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Test Report

Prepared for: Freewave Technologies, Inc.

Model: ZumLink Z9-C or Z9-T

Description: Digital Transmission System Radio Transceiver

Serial Number: N/A

FCC ID: KNYPMT0101AB
IC: 2329B-PMT0101AB

To

FCC Part 15.247 DTS
IC RSS-247

Date of Issue: June 22, 2016

On the behalf of the applicant:	**Freewave Technologies** **5395 Pearl Parkway** **Suite 100** **Boulder, CO 80301**
Attention of:	**Dean Busch, Sr. Compliance Engineer** **Ph: (303)962-7879** **E-Mail: dbusch@freewave.com**

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Project No: p1660006

Alex Macon
Project Test Engineer

Test Report Revision History

Revision	Date	Revised By	Reason for Revision
1.0	June 10, 2016	Alex Macon	Original Document
2.0	June 21, 2016	Kenneth Lee	Added statement in Output Power section
3.0	August 28, 2019	Michelle O'Hern	Changed FCC and IC ID on page 1

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ILAC / A2LA

Compliance Testing, LLC, has been accredited in accordance with the recognized International Standard ISO/IEC 17025:2005. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (refer to the joint ISO-ILAC-IAF Communiqué dated January 2009).

The tests results contained within this test report all fall within our scope of accreditation, unless noted below.

Please refer to http://www.compliancetesting.com/labscope.html for current scope of accreditation.

Testing Certificate Number: **2152.01**

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FCC Site Reg. #349717

IC Site Reg. #2044A-2

Non-accredited tests contained in this report:

N/A

The applicant has been cautioned as to the following

15.21 - Information to User

The user's manual or instruction manual for an intentional radiator shall caution the user that changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

15.27(a) - Special Accessories

Equipment marked to a consumer must be capable of complying with the necessary regulations in the configuration in which the equipment is marketed. Where special accessories, such as shielded cables and/or special connectors are required to enable an unintentional or intentional radiator to comply with the emission limits in this part, the equipment must be marketed with, i.e. shipped and sold with, those special accessories. However, in lieu of shipping or packaging the special accessories with the unintentional or intentional radiator, the responsible party may employ other methods of ensuring that the special accessories are provided to the consumer without an additional charge.

Information detailing any alternative method used to supply the special accessories for a grant of equipment authorization or retained in the verification records, as appropriate. The party responsible for the equipment, as detailed in § 2.909 of this chapter, shall ensure that these special accessories are provided with the equipment. The instruction manual for such devices shall include appropriate instructions on the first page of text concerned with the installation of the device that these special accessories must be used with the device. It is the responsibility of the user to use the needed special accessories supplied with the equipment.

Standard Test Conditions Engineering Practices

Except as noted herein, the following conditions and procedures were observed during the testing:

In accordance with ANSI C63.10-2009 and unless otherwise indicated in the specific measurement results, the ambient temperature of the actual EUT was maintained within the range of 10° to 40°C (50° to 104°F) unless the particular equipment requirements specified testing over a different temperature range. Also, unless otherwise indicated, the humidity levels were in the range of 10% to 90% relative humidity.

Measurement results, unless otherwise noted, are worst-case measurements.

Environmental Conditions		
Temperature (ºC)	**Humidity (%)**	**Pressure (mbar)**
23.2 – 4.4	27.2 – 32.6	965 - 967

EUT Description
Model: ZumLink Z9-C or Z9-T
Description: Digital Transmission System Radio Transceiver
Firmware: N/A
Software: N/A
Serial Number:
Additional Information:
All tests are performed with a 6 dBi antenna in mind.
The data rate determines the frequency selected. Below are the high mid and low frequencies per data rate. Duty cycle percentage is also included which will be used within the test report

500	1M	4M
902.707	903.053	904.550
914.458	914.112	914.227
927.360	927.014	925.747
95.6%	91.8%	76.1%

EUT Operation during Tests
The EUT was controlled with test commands provided by the manufacturer.

Accessories:

Qty	Description	Manufacturer	Model	S/N
1	AC DC power supply	Spectre Power	S036CQ1200300	N/A
1	Laptop	Dell	Latitude E6520	N/A

Cables:

Qty	Description	Length (M)	Shielding Y/N	Shielded Hood Y/N	Ferrite Y/N
1	Serial to USB	<3m	N	N	N
1	Power	<3m	N	N	N

15.203: Antenna Requirement:

	The antenna is permanently attached to the EUT
	The antenna uses a unique coupling
X	The EUT must be professionally installed
	The antenna requirement does not apply

