LINK CX (5.3 GHz UNII)

Application for FCC Certification

Abstract

This document provides information required for the FCC type Certification application.

Section 2.1033, Application for Certification

The following information is being submitted in support of interWAVE's application for type certification of its Link CX product operating under the part 15, subpart E – UNII rules.

This document is written in a format that lists each of the appropriate rule sections, along with documentation showing compliance with each section. The information will be either directly presented in this document, or a supporting attachment will be referenced.

The Link CX is a point to point radio that transmits a raw data rate of 50 Mbits/sec in approximately 14 MHz of emission bandwidth. The radio is using 16 QAM modulation with an excess bandwidth of 15% to achieve excellent spectrum efficiency. External interfaces to the radio include coaxial DS3 rate data, and two 10/100 base-T Ethernet interfaces.

The table below summarizes the technical parameters of the Link CX.

Parameter	Description
Frequency Band	5250 – 5350 MHz, UNII per 15.407
Mode of Operation	Full Duplex, 100% duty cycle
Channel spacing	16 MHz
Transmit / Receive separation	60 MHz
Number of channel pairs	2
Channel pair #1	5262 MHz / 5322 MHz
Channel pair #2	5278 MHz / 5338 MHz
Modulation	16 QAM, $\alpha = 0.15$
Emission Bandwidth (26 dB)	13.9 MHz
Frequency Stability	+/- 5.0 PPM
Maximum output power	-1.0 dBm average (+7.4 dBm peak)
Antenna type	Integral flat panel
Antenna gain	21 dBi
User interfaces	DSX3 coaxial, 10/100 base-T Ethernet, craft RS-232 interface

Section 2.1033 (b)(1), Name of applicant / manufacturer

The applicant and manufacturer of the Link CX is:

interWAVE Communications, Inc.
312 Constitution Drive
Menlo Park, CA 94025-1164

Section 2.1033 (b)(2), FCC identifier

The FCC identifier for the Link CX is OEWCX-DS3-53G.

Section 2.1033 (b)(3), Copy of installation manual

See attachment A (*attachment_a.pdf*) for a copy of the installation and operating manual.

The installation manual covers both the 5.3 GHz product and a 5.8 GHz version of the Link CX. The 5.8 GHz version of the Link CX is being certified under a separate concurrent application. Please see the manual section that discusses the regulatory information, along with the differences in the 5.3 GHz and 5.8 GHz versions of the product.

Section 2.1033 (b)(4), Circuit description

See attachment B (*attachment_b.pdf*) for a product and circuit description of the Link CX.

Section 2.1033 (b)(5), Block diagrams and schematics

See attachment C (*attachment_c.pdf*) for the Link CX block diagrams, and attachment D (*attachment_d.pdf*) for a copy of the Link CX board schematic.

Section 2.1033 (b)(6), Technical compliance data

See the following sections illustrating part 15 requirements and measurements. Unless otherwise stated all measurements were performed in interWAVE's engineering laboratory on May 14th of the year 2002. See appendix C for a serialized list of test equipment and radios used for the testing.

Section 15.203, Antenna requirements

The Link CX uses an integral antenna that also forms the top of the enclosure. The antenna is permanently attached to the enclosure, and therefore is compliant with the requirements of this section.

In addition the Link CX is intended for professional installation only. The following section that describes the market that the Link CX is going to be sold into.

Justification for professional installation

Marketing and Application

The Link CX system has been designed and is intended for use as an alternative to traditional wireline methods of providing DS3 and High-Speed Ethernet connectivity. As such the end user of this system will be enterprise businesses, local telephone companies or utility companies. The actual customer for, and operator of Link CX networks will be Service Providers such as ISP's, Competitive Access Providers (CAP's) or the local telco's themselves. This places the use of the system decidedly in the industrial/commercial application arena.

Furthermore, many of the aforementioned target customers are already involved in wireless communications technologies and have on staff professional RF installation crews. For those Service Providers who do not to date have in-house talent for the RF installation of the Link CX system, e.g. ISP's, they will be directed to a network of third party providers (largely from the cellular/PCS arena) who specialize in microwave equipment installations. Examples of some of these support shops are Valcom in the mid-west, and Netcom International based in Atlanta.

