786	12	11/13/97	5/13/99
☐ EMCO	Double Ridge Horn Antenna, 1-18	3115	487	12	6/3/97	6/3/98
☐ Hewlett Packard	EMC Receiver /Analyzer	8595EM	780	24	10/24/97	10/24/99
☐ Hewlett Packard	EMC Receiver /Analyzer	8595EM	787	12	10/27/97	10/27/98
☐ Hewlett Packard	Microwave Preamplifier, 1-26.5	8449B	263, (F303)	12	6/6/97	6/6/98
☐ Hewlett Packard	Microwave Preamplifier, 1-26.5GHz	8449B	785	12	11/10/97	11/10/98
☐ Hewlett Packard	Power Meter	432A	259, (F304)	12	3/10/98	3/10/99
☐ Hewlett Packard	Spectrum Analyzer	8563E	284, (F194)	24	1/14/98	1/14/2000
☐ Hewlett Packard	Thermistor Mount	478A	652	12	3/10/98	3/10/99
☐ Narda-West	EMI Filter 2.4 GHz, High Pass	60583 HPF-161	248	12	4/22/97	4/22/98
☐ Narda-West	EMI Filter 5.6 GHz, High Pass	60583 HXF370	247	12	4/22/97	4/22/98
☒ Rohde & Schwarz	10 dB Pad / Pulse Limiter	ESH3 Z2	372	12	6/17/97	6/17/98
☐ Rohde & Schwarz	10 dB Pad / Pulse Limiter, 50W	ESH3 Z2	371	12	7/24/96	7/24/97
☐ Rohde & Schwarz	T1 Conducted LISN	ESH3-Z4,	267			
☒ Rohde & Schwarz	Test Receiver	ESN	775	12	6/30/97	6/30/98
☐ Solar Electronics	High Pass Filter, fc = 8 kHz	7930-8.0	277	12	7/18/97	7/18/98

File Number: T26039

Date: 04/03/98

Engr: Mehran M Birgani

Test Equipment List - SVOATS#2

Manufacturer/Description		Model	Asset #	Interval	Last Cal	Cal Due
☑ Rohde & Schwarz	Test Receiver, 0.009-30 MHz	ESH3	215, (F197)	12	1/16/98	1/16/99
☐ Rohde & Schwarz	T1 Conducted LISN	ESH3-Z4,	267			
☑ Rohde &Schwarz	Test Receiver, 20-1300MHz	ESVP	273	12	1/16/98	1/16/99
☑ Rohde& Schwarz	Pulse Limiter	ESH3Z2	811	12	2/5/98	2/5/99
☐ Narda-West	EMI Filter 5.6 GHz, High Pass	60583 HXF370	247	12	4/22/97	4/22/98
☑ Narda-West	EMI Filter 2.4 GHz, High Pass	60583 HPF-161	248	12	4/22/97	4/22/98
☐ Hewlett Packard	Power Meter	432A	259, (F304)	12	3/10/98	3/10/99
☑ Hewlett Packard	Spectrum Analyzer	8563E	284, (F194)	24	1/14/98	1/14/2000
☑ Hewlett Packard	Microwave Preamplifier, 1-26.5	8449B	263, (F303)	12	6/6/97	6/6/98
☐ Hewlett Packard	Thermistor Mount	478A	652	12	3/10/98	3/10/99
☐ Hewlett Packard	EMC Receiver /Analyzer	8595EM	780	24	10/24/97	10/24/99
☐ Hewlett Packard	Microwave Preamplifier, 1-26.5GHz	8449B	785	12	11/10/97	11/10/98
☐ Hewlett Packard	EMC Receiver /Analyzer	8595EM	787	12	10/27/97	10/27/98
☑ Fischer	LISN	FCC-LISN-50/2	810	12	1/29/98	1/29/99
☑ EMCO	Double Ridge Horn Antenna, 1-18	3115	487	12	6/3/97	6/3/98
☐ EMCO	Double Ridge Horn Antenna, 1-18	3115	786	12	11/13/97	5/13/99
☑ EMCO	Biconical Antenna	3110B	801		6/4/97	12/4/98
☑ EMCO	Log Periodic Antenna	3146A	802	12	6/13/97	12/13/98

File Number: T26229

Date: 4-16-98
Engr: Rudy

EXHIBIT B

Test Measurement Data

The following data includes conducted emission measurements of the OTC Telecom model Air EZY éLAN II and maximized radiated emissions measurements of the complete system.

Elliott

EMC Test Log

Client:	OTC Telecomm.	Date:	4/16/98	Test Engr:	Rudy Suy
Product:	Air EZY e'LAN II	File:	T26229	Proj. Eng:	Mark Briggs
Objective:	Final Qualification	Site:	SVOATS #2	Contact:	York Sung
Spec:	FCC part 15	Page:	1 of 4	Approved:	

Test Objective

The objective of this test session is to perform final qualification testing the EUT defined below relative to the specification(s) defined above.

Test Summary

Run #1a - Transmitted Power Measurements @ 2443 MHz In Accordance With 15.247 (b)

PASS Results: Output power was measured to be 14.2 dBm, 15.8 dB below the maximum permitted output of 30 dBm (1 Watt).

Run #1b - Power Density Measurements @ 2443 MHz In Accordance With 15.247 (d)

PASS Results: Output power density in 3 KHz bandwidth was measured to be -14.7 dBm, -22.7 dB below the maximum permitted density of 8 dBm/3KHz.

Run #1c - 6dB Bandwidth measurement @ 2443 MHz In Accordance With §15.247 (a) (2)

PASS Results: 6dB bandwidth was 11.32 MHz, meeting the minimum requirement of 500 KHz.

Run #2 - Maximized Spurious Emissions Falling In Restricted bands Above 1 GHz **For Antenna #1 with 2dBi.**

PASS Results: §15.247c -4.1 dB Peak @ 7327.630 MHz Vertical

Run #3 - Maximized Spurious Emissions Falling In Restricted bands Above 1 GHz **For Antenna #2 with 11dBi.**

PASS Results: §15.247c -10.9 dB Ave @ 7327.630 MHz Vertical

Client:	OTC Telecomm.	Date:	4/16/98	Test Engr:	Rudy Suy
Product:	Air EZY e'LAN II	File:	T26229	Proj. Eng:	Mark Briggs
Objective:	Final Qualification	Site:	SVOATS #2	Contact:	York Sung
Spec:	FCC part 15	Page:	2 of 4	Approved:	MWB

Run #4 - Maximized Spurious Emissions Falling In Restricted bands Above 1 GHz **For Antenna #3 with 8dBi.**

PASS Results: §15.247c -11.1 dB Ave @ 7327.630 MHz Vertical

Run #5 - Maximized Spurious Emissions Falling In Restricted bands Above 1 GHz **For Antenna #4 with 24dBi.**

PASS Results: §15.247c -9.7 dB Ave @ 7327.630 MHz Vertical

Run #6 - Conducted Measurement, 30-25000 MHz.

PASS Results: Refer to the plots attached on D-file.

Equipment Under Test (EUT) General Description

The EUT is a Spread Spectrum radio system which utilizes direct sequence and is designed to use the 1 channels in the allocated frequency band of 2400-2483.5 MHz. Normally, the EUT would attached to a personal computer ethernet port. The EUT was placed on a table top during emissions testing to simulate the end user environment.

Equipment Under Test (EUT)

Manufacturer/Model/Description	Serial Number	FCC ID Number
OTC Telecom AirEzy 2400 e'LAN Bridge	241650	MKZAEZY 2411BRG

Local Support Equipment

Manufacturer/Model/Description	Serial Number	FCC ID Number
HP / Multimedia 6170 S	US52120866	EJMMORRISON
AMAX/Impression3 Plus3428N / Monitor	59252636	H79DCM-1458
HP / Mouse	LCA51105563	DZL210472
HP / Keyboard	30250393	AQ6MTN4XZ15
Ethernet Adapter NIC	-	-
HP 2225C Parallel Thinkjet Printer	2714S40166	DSI6XU2225

Client:	OTC Telecomm.	Date:	4/16/98	Test Engr:	Rudy Suy
Product:	Air EZY e'LAN II	File:	T26229	Proj. Eng:	Mark Briggs
Objective:	Final Qualification	Site:	SVOATS #2	Contact:	York Sung
Spec:	FCC part 15	Page:	3 of 4	Approved:	AWB

Remote Support Equipment

Manufacturer/Model/Description	Serial Number	FCC ID Number
CompuStar/ AT	01F23NP	-
AMAX/ Zmpersion3 Plus / Monitor	E134786	-
AMAX/ Keyboard	D00100608	-
OTC Telecom/ Air EZY 2400 e'LAN Bridge	24166561	-
Scepter/ Power Supply	LR67888	-

Power Supply and Line Filters

Description	Manufacturer	Model
AC / DC Converter	AKII	A10D1-05MP

Interface Cabling

Cable Description	Length (m)	From Unit/Port	To Unit/Port
RJ45	2.5	EUT	PC NIC
Shielded Serial	2	Host PC Serial	Modem
Shielded Parallel	2	Host PC Parallel	Printer
Shielded Keyboard	2	Host PC Keyboard	Keyboard
Shielded Mouse	2	Host PC Mouse	Mouse
Coax	20'	EUT	Lighting Arrester
Coax	20'	Lighting Arrester	Antenna

Test Software

During emissions testing the EUT transmitter was set to continuous transmit and receive mode, using OTC Telecom test program OTCFCC.

EUT Enclosure(s)

The EUT enclosure is primarily constructed of fabricated sheet steel. It measures approximately 9.8 cm wide by 15.3 cm deep by 3.8 cm high.

Printed Wiring Boards in EUT

Manufacturer/Description	Assembly #	Rev.	Serial Number	Crystals (MHz)
OTC/ Telecom/ RF Board	17100-242001-05	05	None	10
OTC/ Telecom/ Digital Board	1700-2410BT-0A	0A	None	44

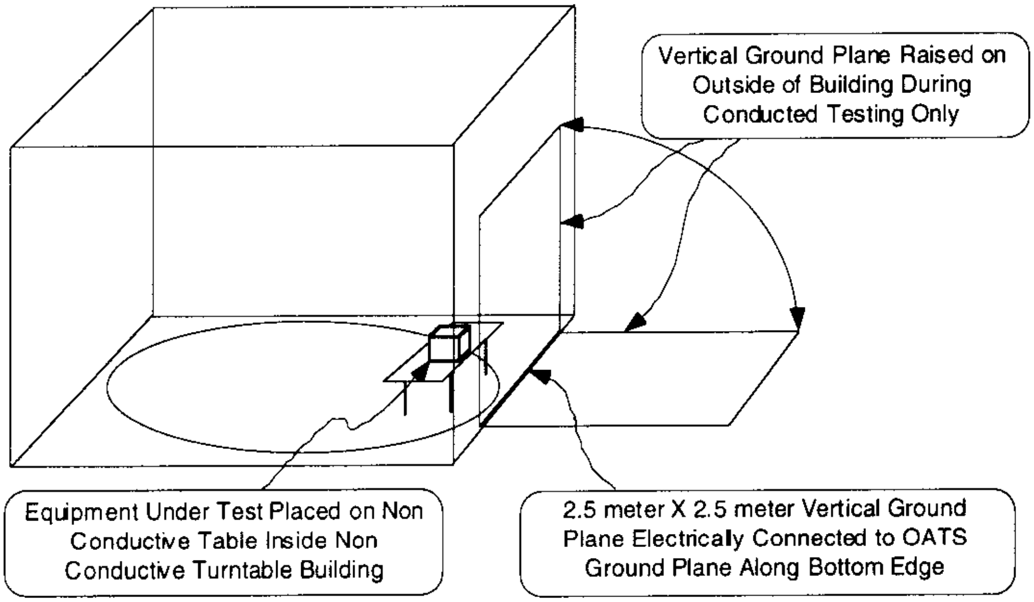
Elliott **EMC Test Log**

Client:	OTC Telecomm.	Date:	4/16/98	Test Engr:	Rudy Suy
Product:	Air EZY e'LAN II	File:	T26229	Proj. Eng:	Mark Briggs
Objective:	Final Qualification	Site:	SVOATS #2	Contact:	York Sung
Spec:	FCC part 15	Page:	4 of 4	Approved:	

General Test Conditions

During radiated testing, the EUT was connected to 120V, 60Hz power input. The EUT and all local support equipment were located on the turntable for radiated testing and conducted testing. All remote support equipment was located approximately 30 meters from the EUT.

During conducted emissions testing, the EUT was connected to 120V, 60Hz power input as noted. A 2.5 meter X 2.5 meter ground plane is raised to a vertical position 40 cm from the EUT as shown below:



EMI Suppression Devices (filters, gaskets, etc.)

Description	Manufacturer	Part Number
None		

Test Data Tables

See the attached D-File

Elliott

Emissions Test Data

Client:	OTC Telecomm.	Date:	4/16/98	Test Engr:	Rudy Suy
Product:	Air EZY e'LAN II	File:	D26229	Proj. Engr:	Mark Briggs
Objective	Final Data	Site:	SVOATS #2	Contact:	York Sung
Spec:	FCC part 15	Distance:	3 M	Approved:	

Run #1a: Transmit Power Measurement

Direct measurement was made by connecting the spectrum analyzer to the antenna port

RBW = 3MHz.

Frequency	Level	FCC	FCC	Detector	Detector	
MHz	dBm	Limit	Margin	Pk / Ave	Pk / Ave	
2443.000	14.2	30.0	**-15.8**	Peak	Peak	

Run #1b: Power Density Measurement

Direct measurement was made by connecting the spectrum analyzer to the antenna port

RBW = 3KHz, Span 300KHz, Sweep time of 100 second

Frequency	Level	FCC	FCC	Detector	Detector	
MHz	dBm	Limit	Margin	Pk / Ave	Pk / Ave	
2443.000	-14.7	8.0	**-22.7**	Peak	Peak	

Run #1c: 6dB Bandwidth Measurement

Direct measurement was made by connecting the spectrum analyzer to the antenna port

RBW = 100KHz.

The 6dB Bandwidth was measured to be 11.32MHz, meeting the minimum requirement of 500KHz.

Run #2: Maximized radiated emissions 1-25 GHz

Antenna #1 (2dBi)

Frequencies that fall within Restricted Band was compared to FCC B.

All readings have included AF, Cable Loss and Pre-Amp. Gain.

Frequency	Level	Pol	FCC B	FCC B	Detector	Azimuth	Height	Comments
MHz	dBuV/m	v/h	Limit	Margin	Pk/QP/Avg	degrees	meters	
7327.630	69.9	v	74.0	**-4.1**	Peak	100	1.5	Restricted Band
7327.630	48.3	v	54.0	**-5.7**	Average	100	1.5	Restricted Band
7327.630	46.1	h	54.0	**-7.9**	Average	60	1.3	Restricted Band
7327.630	65.2	h	74.0	**-8.8**	Peak	60	1.3	Restricted Band
2488.800	64.6	v	74.0	**-9.4**	Peak	200	1.3	Restricted Band
2488.800	63.8	h	74.0	**-10.2**	Peak	200	1.3	Restricted Band
4885.000	39.8	h	54.0	**-14.2**	Average	220	1.3	Restricted Band
4885.000	39.5	v	54.0	**-14.5**	Average	200	1.5	Restricted Band
4885.000	57.7	h	74.0	**-16.3**	Peak	220	1.3	Restricted Band
2488.800	35.0	h	54.0	**-19.0**	Average	200	1.3	Restricted Band
2488.800	34.7	v	54.0	**-19.3**	Average	200	1.3	Restricted Band
4885.000	53.8	v	74.0	**-20.2**	Peak	200	1.5	Restricted Band

Elliott

Emissions Test Data

Client:	OTC Telecomm.	Date:	4/16/98	Test Engr:	Rudy Suy
Product:	Air EZY e'LAN II	File:	D26229	Proj. Engr:	Mark Briggs
Objective	Final Data	Site:	SVOATS #2	Contact:	York Sung
Spec:	FCC part 15	Distance:	3 M	Approved:	

Run #3: Maximized radiated emissions 1-25 GHz

Antenna #2 (11dBi)

Frequencies that fall within Restricted Band was compared to FCC B.

All readings have included AF, Cable Loss and Pre-Amp. Gain.

