EMC Technologies (NZ) Ltd
PO Box 68-307, Newton
Auckland
New Zealand
Phone 09 360 0862
Fax 09 360 0861
E-Mail Address: aucklab@ihug.co.nz
Web Site: www.emctech.com.au

TEST REPORT

Etherstack Inc. SFFR615WUH1
UHF Small Form Factor Repeater

tested to the

Code of Federal Regulations (CFR) 47

Part 90 –Private Land Mobile Services

for

Etherstack Inc.

This Test Report is issued with the authority of:

Andrew Cutler - General Manager

IANZ ACCREDITED LABORATORY

All tests reported herein have been performed in accordance with the laboratory's scope of accreditation

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1. COMPLIANCE STATEMENT

The **Etherstack Inc. SFFR615WUH1 UHF Small Form Factor Repeater** complies with the limits defined in 47 CFR Part 90 and 47 CFR Part 2 when tested in-accordance with the test methods described in 47 CFR Part 2 and ANSI/ TIA-603-C.

2. RESULT SUMMARY

The results of testing, carried out between 12th and the 25th November 2014, are summarised below.

Clause	Description	Result
90.203	Certification required	Noted
2.1046	RF power output	Noted
90.205	Power and antenna height limits	Complies
2.1049	Occupied bandwidth	Noted
2.202	Bandwidths	Noted
90.207	Types of emissions	Complies
90.209	Bandwidth limitations	Complies
90.210	Emission masks	Complies
2.1051	Spurious emissions at antenna terminals	Complies
2.1053	Field strength of spurious radiation	Complies
2.1055	Frequency stability	Noted
90.213	Frequency stability	Complies
90.214	Transient frequency behaviour	Complies
1.1310	Radio frequency exposure limits	Complies

3. ATTESTATION

This report describes the tests and measurements performed for the purpose of determining compliance with the specification with the following conditions:

The client selected the test sample.

The report relates only to the sample tested.

This report does not contain corrections or erasures.

Measurement uncertainties with statistical confidence intervals of 95% are shown below test results. Both Class A and Class B uncertainties have been accounted for, as well as influence uncertainties where appropriate.

In addition this equipment has been tested in accordance with the requirements contained in the appropriate Commission regulations.

All compliance statements have been made with respect of the specification limit with no reference to the measurement uncertainty.

To the best of my knowledge, these tests were performed using measurement procedures that are consistent with industry or Commission standards and demonstrate that the equipment complies with the appropriate standards.

I further certify that the necessary measurements were made by EMC Technologies NZ Ltd, 47 MacKelvie Street, Grey Lynn, Auckland, New Zealand.

Andrew Cutler
General Manager
EMC Technologies NZ Ltd

4. CLIENT INFORMATION

Company Name	Etherstack Inc.
Address	1115 Broadway, Suite 1276, New York, NY10010
Country	United States of America
Contact	Mr Doug Chapman

5. TEST SAMPLE DESCRIPTION

Brand Name	Etherstack Inc.
Model Number	SFFR615WUH1
Product	UHF Small Form Factor Repeater
Manufacturer	Etherstack London Ltd
Country of Origin	Australia
Serial Number	1200018
FCC I.D	2ADAKSFFR615WUH1

Product overview

The SFFR615WUH1 is a small form factor portable repeater that is self-powered and can operate as an APCO P25 standalone repeater.

Power Supply:

- DC Supply 12 Vdc 10.8 – 15.6 volt dc Max 10 amps
- AC Supply: 100 - 240 Vdc (47-63 Hz)
- Internal Batteries 11.25 Vdc Li-ION rechargeable x 2

Output Power

1 W (+30.0 dBm) to 15 watts (+41.8 dBm)

Transmitter FCC Frequency Bands

Part 90: 440 - 512 MHz

Test frequency

Frequency (MHz)	Power (Watts)	Spacing (kHz)
487.7250	15.0	12.5

Emission Designators

8K10F1D
8K10F1E
8K10F7D
8K10F7E
8K10F1W
8K10F7W

Standard Temperature and Humidity

Temperature: +15 °C to + 30 °C maintained.
Relative Humidity: 20% to 75% observed.

