



LINK CX (5.8 GHz 15.247)

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 C – Intentional Radiator rules. Specifically the Link CX will operate under 15.247 as a digital modulation emission type.

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	5725 – 5850 MHz, per 15.247, revised 5/16/02
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	5737 MHz / 5797 MHz
Channel pair #2	5753 MHz / 5813 MHz
Modulation	16 QAM, $\alpha = 0.15$
Emission Bandwidth (26 dB)	13.9 MHz
Frequency Stability	+/- 5.0 PPM
Maximum output power	+16 dBm average (+24.1 dBm peak)
Antenna types	Integral flat panel, 2 ft. parabolic, 4 ft. parabolic
Antenna gains	21 dBi, 28.3 dBi, and 34.6 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-DS3-58G.

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

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

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 attachments D1 and D2 (*attachment_d1.pdf*, *attachment_d2.pdf*) for a copies of the Link CX board schematics.

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 21st 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 can be supplied with either an integral antenna, or it can be supplied with an external antenna connector. The external antenna connector is a standard N type female.

This radio is intended for professional installation only. As this radio is professionally installed it is exempt from the non-standard antenna connector requirement. See 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. This data is for the Link CX operating with the integral antenna.

Pages 4 and 5 show the restricted band emissions using the 2 foot parabolic antenna.

Pages 6 and 7 show the restricted band emissions using the 4 foot parabolic antenna.

Page 8 is a serialized list of equipment used for the radiated measurements.

This data shows that the Link CX is compliant with both the 15.205, and 15.209 radiated emissions when using the any one of the three antennas, integral, 2 foot parabolic, or 4 foot parabolic.

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 15.247, Technical requirements for operation within the bands 902-928 MHz, 2400 – 2483.5 MHz, and 5725 – 5850 MHz.

Section 15.247 (a) (2), Modulation

Systems using direct sequence spread spectrum and digital modulation techniques may operate in the 902-928 MHz, 2400 – 2483.5 MHz, and 5725 – 5850 MHz bands.

The Link CX uses 16 QAM modulation, which is a digital modulation technique so it is qualified to operate in the 5725 – 5850 MHz band.

Section 15.247 (b) (3), Peak Power Limit

This paragraph states that the maximum allowed peak transmit power for radio using digital modulation techniques is 1 Watt (+30 dBm).

The Link CX is a wide band radio with base band modulation frequencies approaching 7 MHz. To measure the true peak power on the spectrum analyzer, a bandwidth correction factor must be used.

The peak power was measured using a 1 MHz resolution and video bandwidth for the spectrum analyzer. The peak hold function was employed.

In addition, the 3 dB bandwidth of the emission was measured at the same 1 MHz bandwidth, also using the peak hold function.

The peak power reading is derived by adding a correction factor of $10 \log (3 \text{ dB BW})$ to the power reading shown by the analyzer.

The table below shows the peak power for each channel of the Link CX.

Parameter	Ch. 1	Ch. 2	Ch. 1'	Ch. 2'
Plot of peak power	Plot A	Plot C	Plot E	Plot G
Peak reading from plot	13.0 dBm	12.3 dBm	13.2 dBm	13.2 dBm
Plot of 3 dB bandwidth	Plot B	Plot D	Plot F	Plot H
Value of 3 dB bandwidth	12.4 MHz	12.3 MHz	12.4 MHz	12.3 MHz
Correction Factor (dB)	10.9 dB	10.9 dB	10.9 dB	10.9 dB
True Peak Power	23.9 dBm	23.3 dBm	24.1 dBm	24.1 dBm

For reference only, the above readings were taken with average output power set for +16.0 dBm. When set at +16 dBm average power, the Link CX is compliant with the requirement that the peak transmitter power be less than or equal to 1 watt (+30 dBm) maximum.

The maximum peak output power of the Link CX is 257 mW (+24.1 dBm) which is below the required limit.

Section 15.247 (b) (4) (ii), Antenna gain

Per this paragraph, systems operating in the 5725 – 5850 MHz band that are used exclusively for point to point operations may employ antennas with directional gain in excess of 6 dBi without any corresponding reduction in transmitter peak output power.

The Link CX falls into this category as it is designed exclusively for point to point operations. As such the +16 dBm maximum transmitter output power does not have to be reduced regardless of the gain of the antenna attached to it.