Frequency	Level	Pol	FCC B	FCC B	Detector	Azimuth	Height	Comments
MHz	dBuV/m	v/h	Limit	Margin	Pk/QP/Avg	degrees	meters	
2488.800	64.6	v	74.0	**-9.4**	Peak	200	1.3	Restricted Band
2488.800	63.8	h	74.0	**-10.2**	Peak	200	1.3	Restricted Band
7327.630	43.1	v	54.0	**-10.9**	Average	150	1.5	Restricted Band
7327.630	42.6	h	54.0	**-11.4**	Average	130	1.3	Restricted Band
4885.000	39.7	v	54.0	**-14.3**	Average	170	1.3	Restricted Band
4885.000	39.4	h	54.0	**-14.6**	Average	200	1.3	Restricted Band
7327.630	59.2	v	74.0	**-14.8**	Peak	150	1.5	Restricted Band
4885.000	59.1	v	74.0	**-14.9**	Peak	170	1.3	Restricted Band
7327.630	57.3	h	74.0	**-16.7**	Peak	130	1.3	Restricted Band
4885.000	57.0	h	74.0	**-17.0**	Peak	200	1.3	Restricted Band
2488.800	35.0	h	54.0	**-19.0**	Average	200	1.3	Restricted Band
2488.800	34.7	v	54.0	**-19.3**	Average	200	1.3	Restricted Band

Run #4: Maximized radiated emissions 1-25 GHz

Antenna #3 (8dBi)

Frequencies that fall within Restricted Band was compared to FCC B.

All readings have included AF, Cable Loss and Pre-Amp. Gain.

Frequency	Level	Pol	FCC B	FCC B	Detector	Azimuth	Height	Comments
MHz	dBuV/m	v/h	Limit	Margin	Pk/QP/Avg	degrees	meters	
2488.800	64.6	v	74.0	**-9.4**	Peak	200	1.3	Restricted Band
2488.800	63.8	h	74.0	**-10.2**	Peak	200	1.3	Restricted Band
7327.630	42.9	v	54.0	**-11.1**	Average	170	1.3	Restricted Band
7327.630	42.5	h	54.0	**-11.5**	Average	200	1.3	Restricted Band
4885.000	39.8	v	54.0	**-14.2**	Average	190	1.0	Restricted Band
4885.000	39.5	h	54.0	**-14.5**	Average	210	1.4	Restricted Band
7327.630	59.3	v	74.0	**-14.7**	Peak	170	1.3	Restricted Band
4885.000	56.6	h	74.0	**-17.4**	Peak	210	1.4	Restricted Band
4885.000	55.5	v	74.0	**-18.5**	Peak	190	1.0	Restricted Band
7327.630	55.0	h	74.0	**-19.0**	Peak	200	1.3	Restricted Band
2488.800	35.0	h	54.0	**-19.0**	Average	200	1.3	Restricted Band
2488.800	34.7	v	54.0	**-19.3**	Average	200	1.3	Restricted Band

Client:	OTC Telecomm.	Date:	4/16/98	Test Engr:	Rudy Suy
Product:	Air EZY e'LAN II	File:	D26229	Proj. Engr:	Mark Briggs
Objective	Final Data	Site:	SVOATS #2	Contact:	York Sung
Spec:	FCC part 15	Distance:	3 M	Approved:	

Run #5: Maximized radiated emissions 1-25 GHz

Antenna #3, Parabolic Reflector (24dBi)

Frequencies that fall within Restricted Band was compared to FCC B.

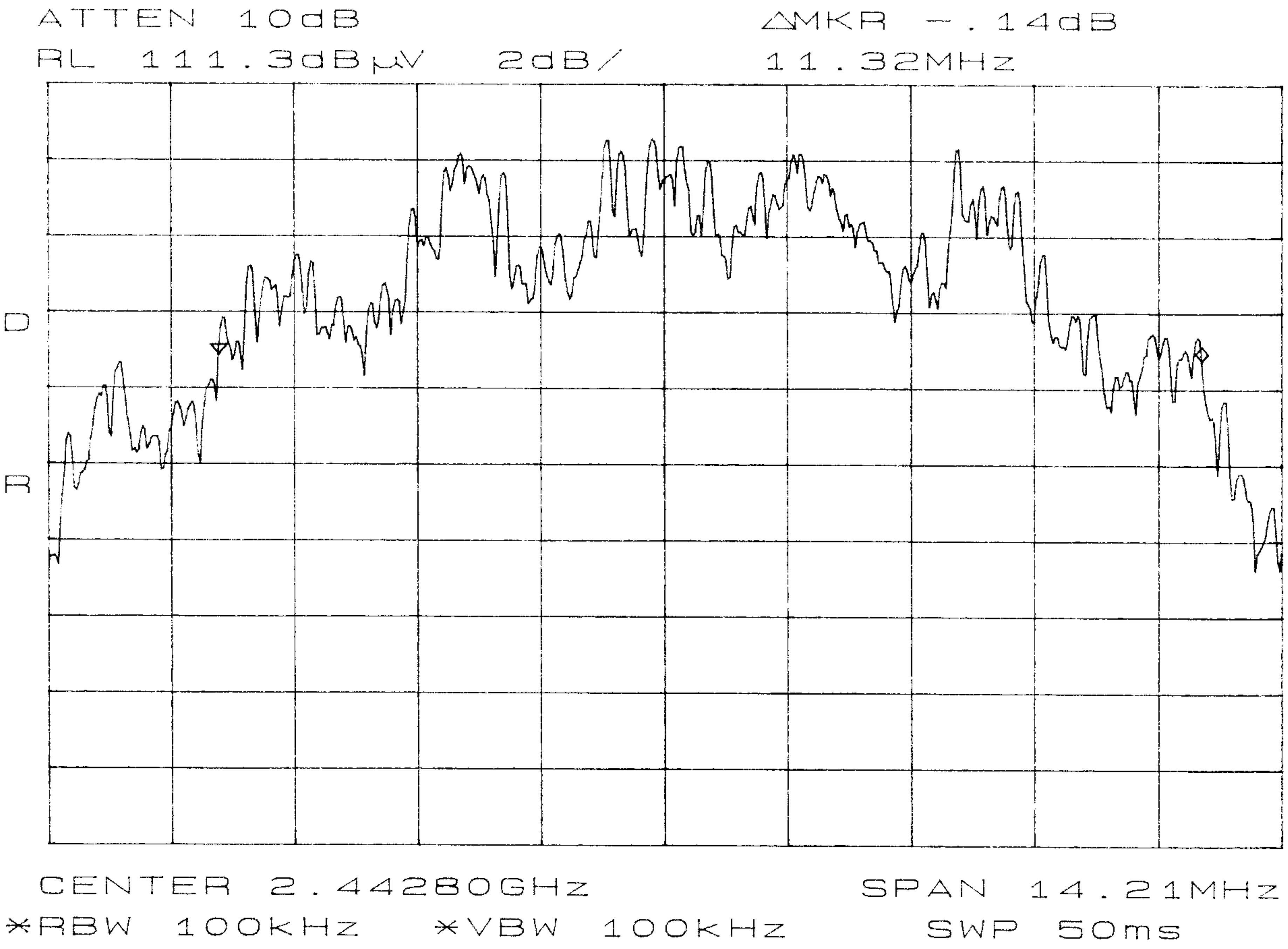
All readings have included AF, Cable Loss and Pre-Amp. Gain.

Frequency	Level	Pol	FCC B	FCC B	Detector	Azimuth	Height	Comments
MHz	dBuV/m	v/h	Limit	Margin	Pk/QP/Avg	degrees	meters	
2488.800	64.6	v	74.0	**-9.4**	Peak	200	1.3	Restricted Band
7327.630	44.3	v	54.0	**-9.7**	Average	170	1.3	Restricted Band
2488.800	63.8	h	74.0	**-10.2**	Peak	200	1.3	Restricted Band
7327.630	43.6	h	54.0	**-10.4**	Average	160	1.2	Restricted Band
7327.630	62.4	v	74.0	**-11.6**	Peak	170	1.3	Restricted Band
4885.000	42.0	h	54.0	**-12.0**	Average	180	1.0	Restricted Band
4885.000	61.3	v	74.0	**-12.7**	Peak	170	1.2	Restricted Band
4885.000	40.1	v	54.0	**-13.9**	Average	170	1.2	Restricted Band
4885.000	59.6	h	74.0	**-14.4**	Peak	180	1.0	Restricted Band
7327.630	58.4	h	74.0	**-15.6**	Peak	160	1.2	Restricted Band
2488.800	35.0	h	54.0	**-19.0**	Average	200	1.3	Restricted Band
2488.800	34.7	v	54.0	**-19.3**	Average	200	1.3	Restricted Band

Run #6: Conducted measurement, 30-25000MHz

Refer to the attached plots.