Standard Test Power Source

Standard Test Voltage: 13.8 Vdc

Extreme Temperature

High Temperature: + 50 °C maintained.
Low Temperature: - 30 °C maintained.

Extreme Test Voltages

Low Voltage: 10.8 Vdc
High Voltage: 15.6 Vdc

6. TEST RESULTS

Certification required

Certification of this device is sought for digital and analogue speech transmissions in accordance with section 90.203(j)(4)(iii).

- certification has been sought after January 1, 2015.

- the equipment operates under FCC Part 90

- the equipment is designed to operate in various FCC Part 90 bands between 440 - 512 MHz

- the equipment can operate in multi-bandwidth mode

- the equipment meets the spectrum efficiency standard of one voice channel per 6.25 kHz of channel bandwidth by using two voice channels per 12.5 kHz bandwidth.

- the equipment can operate with a data rate greater than 4.8 kbps per 6.25 kHz of channel

Result: Complies.

RF power output

Measurements were carried out at the RF output terminals of the transmitter using a 30 dB power attenuator and a 50 Ω dummy load.

Measurements were carried out when the transmitter was modulated.

Testing was carried out at maximum power output.

Frequency (MHz)	Voltage (Vdc)	Rated Output Power (dBm)	Measured (dBm)
487.725	15.6	41.8	41.2
487.725	13.8	41.8	41.2
487.725	10.8	41.8	41.2

Limits:

Part 90 does not specify the transmitter output power.

Result: Complies.
Measurement Uncertainty: ±0.5 dB

Part 90.207 – Emission types:

The following emission types are used with 12.5 kHz channelling using various combinations of data and speech

8K10F1D - data
8K10F1E - voice
8K10F7D - two digital data channels
8K10F7E - two digital voice channels
8K10F1W - voice and data channel
8K10F7W - voice + data

All modulation types se standardised C4FM modulation where:

- the same symbol rate (i.e. 4800 symbols/ 9600 bps) is used
- the same symbol deviation is used
- then same transmit shaping filters is used
- the same frequency modulation is used

The output spectrum generated will therefore be the same for each emission designator.

The only difference is the type of information transmitted, i.e. voice, data, 2x voice, 2x data, and combinations of.

Part 90.209 – Bandwidth limitations:

The authorised bandwidth is taken to be the necessary bandwidth.

Various emission designators declared by the client.

Measurements have also been made to verify this declared bandwidth.

The occupied bandwidth has been measured and compared against the occupied bandwidth declared by the client.

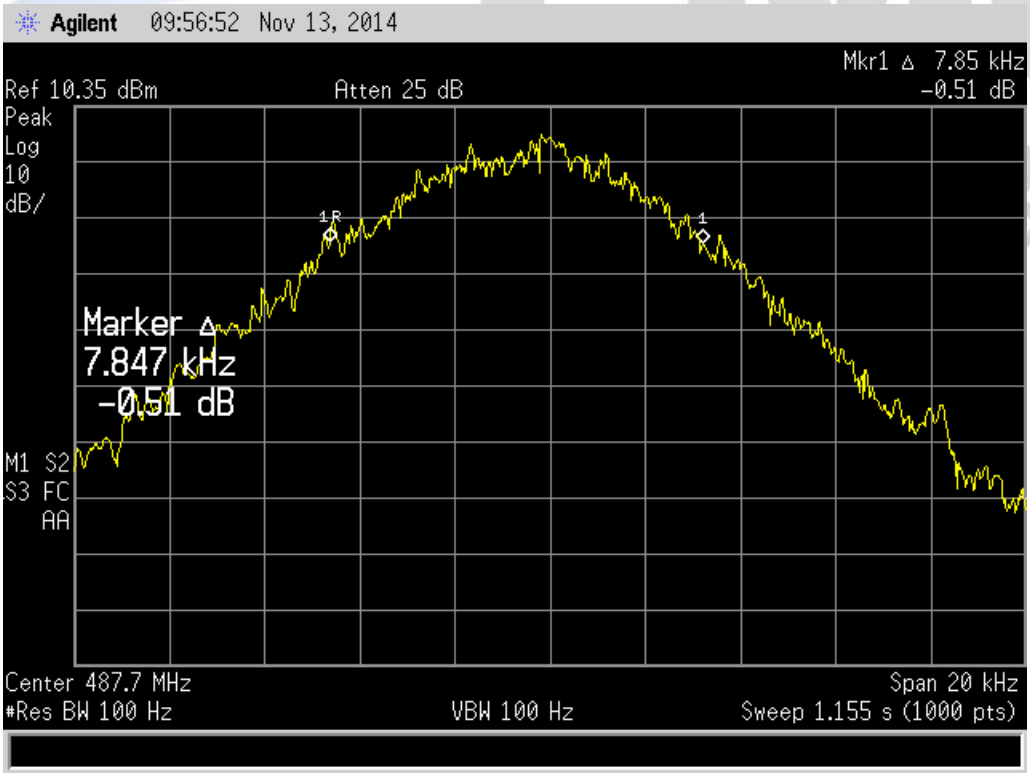
Measurements have been made of each modulation type using a spectrum analyser operating in peak hold mode and a 30 dB attenuator.

