Spectrum Engineering Services

WPT Bus Charging System Final Report

Measurements at Canning Town Bus Station

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# Report Number: SES (17)001RD	
WPT Bus Charging System at Canning Town Bus Station	
Assistance requested	2 May 2017
Tests carried out	2 November 2017
Final Report	

 # SES (17)001RD is to be read alongside SES (16)012 which described similar measurements of WPT busses in the alternative location of Milton Keynes (Bletchley Bus station)

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Section Page

1 Introduction

This is a trial of Wireless Power Transfer (WPT) enabled busses by Transport for London (TfL).

The system is operated by the number 69 bus service being used between Walthamstow bus station and Canning Town bus station. The electric buses (3 in total) are charged from a standard cabled supply each night when in the bus depot. During their normal daily service they park for between approximately 20 minutes at each end of the route. During this time they lower a vehicle, including its mounted induction loop plate, over an induction pad set in the road.

Figure 1: Bus Bay at Canning Town with the bus lowered over the induction pad.

The selected bus is an Alexander Dennis, Enviro 400 MMC. The bus can recharge the on-board batteries from 20% charge to 90% in twenty minutes. Recharging in this manner allows the busses to remain operational throughout the day before returning to the depot in the evening. The charging system was developed by IPT Technology GmbH.

1.1 Company

Transport for London https://tfl.gov.uk/

197 Blackfriars Road, Southwark, London, SE1 8NJ

IPT Technology GmbH www.ipt-technology.com

Im Martelacker 14 | 79588 Efringen-Kirchen | Germany |

1.2 Equipment Under Test (EUT)

The frequency of operation is 20 kHz and the charging is done at the rate of 100 kW using two 50 kW plates (set in the road surface).

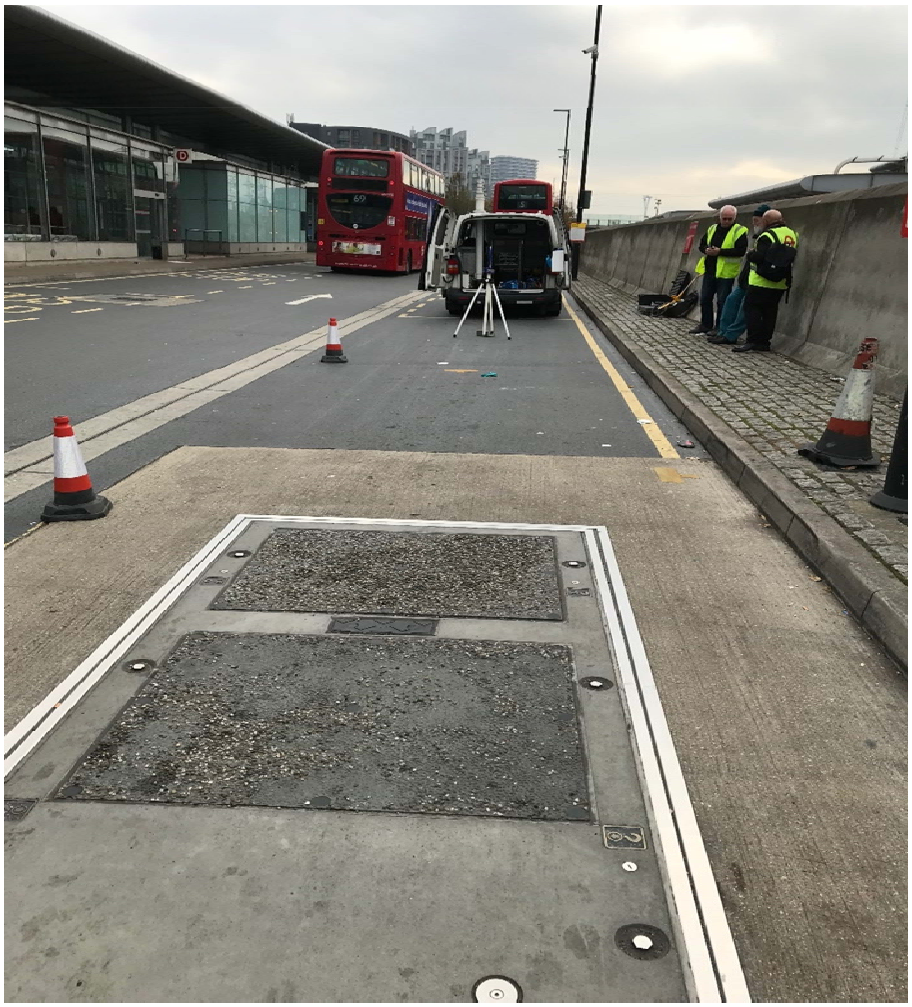


Figure 2: Loop antenna 10 m from centre of pads

1.3 Classification

The UK Interface Requirements 2030 (Licence Exempt Short Range Devices); Interface number IR2030/15/1 identifies inductive applications in the band 9 – 90 kHz. The transmit power/power density limit is quoted as 72 dBμA/m measured at 10 metres. (there is a notch down to 48 dBuA/m in the band 59.75 kHz to 60.25 kHz to protect the standard National Frequency Time signal). Above 90 kHz, the power limit drops away at 3 dB/octave (albeit with notches to protect other sensitive radio services).

This is referenced from the European Standard EN 303 417 v1.1.1 dated September 2017.

The standard also covers the following parameters:

Table 1: H-field limits

Frequency range [MHz]	H-field strength limit [dBµA/m at 10 m]	Comments
0,019 ≤ f < 0,021	72	
0,059 ≤ f < 0,061	69,1 descending 10 dB/dec above 0,059 MHz	See note 1
0,079 ≤ f < 0,090	67,8 descending 10 dB/dec above 0,079 MHz	See note 2
0,100 ≤ f < 0,119	42	
0,119 ≤ f < 0,135	66 descending 10 dB/dec above 0,119 MHz	See note 1
0,135 ≤ f < 0,140	42	
0,140 ≤ f < 0,1485	37,7	
0,1485 ≤ f < 0,30	-5	
6,765 ≤ f < 6,795	42	
NOTE 1: Limit is 42 dBµA/m for the following spot frequencies: 60 kHz ± 250 Hz and 129,1 kHz ± 500 Hz. NOTE 2: At the time of preparation of the present document the feasibility of increased limits for high power wireless power transmission systems to charge vehicles [i.4] was prepared. New specific requirements for such systems (e.g. higher H-field emission limits in the 79 - 90 kHz band) will be reflected within a future revision of the present document.		