6dB BANDWIDTH



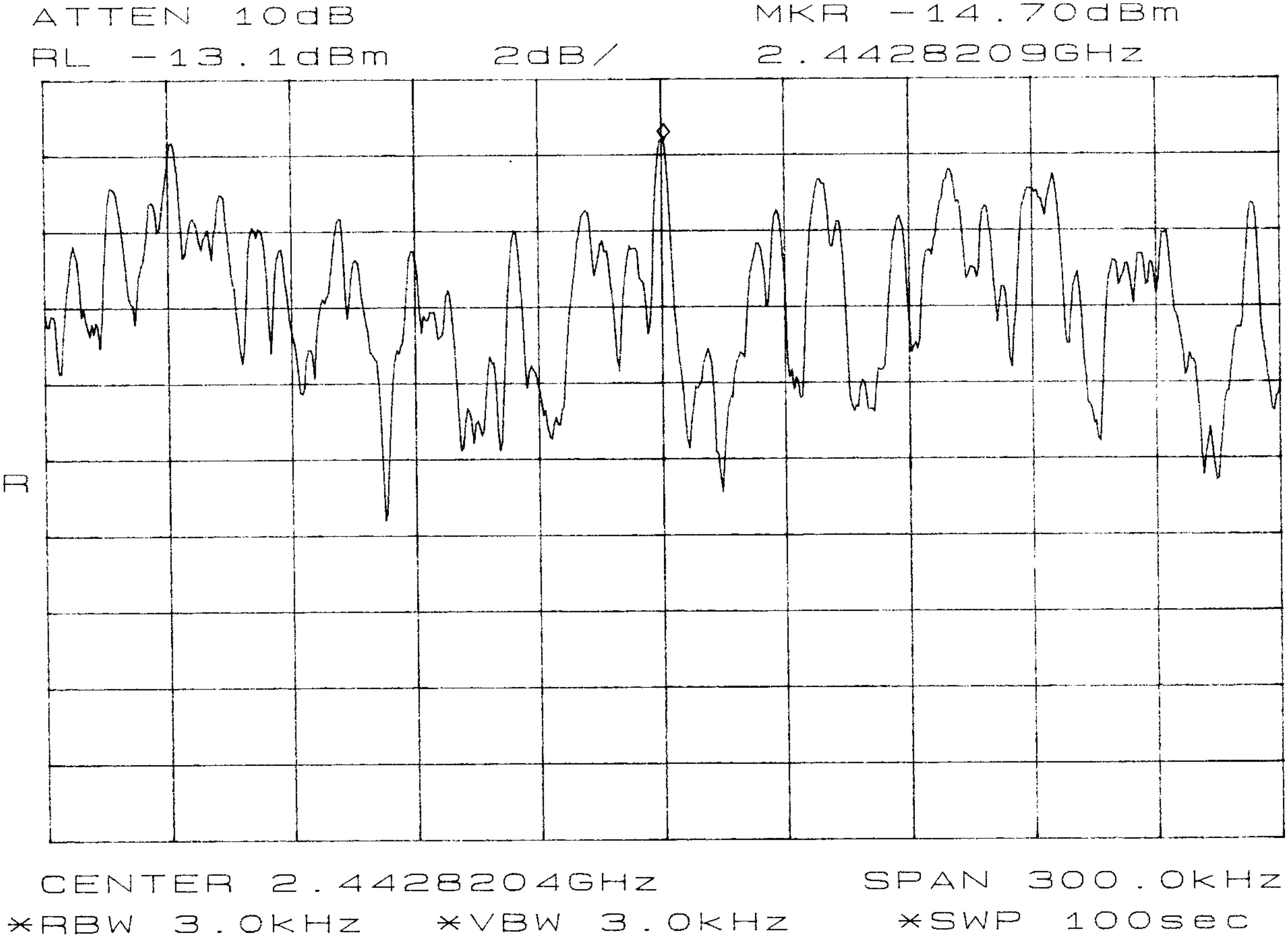
ATTEN 10dB ΔMKR -.14dB

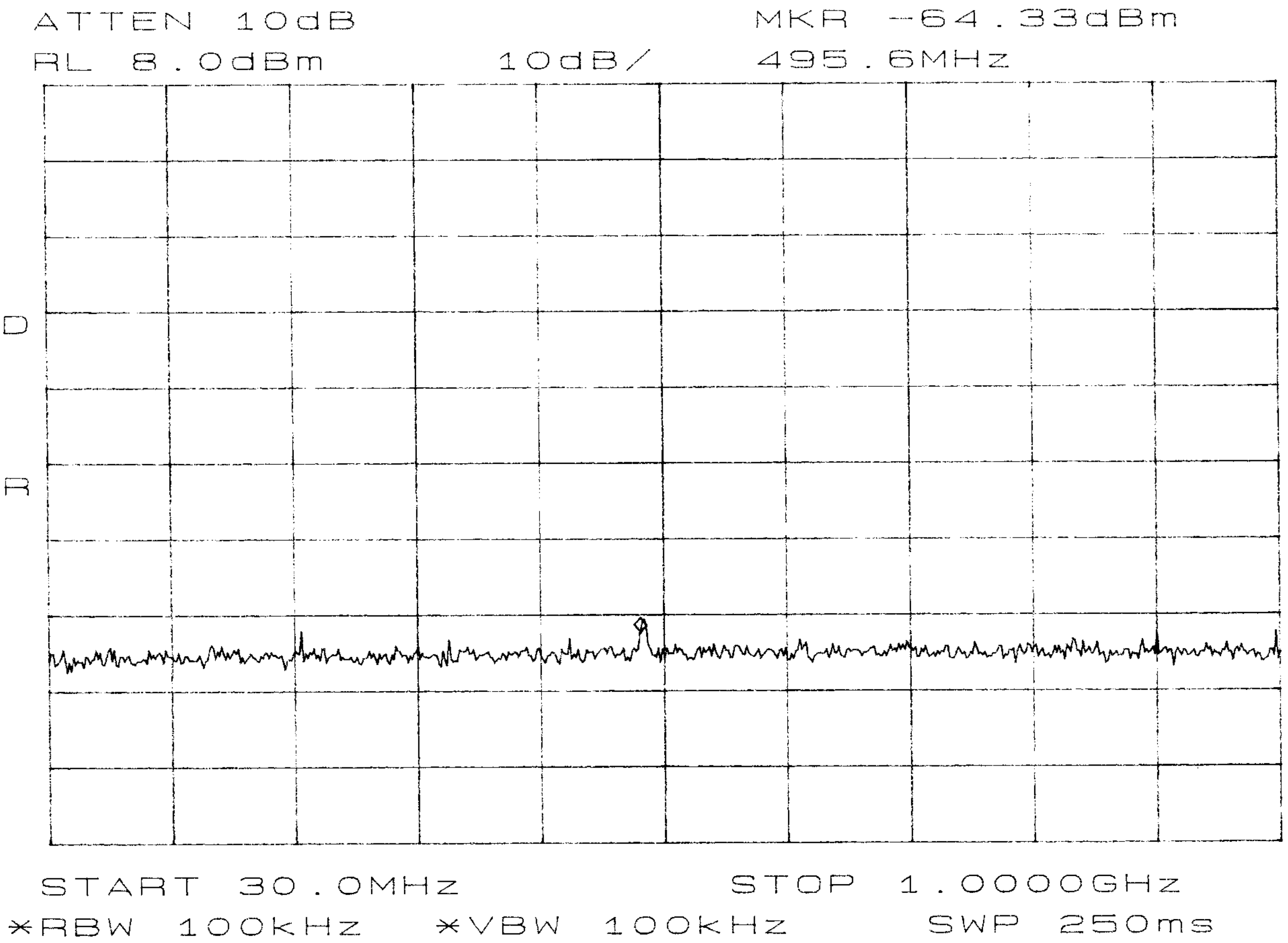
RL 111.3dBμV 2dB/ 11.32MHz

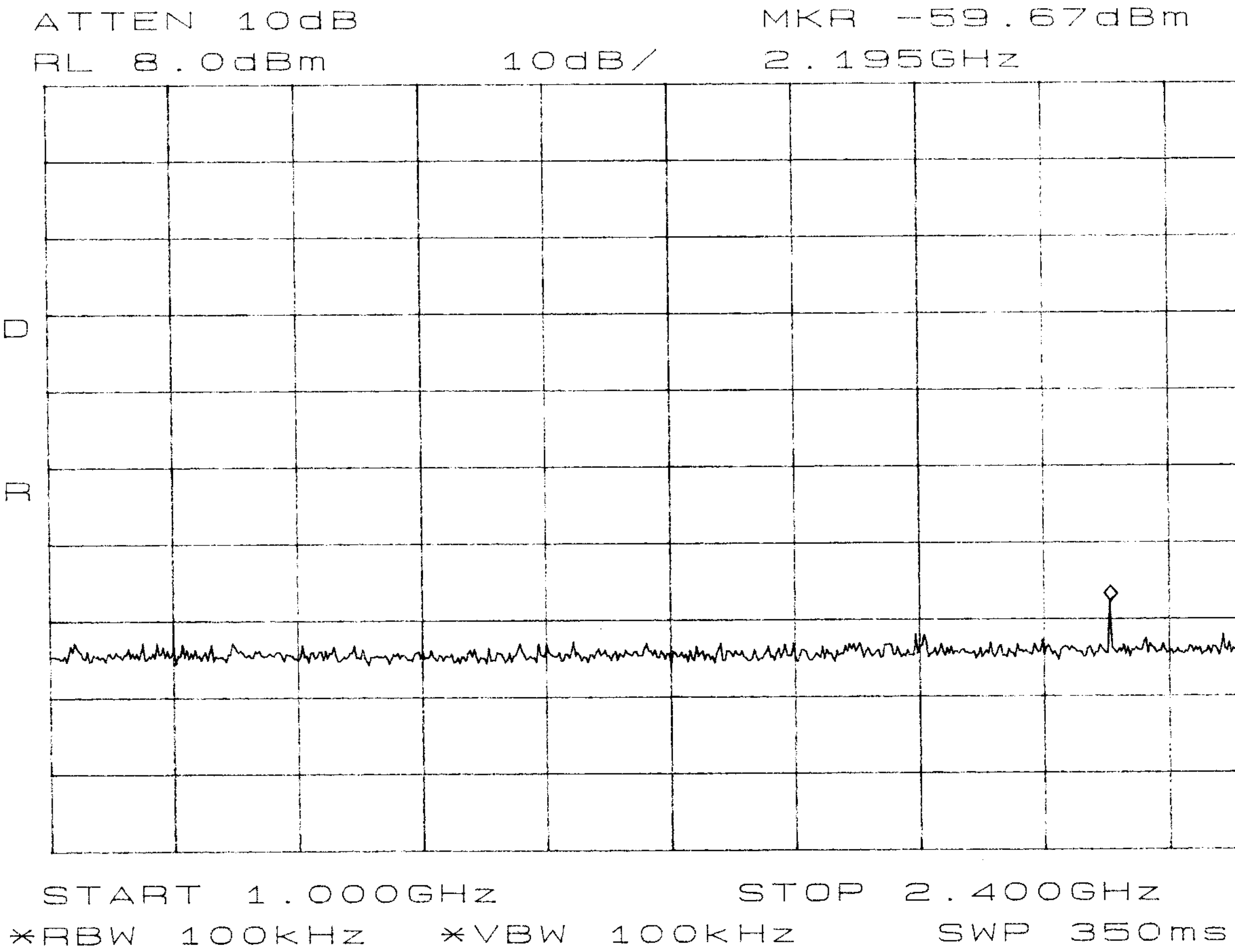
CENTER 2.44280GHz SPAN 14.21MHz

*RBW 100kHz *VBW 100kHz SWP 50ms

POWER DENSITY




ATTEN 10dB
RL 8.0dBm
10dB/
MKR -64.33dBm
495.6MHz
D
R
START 30.0MHz
STOP 1.0000GHz
*RBW 100kHz
*VBW 100kHz
SWP 250ms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RL 8.0dBm
10dB/
MKR -59.67dBm
2.195GHz
D
R
START 1.000GHz
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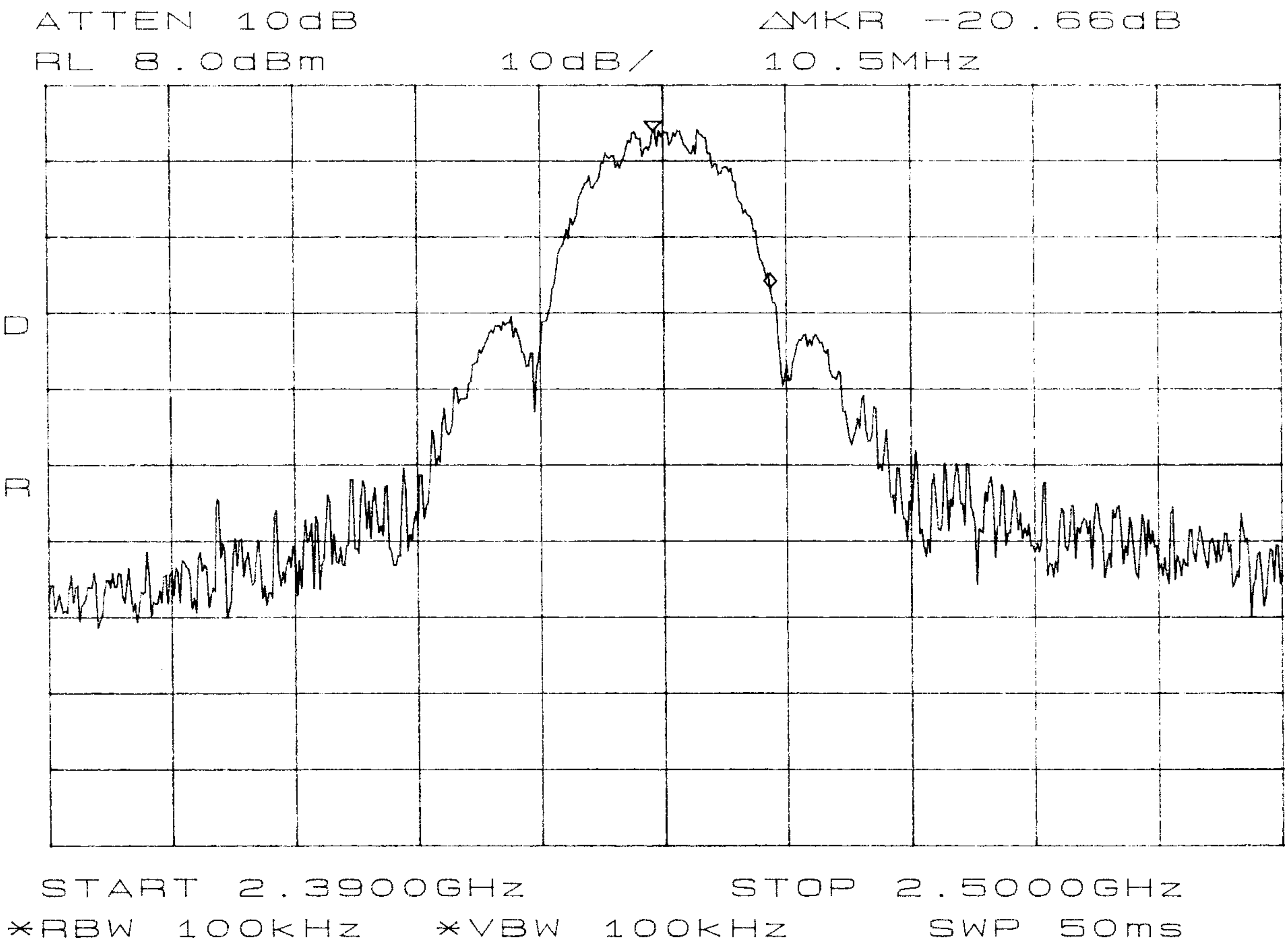
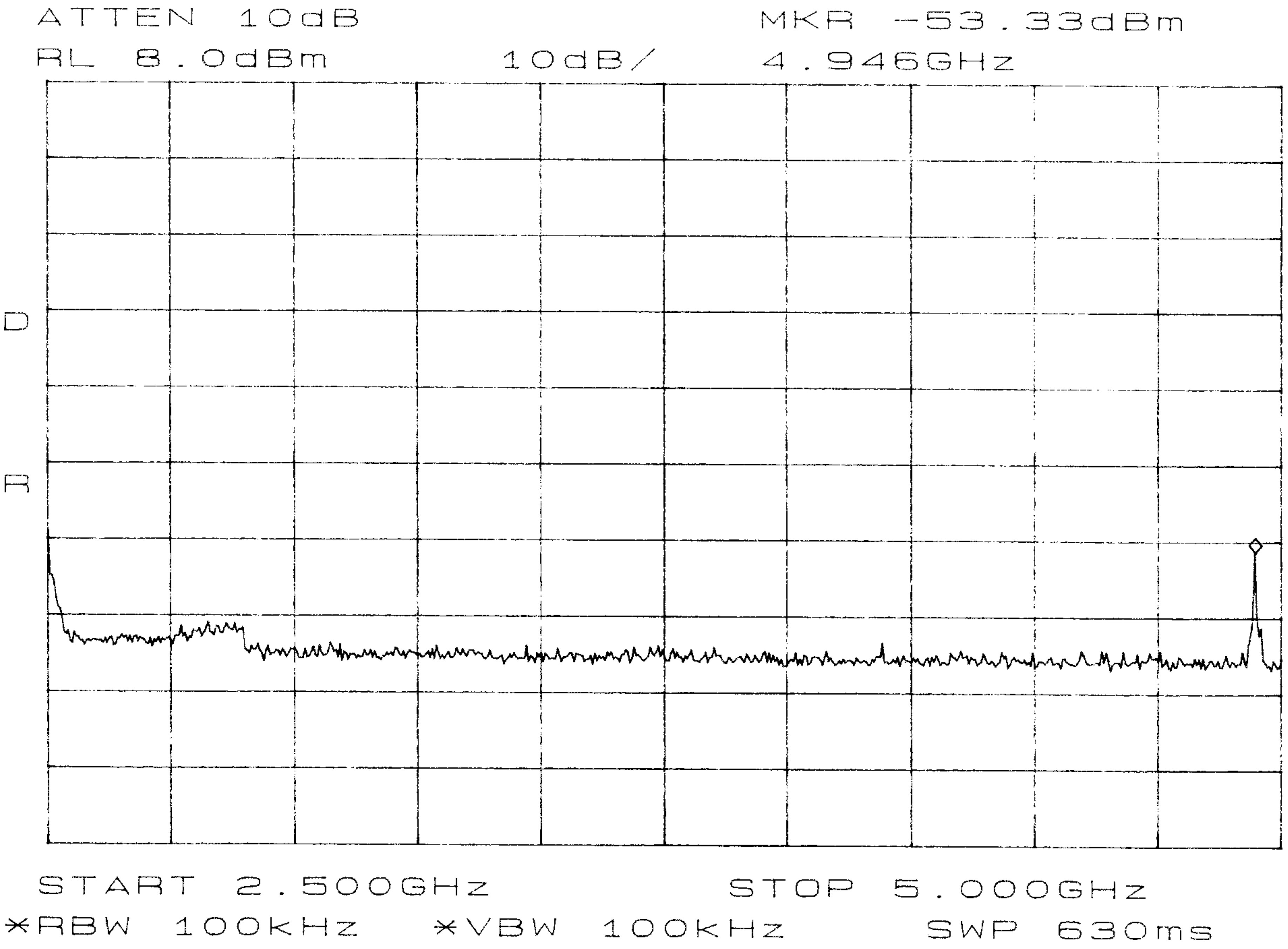
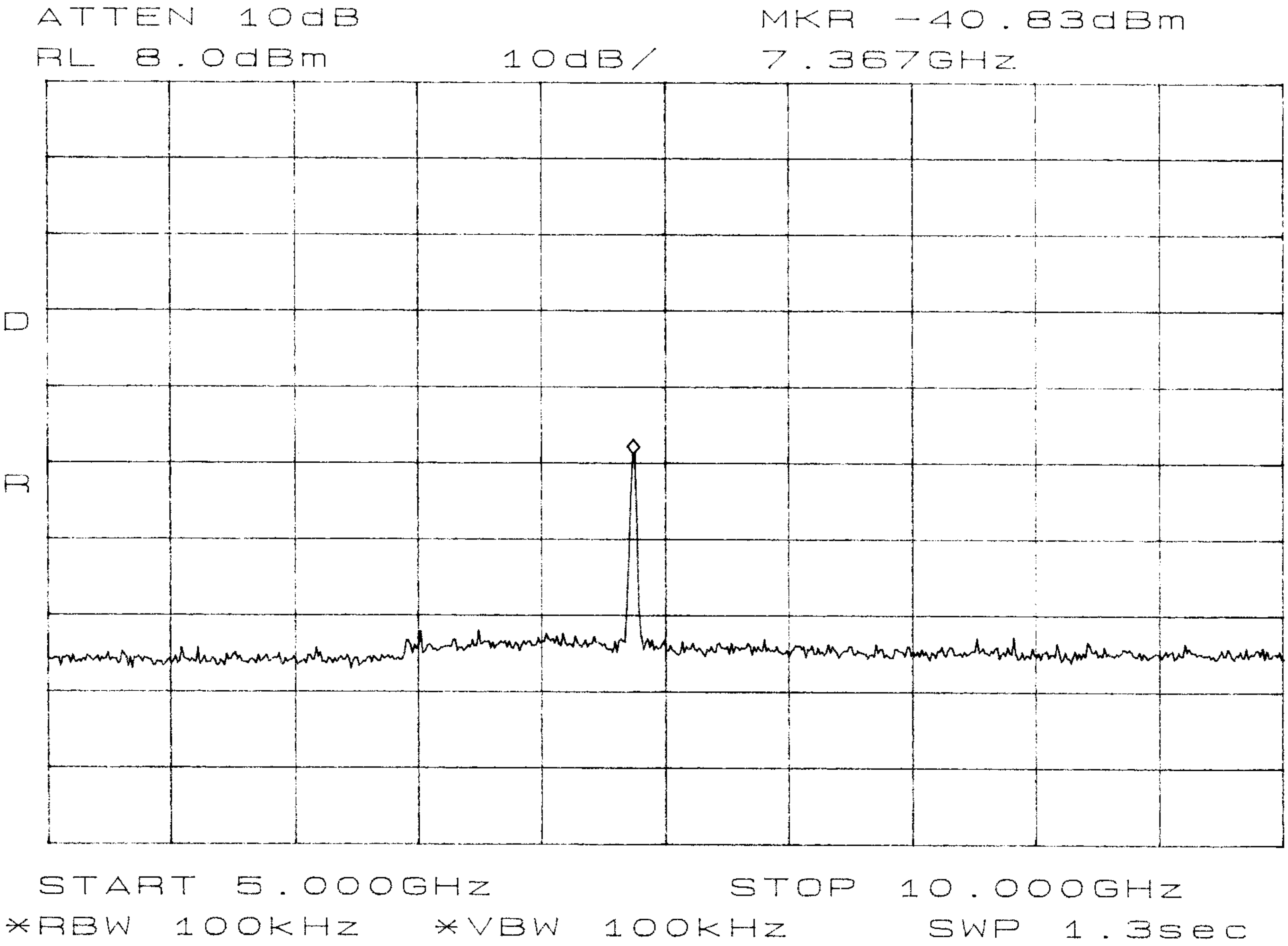
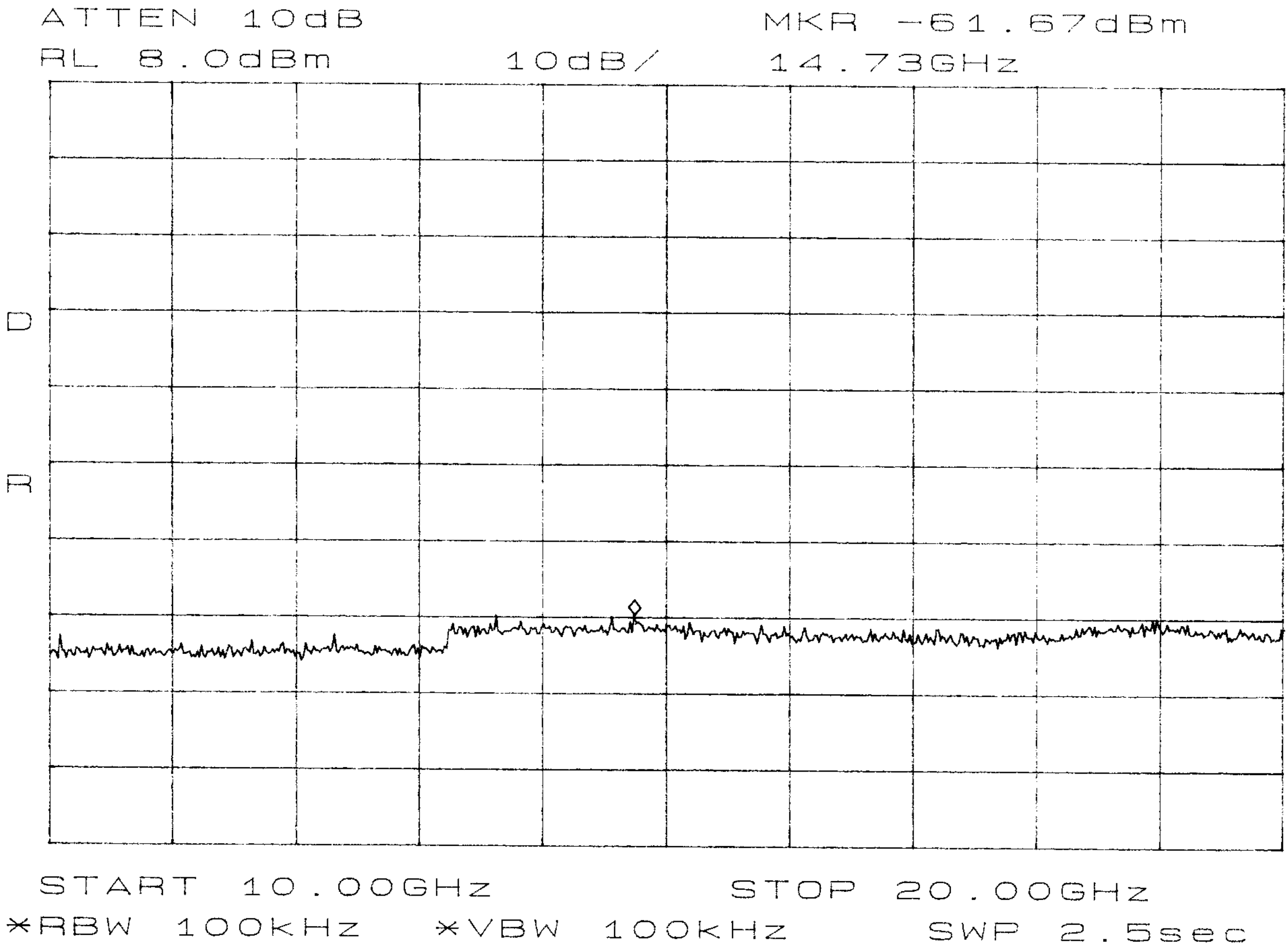
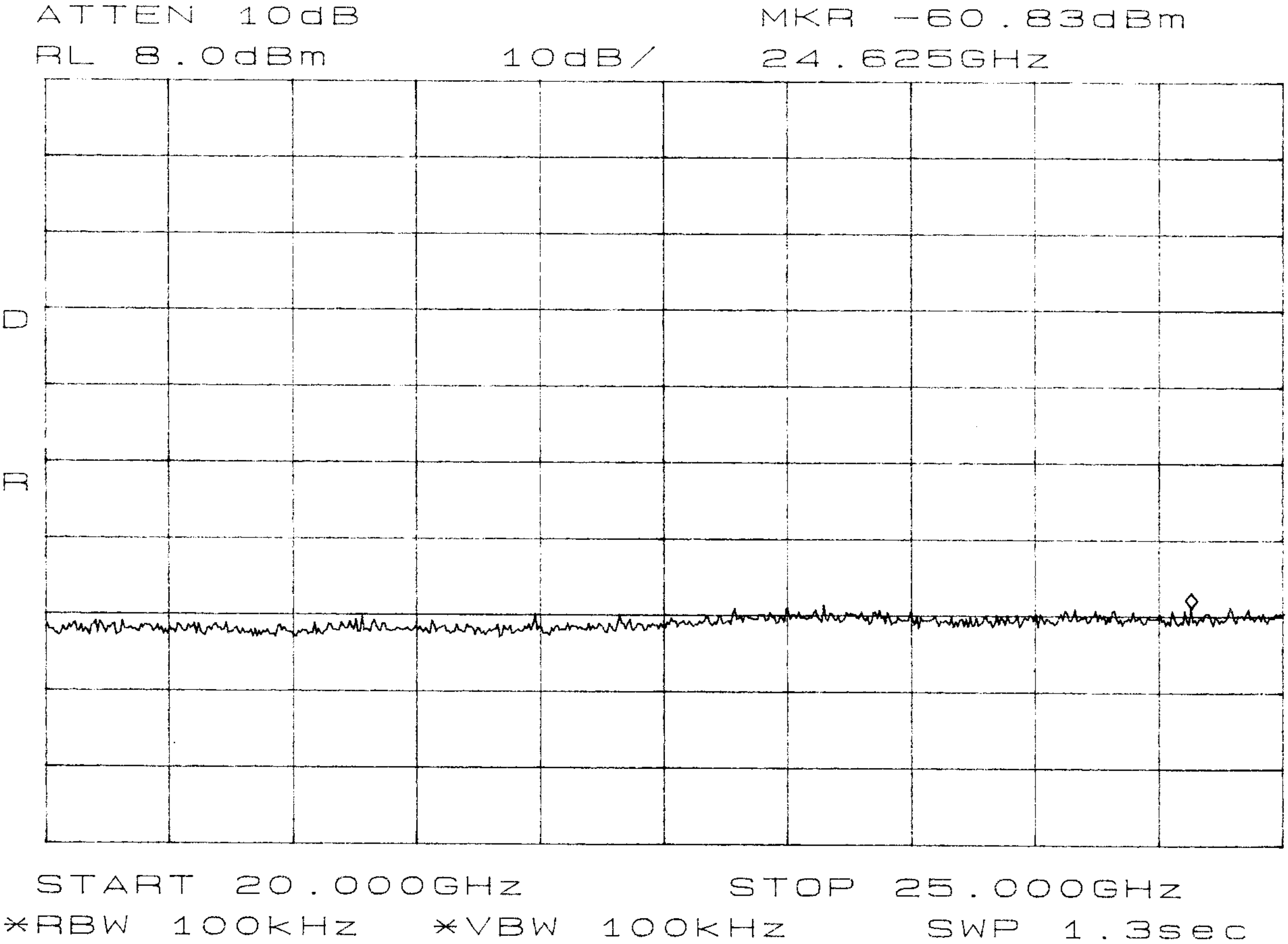
*RBW 100kHz
*VBW 100kHz
SWP 350ms