Initially power measurements are made using a resolution bandwidth of 120 kHz.

This level is used as a reference level on the spectrum analyser.

The resolution bandwidth is then changed to 100 Hz and the reference level minus 23 dB (99%) absolute bandwidth points determined

Channelling	Measured	Designated
12.5 kHz	7.847 kHz	8.100 kHz



Result: Complies.

Spectrum Masks

The spectrum masks are defined in:

Section 90.210(d) – Mask D has been applied as the transmitter can operate in the band 421 - 512 MHz using an authorised bandwidth of 12.5 kHz as per Section 90.209(b)(5).

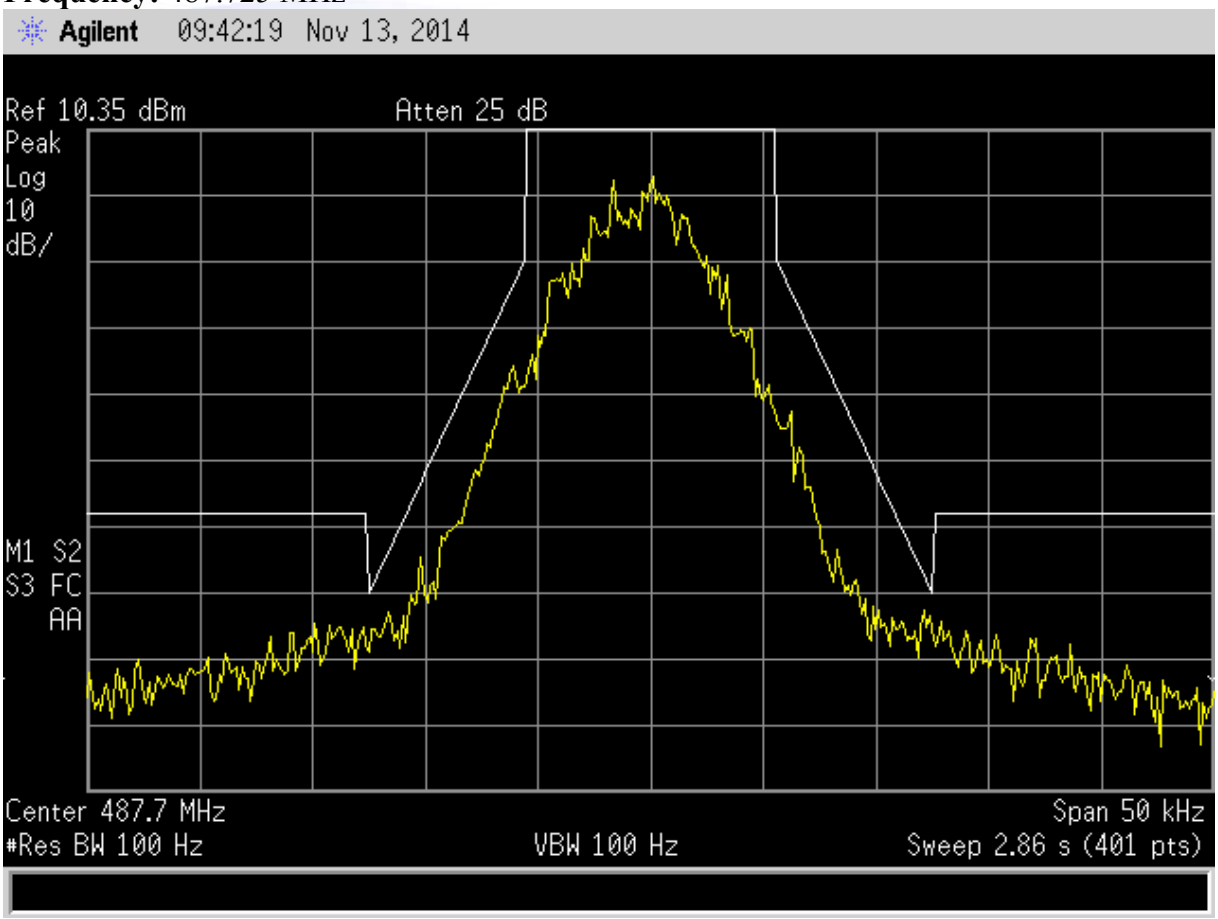
The reference level for the following emission mask measurements has been determined using a resolution bandwidth of 120 kHz with the transmitter modulated.