Technical Requirements

There are several steps involved in the setup and installation of the system that require tools and skills not found in the average technically inclined person's skill set. Some of these are:

- Physical Installation - these units are designed and intended for outdoor installation. The units will be located on towers on tall buildings typical for microwave equipment sites. Access to these locations is typically restricted to those with authorization, which restricts access from the average lay person. Furthermore, when installing the systems weather sealing of connectors is required, an additional somewhat specialized task.

- Antenna Alignment – in order to align the antennas of the system, it is necessary for the installer to adjust the antenna based upon an RSSI (Received Signal Strength Indicator) voltage measured at a test point on the radio unit

- Power Requirements – The Link CX radio requires a DC voltage from 21 to 60 VDC to operate. As this is outside the normal household appliance voltage, the user must seek AC to DC or Battery systems which unique to systems requiring professional expertise or installation.

Sections 15.205, 15.209, Restricted band radiated emission limits

Measurements of the radiated emissions from the Link CX were performed by Compliance Certification Services at their Morgan Hill open field site. Attachment E contains the radiated emissions test data results.

Pages 1 and 2 (attachment E1, E2) are the test data showing compliance with the 15.209 radiated emission limits below 1 GHz.

Page 3 (attachment E3) is the test data showing compliance with the restricted band emissions of section 15.205.

Page 4 shows the band edge plots with the first page showing the lower band edge while the Link CX transmitting on the lowest channel. The display line is set at 54μV showing that the Link CX is compliant with the limit at the band edge.

Page 5 shows the upper band edge plot with the Link CX transmitting on the highest channel. The display line is set at 54μV showing that the Link CX is compliant with the limit at the band edge.

Page 6 is a serialized list of equipment used for the radiated measurements.

See attachment I for the different set up photos for the measurements.

Section 15.207, Line conducted emissions

Measurements of the AC Line conducted emissions from the Link CX were performed by Compliance Certification Services at their Morgan Hill open field site. Attachment F shows the test data results.

The first page of this attachment is a plot of the AC line conducted emissions for the Link CX. This plot shows that the Link CX is in compliance with FCC class B limits.

The second page shows the 6 worst data points from the AC Line conducted emissions data.

See attachment I for the setup photographs.

Section 15.407 General technical requirements

Section 15.407 (a)(2), Power limits.

For radios operating in the 5.25 – 5.35 GHz band the peak transmit power shall not exceed the lesser of 250 mW, or 11 dBm + 10 Log B where B is the 26 dB emission bandwidth in MHz. Also the peak power spectral shall not exceed 11 dBm in any 1 MHz band.

The bandwidth of the Link CX transmitter is shown on attached plots[1] A, B, C, and D for each channel of the radio. For these plots, a resolution bandwidth of 30 kHz was used, which is approximately 2% of the signal BW. The spectrum analyzer trace was captured with the "view" function and the marker delta function was used to find the 26 dB bandwidth. For the Link CX the 26 dB bandwidth is 13.9 MHz. Using the formula above the maximum peak transmit power is 11 dBm + 10 Log 13.9 = +22.4 dBm. As this is less than 250 mW (+24 dBm) the Link CX is limited to +22.4 dBm peak transmit power.

Also per section 15.407 (a)(2), if transmitting antennas of directional gain greater than 6 dBi are used, both the peak transmit power, and the peak power spectral density shall be reduced by the amount in excess of 6 dBi. The integral antenna used on the Link CX has a gain of 21 dBi, so both the peak transmit power, and the peak power spectral density must be reduced by 21 dBi – 6 dBi = 15 dB.

After adjusting the limits by 15dB to compensate for the antenna gain, the Link CX is limited to +7.4 dBm peak transmit power, and the power spectral density cannot exceed –4.0 dBm in any 1 MHz band.