The measurement method is however referenced within EN 303 417 to the generic SRD standard EN 300 330. EN 300 330 v2.1.1 in Section 5.12 sets the parameters for the measuring receiver and spectrum analyser as,

Table 2: Receiver Settings

Frequency: (f)	Detector type	Measurement receiver bandwidth	Spectrum analyser bandwidth
9 kHz ≤ f < 150 kHz	Quasi Peak	200 Hz	300 Hz
150 kHz ≤ f < 30 MHz	Quasi Peak	9 kHz	10 KHz
30 MHz ≤ f ≤ 1 000 MHz	Quasi Peak	120 kHz	100 kHz
NOTE: For the measurement of the ranges 6,765 MHz ≤ f ≤ 6,795 MHz and 11,810 MHz ≤ f ≤ 15,310 MHz, the measurement bandwidth has to be 200 Hz respectively 300 Hz.			

Published in the Official Journal of the European Union an amendment to Decision 2006/771/EC on harmonisation of the radio spectrum for use by SRDs identifies the same band and quotes the same limits for use by inductive devices.

Reference to the Standard EN 303 417 v1.1.1 in this report does not infer compliance with the whole of that standard but the magnetic field strength limit (H_f) measured at 10 metres - has been used as a guide to the results published herein.

Since the measurements were completed in-situ using a peak detector the results must be treated as an indicative measurement of the H-field (H_f) radiated disturbance produced by the Wireless Power Transfer (WPT) installation.

2 Method

2.1 Antenna polarisation and orientation

Measurements were completed with the shielded loop antenna mounted on tripod 1 metre above ground level. A loop antenna has directional properties. Figure 3 shows the loop orientated for maximum pick-up from the induction pads set in the road surface of the WPT bus Bay.

Figure 3: Loop orientation for maximum received signal from the induction pads.

The *figure of eight* polar pattern produced by a loop antenna means that the response should change with its orientation to the signal source. Measurements were completed with two antenna orientations, the Maximum (Max) as shown in Figure 4 and at 90^0 to this, the (Null). The results do reflect the change in amplitude with respect to the orientation.

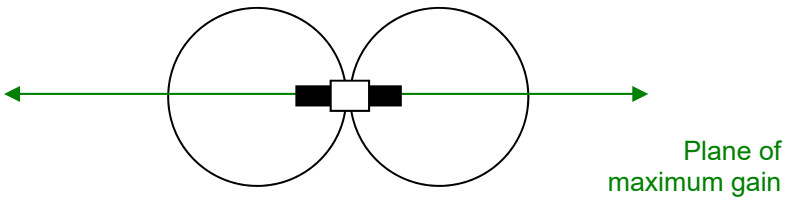


Figure 4: Polar diagram of loop antenna showing the plane of maximum gain.

2.2 Measurement Site

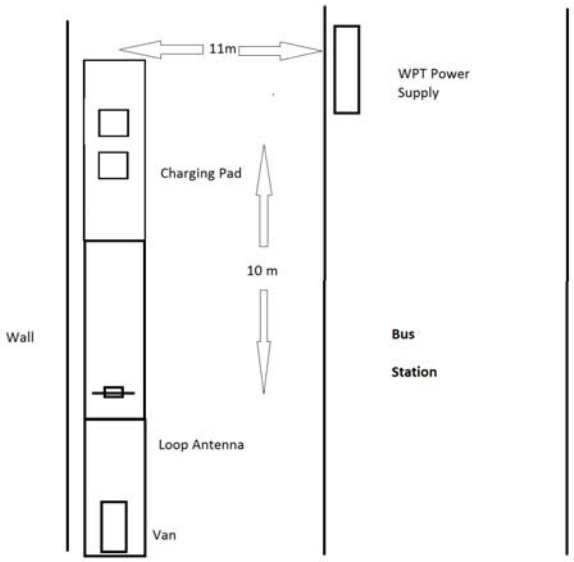


Figure 4: Bus station plan showing position of mobile laboratory and antenna locations.

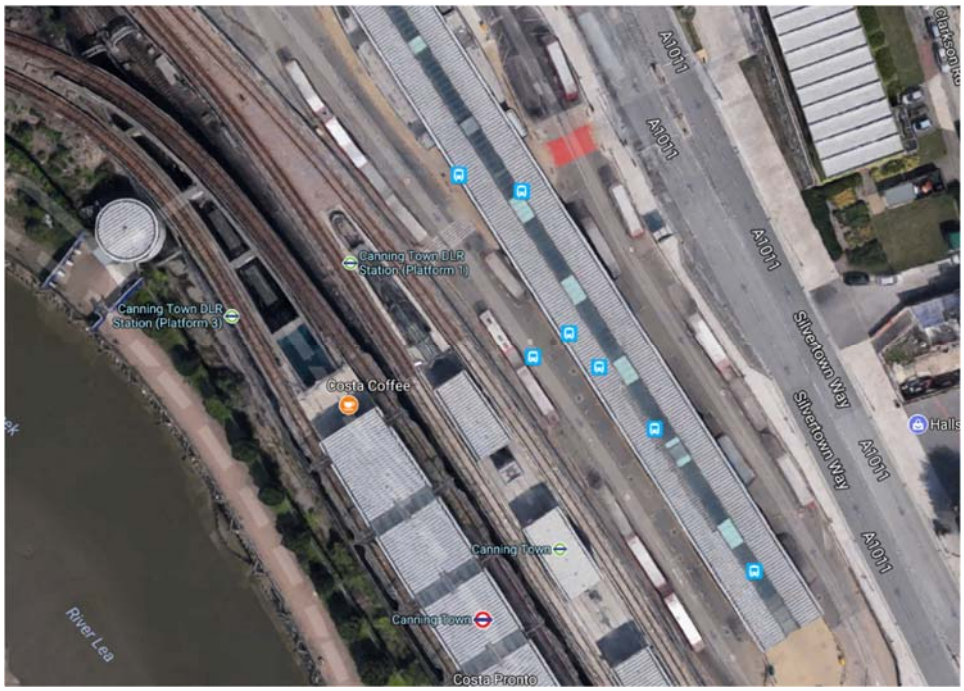


Figure 5: Canning Town bus Station aerial view

Measurements were completed at the Canning Street Bus Station around midday on a week day, outside of the busy commuting times and the deployment of the antenna and cables did not restrict passenger and pedestrian movements.

Figure 4 identifies the measurement position used within the Bus Station. The measurements were carried out with the tripod mounted loop set 10 metres from the centre of the induction

pads Figure 2) but without obstructing the free access to the bus passenger doors or pedestrian movements within the bus station.