Test Results Summary

FCC 15.247 Specification	Test Name	Pass, Fail, N/A	Comments
15.247(b)	Peak Output Power	Pass	
15.247(b)	Conducted Spurious Emissions	Pass	
15.247(d), 15.209(a), 15.205	Radiated Spurious Emissions	Pass	
15.247(d), 15.209(a), 15.205	Emissions At Band Edges	Pass	
15.247(a)(2)	Occupied Bandwidth	Pass	
15.247(e)	Transmitter Power Spectral Density	Pass	
15.207	A/C Powerline Conducted Emissions	Pass	

References	Description
CFR47, Part 15, Subpart B	Unintentional Radiators
CFR47, Part 15, Subpart C	Intentional Radiators
ANSI C63.10-2009	American National standard for testing Unlicensed Wireless Devices
ANSI C63.4-2009	Method and Measurements of Radio-Noise Emissions from low-Voltage Electrical and Electronic Equipment in the range 9kHz to 40GHz.
ISO/IEC 17025:2005	General requirements for the Competence of Testing and Calibrations Laboratories
KDB 558074 D01 v03r03	Guidance for Performing Compliance Measurements on Digital Transmission Systems (DTS) Operating under §15.247

Conducted Output Power
Engineer: Alex Macon
Test Date: 6/8/16

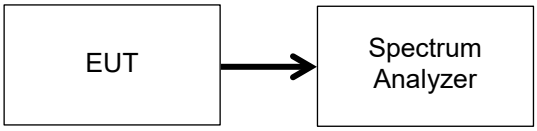
Test Procedure

The EUT was connected directly to a spectrum analyzer through a power attenuator

The method AVGSA-2 in section 11.9.2.2.4 of ANSI C63.10:2013 was used to make the measurement. This method uses trace averaging across ON and OFF times of the EUT transmissions in the spectrum analyzer channel power function using an RMS detector. Following the measurement a duty cycle correction was applied by adding [10 log (1 / D)], where D is the duty cycle, to the measured power to compute the average power during the actual transmission times.

The EUT was set to transmit on the lowest, middle and highest frequencies at the maximum power level. The RF output power was measured using the spectrum analyzer's channel power function

Test Setup



Transmitter Peak Output Power

Channel	Data Rate: 500 kb			
	Average Conducted Power (dBm)	Duty Cycle Factor (dB)	Value (dBm)	Limit (dBm)
Low	29.48	0.2	29.68	30
Mid	29.41	0.2	29.61	30
High	28.96	0.2	29.16	30

Channel	Data Rate: 1 Mb			
	Average Conducted Power (dBm)	Duty Cycle Factor (dB)	Value (dBm)	Limit (dBm)
Low	29.23	0.4	29.63	30
Mid	29.49	0.4	29.89	30
High	29.05	0.4	29.45	30

Channel	Data Rate: 4 Mb			
	Average Conducted Power (dBm)	Duty Cycle Factor (dB)	Value (dBm)	Limit (dBm)
Low	28.46	1.2	29.66	30
Mid	28.76	1.2	29.96	30
High	28.29	1.2	29.49	30

Note: For all antenna gains greater than 6dBi the output power must be reduced per the tables in Annex E.

Conducted RF Measurements (15.209)
Engineer: Alex Macon
Test Date: 6/9/16

Test Procedure

Antenna-port conducted measurements were performed as an alternative to radiated measurements for demonstrating compliance in the restricted frequency bands for 15.209.

The following offsets were added to the measurements:
The maximum transmit antenna gain (in dBi) to the measured output power level to determine the EIRP level
A maximum ground reflection factor to the EIRP level, 6 dB for frequencies ≤ 30 MHz, 4.7 dB for frequencies between 30 MHz and 1000 MHz, inclusive and 0 dB for frequencies > 1000MHz.

The following equations were used to determine the field strength from the conducted values.
E[dBµV/m] = EIRP[dBm] - 20 log(d[meters]) + 104.77, where E = field strength and d = 3m
E[dBµV/m] = EIRP[dBm] + 95.2, for d = 3 meters.

The Spectrum Analyzer was set to the following:

The Spectrum Analyzer was set to the following for emissions > 1000MHz:

a. RBW = 1 MHz
b. VBW ≥ 3 MHz
c. Detector = Peak.
d. Sweep time = auto
e. Trace mode = max hold
    1. Note: For emissions where the peak exceeded that of the average 15.209 emission limit the following was performed.
f. RBW = 1 MHz
g. VBW ≤ RBW/100 (i.e., 10 kHz) but not less than 10 Hz

For emissions below 1000MHz the Spectrum Analyzer settings were as follows:

a. RBW = 100 kHz
b. VBW ≥ 300 kHz
c. Detector = Peak
d. Sweep time = auto
e. Trace mode = max hold

The EUT was connected to a spectrum analyzer to verify that the EUT met the requirements for spurious emissions. The EUT was set to transmit on the lowest, middle and highest frequencies at the maximum power level. The frequency range from 30 MHz to the 10th harmonic of the fundamental transmitter was investigated.