Section 15.247 (b) (5), RF radiation hazard

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 output power of +16 dBm (40 mW) at 5.8 GHz. The 5.8 GHz version of the Link CX can be used with three different antennas¹: a 21 dBi integrated panel antenna, and either a 2-ft. (28 dBi), or a 4-ft. (34.6 dBi) external parabolic antenna. Once again, to assume worst case radiation numbers, the gain numbers from the 4-ft. antenna will be used. The 34.6 dBi gain of the 4-ft. antenna has a decimal gain (G) of 2884, i.e. $10^{36.4/10}$. The duty cycle of the transmitter is 100%. A maximum EIRP of +50.6 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:

$$R(5 \text{ mW/cm}^2) = \sqrt{40 \text{ mW} * 2884 / 4\pi * 5} = 43 \text{ cm, or 17 inches.}$$

$$R(1 \text{ mW/cm}^2) = \sqrt{40 \text{ mW} * 2884 / 4\pi * 1} = 96 \text{ cm, or 37 inches.}$$

These results show that the general population RF exposure limits are not exceeded as long as the general population is kept 37-inches from the feed point of the antenna.

¹ See attachment H for the antenna data sheets.

The propagation characteristics at 5.8 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 37-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 off 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 each of the antennas has been modified by the specified front to back ratio as specified by the antenna manufacture.

As each of the antennas has different front-to-back ratios, the gain (loss) numbers will be examined for each of the antennas.

Antenna type	Gain (dBi)	Front to Back Ratio (dB)	Net Backwards Gain (dBi)
Integral antenna	+21.0	30	-9.0
RadioWaves SP2-5.2, 2-ft. parabolic	+28.3	36	-7.7
Gabriel SSP2-52B, 2-ft. parabolic	+28.5	38	-9.5
Gabriel SSP4-52B, 4-ft parabolic	+34.6	46	-11.4

The worst case number of -7.7 dBi ($G = .169$) 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:

$$R(5 \text{ mW/cm}^2) = \sqrt{40 \text{ mW} * .169 / 4\pi * 5} = .33\text{-cm, or .13-inches.}$$

$$R(1 \text{ mW/cm}^2) = \sqrt{40 \text{ mW} * .169 / 4\pi * 1} = .73\text{-cm, or .29-inches.}$$

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.

In the case of the external antennas, the mounting structure and pole normally preclude the installer from getting this close to the back of the antenna. 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. Instructions are also provided to the installer to minimize the time spent aligning antennas to further reduce the RF exposure potential.

15.247 (c) Spurious emissions

Per this paragraph all emissions outside the band of operation must be at least 20 dB below the level of the in band emissions when measured in a 100 kHz bandwidth.

Attached plots² I, J, and K show the out of band emissions with the Link CX set to the lowest channel (channel 1). Plots L and M show the out of band emissions with the radio set on channel 2. Plots N and O show the out of band emissions with the Link CX set to the channel 1', and Plots P and Q show the out of band emissions with the radio set to the highest operating channel (channel 2'). The peak hold function was used on the spectrum analyzer to eliminate noise, and to show the worst case condition.

These plots show that the Link CX is compliant with the out of band emission requirements.

² See Appendix A for a legend to the data plots

15.247 (c) Radiated emissions in restricted bands

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

15.247 (d) Peak power spectral density

This paragraph states that the peak power spectral density conducted from radio shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

See attached plots R, S, T, and U showing the peak power spectral density for each channel of the Link CX. The peak hold function on the analyzer was used to obtain the worst case peak reading on the analyzer.

These plots show that the peak power spectral density of the Link CX is -10.2 dBm in a 3 kHz bandwidth. This is below the 8 dBm limit therefore the Link CX is compliant with the peak power spectral density requirement.