All measurements have been made with a -30 dB correction factor as a 30 dB attenuator is placed between the transmitter and the spectrum analyser.

Measurements were made in peak hold.

The transmitter was modulated using the modulation sources internal to the transmitter as supplied by the client.

Frequency: 487.725 MHz



Result: Complies

Transmitter spurious emissions at the antenna terminals

Frequency: 487.725 MHz

Spurious emission (MHz)	Emission level (dBm)	Limit (dBm)
975.450	<-70.0	-20.0
1463.175	<-70.0	-20.0
1950.900	<-70.0	-20.0
2438.625	-69.6	-20.0
2926.350	<-70.0	-20.0
3414.075	<-70.0	-20.0
3901.800	<-70.0	-20.0
4389.525	<-70.0	-20.0
4877.250	<-70.0	-20.0

No other emissions were observed

Limit:
Part 90.210(d) Mask D, (3) on any frequency removed from the centre of the authorised bandwidth by a displacement frequency of more than 12.5 kHz shall be attenuated by at least 50 + 10 log (P) or 70 dB whichever is the lesser attenuation.

The spurious emission limit defined by Mask D has been applied as this transmitter can operate using channel spacing of 12.5 kHz.

Part 2.1051 states that emissions greater than 20 dB below the limit need not be specified.

Part 2.1057 states that the spectrum should be investigated up to the 10^{th} harmonic if the transmitter operates below 10 GHz.

A rated power of 15.0 watts gives a limit of –20.0 dBm.

No measurements were made above the 10^{th} harmonic.

Result: Complies
Measurement Uncertainty: ±3.3 dB

Field strength of the transmitter spurious emissions

Frequency: 487.725 MHz

Frequency (MHz)	Level (dBµV/m)	Level (dBm)	Limit (dBm)	Antenna	Margin (dB)	Result
975.4500	41.7	-55.7	-20.0	Vertical	35.7	Pass
975.4500	27.3	-70.1	-20.0	Horizontal	50.1	Pass
1463.1750	41.5	-55.9	-20.0	Vertical	35.9	Pass
1463.1750	41.6	-55.8	-20.0	Horizontal	35.8	Pass
1950.9000	44.5	-52.9	-20.0	Vertical	32.9	Pass
1950.9000	44.5	-52.9	-20.0	Horizontal	32.9	Pass
2438.6250	46.1	-51.3	-20.0	Vertical	31.3	Pass
2438.6250	46.0	-51.4	-20.0	Horizontal	31.4	Pass
2926.3500	48.5	-48.9	-20.0	Vertical	28.9	Pass
2926.3500	48.1	-49.3	-20.0	Horizontal	29.3	Pass
3414.0750	50.0	-47.4	-20.0	Vertical	27.4	Pass
3414.0750	50.0	-47.4	-20.0	Horizontal	27.4	Pass
3901.8000	53.0	-44.4	-20.0	Vertical	24.4	Pass
3901.8000	53.0	-44.4	-20.0	Horizontal	24.4	Pass
4389.5250	54.0	-43.4	-20.0	Vertical	23.4	Pass
4389.5250	54.0	-43.4	-20.0	Horizontal	23.4	Pass
4877.2500	55.0	-42.4	-20.0	Vertical	22.4	Pass
4877.2500	55.0	-42.4	-20.0	Horizontal	22.4	Pass

The transmitter was tested while transmitting continuously while attached to a dummy load.