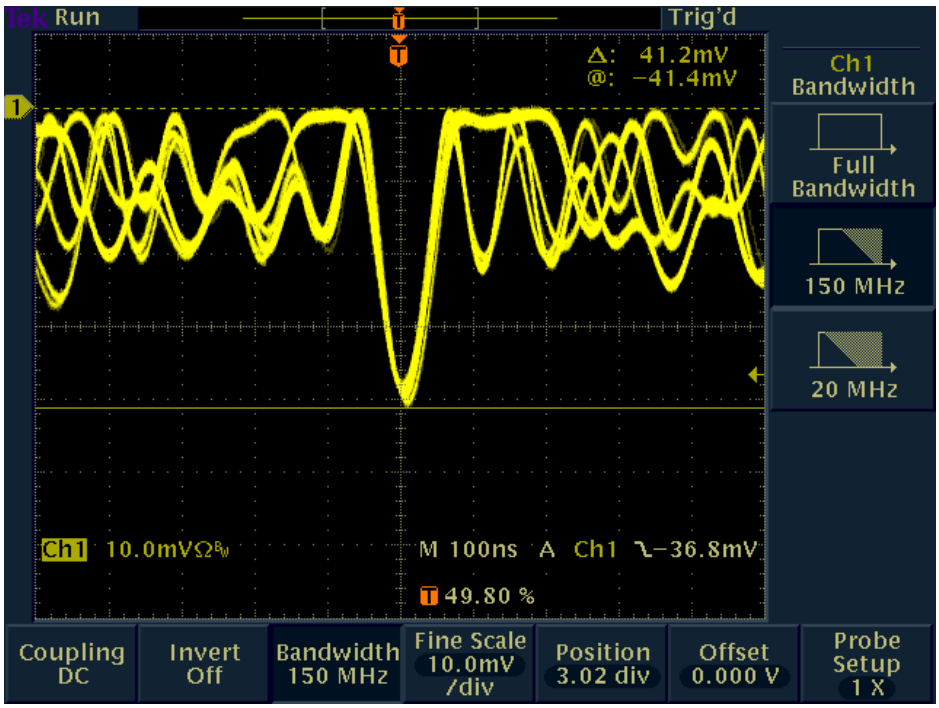
[1] See Appendix A for a legend to the data plots.

15.407 (a)(4), Peak power measurements.

The Link CX is a wide band radio with base band modulation frequencies approaching 7 MHz. Both spectrum analyzers and peak power meters have about a 1 MHz bandwidth limitation and cannot be used to accurately measure the peak power of the Link CX. When measured with either a spectrum analyzer, or a peak power meter, the peak to average ratio is 3 dB. As the Link CX is running 16 QAM modulation with a 15% excess bandwidth the peak to average power ratio should be approximately 8 dB, not the 3 dB number read by a peak power meter. To accurately measure the peak transmit power, a diode detector must be used. This method closely follows the procedures called out in ETSI 300 328.

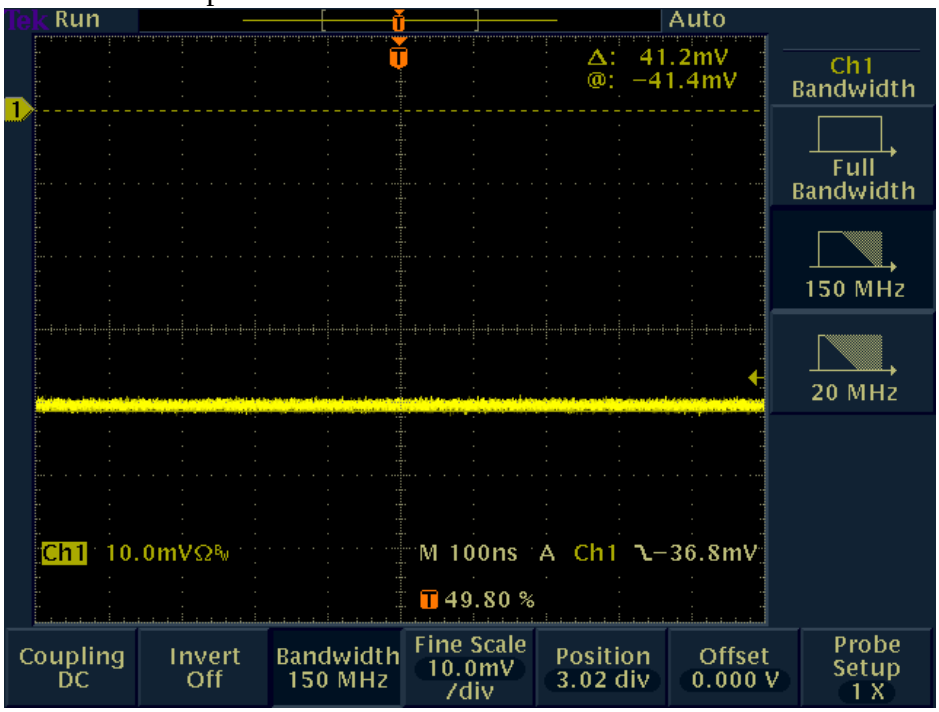
For the purposes of the conducted tests, the integral antenna was disconnected, and all measurements were made at the antenna connector interface on the duplexer.