ATTEN 10dB
RL 8.0dBm
10dB/
ΔMKR -20.66dB
10.5MHz
D
R
START 2.3900GHz
STOP 2.5000GHz
*RBW 100kHz
*VBW 100kHz
SWP 50ms


ATTEN 10dB
RL 8.0dBm
10dB/
MKR -53.33dBm
4.946GHz
D
R
START 2.500GHz
STOP 5.000GHz
*RBW 100kHz
*VBW 100kHz
SWP 630ms


ATTEN 10dB
RL 8.0dBm
10dB/
MKR -40.83dBm
7.367GHz
D
R
START 5.000GHz
STOP 10.000GHz
*RBW 100kHz
*VBW 100kHz
SWP 1.3sec


ATTEN 10dB
RL 8.0dBm
10dB/
MKR -61.67dBm
14.73GHz
D
R
START 10.00GHz
STOP 20.00GHz
*RBW 100kHz
*VBW 100kHz
SWP 2.5sec


ATTEN 10dB
RL 8.0dBm
10dB/
MKR -60.83dBm
24.625GHz
D
R
START 20.000GHz
STOP 25.000GHz
*RBW 100kHz
*VBW 100kHz
SWP 1.3sec

ELLIOTT
LABORATORIES

EMC Test Log

Client Name OTC Telecom	Date 03/04/98	Test Engineer	Mehran M Birgani
Product e'LAN Bridge	Page 1 of 5	Project Engineer	Jay Dickinson
Test Type Final Qualification	File T26039	Client Contact	Weiming Ou
Specification FCC B	Site SV OATS #1	Approved	

Test Objective

The objective of this test session is to perform final qualification testing of the EUT defined below relative to the specification defined above.

Test Summary

Run #1 - Unmaximized Preliminary Radiated Emissions Scan, 30-1000 MHz

Results: FCC B -3.0 dB QP @ 600.093 MHz Horizontal

Run #2 - Maximized Radiated Emissions from Run #1

PASS Results: FCC B -2.6 dB QP @ 600.093 MHz Vertical

Run #3 - Conducted Emissions Scan of EUT, 0.15-30.00 MHz

PASS Results: FCC B -10.9 dB QP @ 0.6500 MHz Line

Equipment Under Test (EUT) General Description

The EUT is a Spread Spectrum radio system which utilises direct sequence and is designed to use the 1 channels in the allocated frequency band of 2400-2483.5 MHz. Normally, the EUT would attached to a personal computer ethernet port. The EUT was placed on a table top during emissions testing to simulate the end user environment.

EMC Test Log

Client Name	OTC Telecom	Date	03/04/98	Test Engineer	Mehran M Birgani
Product	e'LAN Bridge	Page	2 of 5	Project Engineer	Jay Dickinson
Test Type	Final Qualification	File	T26039	Client Contact	Weiming Ou
Specification	FCC B	Site	SV OATS #1	Approved	

Equipment Under Test (EUT)

Manufacturer/Model/Description	Serial Number	FCC ID Number
OTC Telecom AirEzy 2400 e'LAN Bridge	241650	MKZAEZY 2411BRG

Local Support Equipment

Manufacturer/Model/Description	Serial Number	FCC ID Number
HP / Multimedia 6170 S	US52120866	EJMMORRISON
AMAX/Impression3 Plus3428N / Monitor	59252636	H79DCM-1458
HP / Mouse	LCA51105563	DZL210472
HP / Keyboard	30250393	AQ6MTN4XZ15
Ethernet Adapter NIC	-	-
HP 2225C Parallel Thinkjet Printer	2714S40166	DSI6XU2225

Remote Support Equipment

Manufacturer/Model/Description	Serial Number	FCC ID Number
CompuStar/ AT	01F23NP	-
AMAX/ Zmpersion3 Plus / Monitor	E134786	-
AMAX/ Keyboard	D00100608	-
OTC Telecom/ AEZY 2400 e'LAN Bridge	24166561	-
Scepter/ Power Supply	LR67888	-

Power Supply and Line Filters

Description	Manufacturer	Model
AC / DC Converter	AKII	A10D1-05MP

Interface Cabling

Cable Description	Length (m)	From Unit/Port	To Unit/Port
RJ45	2.5	EUT	PC NIC
Shielded Serial	2	Host PC Serial	Modem
Shielded Parallel	2	Host PC Parallel	Printer
Shielded Keyboard	2	Host PC Keyboard	Keyboard
Shielded Mouse	2	Host PC Mouse	Mouse
Coax	20'	EUT	Lighting Arrester
Coax	20'	Lighting Arrester	Antenna

ELLIOTT
LABORATORIES

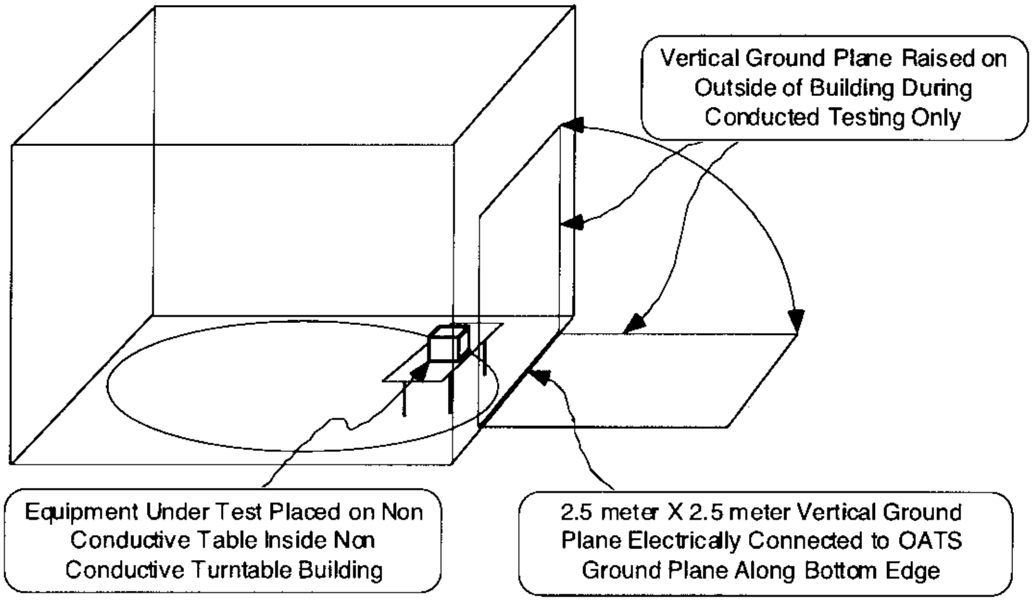
EMC Test Log

Client Name	OTC Telecom	Date	03/04/98	Test Engineer	Mehran M Birgani
Product	e'LAN Bridge	Page	3 of 5	Project Engineer	Jay Dickinson
Test Type	Final Qualification	File	T26039	Client Contact	Weiming Ou
Specification	FCC B	Site	SV OATS #1	Approved	

General Test Conditions

During radiated testing, the EUT was connected to 120V, 60Hz power input. The EUT and all local support equipment were located on the turntable for radiated testing and conducted testing. All remote support equipment was located approximately 30 meters from the EUT.

During conducted emissions testing, the EUT was connected to 120V, 60Hz power input as noted. A 2.5 meter X 2.5 meter ground plane is raised to a vertical position 40 cm from the EUT as shown below:



Test Software

During emissions testing the EUT transmitter was set to continuous transmit and recieve mode, using OTC Telecom test program OTCFCC.

EUT Enclosure(s)

The EUT enclosure is primarily constructed of fabricated sheet steel. It measures approximately 9.8 cm wide by 15.3 cm deep by 3.8 cm high.

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LABORATORIES

EMC Test Log

Client Name	OTC Telecom	Date	03/04/98	Test Engineer	Mehran M Birgani
Product	e'LAN Bridge	Page	4 of 5	Project Engineer	Jay Dickinson
Test Type	Final Qualification	File	T26039	Client Contact	Weiming Ou
Specification	FCC B	Site	SV OATS #1	Approved	

Printed Wiring Boards in EUT

Manufacturer/Description	Assembly #	Rev.	Serial Number	Crystals (MHz)
OTC/ Telecom/ RF Board	1710-2410BT-00	-	None	10
OTC/ Telecom/ Digital Board	1700-2410BT-0A	-	None	44

EMI Suppression Devices (filters, gaskets, etc.)