Test Setup

See Annex A for test data

Radiated Spurious Emissions
Engineer: Alex Macon
Test Date: 6/9/16

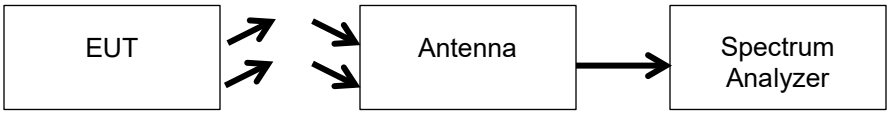
Test Procedure
Radiated Spurious Emissions: 30 – 1000 MHz

The EUT was setup in a semi-anechoic test chamber set 3m from the receiving antenna. The output of the transmitter was connected to a non-radiating balance load. The EUT was set to transmit on the lowest, middle and highest frequencies at the maximum power level. A spectrum analyzer was used to verify that the EUT met the requirements for Radiated Emissions. The EUT was tested by rotating it 360° with the antennas in both the vertical and horizontal orientation and was raised from 1 to 4 meters to ensure the TX signal levels were maximized.

All emissions from 30 MHz to 1 GHz were examined.
Measured Level includes antenna and receiver cable correction factors.
Correction factors were input into the spectrum analyzer before recording "Measured Level".

RBW = 100 KHz
VBW = 300 KHz
Detector –Peak

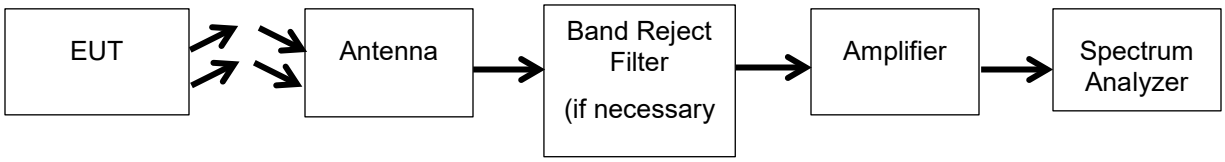
Test Setup



Test Procedure for
Radiated Spurious Emissions above 1 GHz

The EUT was setup in a semi-anechoic test chamber set 3m from the receiving antenna. The output of the transmitter was connected to a non-radiating balance load. The EUT was set to transmit on the lowest, middle and highest frequencies at the maximum power level. A spectrum analyzer was used to verify that the EUT met the requirements for Radiated Emissions. The EUT was tested by rotating it 360° with the antennas in both the vertical and horizontal orientation and was raised from 1 to 4 meters to ensure the TX signal levels were maximized.

Test Setup



See Annex B for test data

Conducted Spurious Emissions
Engineer: Alex Macon
Test Date: 6/8/16

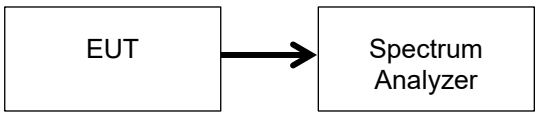
Test Procedure

The EUT was connected directly to a spectrum analyzer. The Spectrum Analyzer was set to the following:

RBW = 100 kHz
VBW ≥ 3 x RBW
Peak Detector
Trace mode = max hold
Sweep = auto couple
Frequency Range = 30MHz – 10th Harmonic of the fundamental

The EUT was set to transmit on the lowest, middle and highest frequencies at the maximum power level. The trace was allowed to stabilize. All emission were investigated to insure they were attenuated from the peak fundamental by at least 20dB. If the average power levels were measured then the out-of-band emissions needed to be attenuated by 30dB. In addition emissions were investigated at the band edges to insure all out-of-band emissions were attenuated 20 or 30dB as necessary.

Test Setup



See Annex C for test data

DTS Bandwidth
Engineer: Alex Macon
Test Date: 6/8/16

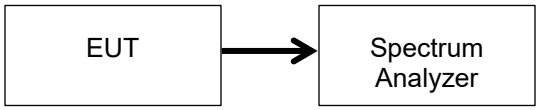
Test Procedure

The EUT was connected directly to a spectrum analyzer. The Spectrum Analyzer was set to the following:

RBW = 100 kHz
VBW ≥ 3 x RBW
Peak Detector
Trace mode = max hold
Sweep = auto couple
Span = 1.5 x EBW

The EUT was set to transmit at the lowest, middle and highest channels of the band at the maximum power levels. The maximum width of the emission that was determined by the frequencies associated with the two outermost amplitude points (upper and lower frequencies) that were attenuated by 6db and this value was used to determine the width of the carrier. Alternatively the spectrum analyzer's automatic bandwidth capability was used.