The test methodology uses a diode detector to measure the voltage produced by the RF envelope of the transmit signal. The output of the detector is terminated into an oscilloscope with its input impedance set to 50 ohms. (The detectors output impedance is approximately 1.3 kilo ohms with a shunt capacitance of 50 pF. When this is terminated into 50 ohms, the resulting detection bandwidth is approximately 63 MHz)
The oscilloscope is set to trigger on the most negative going peak, corresponding to the peak of the RF envelope. See the following picture showing the detector output as viewed on the oscilloscope.



The peaks are all negative as the detector is a half wave rectifier that outputs the negative peaks. Note that a horizontal line has been placed at the point of the peak excursion.

The next step is to connect the diode detector to a CW RF generator that is set to the same frequency that the radio is transmitting on. The power level of the generator is then increased until the detector output reads the same as the horizontal reference line from above. See the photo below:



The peak power is now determined by measuring the output power of the signal generator with a power meter.

Here is the table of measurement values for each channel of the Link CX.

Measurement	**Ch. 1**	**Ch. 2**	**Ch. 1'**	**Ch. 2'**
Peak power, generator reference	+6.8 dBm	+6.9 dBm	+7.4 dBm	+7.2 dBm

For reference only, the above readings were taken with average output power set for –1.0 dBm. When set at -1.0 dBm average power, the Link CX is compliant with the requirement that the peak transmitter power be less than or equal to +7.4 dBm maximum.

15.407 (a)(5), Peak power spectral density.

The peak power spectral density is measured as a conducted emission by direct connection of the test equipment.

The average output power of the Link CX was adjusted to –1.0 dBm at the test equipment interface as read by a regular power meter. The emission was then monitored on a spectrum analyzer using a 1 MHz resolution bandwidth and a 3 MHz video bandwidth. Video averaging of 100 sweeps was used, and the marker is set on the peak of the emission.

From the earlier sections above the Link CX is limited to a peak power spectral density of –4 dBm / MHz. See data plots[2] E, F, G, and H for the peak power spectral density as measured on each of the radio's channels. The table below lists the results for each channel.

Measurement	Ch. 1	Ch.2	Ch. 1'	Ch. 2'
Peak power spectral density	-14.0 dBm	-12.5 dBm	-12.3 dBm	-14.3 dBm

Note that all the values are compliant as they are below the –4 dBm maximum value.

15.407 (a)(6), Peak Excursion Ratio.

This section states that the ratio of the peak excursion of the modulation envelope (measured using a peak hold function) to the peak transmit power shall not exceed 13 dB in any 1 MHz bandwidth.

This measurement is made by superimposing two traces on the spectrum analyzer display. See spectrum analyzer trace plots I, J, K, and L. Both traces are made using the peak hold function. The higher trace is made with a resolution bandwidth and video bandwidth of 1 MHz. The lower trace is made using a resolution bandwidth of 1 MHz and a video bandwidth of 30 kHz. The difference between the two traces is the Peak Excursion Ratio. The values in the table below are the maximum difference between the two traces within the 26 dB emission bandwidth of the radio.

Measurement	Ch. 1	Ch.2	Ch. 1'	Ch. 2'
Peak Excursion Ratio	7.6 dB	7.6 dB	7.6 dB	7.6 dBm

The maximum peak excursion measured is 7.6 dB, and as this is less than 13 dB the Link CX is compliant with this section.

[2] See Appendix A for a legend to the data plots.

15.407 (b)(2), Undesirable emission limits.

For transmitters operating in the 5.25 – 5.35 GHz band all emissions outside the band must not exceed a peak EIRP of –27 dBm / MHz.