When operating in transmit mode no significant emissions were detected between the harmonic emissions that were detected.

Device was tested on an open area test site at a distance of 3 metres.

Testing was carried out at EMC Technologies NZ Ltd Open Area Test Site, which is located at Driving Creek, Orere Point, Auckland.

The level recorded is the signal generator output level in dBm less any gains / losses due to the coax cable and the dipole antenna.

Limit:

All spurious emissions are to be attenuated by at least 50 + 10 log (P). The rated power of 15 watts gives a limit of –20 dBm.

No measurements were made above the 10^{th} harmonic.

Result: Complies.
Measurement Uncertainty: ± 4.1 dB

Frequency Stability

Frequency stability measurements were between - 30 °C and + 50 °C in 10 °C increments.

At each temperature the transmitter was given a period of 30 minutes to stabilise.

The transmitter was then turned on and the frequency error measured after a period of 1 minute.

Frequency: 487.725 MHz

Temperature (°C)	10.0 Vdc (Hz)	13.8 Vdc (Hz)	15.6 Vdc (Hz)
+50	-460.0	-468.0	-464.0
+40	-488.0	-487.0	-485.0
+30	-475.0	-472.0	-470.0
+20	-377.0	-380.0	-383.0
+10	-493.0	-488.0	-485.0
0	-487.0	-487.0	-483.0
-10	-460.0	-459.0	-461.0
-20	-432.0	-433.0	-434.0
-30	-399.0	-424.0	-422.0

Limit:

Part 90.213 states that fixed / base station transmitters operating between 421 – 512 MHz with 12.5 kHz channelling are required to have a frequency tolerance of 1.5 ppm.

A worst case frequency error of 1.0 ppm (488 Hz / 487.725 MHz) was observed.

Result: Complies.
Measurement Uncertainty: ± 30 Hz

Transient frequency behaviour

Transient frequency behaviour measurements are applicable to wide band and narrow band transmitters operating in the frequency band 421 - 512 MHz.

Measurements were carried out using the method described in TIA-603.

In summary this method calls for the use of an external signal generator tuned to transmitter transmit frequency with an output level 0.1 % (-30 dB) of the level from the transmitter with a 1 kHz tone with a frequency deviation of 12.5 kHz being applied to the input of a modulation analyser along with the output from the transmitter.

The modulation analyser produces an amplitude difference signal and a frequency difference signal, which are applied to the input of a storage oscilloscope.

The unmodulated transmitter is then keyed which produces a trigger pulse that is AC coupled to the oscilloscope that produces a display on the screen.

The result of the change in the ratio of power between the test signal from the signal generator and the transmitter output will produce 2 separate sides on the oscilloscope picture. One will show the 1000 Hz test modulation and the other will be the frequency difference of the transmitter versus time.

Channel Spacing (kHz)	Period t_1 (kHz)	Period t_2 (kHz)	Period t_3 (kHz)
12.5	<12.5	Nil	Nil

Limits:

Time Interval	Period	12.5 kHz Deviation (kHz)
t_1	10 ms	± 12.5
t_2	25 ms	± 6.25
t_3	10 ms	± 12.5

Result: Complies.
Measurement Uncertainty: Frequency difference ±1.6 kHz, Time period ±1 ms