The bus is aligned using an optical system. The bus driver has a small screen in the cab (Figure 7), linked to a camera affixed to the outside of the bus. The driver needs to align cross-hairs on the screen to a yellow painted mark on the road (Figure 6). The driver reported that he has approximately 20mm of tolerance otherwise the charging system will not function.

Figure 6: Alignment mark for bus camera system

Figure 7: Alignment Camera screen in bus

2.3 Measurement method

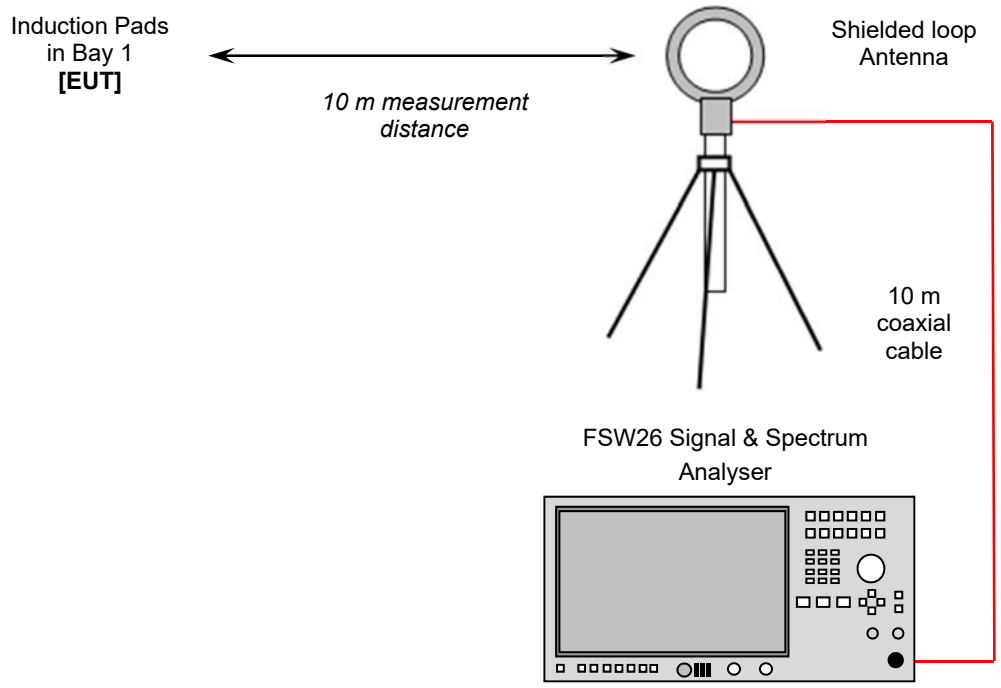


Figure 8: Equipment configuration.

The FSW analyser was used in the measurements and the results are recorded in this report as an accurate representation of the signal levels associated with the Wireless Power Transfer (WPT) system. The characteristics of the adapter are included in the Annex and a correction factor at 20 kHz added to the calculations in the results Table 1.

Eight background measurements were completed for each setting of the four settings of the FSW analyser, in both the Max and Null positions of the loop antenna. These corresponded to the eight measurements taken when the bus was present and being charged.

3 Results

The results detailed in this section apply only to the tests made at that time, using the test equipment detailed. They do not indicate that on another date an identical set of results may be achieved, due to changes in local environmental conditions or other factors which may or may not have an effect on the measurement results obtained at that future time.

Measurement Results – Loop antenna at 10m								
Harmonic	Frequency span 0 – 200 kHz				Frequency span 0 – 30 MHz			
	RBW 200 Hz		RBW 10 kHz		RBW 200 Hz		RBW 10 kHz	
	MAX	NUL	MAX	NUL	MAX	NUL	MAX	NUL
20	24.09	75.40	66.37	75.80	66.14	76.15	63.46	74.72
40	22.83	21.74	42.10	43.04	30.45	21.32	42.81	37.44
60	6.93	24.87	42.72	28.59	38.01	23.12	39.31	29.05
80	0.41	4.56	32.11	22.36	16.14	14.54	23.36	22.56
198	23.27	36.52	28.60	37.82	25.89	35.68	24.83	37.77