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, peak power measurement, 50 MHz span, channel 1, resolution and video BW of 1 MHz, peak hold on. Marker shows peak reading.
- B. Link CX, 3 dB bandwidth measurement, 50 MHz span, channel 1, resolution and video BW of 1 MHz, peak hold on. Marker delta shows 3 dB bandwidth.
- C. Link CX, peak power measurement, 50 MHz span, channel 2, resolution and video BW of 1 MHz, peak hold on. Marker shows peak reading.
- D. Link CX, 3 dB bandwidth measurement, 50 MHz span, channel 2, resolution and video BW of 1 MHz, peak hold on. Marker delta shows 3 dB bandwidth.
- E. Link CX, peak power measurement, 50 MHz span, channel 1', resolution and video BW of 1 MHz, peak hold on. Marker shows peak reading.
- F. Link CX, 3 dB bandwidth measurement, 50 MHz span, channel 1', resolution and video BW of 1 MHz, peak hold on. Marker delta shows 3 dB bandwidth.
- G. Link CX, peak power measurement, 50 MHz span, channel 2', resolution and video BW of 1 MHz, peak hold on. Marker shows peak reading.
- H. Link CX, 3 dB bandwidth measurement, 50 MHz span, channel 2', resolution and video BW of 1 MHz, peak hold on. Marker delta shows 3 dB bandwidth.
- I. Link CX, out of band emissions, 50 MHz span, channel 1, resolution and video BW of 100 kHz, peak hold on. Limit lines show -20 dBc maximum emission limit.
- J. Link CX, out of band emissions, 500 MHz span, channel 1, resolution and video BW of 100 kHz, peak hold on. Limit lines show -20 dBc maximum emission limit.
- K. Link CX, out of band emissions, 26.5 GHz span, channel 1, resolution and video BW of 100 kHz, peak hold on. Limit lines show -20 dBc maximum emission limit. Marker on desired in band signal.
- L. Link CX, out of band emissions, 500 MHz span, channel 2, resolution and video BW of 100 kHz, peak hold on. Limit lines show -20 dBc maximum emission limit.

- M. Link CX, out of band emissions, 26.5 GHz span, channel 2, resolution and video BW of 100 kHz, peak hold on. Limit lines show –20 dBc maximum emission limit. Marker on desired in band signal.
- N. Link CX, out of band emissions, 500 MHz span, channel 1', resolution and video BW of 100 kHz, peak hold on. Limit lines show –20 dBc maximum emission limit.
- O. Link CX, out of band emissions, 26.5 GHz span, channel 1', resolution and video BW of 100 kHz, peak hold on. Limit lines show –20 dBc maximum emission limit. Marker on desired in band signal.
- P. Link CX, out of band emissions, 500 MHz span, channel 2', resolution and video BW of 100 kHz, peak hold on. Limit lines show –20 dBc maximum emission limit.
- Q. Link CX, out of band emissions, 26.5 GHz span, channel 2', resolution and video BW of 100 kHz, peak hold on. Limit lines show –20 dBc maximum emission limit. Marker on desired in band signal.
- R. Link CX, peak power spectral density, channel 1, resolution and video bandwidth of 3 kHz, peak hold on.
- S. Link CX, peak power spectral density, channel 2, resolution and video bandwidth of 3 kHz, peak hold on.
- T. Link CX, peak power spectral density, channel 1', resolution and video bandwidth of 3 kHz, peak hold on.
- U. Link CX, peak power spectral density, channel 2', resolution and video bandwidth of 3 kHz, peak hold on.

Appendix B, List of Attachments

Attachment letter	Description of attachment	Filename
A	Installation and user manual	<i>attachment_a.pdf</i>
B	Circuit and product description	<i>attachment_b.pdf</i>
C	Link CX block diagrams	<i>attachment_c.pdf</i>
D1	Link CX schematic, Transmit low	<i>attachment_d1.pdf</i>
D2	Link CX schematic, Transmit high	<i>attachment_d2.pdf</i>
E	Radiated emissions test results	<i>attachment_e.pdf</i>
F	AC line conducted test results	<i>attachment_f.pdf</i>
G1	Link CX external photographs	<i>attachment_g1.pdf</i>
G2	Link CX internal photographs	<i>attachment_g2.pdf</i>
G3	Link CX FCC label photographs	<i>attachment_g3.pdf</i>
H	Antenna datasheets	<i>attachment_h.pdf</i>
I	Setup photographs	<i>attachment_i.pdf</i>
MPE	MPE calculation and write-up	<i>mpe.pdf</i>

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 on May 21st of the year 2002.

Product tested

Description	Serial Number
Link CX, 5.8 GHz, transmit low	006449
Link CX, 5.8 GHz, transmit high	00644D

Test Equipment List

Manufacturer	Model	Description	Serial Number
HP	8563EC	Spectrum Analyzer	3946A00336
HP	435B	Power Meter	2005A01627
HP	8481	Power Sensor	1550A10576