12.5 kHz transmitter turn on

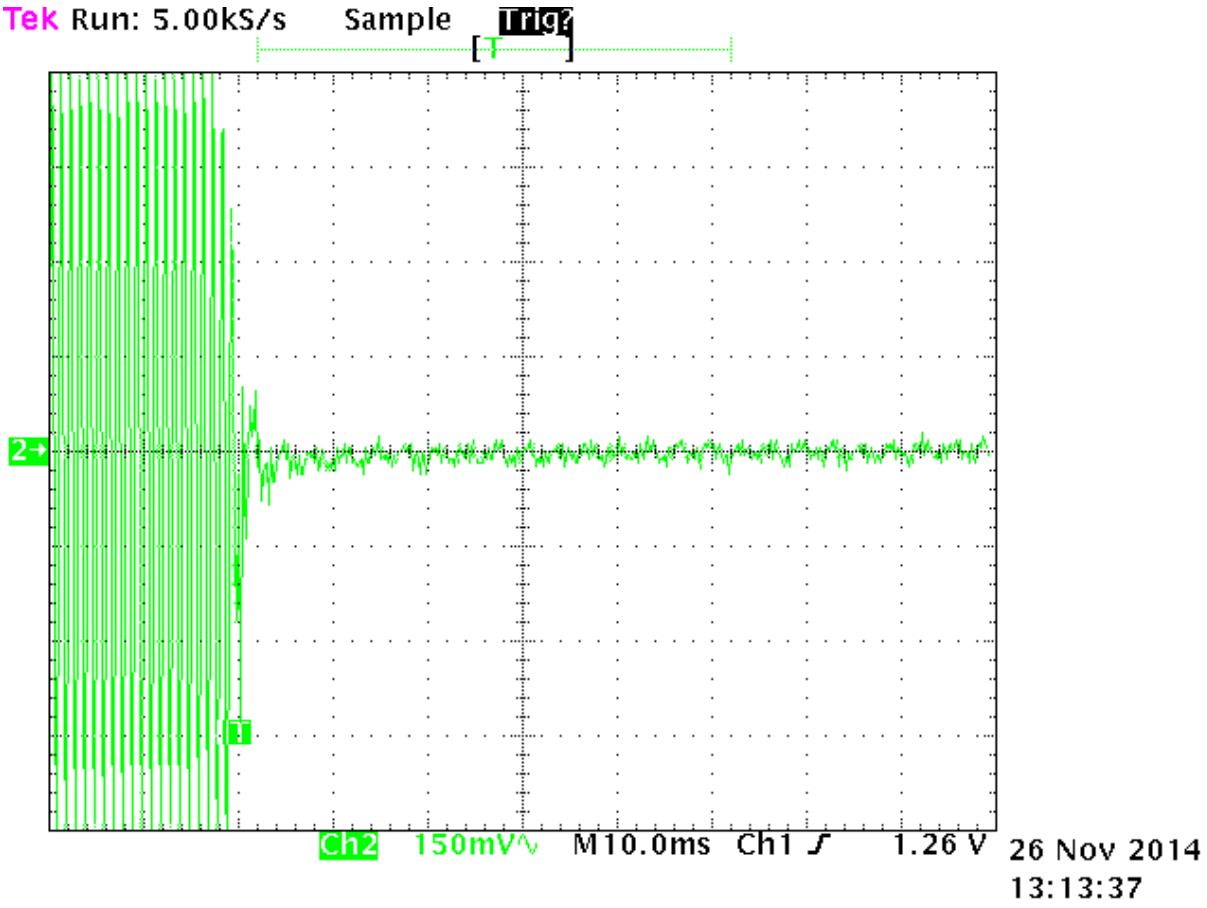
Green Trace = 1 kHz tone with FM deviation of 12.5 kHz and any transient.

Green trace has been maximised to give full screen indication of a ±12.5 kHz.
Therefore each Y axis division = 3.125 kHz per division.
The X axis has been set to a sweep rate of 10 ms/division.

Triggering has been set to occur 2 divisions from the left hand edge (20 ms). This is position *t*on.

*t*1 occurs between 2.0 and 3.0 divisions from the left-hand edge.
t2 occurs between 3.0 and 5.5 divisions from the left-hand edge.

A small transient can be observed just after *t*on.



12.5 kHz transmitter turn off

Green Trace = 1 kHz tone with FM deviation of 12.5 kHz and any transient.