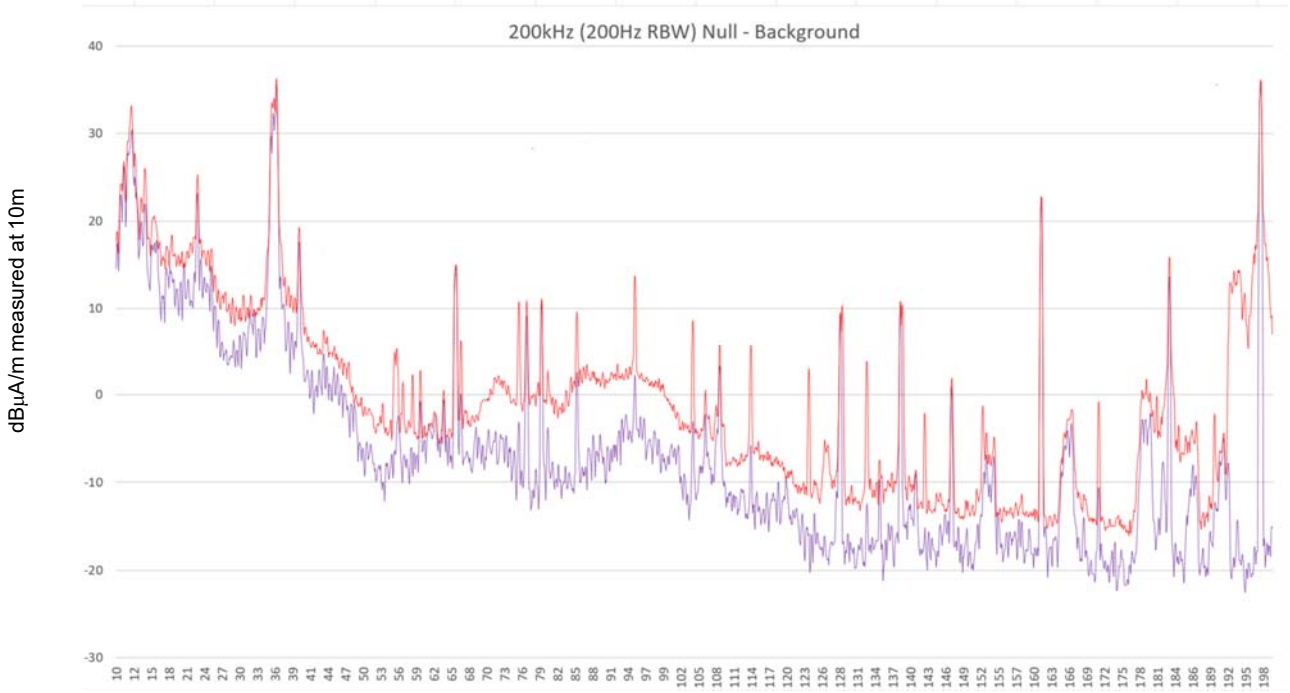
Table 3: Table of Results

The Plots have been produced from the captured c.s.v. files referred to in the previous section. Both the 'max hold (red or orange) and Clr/Write (purple or blue) traces are shown in the following sections. On each page below in Section 3.1, we show both the "Background" plot where no charging is occurring, and the corresponding measurement in the same configuration, where the "WPT charging" is occurring.

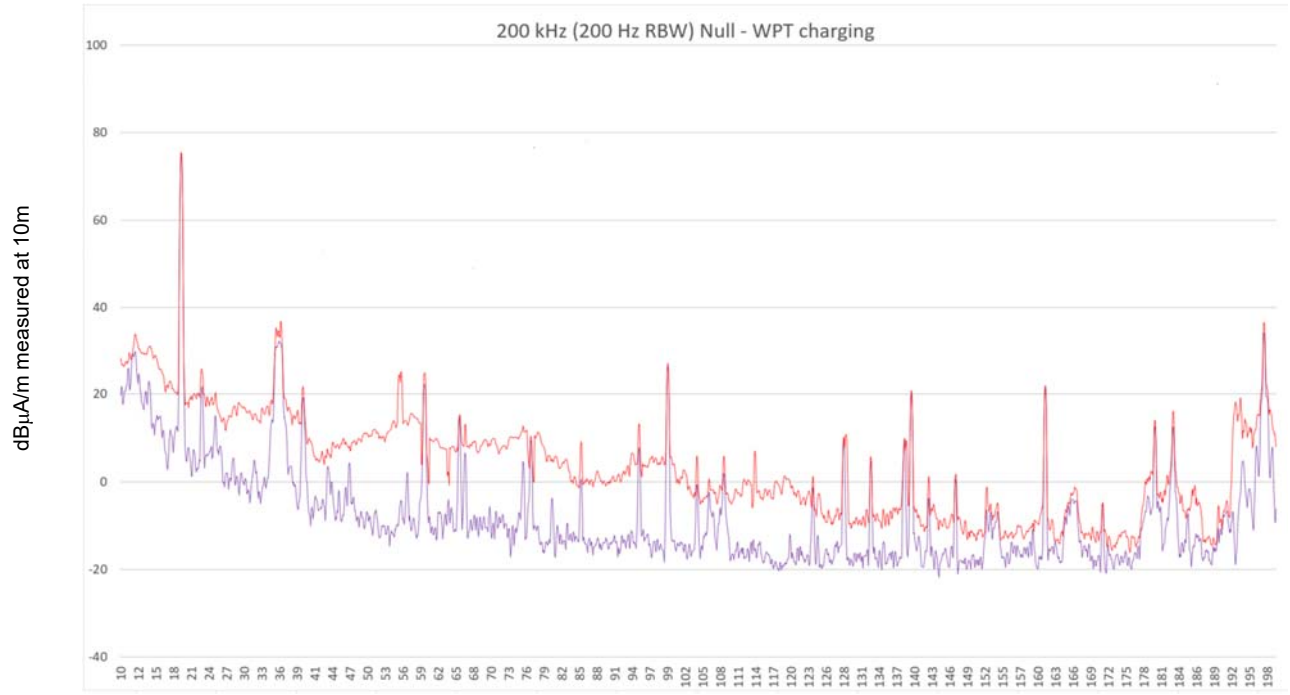
Independently, the chairman of the European standards body for audio apparatus (ETSI TG17) accompanied the team during these measurements. Any measurements taken by the TG17 chairman are completely independent of this report.

3.1 10-200 kHz (RBW = 200 Hz)