Description	Manufacturer	Part Number
None		

Test Data Tables

Run #1 - Unmaximized Preliminary Radiated Emissions Scan, 30-1000 MHz, Quasi-Peak Readings, Sorted by Margin

Frequency MHz	Level dBuV/m	Pol v/h	FCC B Limit	FCC B Margin	Azimuth degrees	Height meters	Comments
600.093	43.0	h	46.0	**-3.0**	187	1.9	
60.003	36.5	v	40.0	**-3.5**	236	1.0	
55.400	36.5	v	40.0	**-3.5**	270	1.0	
600.093	41.1	v	46.0	**-4.9**	85	1.0	Borad Band
330.000	39.4	h	46.0	**-6.6**	64	1.9	
44.000	31.7	v	40.0	**-8.3**	0	1.0	
360.040	37.3	v	46.0	**-8.7**	275	1.0	Borad Band
440.080	37.3	v	46.0	**-8.7**	158	1.0	Borad Band
330.000	37.1	v	46.0	**-8.9**	0	3.0	
190.000	32.3	h	43.5	**-11.2**	340	3.4	
132.000	32.0	v	43.5	**-11.5**	100	1.0	
450.000	34.1	v	46.0	**-11.9**	258	1.0	
440.043	33.2	h	46.0	**-12.8**	207	1.9	
100.000	30.7	v	43.5	**-12.8**	0	1.0	Signal Subsitution
198.000	30.2	h	43.5	**-13.3**	230	3.6	
198.000	30.0	v	43.5	**-13.5**	0	1.0	
396.043	31.4	h	46.0	**-14.6**	195	1.9	
800.000	31.2	h	46.0	**-14.8**	111	1.9	
660.000	31.1	v	46.0	**-14.9**	202	1.0	
130.000	27.8	h	43.5	**-15.7**	32	3.6	
400.000	30.3	h	46.0	**-15.7**	70	3.4	
360.040	30.1	h	46.0	**-15.9**	195	1.9	
280.000	27.4	v	46.0	**-18.6**	72	1.0	
190.000	24.2	v	43.5	**-19.3**	127	1.0	
150.000	23.8	v	43.5	**-19.7**	0	1.0	
90.000	23.6	v	43.5	**-19.9**	159	2.0	
132.000	22.9	h	43.5	**-20.6**	121	2.9	

ELLIOTT
LABORATORIES

EMC Test Log

Client Name	OTC Telecom	Date	03/04/98	Test Engineer	Mehran M Birgani
Product	e'LAN Bridge	Page	5 of 5	Project Engineer	Jay Dickinson
Test Type	Final Qualification	File	T26039	Client Contact	Weiming Ou
Specification	FCC B	Site	SV OATS #1	Approved	OwB

Run #2 - Maximized Radiated Emissions from Run #1, Quasi-Peak Readings, Sorted by Margin

Frequency MHz	Level dBuV/m	Pol v/h	FCC B Limit	FCC B Margin	Azimuth degrees	Height meters	Comments
600.093	43.4	v	46.0	**-2.6**	91	1.0	Borad Band
55.400	37.1	v	40.0	**-2.9**	254	1.0	
600.093	43.0	h	46.0	**-3.0**	183	1.9	Borad Band
60.003	36.5	v	40.0	**-3.5**	236	1.0	
330.000	41.3	h	46.0	**-4.7**	64	3.4	
44.000	31.7	v	40.0	**-8.3**	0	1.0	

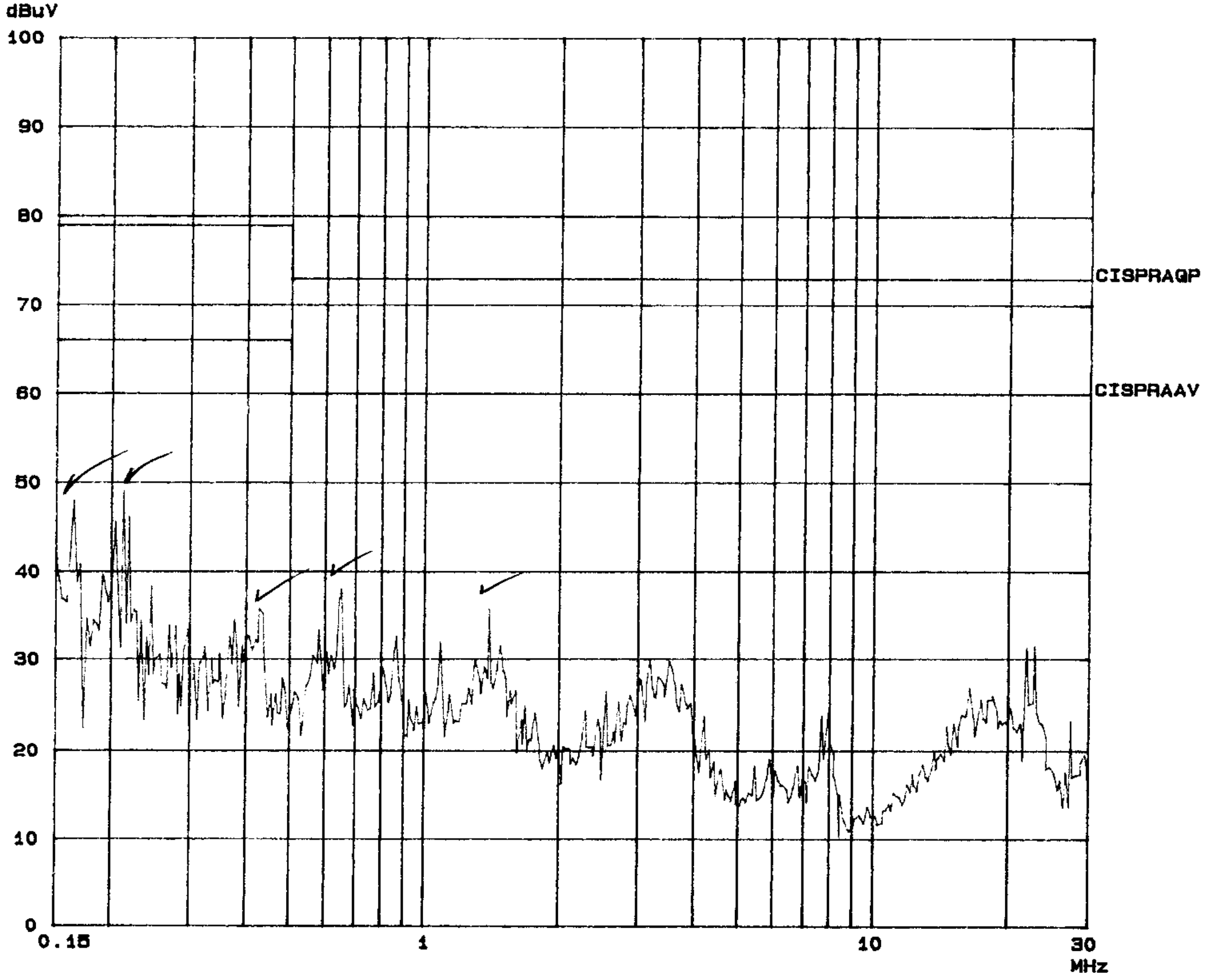
Run #3 - Conducted Emissions, 0.15-30.0 MHz, Sorted by Margin

Frequency MHz	Level dBuV	Power Lead	FCC B Limit	FCC B Margin	Detector Function	Comments
0.6500	37.1	line	48.0	**-10.9**	QP	
0.6500	36.6	neutral	48.0	**-11.4**	QP	
0.8700	34.9	line	48.0	**-13.1**	QP	
0.8700	33.4	neutral	48.0	**-14.6**	QP	
1.0800	32.4	line	48.0	**-15.6**	QP	
1.0800	29.2	neutral	48.0	**-18.8**	QP	
0.1500	51.0	line	N/A	**N/A**	QP	
0.1500	49.9	neutral	N/A	**N/A**	QP	

Elliott Laboratories
Conducted

03. Apr 98 03:18

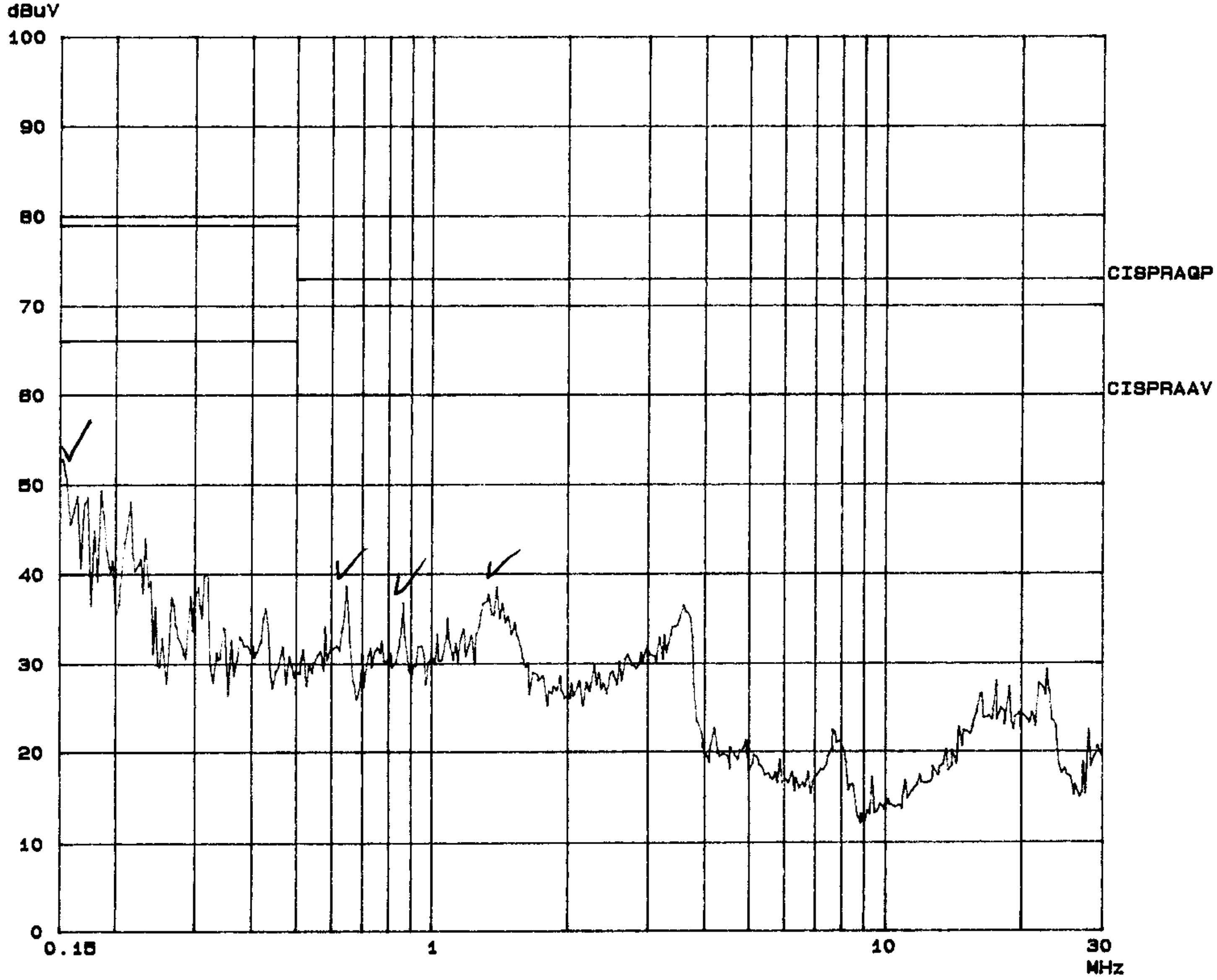
Operator: Mehran M Birgani MMB
Comment: OTC Telecom
e'LAN Bridge
T26039 Run 3
120V, 60Hz
A=Ambient, √=EUT
NEUTRAL



Elliott Laboratories
Conducted

03. Apr 98 03:02

Operator: Mehran M Birgani MMB
Comment: OTC Telecom
e'LAN Bridge
T26039 Run 3
120V, 60Hz
A=Ambient, ✓=EUT
LINE



PROCESSING GAIN MEASUREMENT

1.1 Measurement Setup

Figure 1 shows the setup for measuring the processing gain of AirEzy2411 eLAN Bridge. A Transmitting Computer A and a Receiving Computer B are used to execute a Bit Error Rate (BER) Testing Computer Program. The BER is determined by repetitively transmitting a testing data file from Computer A to Computer B. At Computer B the received data file is compared with a pre-stored version of the testing data file to compute the bit error rate. An HP 8648C Signal Generator is used to generate interference or jamming signal.

Data signal from the Transmitting Computer is sent to the Transmitting AirEzy2411 eLAN Bridge unit for modulation. It is then combined with the interference signal from the Signal Generator through a equal power (3 dB) combiner. The combined signal is fed into a Receiving AirEzy2411 eLAN Bridge, the Device Under Test (DUT), for demodulation, and the demodulated signal is sent into the Receiving Computer for Bit Error Rate computation.

1.2 Measurement Procedure

The data signal level at the input of the Receiving AirEzy2411 eLAN Bridge, point P in Figure 1, is determined. With Attenuator A set at 60 dB attenuation, the data signal level at point P is measured to be -44 dBm.

Then the Signal Generator is set at a certain CW frequency between 2434.5 MHz and 2450.5 MHz. The interference level at the input of the Receiving AirEzy2411 eLAN Bridge, the DUT, can be varied by adjusting the output level of the Signal Generator.

The measurement of processing gain is carried out by adjusting the output level of the Signal Generator such that the Bit Error Rate is maintained at no higher than 10^{-5}. The interference level at the input of the DUT, the point P, is then measured. In the AirEzy2411 eLAN Bridge receiving chain a Surface Acoustic Wave (SAW)IF filter which has a nominal 3-dB bandwidth of ±7.5 MHz centered at 280 MHz (see Fig. 2) is used. Jamming signals outside the 2442.5±7.5 MHz frequency band will be heavily attenuated. The measurement is performed from 2434.5 MHz to 2450.5 MHz at 50 KHz interval. The measured interference power level at point P with BER $\leq 10^{-5}$ at each frequency is shown in the following:

Freq. (MHz)	Jammer Power(dBm)	J/S (dB)	Freq. (MHz)	Jammer Power(dBm)	J/S (dB)
2434.50	-48.5	-4.5	2444.50	-49.2	-5.2
2434.55	-48.6	-4.6	2444.55	-49.3	-5.3
2434.60	-48.7	-4.7	2444.60	-49.3	-5.3
2434.65	-48.7	-4.7	2444.65	-49.4	-5.4
2434.70	-48.6	-4.6	2444.70	-49.4	-5.4
2434.75	-48.6	-4.6	2444.75	-49.4	-5.4
2434.80	-48.6	-4.6	2444.80	-49.4	-5.4
2434.85	-48.7	-4.7	2444.85	-49.5	-5.5
2434.90	-48.7	-4.7	2444.90	-49.5	-5.5
2434.95	-48.8	-4.8	2444.95	-49.4	-5.4
2435.00	-48.8	-4.8	2445.00	-49.3	-5.3
2435.05	-48.9	-4.9	2445.05	-49.3	-5.3
2435.10	-48.9	-4.9	2445.10	-49.2	-5.2
2435.15	-48.9	-4.9	2445.15	-49.2	-5.2
2435.20	-49.0	-5.0	2445.20	-49.2	-5.2
2435.25	-49.2	-5.2	2445.25	-49.2	-5.2
2435.30	-49.3	-5.3	2445.30	-49.1	-5.1
2435.35	-49.4	-5.4	2445.35	-49.1	-5.1
2435.40	-49.4	-5.4	2445.40	-49.0	-5.0
2435.45	-49.4	-5.4	2445.45	-49.0	-5.0
2435.50	-49.4	-5.4	2445.50	-48.9	-4.9
2435.55	-49.4	-5.4	2445.55	-48.9	-4.9
2435.60	-49.3	-5.3	2445.60	-48.9	-4.9
2435.65	-49.4	-5.4	2445.65	-48.9	-4.9
2435.70	-49.4	-5.4	2445.70	-48.8	-4.8
2435.75	-49.4	-5.4	2445.75	-48.8	-4.8
2435.80	-49.3	-5.3	2445.80	-48.7	-4.7
2435.85	-49.3	-5.3	2445.85	-48.7	-4.7
2435.90	-49.2	-5.2	2445.90	-48.7	-4.7
2435.95	-49.3	-5.3	2445.95	-48.7	-4.7
2436.00	-49.3	-5.3	2446.00	-48.6	-4.6
2436.05	-49.3	-5.3	2446.05	-48.7	-4.7
2436.10	-49.3	-5.3	2446.10	-48.7	-4.7
2436.15	-49.4	-5.4	2446.15	-48.7	-4.7
2436.20	-49.4	-5.4	2446.20	-48.7	-4.7
2436.25	-49.4	-5.4	2446.25	-48.8	-4.8
2436.30	-49.3	-5.3	2446.30	-48.8	-4.8
2436.35	-49.3	-5.3	2446.35	-48.8	-4.8

2436.40	-49.3	-5.3	2446.40	-48.8	-4.8
2436.45	-49.4	-5.4	2446.45	-48.7	-4.7
2436.50	-49.4	-5.4	2446.50	-48.6	-4.6
2436.55	-49.4	-5.4	2446.55	-48.7	-4.7
2436.60	-49.4	-5.4	2446.60	-48.7	-4.7
2436.65	-49.3	-5.3	2446.65	-48.7	-4.7
2436.70	-49.2	-5.2	2446.70	-48.7	-4.7
2436.75	-49.2	-5.2	2446.75	-48.7	-4.7
2436.80	-49.2	-5.2	2446.80	-48.7	-4.7
2436.85	-49.2	-5.2	2446.85	-48.8	-4.8
2436.90	-49.2	-5.2	2446.90	-48.9	-4.9
2436.95	-49.2	-5.2	2446.95	-49.0	-5.0
2437.00	-49.1	-5.1	2447.00	-49.0	-5.0
2437.05	-49.1	-5.1	2447.05	-49.0	-5.0
2437.10	-49.1	-5.1	2447.10	-49.0	-5.0
2437.15	-49.1	-5.1	2447.15	-49.1	-5.1
2437.20	-49.0	-5.0	2447.20	-49.1	-5.1
2437.25	-49.0	-5.0	2447.25	-49.2	-5.2
2437.30	-48.9	-4.9	2447.30	-49.2	-5.2
2437.35	-48.9	-4.9	2447.35	-49.3	-5.3
2437.40	-48.9	-4.9	2447.40	-49.3	-5.3
2437.45	-48.9	-4.9	2447.45	-49.4	-5.4
2437.50	-48.8	-4.8	2447.50	-49.4	-5.4
2437.55	-48.9	-4.9	2447.55	-49.4	-5.4
2437.60	-49.0	-5.0	2447.60	-49.3	-5.3
2437.65	-49.1	-5.1	2447.65	-49.3	-5.3
2437.70	-49.2	-5.2	2447.70	-49.2	-5.2
2437.75	-49.3	-5.3	2447.75	-49.2	-5.2
2437.80	-49.4	-5.4	2447.80	-49.1	-5.1
2437.85	-49.5	-5.5	2447.85	-49.1	-5.1
2437.90	-49.5	-5.5	2447.90	-49.0	-5.0
2437.95	-49.5	-5.5	2447.95	-49.0	-5.0
2438.00	-49.5	-5.5	2448.00	-49.0	-5.0
2438.05	-49.4	-5.4	2448.05	-49.0	-5.0
2438.10	-49.4	-5.4	2448.10	-48.9	-4.9
2438.15	-49.4	-5.4	2448.15	-48.9	-4.9
2438.20	-49.3	-5.3	2448.20	-48.8	-4.8
2438.25	-49.3	-5.3	2448.25	-48.8	-4.8
2438.30	-49.4	-5.4	2448.30	-48.8	-4.8
2438.35	-49.4	-5.4	2448.35	-48.8	-4.8
2438.40	-49.4	-5.4	2448.40	-48.7	-4.7
2438.45	-49.4	-5.4	2448.45	-48.7	-4.7
2438.50	-49.4	-5.4	2448.50	-48.7	-4.7
2438.55	-49.4	-5.4	2448.55	-48.8	-4.8
2438.60	-49.4	-5.4	2448.60	-48.9	-4.9

