Report on the Exposure Calculation for DetNet South Africa (Pty) of the Commander, Model: CE4 Commander 1 (declared variant: CE4 Commander 2) In accordance with FCC CFR 47 and ISED RSS-102

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COMMERCIAL-IN-CONFIDENCE

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RESPONSIBLE FOR	NAME	DATE	SIGNATURE
Project Management	Natalie Bennett	03 February 2022	
Authorised Signatory	Matthew Russell	03 February 2022	

Signatures in this approval box have checked this document in line with the requirements of TÜV SÜD document control rules.

ENGINEERING STATEMENT
The calculations shown in this report were made in accordance with the procedures described in FCC CFR 47 and ISED RSS-102.

RESPONSIBLE FOR	NAME	DATE	SIGNATURE
Calculation	Pete Dorey	03 February 2022	

EXECUTIVE SUMMARY
The calculation of exposure for this product was found to be compliant at 20 cm with FCC CFR 47 and ISED RSS-102.

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Contents

1 Report Summary

1.1 Report Modification Record

Alterations and additions to this report will be issued to the holders of each copy in the form of a complete document.

Issue	Description of Change	Date of Issue
1	First Issue	21 November 2018
2	Added Declared Variant	03 February 2022

1.2 Introduction

Objective	To perform electromagnetic field exposure assessment to determine the equipment under test's (EUT's) compliance with the applied specifications.
Applicant	DetNet South Africa (Pty)
Manufacturer	DetNet South Africa (Pty)
Model Number(s)	Commander 1 (declared variant: Commander 2)
Manufacturer's Declared Variant(s)	CE4 Commander DS600
Hardware Version(s)	V5
Software Version(s)	36230C
Specification/Issue/Date	FCC: CFR 47 Pt1.1310:2017 ISED Canada: Health Canada Safety Code 6:2015
Order Number Date	4500347895 14 August 2018
Related Document(s)	• OET65:97 Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields • IEEE C95.3:2002 IEEE Recommended Practice for Measurements and Computations of Radio Frequency Electromagnetic Fields With Respect to Human Exposure to Such Fields, 100 kHz–300 GHz • RSS-102 Issue 5 Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands)

1.3 Brief Summary of Results

The wireless device described within this report was compliant with the restrictions related to human exposure to electromagnetic fields for both general public and worker/occupational exposures.

The calculations shown in this report were made in accordance with the procedures specified in the applied test specification(s).

1.3.1 CE4 Commander 1 (declared variant: CE4 Commander 2)

Regional Requirement	Calculated RF exposure level at compliance boundary of 0.2 m as a fraction of the limit			
	S Power Density	E Field	H Field	B Field
	Summation for simultaneous exposure; value to be <1			
FCC	0.0094 Note 1			N/A
CANADA	0.0152	0.0152	0.0152	N/A
Note 1: FCC summation combines S Power Density and E Field contributions as FCC limits are not provided for all frequencies of the EUT.				

Table 1 – Worker/Occupational Exposure Results

The calculations show that the EUT complies with the worker/occupational exposure levels described in in the listed specifications in Annex A at the point of investigation, 0.2 m.

Regional Requirement	Calculated RF exposure level at compliance boundary of 0.2 m as a fraction of the limit			
	S Power Density	E Field	H Field	B Field
	Summation for simultaneous exposure; value to be <1			
FCC	0.0469 Note 1			N/A
CANADA	0.0986	0.0986	0.0986	N/A
Note 1: FCC summation combines S Power Density and E Field contributions as FCC limits are not provided for all frequencies of the EUT.				

Table 2 – General Public Exposure Results

The calculations show that the EUT complies with the general public exposure levels described in in the listed specifications in Annex A at the point of investigation, 0.2 m.

1.3.2 Manufacturer's Declared Variant(s)

Classification:	System/Product:	Document Ref:	Revision:
Restricted	DigiShot 600	TGN-00106	1
	Document Type: TGN-Tech General	Current Author: Morgan Lombard	
detnet the future of electronic initiation	Title: Changes between DigiShot 600 Commander and CE4 Commander.	Original Author: Morgan Lombard	
		Page: Page 1 of 3	

1 INTRODUCTION

1.1 Objective

This document describes the differences between the standard CE4 Commander and the DigiShot Commander. Note that from a branding perspective, the system will be branded as 'DigiShot' not 'DigiShot 600' – the latter name being used internally in DetNet to distinguish between the new and old systems.

1.2 Reference Documents

- URS-00111 : DigiShot 600

2 CHANGES

2.1 Hardware Changes

The number of Channels have been reduced to from 4 IOM to 2 IOM.