Measuring Loop in Null Position

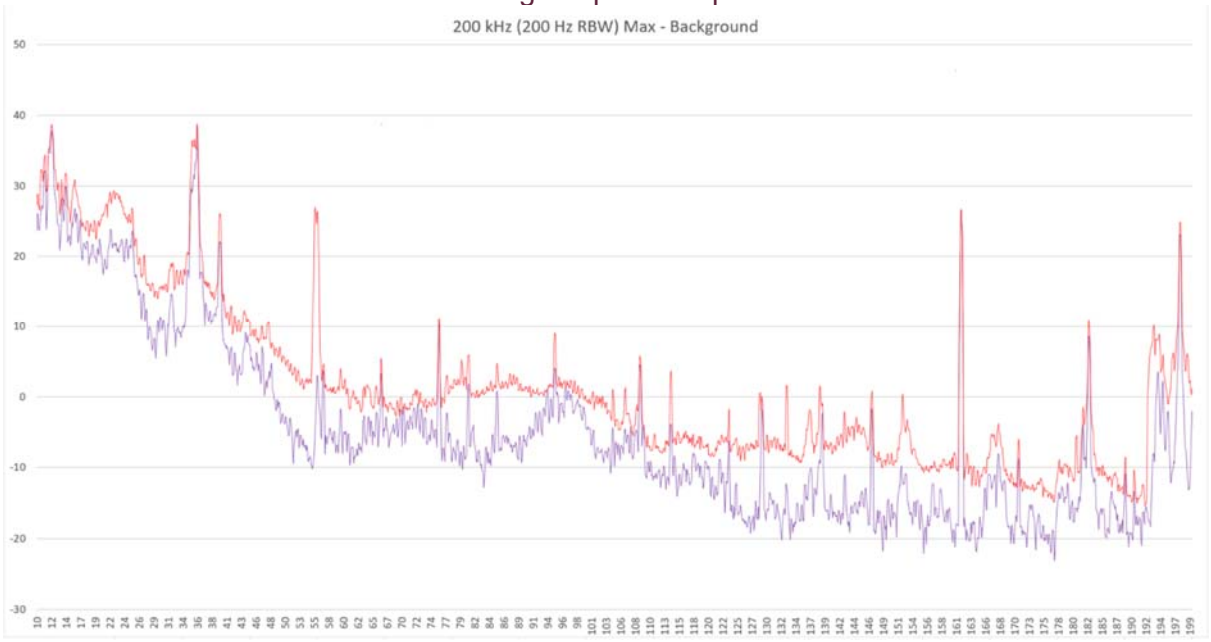


Plot 1

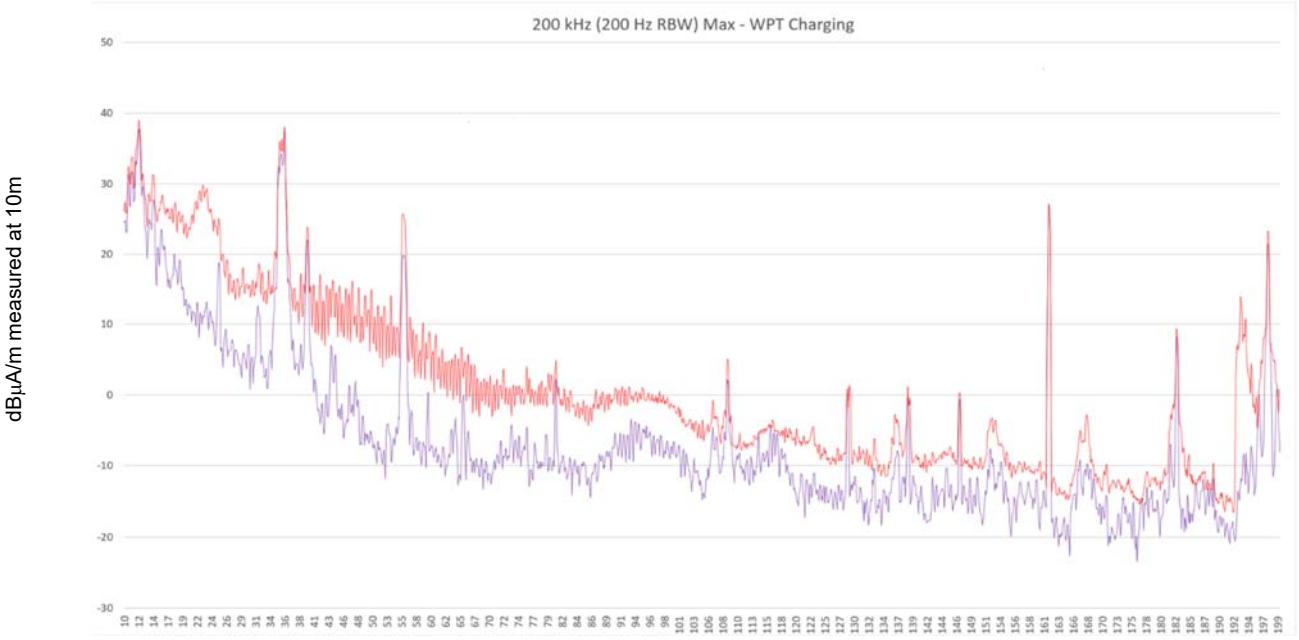


Plot 2