2438.65	-49.4	-5.4
2438.70	-49.4	-5.4
2438.75	-49.5	-5.5
2438.80	-49.5	-5.5
2438.85	-49.5	-5.5
2438.90	-49.5	-5.5
2438.95	-49.5	-5.5
2439.00	-49.4	-5.4
2439.05	-49.4	-5.4
2439.10	-49.3	-5.3
2439.15	-49.3	-5.3
2439.20	-49.2	-5.2
2439.25	-49.2	-5.2
2439.30	-49.2	-5.2
2439.35	-49.2	-5.2
2439.40	-49.1	-5.1
2439.45	-49.1	-5.1
2439.50	-49.1	-5.1
2439.55	-49.1	-5.1
2439.60	-49.0	-5.0
2439.65	-49.1	-5.1
2439.70	-49.1	-5.1
2439.75	-49.2	-5.2
2439.80	-49.2	-5.2
2439.85	-49.2	-5.2
2439.90	-49.2	-5.2
2439.95	-49.2	-5.2
2440.00	-49.2	-5.2
2440.05	-49.3	-5.3
2440.10	-49.3	-5.3
2440.15	-49.2	-5.2
2440.20	-49.1	-5.1
2440.25	-49.1	-5.1
2440.30	-49.1	-5.1
2440.35	-49.1	-5.1
2440.40	-49.0	-5.0
2440.45	-49.0	-5.0
2440.50	-48.9	-4.9
2440.55	-49.0	-5.0
2440.60	-49.0	-5.0
2440.65	-49.0	-5.0
2440.70	-49.0	-5.0
2440.75	-49.1	-5.1
2440.80	-49.2	-5.2
2440.85	-49.3	-5.3

2448.65	-49.0	-5.0
2448.70	-49.1	-5.1
2448.75	-49.2	-5.2
2448.80	-49.3	-5.3
2448.85	-49.4	-5.4
2448.90	-49.4	-5.4
2448.95	-49.4	-5.4
2449.00	-49.4	-5.4
2449.05	-49.4	-5.4
2449.10	-49.3	-5.3
2449.15	-49.3	-5.3
2449.20	-49.3	-5.3
2449.25	-49.3	-5.3
2449.30	-49.3	-5.3
2449.35	-49.3	-5.3
2449.40	-49.2	-5.2
2449.45	-49.2	-5.2
2449.50	-49.2	-5.2
2449.55	-49.2	-5.2
2449.60	-49.1	-5.1
2449.65	-49.0	-5.0
2449.70	-48.9	-4.9
2449.75	-49.0	-5.0
2449.80	-49.0	-5.0
2449.85	-49.0	-5.0
2449.90	-49.0	-5.0
2449.95	-48.9	-4.9
2450.00	-48.8	-4.8
2450.05	-48.8	-4.8
2450.10	-48.8	-4.8
2450.15	-48.8	-4.8
2450.20	-48.7	-4.7
2450.25	-48.7	-4.7
2450.30	-48.7	-4.7
2450.35	-48.8	-4.8
2450.40	-48.8	-4.8
2450.45	-48.8	-4.8
2450.50	-48.7	-4.7

2440.90	-49.3	-5.3
2440.95	-49.3	-5.3
2441.00	-49.2	-5.2
2441.05	-49.2	-5.2
2441.10	-49.2	-5.2
2441.15	-49.3	-5.3
2441.20	-49.3	-5.3
2441.25	-49.3	-5.3
2441.30	-49.2	-5.2
2441.35	-49.3	-5.3
2441.40	-49.3	-5.3
2441.45	-49.3	-5.3
2441.50	-49.3	-5.3
2441.55	-49.4	-5.4
2441.60	-49.4	-5.4
2441.65	-49.6	-5.6
2441.70	-49.8	-5.8
2441.75	-50.1	-6.1
2441.80	-50.3	-6.3
2441.85	-50.8	-6.8
2441.90	-51.2	-7.2
2441.95	-51.4	-7.4
2442.00	-51.5	-7.5
2442.05	-51.7	-7.7
2442.10	-51.9	-7.9
2442.15	-52.1	-8.1
2442.20	-52.3	-8.3
2442.25	-52.5	-8.5
2442.30	-52.7	-8.7
2442.35	-52.8	-8.8
2442.40	-52.8	-8.8
2442.45	-52.8	-8.8
2442.50	-52.7	-8.7
2442.55	-52.6	-8.6
2442.60	-52.5	-8.5
2442.65	-52.3	-8.3
2442.70	-52.1	-8.1
2442.75	-52.0	-8.0
2442.80	-51.8	-7.8
2442.85	-51.8	-7.8
2442.90	-51.7	-7.7
2442.95	-51.6	-7.6
2443.00	-51.4	-7.4
2443.05	-51.2	-7.2
2443.10	-51.0	-7.0

2443.15	-51.9	-7.9
2443.20	-50.7	-6.7
2443.25	-50.6	-6.6
2443.30	-50.4	-6.4
2443.35	-50.3	-6.3
2443.40	-50.1	-6.1
2443.45	-49.9	-5.9
2443.50	-49.7	-5.7
2443.55	-49.6	-5.6
2443.60	-49.4	-5.4
2443.65	-49.3	-5.3
2443.70	-49.2	-5.2
2443.75	-49.2	-5.2
2443.80	-49.1	-5.1
2443.85	-49.1	-5.1
2443.90	-49.0	-5.0
2443.95	-49.0	-5.0
2444.00	-48.9	-4.9
2444.05	-48.9	-4.9
2444.10	-48.9	-4.9
2444.15	-49.0	-5.0
2444.20	-49.0	-5.0
2444.25	-49.1	-5.1
2444.30	-49.1	-5.1
2444.35	-49.2	-5.2
2444.40	-49.2	-5.2
2444.45	-49.2	-5.2

1.3 Determination of Processing Gain

Let the required theoretical signal to noise ratio for achieving a certain BER, say 10^{-5}, in a non-spread-spectrum receiver be SNRN and that for achieving the same BER in a spread-spectrum receiver be SNRS, the processing gain G_p achieved by this spread-spectrum receiver can be computed using the following formula:

$$G_p = SNRN + L_s - SNRS \text{ (in dB)},$$

where L_s is the system loss due to the difference between a practical system and the ideal system such as the non-ideal filter characteristic.

AirEZY2411 eLAN Bridge uses DQPSK M-ary Bi-Orthogonal Keying (MBOK) modulation scheme that converts each 8-bit symbol into a pair of 8-bit chip sequences and transmits each sequence through the I and the Q channels. It is known that the theoretical signal to noise ratio required to achieve a 10^{-5} BER for such a DQPSK receiver with MBOK modulation is 16.6 dB[1],[2]. In Attachment A is a more detailed discussion of the MBOK modulation and the required S/N ratio. The system loss L_s for AirEzy-2411 eLAN Bridge is estimated to be approximately 2 dB.

The signal to noise ratio required by AirEzy2411 eLAN Bridge in the presence of a CW jamming signal to achieved a BER $\leq 10^{-5}$ can be computed by the measured data listed in the preceding section. The data signal level at the input of the DUT is -44 dBm. The lowest interference power level for maintaining a BER of 10^{-5} , after the worst 20% data points being discarded, is -49.4 dBm. The lowest interference to signal power ratio is -5.4 dB

The Processing Gain is therefore

$$G_p = 16.6 + 2 - 5.4 = 13.2 \text{ dB}$$

Reference

[1] William C. Lindsey and Marvin K. Simon, Telecommunication Systems Engineering, Chapter 5, Prentice-Hall, 1973.

[2] Carl Andren, "11Mbps Modulation Techniques", Wireless Symposium, February 1998, San Jose, California.

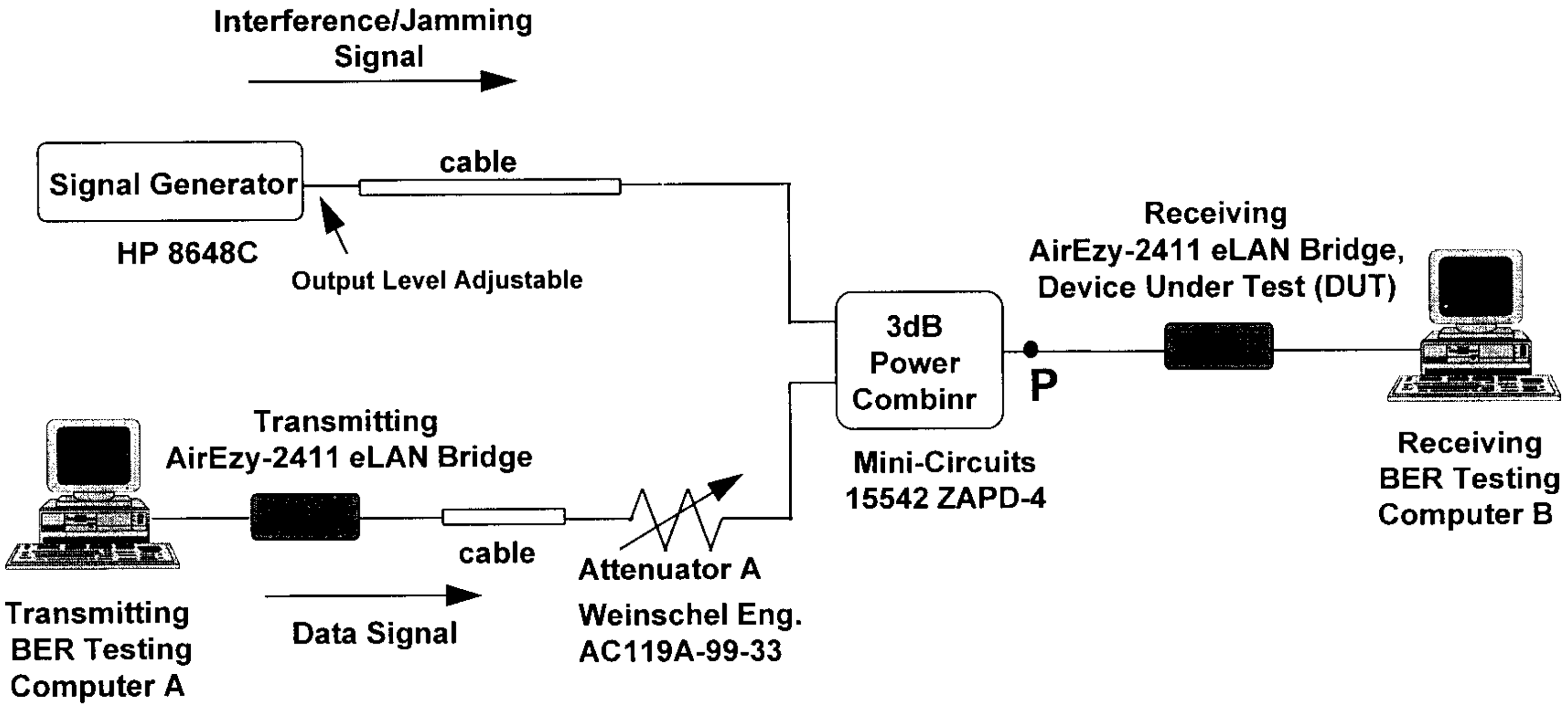


Figure 1. Processing Gain Measurement Setup for AirEzy-2411 eLAN Bridge.

Attachment A

11 MBps Modulation Techniques

Summary

This paper addresses concepts for higher data rates than originally contemplated for the 2.4 GHz ISM band. It shows modulation options that may be used to implement proposed high speed WLANs that will provide 1 to 11 MBps rates in this band. This architecture study looks at all options that not only make sense but obey the unique rules for this band. The FCC has allocated the ISM band for unlicensed use and has set rules for operation in the band. The rules specify that spread spectrum modulations be used to prevent interference with other users. Both Direct Sequence Spread Spectrum (DSSS) and Frequency Hop (FH) modulations are allowed. There are different rules for each of these techniques and they make for different tradeoffs for each.

The main schemes that have been considered for higher rates are variations on DSSS Modulations where more complex modulations are used in place of BPSK and QPSK for the symbol modulation. The methods considered are various forms of M-Ary Orthogonal keying, PPM, and QAM. Multiple parallel channels of FDMA or CDMA carriers are also available for consideration. These can be traded off to find the one with the best combination of properties.

One way to increase the data rate is to simply make the spread rate higher; but that reduces the number of available channels in the band for separate networks. The current IEEE 802.11 Standard implementations in the 2.4 GHz band have 3 DSSS channels with 30 MHz spacing. That is considered the minimum that will allow some degree or cell planning. The techniques that are suggested here can easily be made interoperable with the existing 802.11 networks by employing a preamble and header that is identical to the lower rate modulations.

The other option for high rate modulations involve variations on FH modulation. This is the other allowed modulation in the ISM band. Its rules restrict it to a 20 dB bandwidth of 1 MHz, and this makes it hard to consider modulations that give higher data rates than 2 MBps.

Standards

The new high rate scheme should easily integrate with the IEEE 802.11 network architecture. It should supply higher rates with little or no change of occupied bandwidth. The schemes can use the 802.11 preamble and header that are already designed to support rate switching. This ability to do on the fly rate switching affords the capability to maintain links in a stressed environment and fill coverage gaps. By down shifting to lower rates, additional range and interference tolerance can be achieved.

Waveform Selection

Some of the candidates like Spread Spectrum with 16 PSK can be discarded quickly on the basis of poor energy efficiency which results in a poor interference rejection capability. Others like very wideband spreading can be discarded due to the limited ISM bandwidth and the need to have at least three channels in the band to implement co-located or overlapping networks.

The high energy efficiency spread spectrum waveforms considered were: MOK, CCSK, PPM, OCDM, and OFDM. The trade criteria consist of multipath rejection, interference rejection, number of channels available, the linearity required in the PA, achievable range, and the complexity. In the table below, we included QAM for comparison. The winner in this unweighted scoring is MOK. The others do not have bad scores except for QAM, but the choice depends on how you see the importance of the various attributes.

MOK

The M-ary Orthogonal Keying (MOK) scheme is well known and has been shown to have outstanding properties. It was extensively studied in the 60's where analog implementation techniques were considered. With analog implementations, the technique didn't catch on as the complexity was too high. Now, with integrated digital implementations, we can effectively use the technique and gain the benefits of this waveform.

A variation called M-ary Bi-Orthogonal Keying (MBOK) allows one more bit per symbol essentioally free. It allows multi-channel operation in the ISM band by virtue of keeping the total spread bandwidth the same as the existing 802.11 standard. The spreading is actually more uniform than the 802.11 Barker words, but it has the same chipping rate and the same spectrum shape. The spectrum is filtered to 17 MHz at the 3 dB points and to 35 dB at beyond 22 MHz. This allows three non-interfering channels in the ISM band from 2.40 to 2.483 GHz with allowance for spectral energy reduction at the band edges. With more aggressive filtering you might squeeze 4 channels into the band.