Table 1 - Hardware differences

	CE4 Commander	DigiShot Commander
Channels	4	2 *

* Channel 3 and 4 will be used on DigiShot.

2.2 Mechanical changes

- Main enclosure colour changed from Pantone Yellow 1235C to Pantone Orange 21C. Base material remains PA 66. Other elements remain the same.
- Top two IOM, bezels, spring-loaded wire terminals, associated gaskets and fastening hardware removed.
- The DigiShot UI Faceplate lacks the holes for the above bezels and spring-loaded wire terminals. A Matt Polycarbonate product label is placed over this area.
- Same packaging will be used as the CE4 Commander, at roughly the same weight (14Kg). Packaging tests are conducted to the nearest Kg so the difference in weight from the lack of two IOM is negligible.
- Fitted with an improved UI front plate and sealing.

APPROVER	APPROVER SIGNATURE	SIGNATURE DATE	ISSUE DATE
Abrie Liebenberg	X  Signed by: AJLieb 20200403	2020/10/20	2020/10/20

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	Title:	Original Author:	
	Changes between DigiShot 600 Commander and CE4 Commander.	Morgan Lombard	
		Page:	
		Page 2 of 3	

Figure 1: CE4 Commander UI vs. DigiShot Commander UI


Figure 2: DigiShot System packaging uses existing CE4 Commander Packaging.

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		Page: Page 3 of 3	

2.3 Firmware Changes

The Base is only allowed to connect to one Bench by default. A ticket option can be used to change the number of benches to two. The Bench only allows 300 detonators per channel. The Bench is limited to two channels. The Bench only works with DigiShot detonators.

Table 2 - Firmware differences

	CE4 Commander	DigiShot Commander
Benches	10	1 (2)
Channels	4	2
Detonators per Channel	400	300
Detonator Product	DigiShot+, IntelliShot	DigiShot

3 REVISION HISTORY

Revision 1: New document

1.4 Product Information

1.4.1 Technical Description

The IntelliShot system is a system used in the mining blasting industry. There are 2 components of the system called a "Commander" and Tagger. The Commander is placed on the ground and can be used for long range communication capability which can be further enhanced by a repeater functionality giving the user a defined 6 km communication range allowing for improved safety at blast time.

The Commander contains a 2.4 GHz GainSpan Wi-Fi module. The Commander also contains a 900 MHz Laird Transceiver module. There is also a 13.56 MHz NFC device for various applications.

NOTE 1: There will be another Commander unit which contains a different 900 MHz module to the original 900 MHz module becoming obsolete. For the purposes of this report, these different Commander units will be called "Commander 1" and "Commander 2".

1.4.2 Transmitter Description

The following radio access technologies and frequency bands are supported by the equipment under test.

Radio Access Technology	Antenna Port	Frequency Band	Minimum Frequency	Output Power	Duty Cycle
		MHz	MHz	dBm	%
WiFi	1	2412 - 2457	2412	18	100
Long Range RF (Commander 1) Note 1	2	902 - 928	902	30	5
Long Range RF (Commander 2) Note 1	2	907.125 – 913.325	907.125	27	5
NFC	3	13.56	13.56	6	100
Note 1: Commander 1 RF operates over a wider frequency range, lower frequency and higher output power compared to Commander 2. Therefore the calculation will be based on the Commander 1 specification as worst cae.					

Table 3 – Transmitter Description

1.4.3 Antenna Description

The following antennas are supported by the equipment under test.

Antenna No	Radio Access Technology	Antenna Model	Gain	Antenna length	Minimum Separation Distance
			dBi	cm	cm
1	WiFi	Internal	2	1.4943	20
2	Long Range RF	Internal	2	11.5	20
3	NFC	Internal	2	4.5	20

Table 4 – Antenna description

1.4.4 Equipment Configuration

Commander equipment operating with simultaneous transmission of WiFi, Long Range RF and NFC.

2 Assessment Details

2.1 Assessment Method

The assessment method is by calculation of the power density S, electric field strength E, magnetic field strength H or magnetic flux density B.

The calculation uses the spherical model applicable under far field conditions.

$$S = E \times H = \frac{E^2}{\eta} = H^2 \times \eta = \frac{P \times G_i}{4 \times \pi \times r^2}$$

Where:
η - Impedance of free space (377 ohm in far field)
P – Transmitter power W
G_i – Antenna gain ratio relative to isotropic
R – Separation distance m

The magnetic flux density is related to the magnetic field strength by a constant:

$$B = \mu_o \times H$$

Where:
μo – Permeability of free space 4xπ E-7 H/m

Where additional calculations are required by the regional specifications these are detailed below.