Measuring Loop in Max position



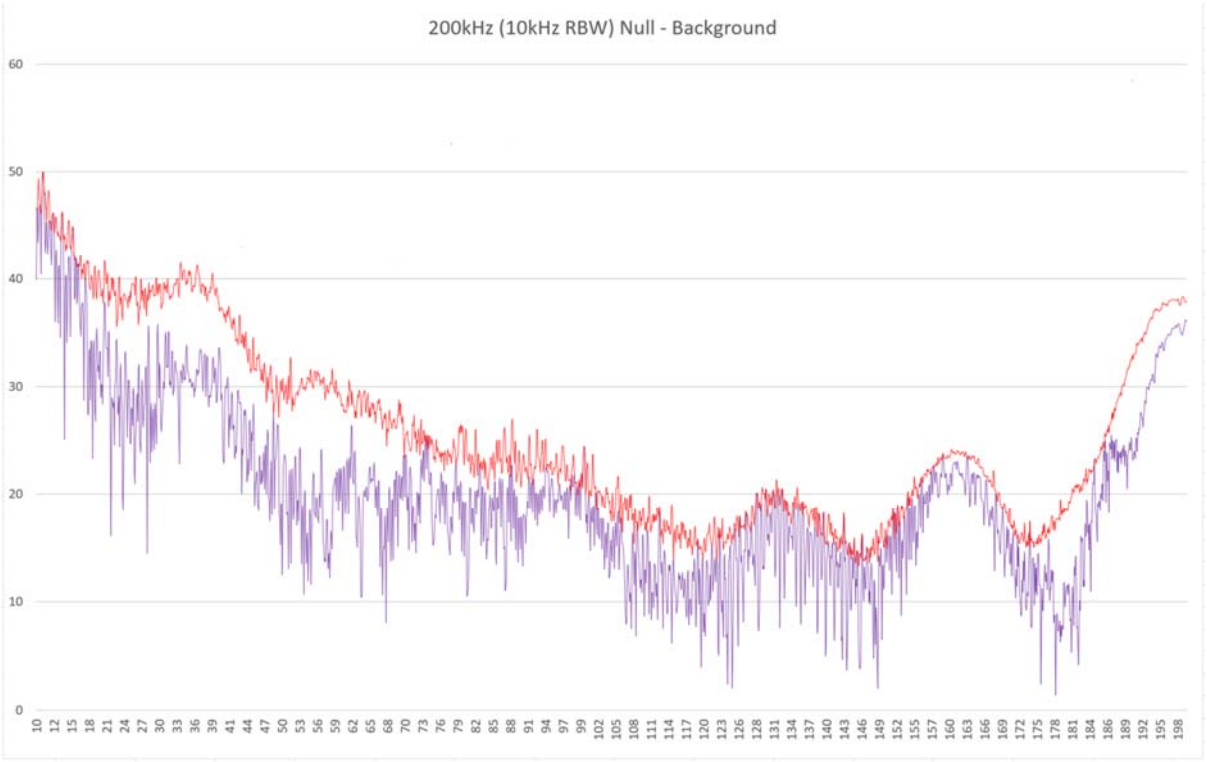
Plot 3



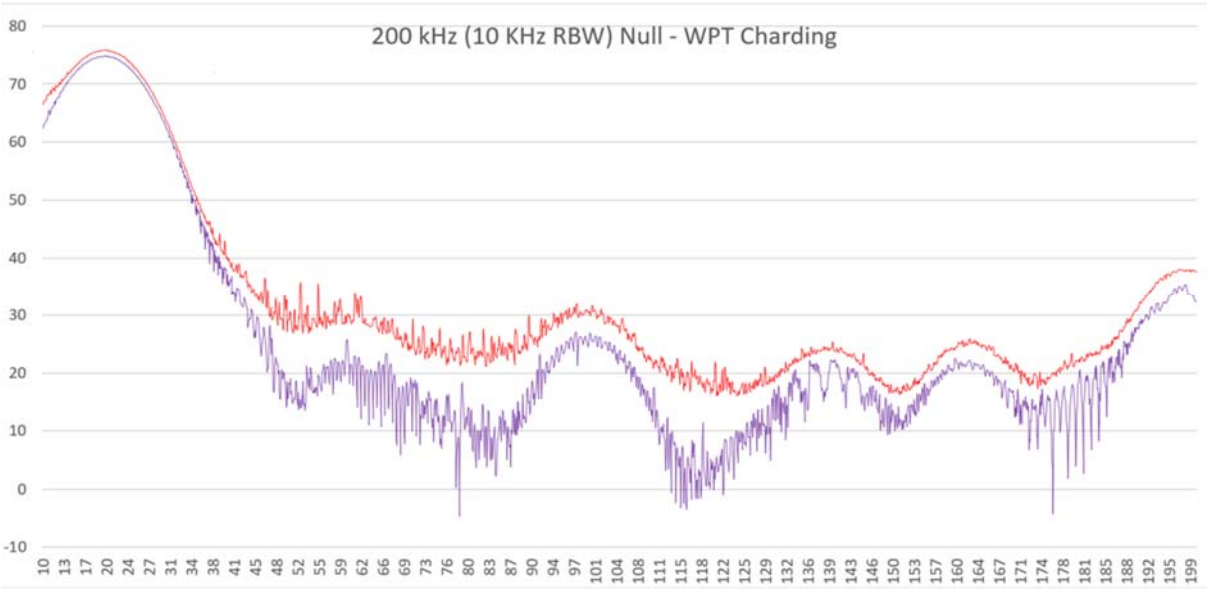
Plot 4

3.2 10-200 kHz (RBW = 10 kHz)