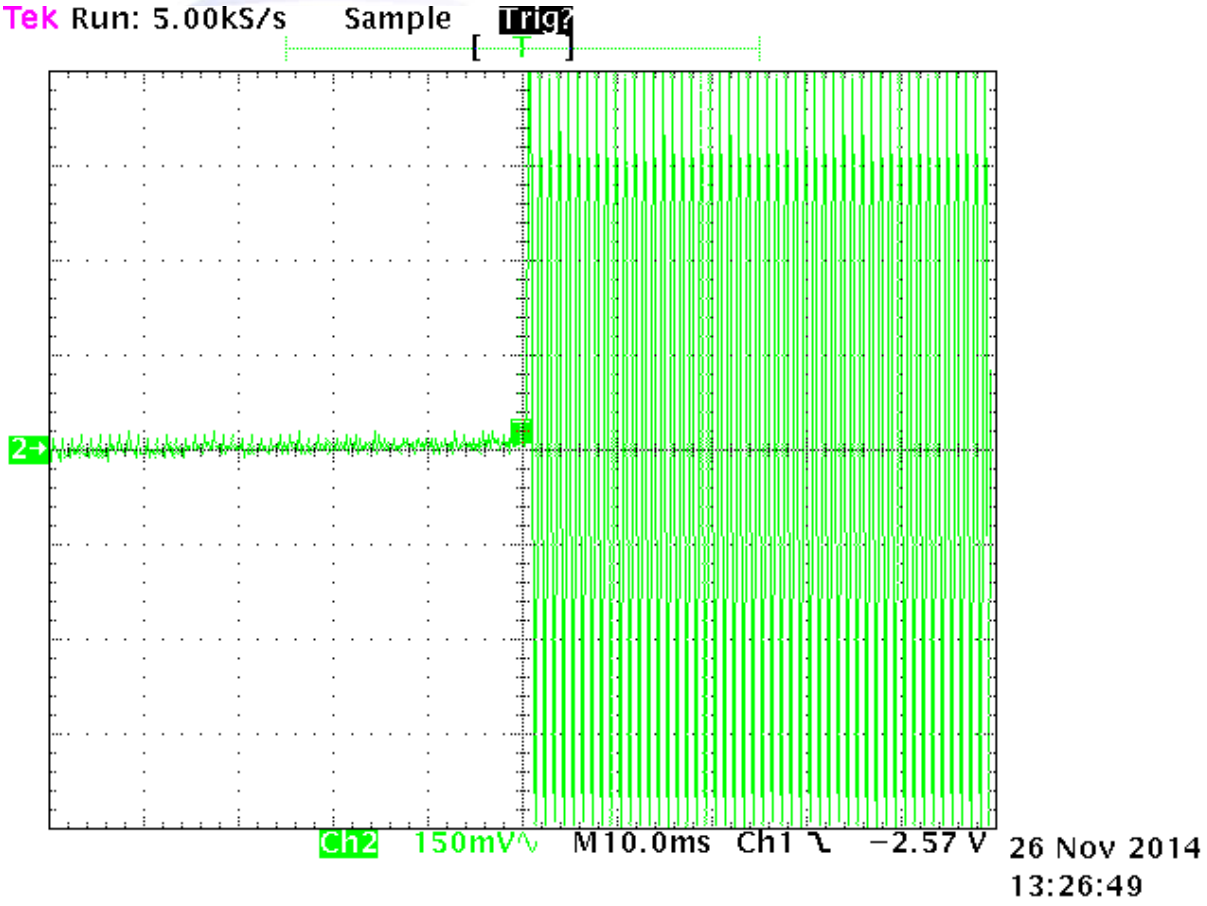
Green trace has been maximised to give full screen indication of a ± 12.5 kHz.
Therefore each Y axis division = 3.125 kHz per division.
The X axis has been set to a sweep rate of 10 ms/division.

The display of the 1 kHz signal rising has been positioned 5 divisions from the left hand edge (50 ms).

This is position *t*off.

*t*3 occurs between 4.0 and 5.0 divisions from the left hand edge.

No transient response can be observed just before toff.



Exposure of humans to RF fields

As per FCC KDB 447498 D01 and Section 2.1091 radio frequency transmitters are required to be operated in a manner that ensures the public is not exposed to RF energy levels.

Calculations have been made using the General Public/Uncontrolled Exposure limits that are defined in Section 1.1310.