The far field region boundary depends on the frequency and wavelength and also on the antenna dimension. The boundary of the far field region is calculated below to demonstrate the validity of using the spherical model.

2.2 Individual Antenna Port Exposure Results

2.2.1 Calculation of Exposure at Specified Separation Distance

The frequencies shown in the tables below have been chosen based on the lowest possible frequency that the EUT can transmit. A full list of the regional requirements is shown in Annex A.

Regional Requirement	Antenna Port	RAT	Frequency (MHz)	RF Exposure Level at compliance boundary of 0.2 m							
				S Power Density (W/m²)		E Field (V/m)		H Field (A/m)		B Field (μT)	
				Result	Limit	Result	Limit	Result	Limit	Result	Limit
FCC	1	WiFi	2412	0.20	50.00	8.66	N/A	0.0230	N/A	0.0289	N/A
FCC	2	Long Range RF	902	0.16	30.07	7.71	N/A	0.0204	N/A	0.0257	N/A
FCC	3	NFC	13.56	0.01	N/A	1.73	135.84	0.0046	0.3606	0.0058	N/A
CANADA	1	WiFi	2412	0.20	31.70	8.66	109.32	0.0230	0.2900	0.0289	N/A
CANADA	2	Long Range RF	902	0.16	19.39	7.71	85.49	0.0204	0.2268	0.0257	N/A
CANADA	3	NFC	13.56	0.01	10.00	1.73	61.40	0.0046	0.1630	0.0058	N/A

Table 5 – Worker/Occupational Transmitter Summary

The calculations show that the EUT complies with the worker/occupational exposure levels described in in the listed specifications in Annex A at the point of investigation, 0.2 m.

Regional Requirement	Antenna Port	RAT	Frequency (MHz)	RF Exposure Level at compliance boundary of 0.2 m							
				S Power Density (W/m^2)		E Field (V/m)		H Field (A/m)		B Field (µT)	
				Result	Limit	Result	Limit	Result	Limit	Result	Limit
FCC	1	WiFi	2412	0.20	10.00	8.66	N/A	0.0230	#N/A	0.0289	N/A
FCC	2	Long Range RF	902	0.16	6.01	7.71	N/A	0.0204	#N/A	0.0257	N/A
FCC	3	NFC	13.56	0.01	N/A	1.73	60.76	0.0046	0.1615	0.0058	N/A
CANADA	1	WiFi	2412	0.20	5.37	8.66	44.97	0.0230	0.1193	0.0289	N/A
CANADA	2	Long Range RF	902	0.16	2.74	7.71	32.14	0.0204	0.0853	0.0257	N/A
CANADA	3	NFC	13.56	0.01	2.00	1.73	27.46	0.0046	0.0728	0.0058	N/A

Table 6 – General Public Transmitter Summary

The calculations show that the EUT complies with the general public exposure levels described in in the listed specifications in Annex A at the point of investigation, 0.2 m.

2.3 Combined Antenna Port RF Exposure Results

As the frequency of operation for each transmitter is not the same, in order to evaluate compliance with the limit which is dependent on frequency, the fractional exposure value is calculated: The calculated S power density is divided by the limit to get a fractional exposure value. The calculated E and H fields are divided by the limit and squared to get a fractional exposure value. The summation of the fractional RF exposure results for each transmitter provides the combined result. Any values less than one are compliant with the limit.

FCC OET 65 specifies the method of summation in clause; Multiple-Transmitter Sites and Complex Environments; with results as follows:

Antenna Port	RAT	Frequency (MHz)	Calculated RF exposure level at compliance boundary of 0.2 m as a fraction of the limit			
			S Power Density	E Field	H Field	B Field
1	WiFi	2412	0.0040	N/A	N/A	N/A
2	Long Range RF	902	0.0052	N/A	N/A	N/A
3	NFC	13.56	N/A	0.0002	0.0002	N/A
Summation			0.0094			N/A

Table 7 – FCC Worker/Occupational Combined Exposure

The calculations show that the EUT complies with the worker/occupational exposure levels described in in the listed specifications in Annex A at the point of investigation, 0.2 m.

Antenna Port	RAT	Frequency (MHz)	Calculated RF exposure level at compliance boundary of 0.2 m as a fraction of the limit			
			S Power Density	E Field	H Field	B Field
1	WiFi	2412	0.0199	N/A	N/A	N/A
2	Long Range RF	902	0.0262	N/A	N/A	N/A
3	NFC	13.56	N/A	0.001	0.001	N/A
Summation			0.0469			N/A

Table 8 – FCC General Public Combined Exposure

The calculations show that the EUT complies with the general public exposure levels described in in the listed specifications in Annex A at the point of investigation, 0.2 m.