Measuring Loop in Null Position

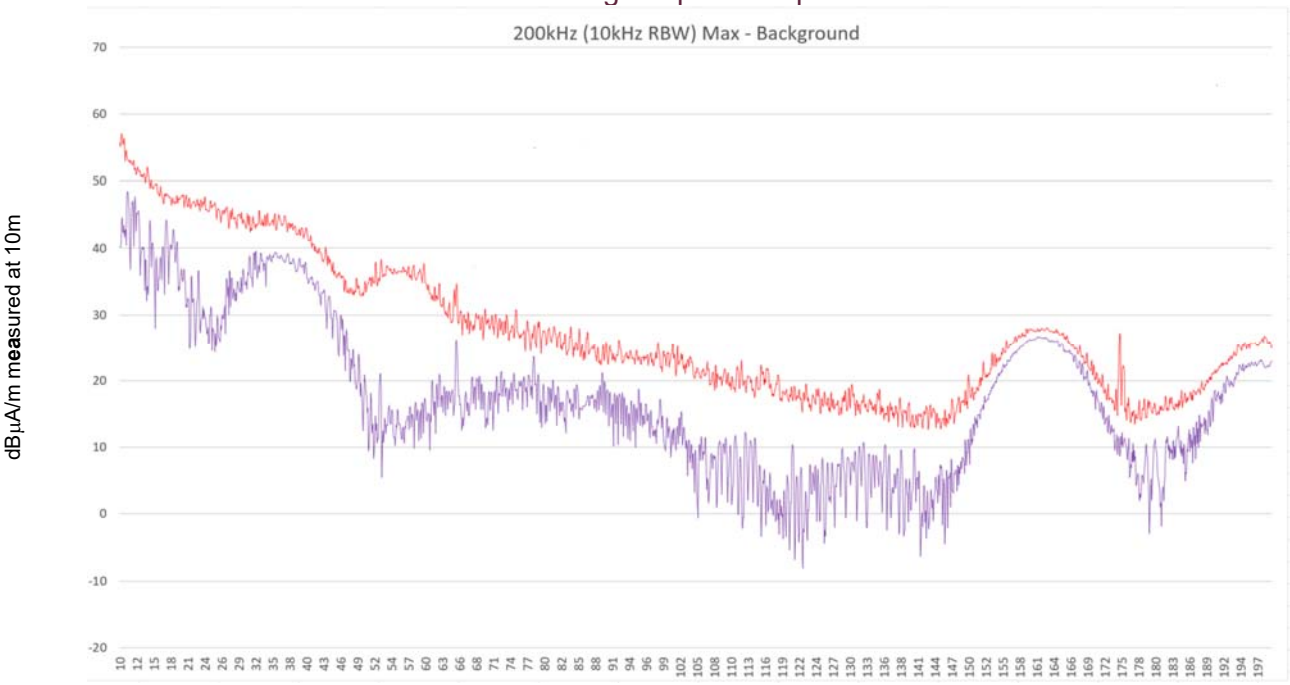


Plot 5

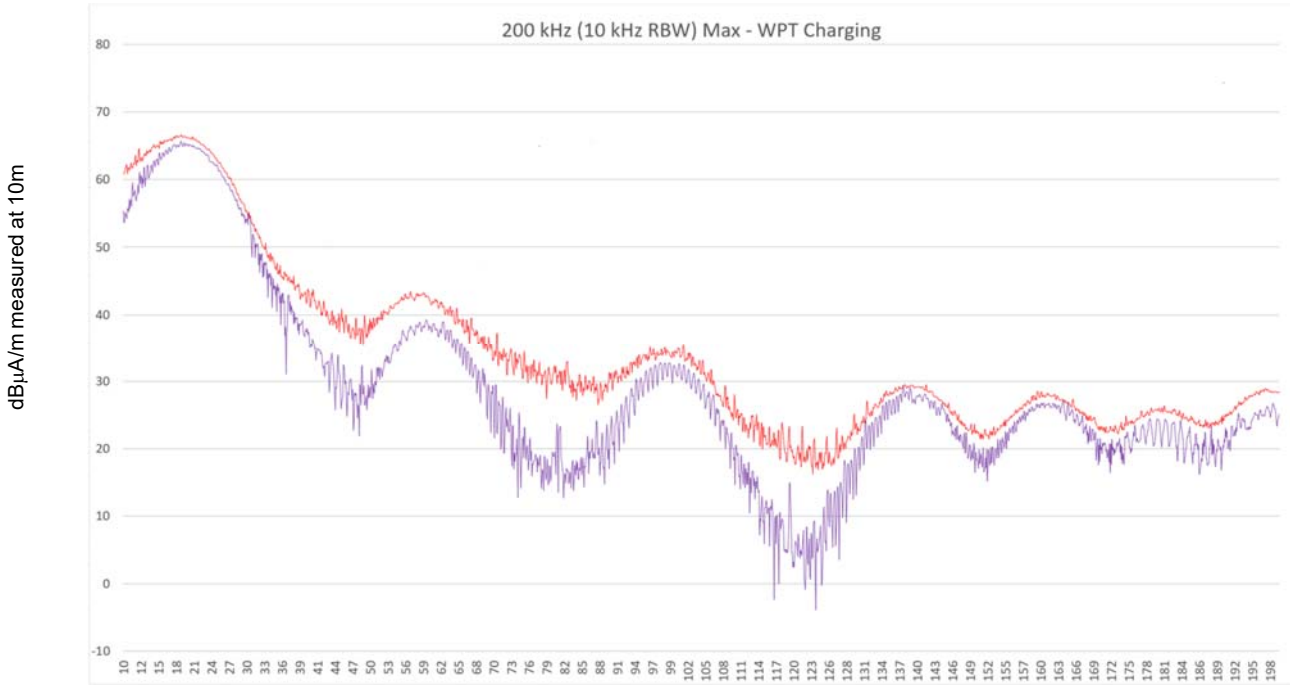


Plot 6

Measuring Loop in Max position



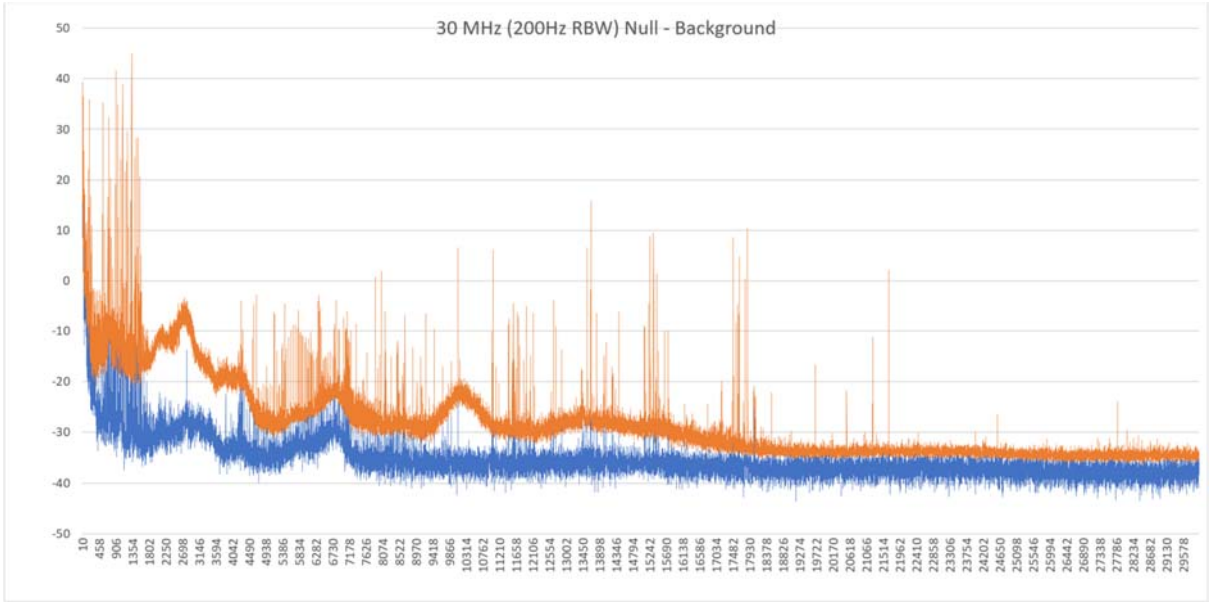
Plot 7



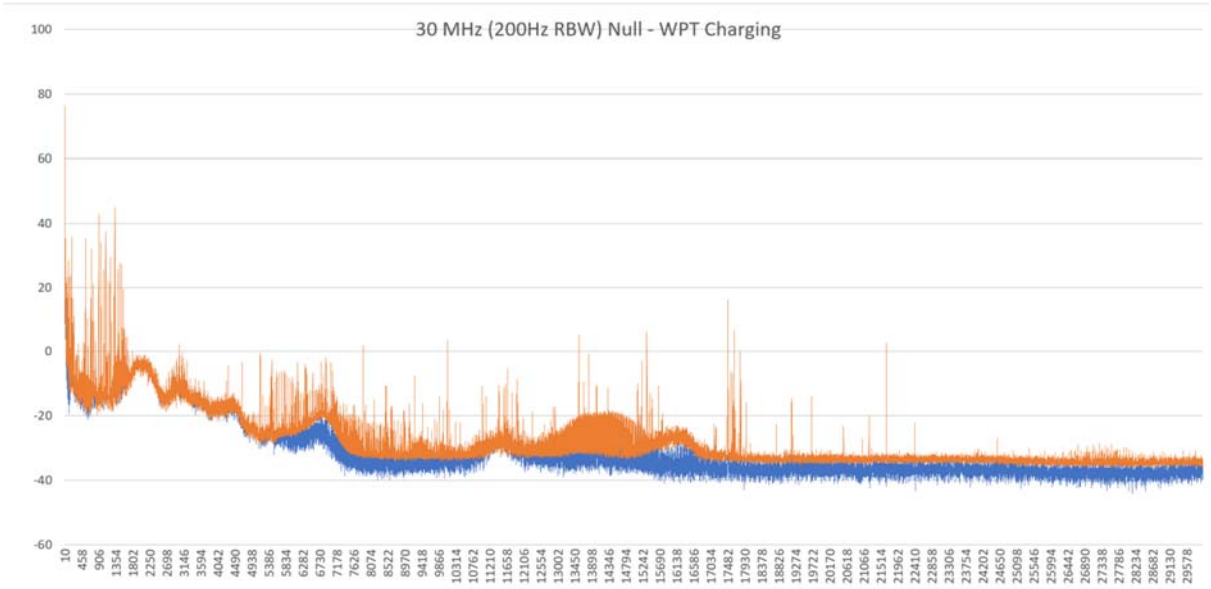
Plot 8

3.3 10kHz-30 MHz (RBW = 200 Hz)