Test Setup



6 dB Occupied Bandwidth Summary
500 kb

Frequency (MHz)	Measured Bandwidth (kHz)	Specification Limit (kHz)	Result
Low	675.81	≥ 500	Pass
Mid	676.85	≥ 500	Pass
High	527.53	≥ 500	Pass

1Mb

Frequency (MHz)	Measured Bandwidth (kHz)	Specification Limit (kHz)	Result
Low	699.26	≥ 500	Pass
Mid	706.53	≥ 500	Pass
High	713.28	≥ 500	Pass

4Mb

Frequency (MHz)	Measured Bandwidth (kHz)	Specification Limit (kHz)	Result
Low	1617	≥ 500	Pass
Mid	1604	≥ 500	Pass
High	1603	≥ 500	Pass

99% Bandwidth Summary

500 kb

Frequency (MHz)	Measured Bandwidth (MHz)	Result
Low	0.510	Pass
Mid	0.511	Pass
High	0.722	Pass

1 Mb

Frequency (MHz)	Measured Bandwidth (MHz)	Result
Low	1.059	Pass
Mid	1.058	Pass
High	1.061	Pass

4 Mb

Frequency (MHz)	Measured Bandwidth (MHz)	Result
Low	3.117	Pass
Mid	3.071	Pass
High	3.00	Pass

See Annex D for test data

Transmitter Power Spectral Density (PSD)

Engineer: Alex Macon

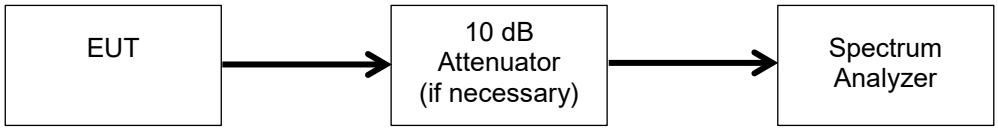
Test Date: 6/8/16

Test Procedure

The EUT was connected directly to a spectrum analyzer.
The method AVGPSD-2 in section 11.10.5 of ANSI C63.10:2013 was used to make the measurement. This method uses trace averaging across ON and OFF times of the EUT transmissions in the spectrum analyzer channel power function using an RMS detector with a 100kHz RBW. Following the measurement a duty cycle correction was applied by adding [10 log (1 / D)], where D is the duty cycle, to the measured power to compute the average power during the actual transmission times. The observed power level is then scaled to an equivalent value in 3kHz by adding a Bandwidth Correction Factor (BWCF) where:
BWCF = 10*LOG(3kHz / 100kHz) = 15.2 dB

The EUT was set to transmit at the lowest, middle and highest channels of the band at the maximum power levels. Once the trace has stabilize the peak marker was used to determine the peak power spectral density.

Test Setup



PSD Summary

Channel	Data Rate: 500 kb				
	Average Conducted Power (dBm)	3khz/100khz Correction	Duty Cycle Factor (dB)	Value (dBm)	Limit (dBm)
Low	22.79	15.2	0.2	7.79	8
Mid	22.8	15.2	0.2	7.8	8
High	22.76	15.2	0.2	7.76	8

Channel	Data Rate: 1 Mb				
	Average Conducted Power (dBm)	3khz/100khz Correction	Duty Cycle Factor (dB)	Value (dBm)	Limit (dBm)
Low	22.43	15.2	0.4	7.63	8
Mid	22.37	15.2	0.4	7.57	8
High	22.04	15.2	0.4	7.24	8

Channel	Data Rate: 4 Mb				
	Average Conducted Power (dBm)	3khz/100khz Correction	Duty Cycle Factor (dB)	Value (dBm)	Limit (dBm)
Low	19.27	15.2	1.2	5.27	8
Mid	19.12	15.2	1.2	5.12	8
High	19.12	15.2	1.2	5.12	8

Test Equipment Utilized

Description	Manufacturer	Model #	CT Asset #	Last Cal Date	Cal Due Date
Horn Antenna	EMCO	3115	i00103	1/20/15	1/20/17
High Pass Filter	Trilithic	4HX3400-3-XX	i00177	Verified on:6/8/16	
Horn Antenna, Amplified	ARA	DRG-118/A	i00271	5/8/14	5/8/16*
Spectrum Analyzer	Agilent	E4407B	i00331	9/18/15	9/18/16
Bi-Log Antenna	Schaffner	CBL 6111D	i00349	10/19/15	10/19/17
Tunable Notch Filter	Eagle	TNF-240MFMF	i00364	Verified on:6/8/16	
Oscilloscope	Tektronix	DPO 3012	i00366	2/29/16	2/28/17
EMI Analyzer	Agilent	E7405A	i00379	2/11/16	2/11/17
3 Meter Semi-Anechoic Chamber	Panashield	3 Meter Semi-Anechoic Chamber	i00428	7/27/14	7/27/16

In addition to the above listed equipment standard RF connectors and cables were utilized in the testing of the described equipment. Prior to testing these components were tested to verify proper operation.

END OF TEST REPORT