CANADA Health Canada Safety Code 6 specifies the method of summation in clause 2.2.1 Note 6 with results as follows:

Antenna Port	RAT	Frequency (MHz)	Calculated RF exposure level at compliance boundary of 0.2 m as a fraction of the limit			
			S Power Density	E Field	H Field	B Field
1	WiFi	2412	0.0063	0.0063	0.0063	N/A
2	Long Range RF	902	0.0081	0.0081	0.0081	N/A
3	NFC	13.56	0.0008	0.0008	0.0008	N/A
Summation			0.0152	0.0152	0.0152	N/A

Table 9 – CANADA Worker/Occupational Combined Exposure

The calculations show that the EUT complies with the worker/occupational exposure levels described in in the listed specifications in Annex A at the point of investigation, 0.2 m.

Antenna Port	RAT	Frequency (MHz)	Calculated RF exposure level at compliance boundary of 0.2 m as a fraction of the limit			
			S Power Density	E Field	H Field	B Field
1	WiFi	2412	0.0371	0.0371	0.0371	N/A
2	Long Range RF	902	0.0575	0.0575	0.0575	N/A
3	NFC	13.56	0.0040	0.0040	0.0040	N/A
Summation			0.0986	0.0986	0.0986	N/A

Table 10 – CANADA General Public Combined Exposure

The calculations show that the EUT complies with the general public exposure levels described in in the listed specifications in Annex A at the point of investigation, 0.2 m.

2.4 Far Field Region Boundary Results

IEEE C95.3 Annex B.2 specifies the far field region boundary calculation:

Near Field / Far Field Boundary	
RAT Name	Antennas - on axis Far Field Region (Ref: IEEE C95.3 Annex B.2)
	$2D^2/\lambda$ (m)
WiFi	0.0036
Long Range RF	0.0795
NFC	0.0002

Table 11 – Far Field Boundary

The worst case far field boundary is 0.08 m. The 0.2 m compliance boundary is beyond this distance and in the far field and therefore the approach described in section 2.1 is valid. However at 0.2 m the compliance boundary is within the NFC wavelength of 22 m and therefore in the reactive near-field. The NFC exposure contribution shown in Section 2.3 is less than 0.004 (0.4 %) and therefore the uncertainties of the calculation method in the reactive near-field are not significant to the overall simultaneous exposure result.

2.5 Uncertainty

The basic computation formulas presented in section 2.1 are conservative formulas for the estimation of RF field strength or power density. No uncertainty estimations are required when using these formulas but there is clear guidance on where and when these formulas are applicable. (Reference EN 62232 clause B.4.1).

For the estimate of S, E or H to be conservative, the transmitter power P and antenna gain G_i values shall be the upper bounds of uncertainty therefore maximum values are used.

The spherical formula is valid under far field conditions which are established in section 0.

ANNEX A

REGIONAL REQUIREMENTS

Frequency Range (MHz)	Power Density (mW/cm^2)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)
0 - 0.3	-	-	-
0.3 - 3	100	614	1.63
3 - 30	900/f^2	1842/f	4.89/f
30 - 300	1	61.4	0.163
300 - 1500	f/300	-	-
1500 - 100000	5	-	-

Table A.1 – CFR 47 Pt1.1310 (2017) Worker/Occupational Limits

Frequency Range (MHz)	Power Density (mW/cm^2)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)
0 - 0.3	-	-	-
0.3 - 3	100	614	1.63
3 - 30	180/f^2	824/f	2.19/f
30 - 300	0.2	27.5	0.073
300 - 1500	f/1500	-	-
1500 - 100000	1	-	-

Table A.2 – CFR 47 Pt1.1310 (2017) General Public Limits

Frequency Range (MHz)	Power Density (W/m^2)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)
10 - 20	10	61.4	0.163
20 - 48	44.72/f^0.5	129.8/f^0.25	0.3444/f^0.25
48 - 100	6.455	49.33	0.1309
100 - 6000	0.6455*f^0.5	15.60*f^0.25	0.04138*f^0.25
6000 - 150000	50	137	0.364

Table A.3 – Health Canada Safety Code 6 Worker/Occupational Limits

Frequency Range (MHz)	Power Density (W/m^2)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)
10 - 20	2	27.46	0.0728
20 - 48	8.944/f^0.5	58.07/f^0.25	0.1540/f^0.25
48 - 300	1.291	22.06	0.05852
300 - 6000	0.02619*f^0.6834	3.142*f^0.3417	0.008335*f^0.3417
6000 - 15000	10	61.4	0.163

Table A.4 – Health Canada Safety Code 6 General Public Limits