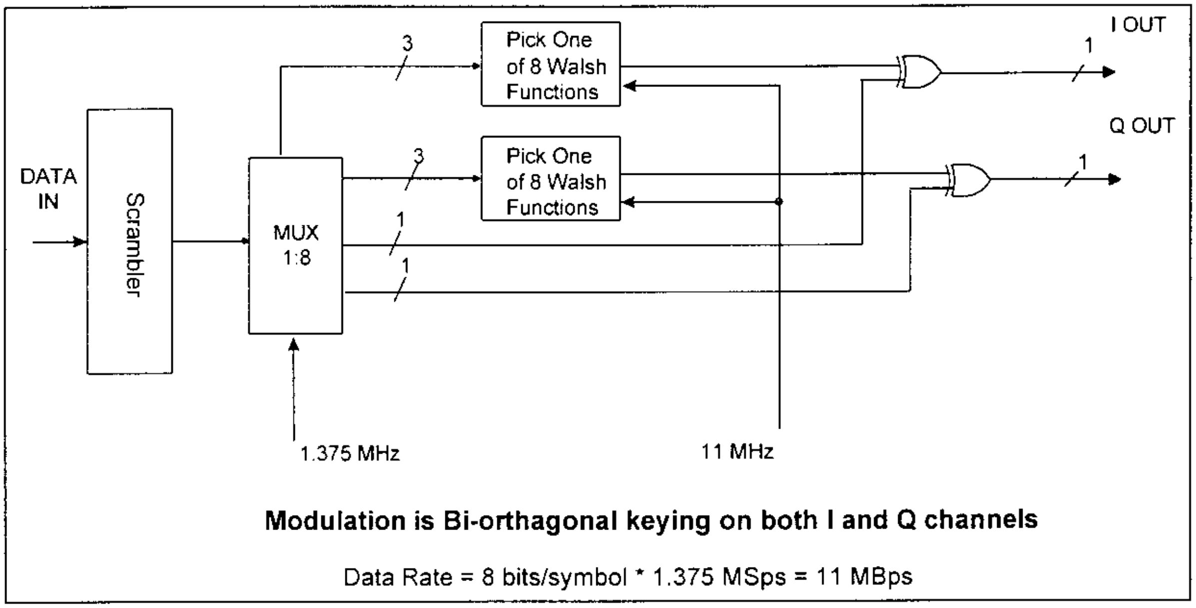


Figure 1 shows how the Bi-Orthogonal modulation is formed

MBOK is a power efficient modulation which means that you will get a good range for the higher data rate. It is robust in having good tolerance for interference and multipath.

Scheme	MBOK	CCSK	QAM	OCDM	OFDM
Multipath	2	5	4	1	1
Jamming	1	1	4	1	1
Spectrum	2	2	3	2	1
AM Mod	2	2	3	4	4
Range	1	2	5	2	2
Complexity	2	1	3	2	5
Total Score	10	13	22	12	14

Table 2, Trade matrix of modulation choices

The M-ary Bi-Orthogonal Keying (MBOK) scheme is well known and rated most of a chapter in Lindsey and Simons book: 'Telecommunications Systems Design', published in 1973. It should therefore have no patent issues other than specific implementation related techniques. M-ary orthogonal keying (MOK) can be shown to be a generalization of many standard waveforms such as FSK.

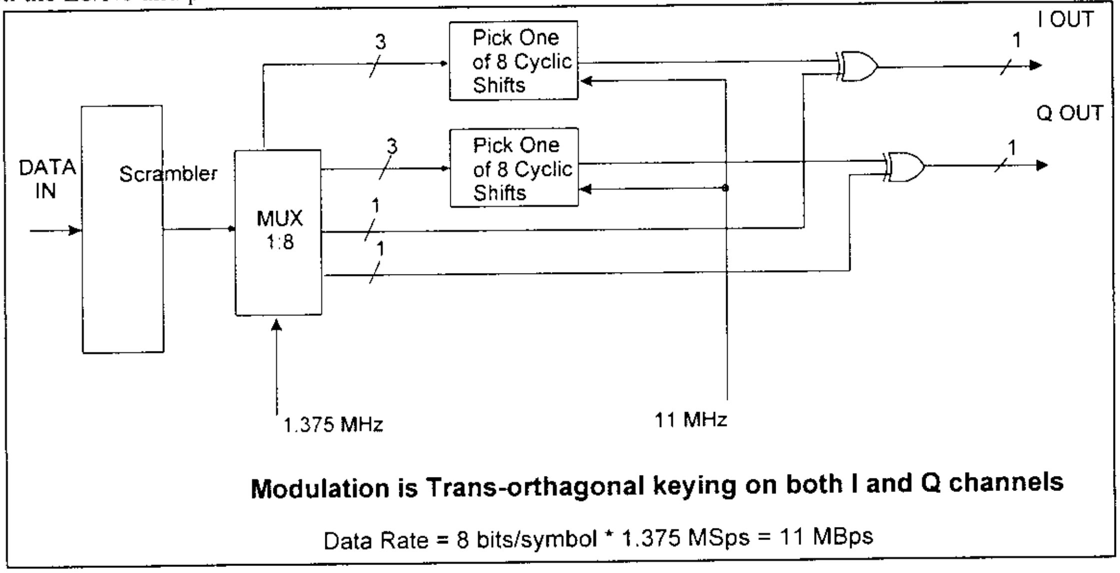
Figure 1 shows how this waveform is created. In this scheme, the spread function is picked from a set of M orthogonal vectors by the data word. Since the I and Q channels can be considered independent when coherently processed, both can be modulated this way. Bi-Orthogonal keying extends this by using both true and inverted versions of the spread function. This allows packing 8 bits into each symbol. The most well known orthogonal vector set is the Walsh function set. It is available for 8 and 16 chip vectors and has true orthogonality.

To make the modulation have the same bandwidth as the existing 802.11 DS modulation, the chipping rate is kept at 11 Mcps while the symbol rate is increased to 1.375 MSps. This makes the overall bit rate 11 Mbps. This also makes it easy to make the system interoperable with the 802.11 preamble and header. Since the spread rate remains constant, the only thing that changes when transitioning into the data from the header is the data clock rate. The figure below shows how the waveform is modulated.

MBOK modulation has been shown to have slightly better Eb/N0 performance than BPSK due to embedded coding properties. This makes the waveform the most power efficient of the candidates. This allows the modulation to tolerate more interference than other waveforms.

Since there are more bits per symbol with this modulation, it naturally requires more Es/N0 than BPSK, but the increase is minimized. The spectrum of this waveform is sinx/x, which is the same as the 802.11 waveform.

The multipath performance will depend on the Eb/N0 and phase distortion tolerance of the waveform. We have shown through simulation, that this signal will have an adequate performance in the indoor environment. It is obviously worse than the 1 Mbps case which can tolerate an SNR of 0 dB.



Modulation is Trans-orthagonal keying on both I and Q channels

Data Rate = 8 bits/symbol * 1.375 MSps = 11 MBps

Figure 2 shows how to modulate MOK with Cyclic Code Shift Keying

To use both I and Q channels independently requires that the system process the signal coherently with an absolute phase knowledge. This is not a large concern as the BPSK preamble and header can supply the necessary means to lock up a PLL in a given state. This and the parallel correlators for the demodulation moderately increase the complexity of the demodulator.

CCSK

The M-Ary Orthogonal Keying theme can be also accomplished with Cyclic Code Shift Keying (CCSK) which is a form of Pulse Position Modulation (PPM). This modulation is simpler to demodulate than MBOK since only one sequence needs to be correlated for. CCSK can be used with an 11 bit Barker sequence at 1 MSps, if desired. The modulation can be applied by time shifting the position of the correlation into one of 8 positions. The remaining 3 out of 11 positions cannot be effectively used to get more bits. This basic scheme gives 3 bits per symbol. BPSK modulating the symbol gives another bit, for a total of 4 bits per symbol. By using both I and Q channels independently, 8 bits per symbol can be achieved. This, however, would not give us the 10 MBps desired since the number of bits per symbol is not great enough. A 20% higher spread rate is needed to make the 10 MBps.

The CCSK modulation technique is not quite as efficient as MOK since the symbols are not entirely orthogonal (they are trans-orthogonal). Cyclically shifted Barker words are reasonably good, however, and achieve close to the same Eb/N0 as MOK.

The CCSK scheme is similar to the a PPM scheme except the correlation pulse is pulse position modulated rather than the whole symbol. This will result in lower AM in the transmitted waveform and therefore lower PA cost.

The main problem with any variety of PPM is the multipath susceptibility when the multipath delay spread gets to be more than a chip's length. Therefore, long (for indoors) multipath will severely degrade these methods. The CCSK scheme is quite simple to demodulate and requires very little added hardware over the basic 802.11 waveform. The modulator for the waveform is shown above.

PPM

PPM is a popular waveform and is efficient to implement. For the purposes of this discussion, we will consider the waveform to be DSSS symbols of 11 chip Barker words that are time shifted to impart up to 3 bits in the time shift. The symbols can also be BPSK or QPSK modulated to give 1 or 2 more bits per symbol. Alternatively, both I and Q channels can be PPM modulated independently with BPSK symbol modulation to make a total of 8 bits per symbol. This gives a total bit rate of 8 MBps.

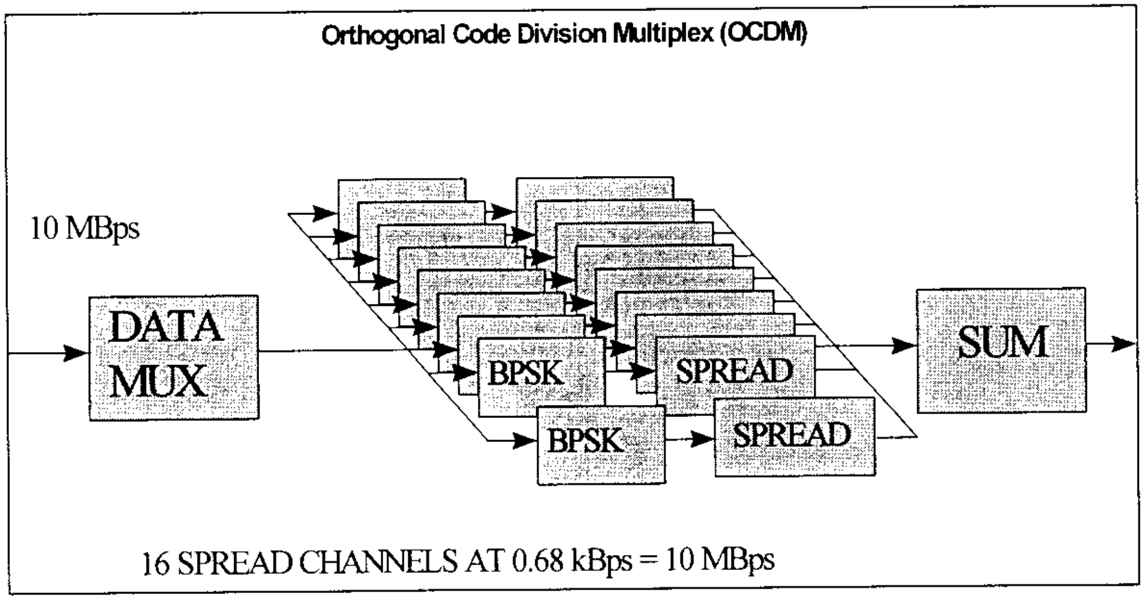


Figure 3 shows how the OCDM waveform is modulated.

One of the properties of the PPM scheme is that adjacent symbols are overlapped or have gaps between them. This makes for 6 dB of amplitude modulation and makes the transmit Power Amplifier less efficient. Lucent Technologies has recently showed a variation where the 11 chip pulses are overlapped by 3 positions to get about 20% more data rate. This exacerbates the amplitude modulation.

QAM

QAM with spreading is straightforward in concept, but suffers from low efficiency. While this modulation has its uses, it is very sensitive to multipath, since 1024 QAM requires a very clean, undistorted signal. The Eb/No performance of QAM is not as good as MOK since it has both phase and amplitude components. This sensitivity to distortion implies the use of an equalizer which is undesirable on two counts. First, it requires a training sequence which will increase the length of the preamble. Second, it will increase the cost to add the equalizer.

OCDM

The Orthogonal Code Division Multiplex (OCDM) modulation method uses multiple spread channels on the same frequency simultaneously. This method sendsmultiple streams of data on orthogonal channels. Sharp has announced that they are using OCDM for their 10 Mbps modem. They use CCSK Barker words for the 'orthogonal' PN spread channels. Basically, this technique uses multiple CDMA channels to send more data. Golden Bridge announced a technique using Walsh codes for the spreading and get better orthogonality. Basically, 16 parallel channels of 16 chip orthogonal symbols are BPSK modulated and summed in an analog sense. This provides 16 parallel channels of data at a modest symbol rate. It could be said to have a 12 dB processing gain. The OCDM scheme produces a high degree of amplitude modulation as it sums 16 independent channels. This is undesirable in that it needs a very linear PA to meet the spectral mask. It also causes more power consumption and rules out limiting in the receiver.

The OCDM technique has good Eb/N0 and a sinx/x spectrum. The processing needed to demodulate it is about the same as the MOK scheme. Figure 3 shows how the waveform is modulated.

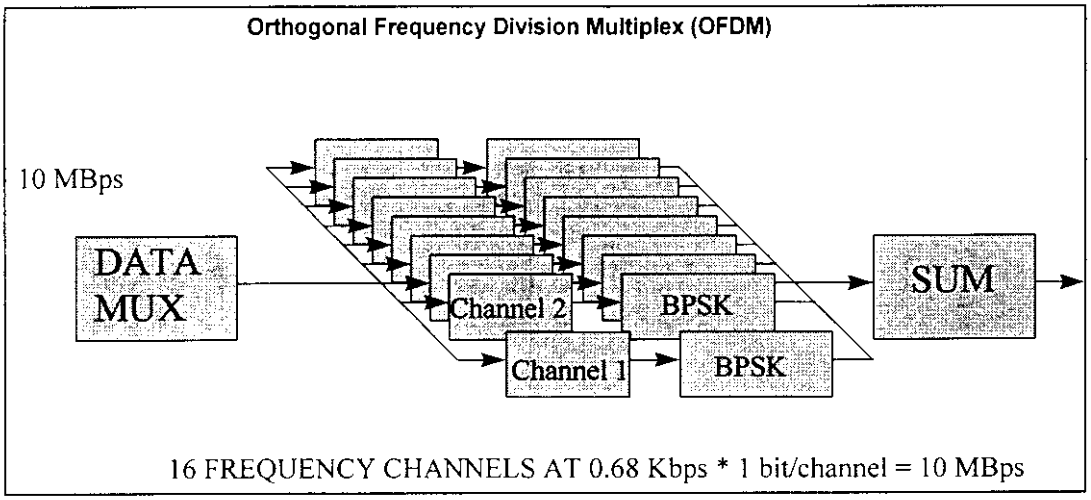


Figure 4 Orthogonal Frequency Division Modulation

OFDM

Orthogonal Frequency Division Multiplex (OFDM) has been adopted by one or more announced 10 Mbps suppliers. It takes the approach of multiple frequency channels at regular spacing with each one modulated by PSK. MIL-STD 188C has used this technique for decades in wireline and radio modems. It is commonly radiated over Single Sideband Radios since it is very tolerant of spectral notches due to multipath fading. Some form of Diversity is necessary to make it work in this environment since a narrowband fade can remove one or more of the carriers. By spreading symbol energy over multiple frequencies, a robust link can be made. This modulation makes best use of the spectrum with the channel filled edge to edge somewhat uniformly. This makes for the least interference to other users with the most noise like spectrum.

The long symbols of OFDM are said to make it more multipath resistant.

The summing of 16 independent carriers can produce large amplitude modulation which makes the transmitter difficult. It also rules out limiting in the receiver.

The processing of OFDM is traditionally done with FFTs and inverse FFTs. These are generally more complex and power hungry than the simple correlation techniques used for the other waveforms. Each of the BPSK or QPSK modulated carriers can employ differential coding to make the baseband processing somewhat simpler.

A recommendation: MBOK

The above trade study has shown that MBOK is a good candidate for the high rate modulation. Here we further examine the performance that might be achieved with this modulation.

PHY Performance Analysis

The excellent range that the M-ary Bi-Orthogonal Keying modulation achieves is due to the fact that MBOK has better power efficiency than BPSK. This can be understood by considering the waveform to have coding properties. The code vectors are selected to have maximum distance. In BPSK, each bit is detected independently. In MOK, a code vector is detected out of an orthogonal set.

The recommended waveform also allows options for lower rates which are more robust, giving fall back rates for stressed links. Harris has run simulations on the two basic types of modulation proposed for the dual rate hardware. These simulations show that the Binary MBOK modulation can achieve 150' range reliably. The simulations show that the high rates are more susceptible to multipath than the lower rates as would be expected from the higher required Eb/N0. There also is the cross rail interference that must be contended with. This is where the multipath interference comes in 90 degrees twisted from the desired carrier. In this case, the information that was on the I channel interferes with the Q channel. If the I and Q channels are not protected by a different cover sequence, there will be significant interference. This performance leads to a recommendation that antenna diversity be used.