As this is being measured as a conducted measurement without the antenna attached to the Link CX the –27 dBm / MHz limit must be adjusted to account for the gain of the integral antenna. The integral antenna has a gain of +21 dBi, so the conducted limit for unwanted emissions at the antenna port must be –48 dBm / MHz to comply with the –27 dBm EIRP number.

As the limits apply to the peak power, the peak hold function will be used on the spectrum analyzer. Per section 15.407 (b) 4, and 15.407 (b) 7 a 1 MHz resolution bandwidth is used, and the radio is set to the channels that are closest to the band edges.

Plots M, N, and O show the emissions with the Link CX set to the highest channel. The limit lines on the analyzer are set –48 dBm for the out of band emission limits.

Plots P, Q, and R show the emissions with the Link CX set to the lowest channel.

These plots show that the Link CX is compliant with the undesirable emission limits.

15.407 (b)(5) and (6), Radiated limits and restricted bands

See earlier references in this report to sections 15.205, 15.207, and 15.209.

15.407 (c), Automatically discontinue transmission

The Link CX is always transmitting data in the form of telemetry and management regardless of the state of the user data interface. As such the Link CX transmitter will normally be on except in the case of a hardware failure. In order to transmit the Link CX must have all of its synthesizers programmed and locked to the correct frequency. Any time one of the synthesizers goes out of lock the transmitter is automatically turned off. This prevents the Link CX from transmitting out of band due to a hardware or software failure.

15.407 (d), and (e)

Not applicable

15.407 (f), RF exposure requirements

As of October 15, 1997, all products must address the issue of Human Exposure to RF electromagnetic fields. Referring to OET Bulletin 65, the limits for Occupational exposure, and General Population exposure are 5 mW/cm ^{2} and 1 mW/cm ^{2}, respectively, above 1.5 GHz.

The Link CX radio transmits a maximum of –1.0 dBm (0.8 mW) average power into a 21 dBi integral flat panel antenna. The 21 dBi gain of the integral antenna has a decimal gain (G) of 126, i.e. $10^{21/10}$. The duty cycle of the transmitter is 100%. A maximum EIRP of +20 dBm would occur at the site when the radio is operating in a fixed, point to point configuration.

RF power density can be calculated with the equation: $S = P * G / 4\pi R^2$, where S = power density in mW/cm, P = power input to the antenna in mW, G = power gain of the antenna, and R = distance to the center of radiation of the antenna in cm. By rearranging this equation, the relationship between distance (R) and Power Density (S) can be found.

Rearranging $R = \sqrt{(PG / 4\pi S)}$, and solving for the maximum limits of 5 mW/ cm^2, and 1 mW/ cm^2 we have:

$R(5\ mW/cm^2) = \sqrt{0.8\ mW * 126 / 4\pi * 5} = 1.3$ cm, or .51-inches.

$R(1\ mW/cm^2) = \sqrt{0.8\ mW * 126 / 4\pi * 1} = 2.8$ cm, or 1.1-inches.

These results show that the general population RF exposure limits are not exceeded as long as the general population is kept 1.1-inches from the feed point of the antenna.

The propagation characteristics at 5.3 GHz dictate a line-of-sight type of RF path. As such, typical installation locations are up on rooftops or masts to get above ground level path obstructions. When the Link CX is installed in this manner, the general population will be further than 1.1-inches from the antenna, and RF exposure limits will be met.

As this application is being processed by a Telecommunications Certification Body there is a requirement that the antenna be installed in such a way that the general population is kept at least 2 meters, or 78 inches away from the main beam radiation of the antenna.

The Link CX is intended for professional installation only, and the product's manual contains appropriate warnings concerning RF exposure, and instructions to place and mount the antenna to maintain a minimum of 2 meters, or 78 inches from general population contact.

RF exposure – Installation issues

The Link CX is intended to be installed and mounted with the DC power <u>off</u> to avoid any RF exposure potential. Appropriate instructions are supplied in the product manual.

After the unit is mounted, the antenna must be aligned with the other end of the link. While a compass is used for rough alignment, final alignment of the antenna is done by monitoring the strength of the signal from the far end of the link. As the Link CX is a

full duplex unit, there is a potential for exposure to RF energy during the antenna alignment process.