Minimum safe distances have been calculated below.

Power density, $mW/cm^2 = E^2/3770$

- General Population / Uncontrolled exposure limit will be 0.29 mW/cm^2
(f/1500 = 440 MHz/1500)

As this radio can operate over the range of 440 - 512 MHz the lowest frequency of operation in the USA, which will give the worst case result, would be 440 MHz.

The minimum distance from the antenna at which the MPE is met is calculated from the equation relating field strength in V/m, transmit power in watts, transmit antenna gain, transmitter duty cycle and separation distance in metres:

Power Density = 0.29 $mW/cm^2 = E^2/3770$

$E = \sqrt{0.29*3770}$

E = 33.1 V/m

The rated maximum transmitter power (P) = 15 watts.

A duty cycle (DC) of 100% as the transmitter is a base station could possibly be operated for long periods of time.

Transmitter is operated using a quarter wave whip antenna with a gain (G) of 2.14 dBi (1.64).

The safe distance would be calculated as follows:

$d = \sqrt{(30 * P * G*DC) / E}$

$d = \sqrt{(30 * 15 * 1.64 * 1) / 33.1}$

d = 0.82 metres or 82 cm

Result: Complies if the safe distances defined above are applied.

7. TEST EQUIPMENT USED

Instrument	Manufacturer	Model	Serial #	Asset	Cal Due	Interval
Aerial Controller	EMCO	1090	9112-1062	3710	N/a	N/a
Aerial Mast	EMCO	1070-1	9203-1661	3708	N/a	N/a
Biconical Antenna	Schwarzbeck	BBA 9106	-	3612	12/01/2015	3 years
Horn Antenna	EMCO	3115	9511-4629	E1526	04/06/2017	3 years
Level generator	Anritsu	MG443B	M61689	E1143	15/01/2015	2 years
Log Periodic Antenna	Schwarzbeck	VUSLP 91111	9111-228	3785	12/01/2015	3 years
Modulation Analyzer	Rohde & Schwarz	FMA	837807/020	E1552	15/01/2015	2 years
Modulation Analyzer	Hewlett Packard	8901B	2608A00782	E1090	15/01/2015	2 years
Oscilloscope	Tektronics	745A	B010643	E1569	15/01/2015	2 years
Power Attenuator	JFW	50FH-030-100	-	-	N/a	N/a
Power Supply	Hewlett Packard	6032A	2743A-02859	E1069	N/a	N/a
Receiver	Rohde & Schwarz	ESIB-40	100171	4003	29/01/2015	1 year
Selective Level Meter	Anritsu	ML422C	M35386	E1140	03/07/2015	2 years
Signal Generator	Rohde & Schwarz	SMHU	838923/028	E1493	22/01/2015	2 years
Spectrum Analyzer	Hewlett Packard	E7405A	US39150142	3776	26/02/2015	1 year
Thermal chamber	Contherm	M180F	86025	E1129	01/06/2015	N/a
Thermometer	DSIR	RT200	035	E1049	01/06/2015	N/a
Turntable	EMCO	1080-1-2.1	9109-1578	3709	N/a	N/a
VHF Balun	Schwarzbeck	VHA9103	-	3603	12/01/2015	3 years

At the time of testing all test equipment was within calibration.

8. ACCREDITATIONS

Testing was carried out in accordance with EMC Technologies Ltd registration with the Federal Communications Commission as a listed facility, registration number: 90838, which was updated in June 2014.

All testing was carried out in accordance with the terms of EMC Technologies (NZ) Ltd International Accreditation New Zealand (IANZ) Accreditation to NZS/ISO/IEC 17025.

All measurement equipment has been calibrated in accordance with the terms of the EMC Technologies (NZ) Ltd International Accreditation New Zealand (IANZ) Accreditation to NZS/ISO/IEC 17025.

International Accreditation New Zealand has Mutual Recognition Arrangements for testing and calibration with various accreditation bodies in a number of economies. This includes NATA (Australia), UKAS (UK), SANAS (South Africa), NVLAP (USA), A2LA (USA), SWEDAC (Sweden). Further details can be supplied on request.

9. PHOTOGRAPHS

Radiated emissions setup