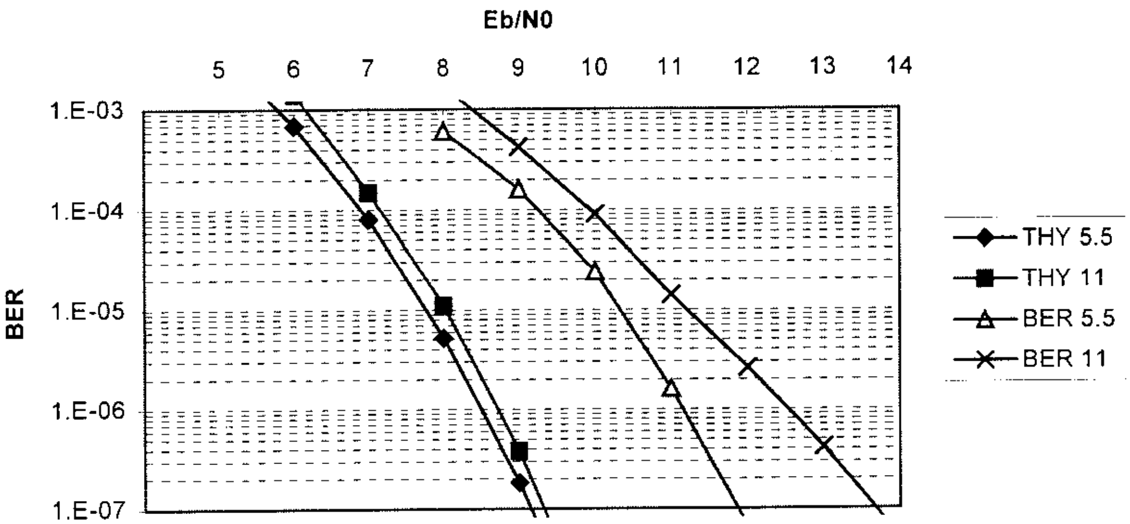


Figure 5, Bit error rates for the new modulations.

The Eb/N0 performance of the MBOK scheme is better than BPSK of the same rate. This performance is due the embedded coding properties of the MOK modulation. The modulation basically ties several bits together so that the receiver is forced to make a symbol decision. If a symbol is in error then all of the bits in that symbol are suspect, but not all will be in error. Thus, the symbol error rate and the bit error rates are similar, but not identical. While the SNR required to make the symbol decision correctly is higher than required to make one bit decision, it is not as high as would be required to make all of the bit decisions separately. Thus, some coding gain is evident in the basic spreading waveform.

Figure 5 shows the simulations of the Es/N0 performance of Binary MBOK and Quadrature MBOK. The theoretical curves agree with data published in several texts[1].

The Es/N0 performance of the waveform can be calculated by adding 10 log(bits per symbol) or 6 dB to the basic 5.5 MBps biphase waveform to account for the 4 bits per symbol. For the 11 MBps case, add 3 dB more when using both I and Q channels which share the carrier power (10 log(8) = 9 dB). This gives a required Es/N0 of 13.6 dB for the 5.5 MBps case and 16.8 dB for the 11 MBps case. This Es/N0 is calculated in the symbol rate bandwidth, so when the spread rate bandwidth is considered, the SNR (in this bandwidth) is 9 dB lower or (13.6 - 9) = 4.6 dB for the 5.5 MBps case and 7.8 dB for the 11 MBps case. The operating Eb/N0 of the 1 MBps 802.11 waveform using the PRISM chip set has been measured at 13 dB. This differs from the ideal performance due to two factors. First, there is a 6 fold error extension due to differential decoding and descrambling and second, there are implementation losses. With 10.4 dB processing gain due to spreading, the operating SNR in the spread bandwidth is 2.6 dB. With QPSK, this is increased by 3 dB to 5.6 dB since the I and Q

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[1] Lindsey and Simon, "Telecommunication Systems Engineering", Prentis Hall, Publisher

channels split the carrier power. One factor that has not been accounted for in the theoretical analysis for the MBOK waveforms is the descrambling effect on the 5.5 MBps and 11 MBps links. No factor was included above for that effect. Thus, the net Eb/N0 is slightly worse for these, but owing to the grouping into symbols, the effect is not great.

One way to analyze the effective processing gain of the spreading of a DSSS waveform is to consider the bandwidth ratios between the spread and unspread (correlated) waveforms. In the IEEE 802.11 BPSK (1 MBps) case, the spread rate is 11 MCps and the symbol rate is 1 MSps. Thus, the IF signal can be passed through a 22 MHz filter and then despread and filtered again in a 2 MHz filter. This is an 11 to one ratio and discards 91 % of the jamming energy. In the 11 MBps case, the chip rate is the same but the symbol rate is 1.375 MSps. This only gives an 8 to 1 or 9 dB ratio for the bandwidth reduction. Clearly some more processing gain is needed to make the processing gain requirement. This comes from the inherent processing gain of the waveform. Above, we showed where the MBOK waveform performs up to 1.6 dB better than BPSK.

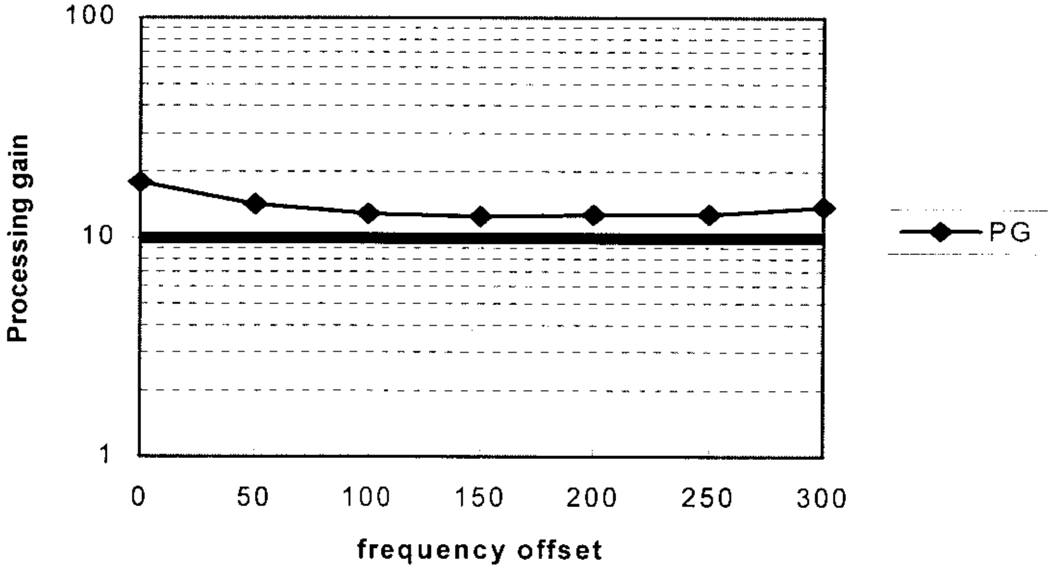

Figure 6, CW jamming data

Figure 6 shows data taken running the CW jamming test run to verify the FCC mandated processing gain.. The data was taken with the whole radio RF to Rf using the packet error rate test mode to predict the jamming margin. We only ran positive frequencies, since the results are symmetrical.

Thus, using the FCC formula:

PG = SNRo + Mj + Loss
where PG is the processing gain
Mj is the jamming margin
Loss is estimated to be 2 dB
and SNRo is the theoretical Es/N0 for the waveform.

We get:
PG = 13.6 -1.5 +2 = 14.1 dB for 5.5 MBps
PG = 16.8 -6.0 +2 = 12.8 dB for 11 MBps

Thus, our data shows a 2.8 dB PG margin over the FCC requirements for the 11 MBps case and 4.1 dB PG margin for the 5.5 MBps case.

Range

Simulations using a Raleigh fading path model were used to predict the packet error rates at various ranges due to multipath and attenuation.

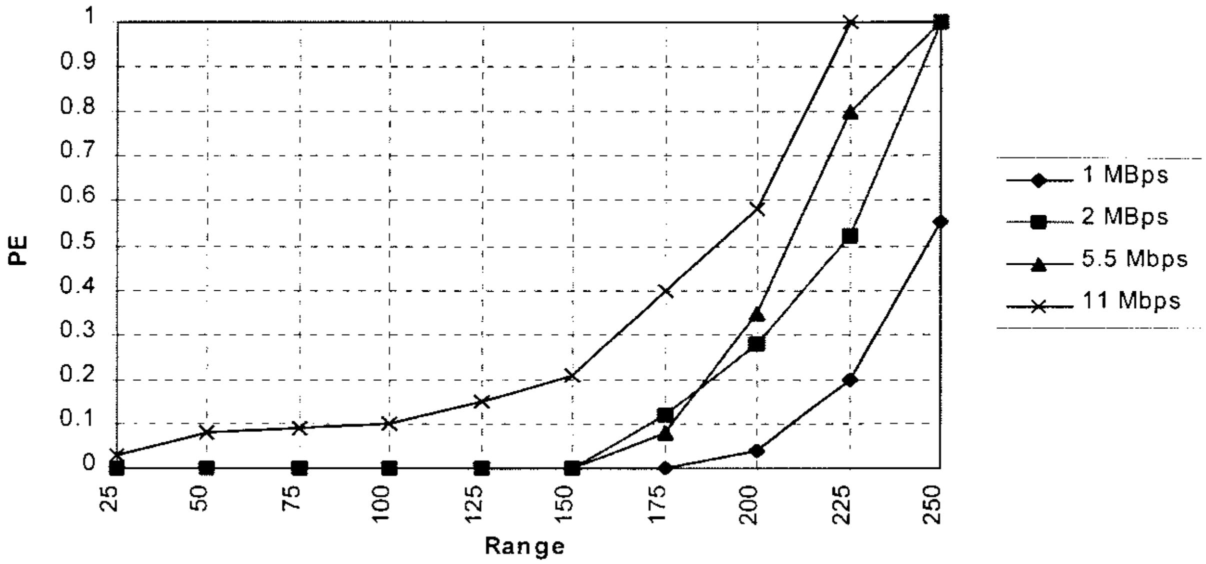

Figure 7, Link range with multipath and no antenna diversity or coding

The simulations show that the probability of a missed packet is strongly influenced by multipath as the required Es/N0 becomes higher.

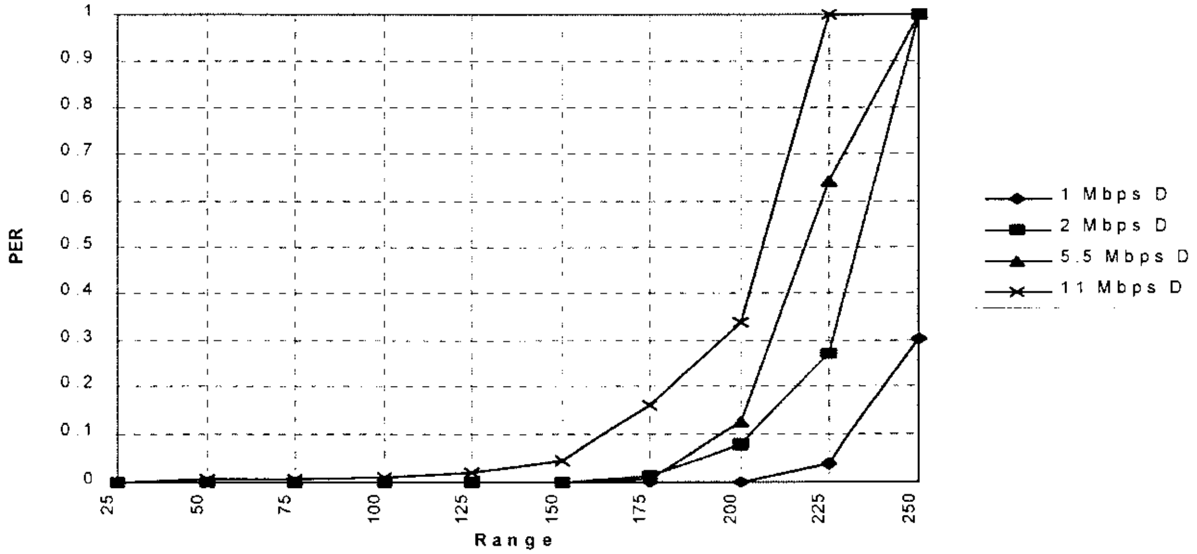

Figure 8, Link range with multipath and antenna diversity

This is intuitively correct as the ratio of the multipath to the signal must improve if the Es/N0 needs to better. This result shown in figures 7 and 8 shows a need to implement antenna diversity to achieve good performance.

A 15 % PER will reduce the network throughput by at least 30% due to the need to retransmit packets. When antenna diversity is taken into account, the PER values can be squared assuming optimum diversity. The performance of the 5.5 MBps case is substantially better as illustrated by figure 7. This curve was taken with +20 dBm TX power, so it is slightly better than the table values above.

The essential message of this data is that stressed links can be substantially improved by lowering the raw data rate which can be readily accomplished with the suggested architecture. The other message is that antenna diversity will greatly improve the 11 MBps throughput when multipath is an issue.

will be an overkill for the high rates and will lower the effective rate as shown in figure 9. Short packets are effected more by the fixed length preamble. This analysis assumes that the 802.11 preamble of 192 us is used for all packets. The two curves show the cases of full protocol with data, and ACK versus the best performance without the ACK.

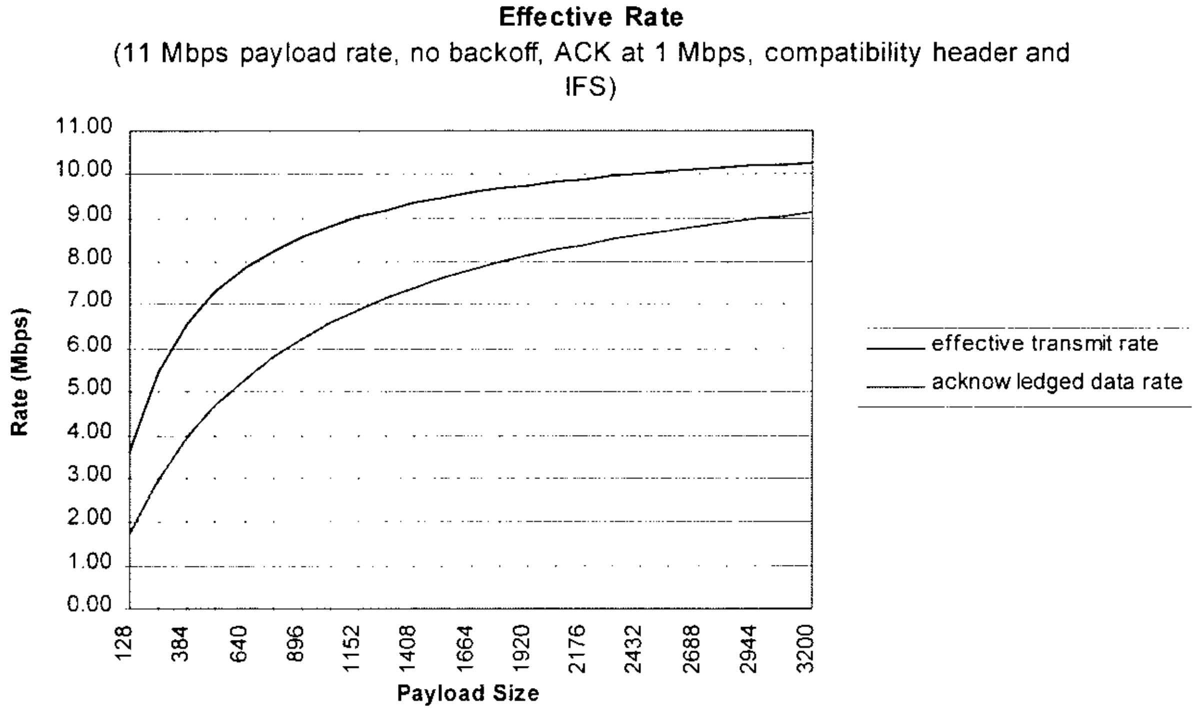

Figure 9, Packet overhead effects.

Data Throughput

The raw data rate only indicates the best rate that the physical layer can support in a continuous mode. The achieved data rate in a network will depend on many factors such as protocol overhead and packet overhead. If an interoperable design is chosen for the IEEE 802.11 network, the packet will be burdened by a preamble sized for 1 MBps operation. This