The manual cautions the installer to always remain behind the antenna during the alignment process. If the integral antenna is used, the entire Link CX enclosure is rotated in elevation and azimuth to align the antenna.

The following section will calculate the RF exposure potential to the installer during antenna alignment. The gain of the antenna has been modified by the specified front to back ratio as specified in the antenna's source control drawing[3].

The table below shows the characteristics of the integral antenna used on the Link CX.

Antenna type	Gain (dBi)	Front to Back Ratio (dB)	Net Backwards Gain (dBi)
Integral antenna	+21.0	30	-9.0

The reverse gain of –9.0 dBi (G = .126) will be used to examine the exposure potential to the installer.

Once again, using the equations from the previous section, the minimum distances that meet the RF exposure guidelines are:

$R(5\ mW/cm^2) = \sqrt{0.8mW * .126 / 4\pi * 5} = .040$-cm, or .015-inches.

$R(1\ mW/cm^2) = \sqrt{0.8\ mW * .126 / 4\pi * 1} = .089$-cm, or .035-inches.

These equations show that RF exposure guidelines are complied with as long as the installer remains at least .1-cm (rounded) behind the primary reflector of the antenna during the alignment process.

The integral antenna and its reflector is mounted on one side of the Link CX enclosure. The 7-cm thickness of the Link CX enclosure prevents the installer from getting close to the reflector of the antenna.

The manual cautions the installer to always align the antenna from the backside, and to avoid exposure from the front of the antenna.

15.407 (g) Frequency stability requirements

This section states that the manufacturer of the equipment are responsible for ensuring that the frequency stability is such that emissions are always maintained within the band of operation under all conditions.

[3] See attachment H, antenna source control drawing for reference.

The Link CX is a fully synthesized radio and all the sources that determine the transmit and receive frequencies are phased locked to a master 60 MHz TXCO that has a +/- 5 PPM stability across the entire operating temperature range of the radio.

Five parts per million at 5.3 GHz translates to a maximum frequency shift of +/- 26.5 kHz. As the edge of the channels are at least one MHz from the either of the band edges, +/- 26.5 kHz is more than sufficient to guarantee that the emissions will remain in the band over the entire operating range of the radio.

Section 2.1033 (b)(7), Photographs and FCC identification label

See attachment G1 (*attachment_g1.pdf*) for the external photographs of the Link CX. Attachment G2 (*attachment_g2.pdf*) contains internal photographs of the Link CX, and attachment G3 (*attachment_g3.pdf*) shows the FCC identification label.

Section 2.1033 (b)(8), Peripheral devices attached

While the Link CX will establish a radio link without any peripherals other than a DC power source, in normal operation the Ethernet and DS3 ports will be connected to an external data source.

To fully test the radiated emissions from the enclosure, the DS3 port is connected through 75 ohm coaxial cable to a Fireberd data test set (Model 6000A). The data test set provides DS3 input and output signals to and from the Link CX simulating normal operation.

The two Ethernet ports will be connected to a 3Com Ethernet hub, and a laptop computer will ping across the Ethernet cable to simulate Ethernet traffic.

The craft / diagnostic port of the Link CX is a RS-232 terminal port. As this port is only used for diagnostic purposes, it is not connected in normal operation.

Section 2.1033 (b)(9), Transition provisions of 15.37

The Link CX is not being authorized pursuant to the transition provisions of section 15.37.

Appendix A, Legend to data plots

All of these data plots are contained in the attachment file (dataplots.pdf). The label for each plot is written in the upper left corner of each plot.

A. Link CX, 26 dB bandwidth, channel 1, 30 kHz resolution and video bandwidth, trace view A, marker delta showing 26 dB bandwidth.

B. Link CX, 26 dB bandwidth, channel 2, 30 kHz resolution and video bandwidth, trace view A, marker delta showing 26 dB bandwidth.

C. Link CX, 26 dB bandwidth, channel 1', 30 kHz resolution and video bandwidth, trace view A, marker delta showing 26 dB bandwidth.

D. Link CX, 26 dB bandwidth, channel 2', 30 kHz resolution and video bandwidth, trace view A, marker delta showing 26 dB bandwidth.

E. Link CX, peak power spectral density, channel 1, 1 MHz resolution BW, 3 MHz video BW, video average 100, marker showing peak power spectral density.

F. Link CX, peak power spectral density, channel 2, 1 MHz resolution BW, 3 MHz video BW, video average 100, marker showing peak power spectral density.

G. Link CX, peak power spectral density, channel 1', 1 MHz resolution BW, 3 MHz video BW, video average 100, marker showing peak power spectral density.

H. Link CX, peak power spectral density, channel 2', 1 MHz resolution BW, 3 MHz video BW, video average 100, marker showing peak power spectral density.

I. Link CX, peak excursion measurement, channel 1, Trace A - 1 MHz resolution BW, 1 MHz video BW, peak hold on, Trace B – 1 MHz resolution BW, 30 kHz video BW, peak hold on. Marker at channel frequency.

J. Link CX, peak excursion measurement, channel 2, Trace A - 1 MHz resolution BW, 1 MHz video BW, peak hold on, Trace B – 1 MHz resolution BW, 30 kHz video BW, peak hold on. Marker at channel frequency.

K. Link CX, peak excursion measurement, channel 1', Trace A - 1 MHz resolution BW, 1 MHz video BW, peak hold on, Trace B – 1 MHz resolution BW, 30 kHz video BW, peak hold on. Marker at channel frequency.

L. Link CX, peak excursion measurement, channel 2', Trace A - 1 MHz resolution BW, 1 MHz video BW, peak hold on, Trace B – 1 MHz resolution BW, 30 kHz video BW, peak hold on. Marker at channel frequency.

M. Link CX, out of band emissions, channel 2', 1 MHz resolution and video bandwidth, 50 MHz span, marker showing signal level at upper band edge, limit lines showing out of band emission limits of -48 dBm /MHz.

N. Link CX, out of band emissions, channel 2', 1 MHz resolution and video bandwidth, 500 MHz span, marker showing signal level at upper band edge, limit lines showing out of band emission limits of -48 dBm /MHz.

O. Link CX, out of band emissions, channel 2', 1 MHz resolution and video bandwidth, 26.5 GHz span, marker showing in band emission, display line at emissions limit of –48 dBm.

P. Link CX, out of band emissions, channel 1, 1 MHz resolution and video bandwidth, 50 MHz span, marker showing signal level at lower band edge, limit lines showing out of band emission limits of -48 dBm /MHz.

Q. Link CX, out of band emissions, channel 1, 1 MHz resolution and video bandwidth, 500 MHz span, marker showing signal level at lower band edge, limit lines showing out of band emission limits of -48 dBm /MHz.

R. Link CX, out of band emissions, channel 1, 1 MHz resolution and video bandwidth, 26.5 GHz span, marker showing in band emission, display line at emissions limit of –48 dBm.

Appendix B, List of Attachments

Attachment name	Description of attachment	Filename
A	Installation and user manual	*attachment_a.pdf*
B	Circuit and product description	*attachment_b.pdf*
C	Link CX block diagrams	*attachment_c.pdf*
D	Link CX schematic	*attachment_d.pdf*
E	Radiated emissions test results	*attachment_e.pdf*
F	AC line conducted test results	*attachment_f.pdf*
G1	Link CX external photographs	*attachment_g1.pdf*
G2	Link CX internal photographs	*attachment_g2.pdf*
G3	Link CX FCC label photographs	*attachment_g3.pdf*
H	Integral antenna source control drawing	*attachment_h.pdf*
I	setup photographs	*attachment_i.pdf*
MPE	MPE calculation and write-up	*mpe.pdf*

Appendix C, Equipment list

This appendix lists the equipment used for all of the conducted tests of the Link CX product. The conducted tests were performed at interWAVE Communications, Inc., in the engineering laboratory. All of the conducted tests were performed May 14th of the year 2002.

Product tested

Description	Serial Number
Link CX, 5.3 GHz, transmit low	00644C
Link CX, 5.3 GHz, transmit high	00644B

Test Equipment List

Manufacturer	Model	Description	Serial Number
HP	8563EC	Spectrum Analyzer	3946A00336
HP	435B	Power Meter	2005A01627
HP	8481	Power Sensor	1550A10576
HP	423A	Crystal Detector	17937
HP	83732B	Signal Generator	US37101283
TEK	TDS3054	Digital Oscilloscope	B013333