Measuring Loop in Null Position

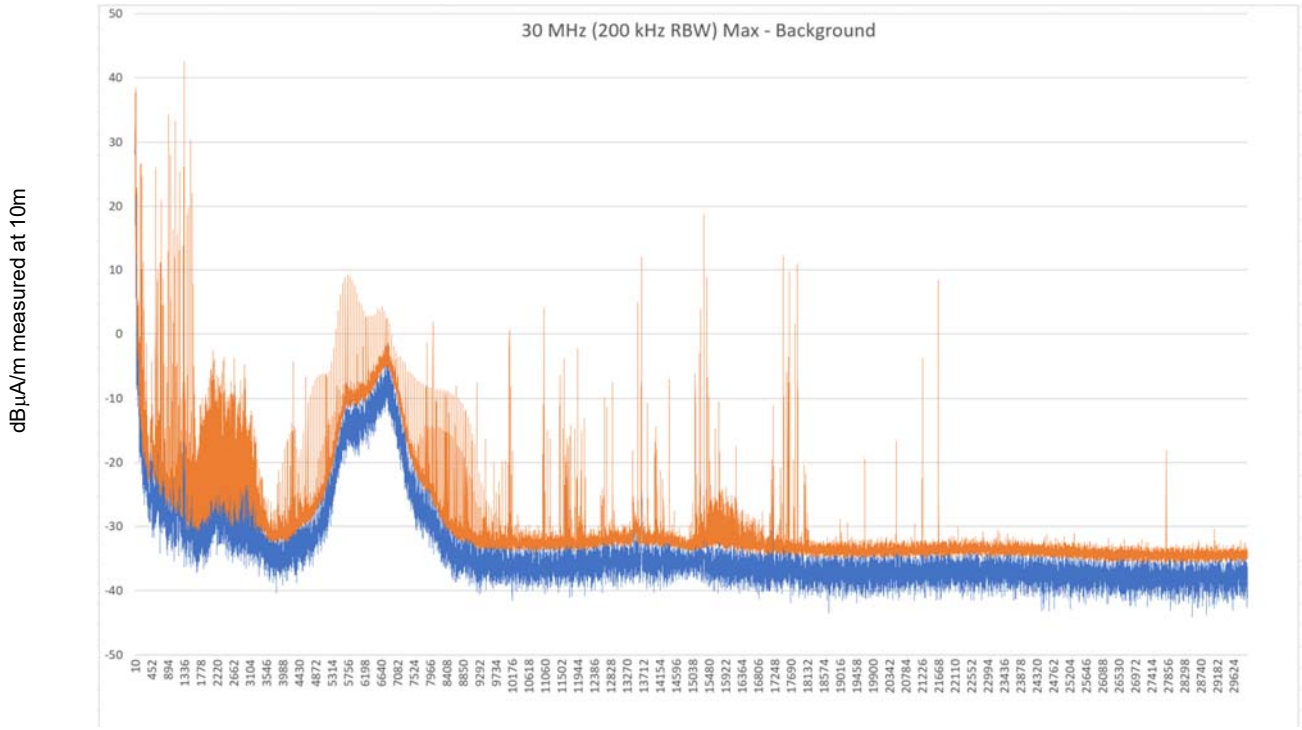


Plot 9

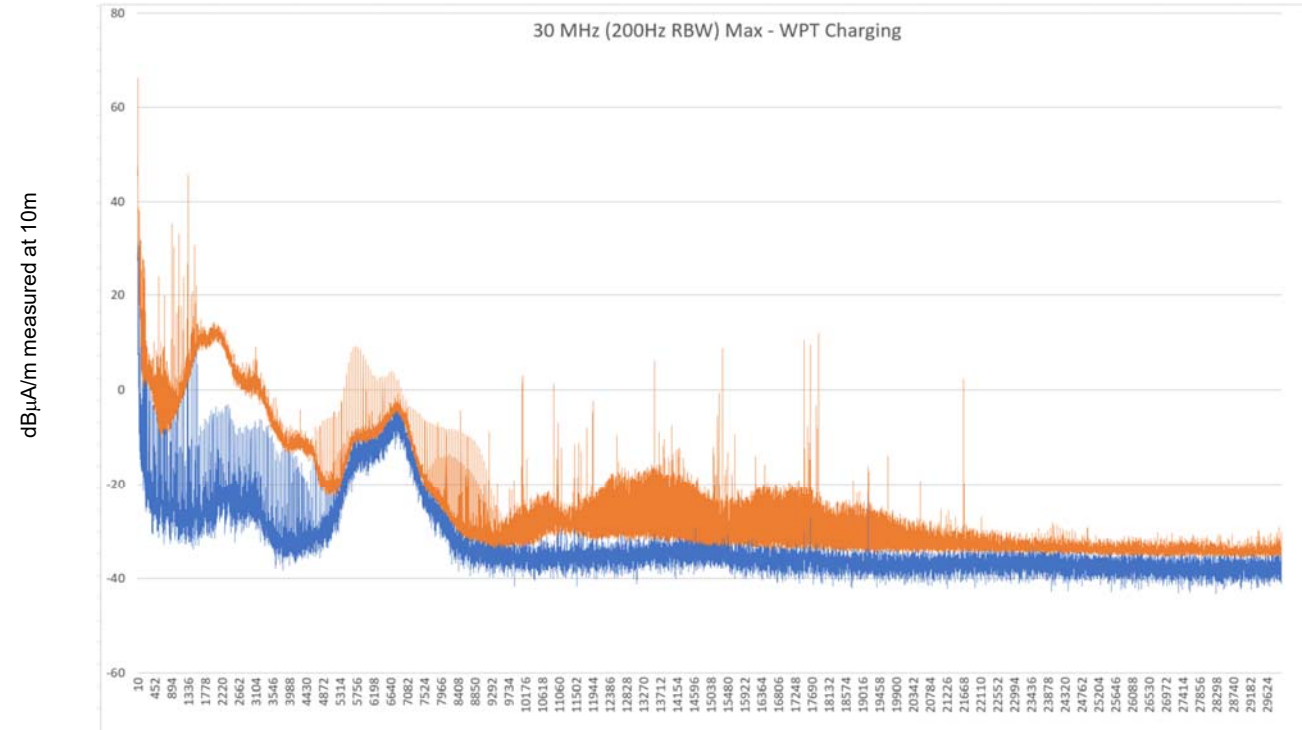


Plot 10

Measuring Loop in Max position



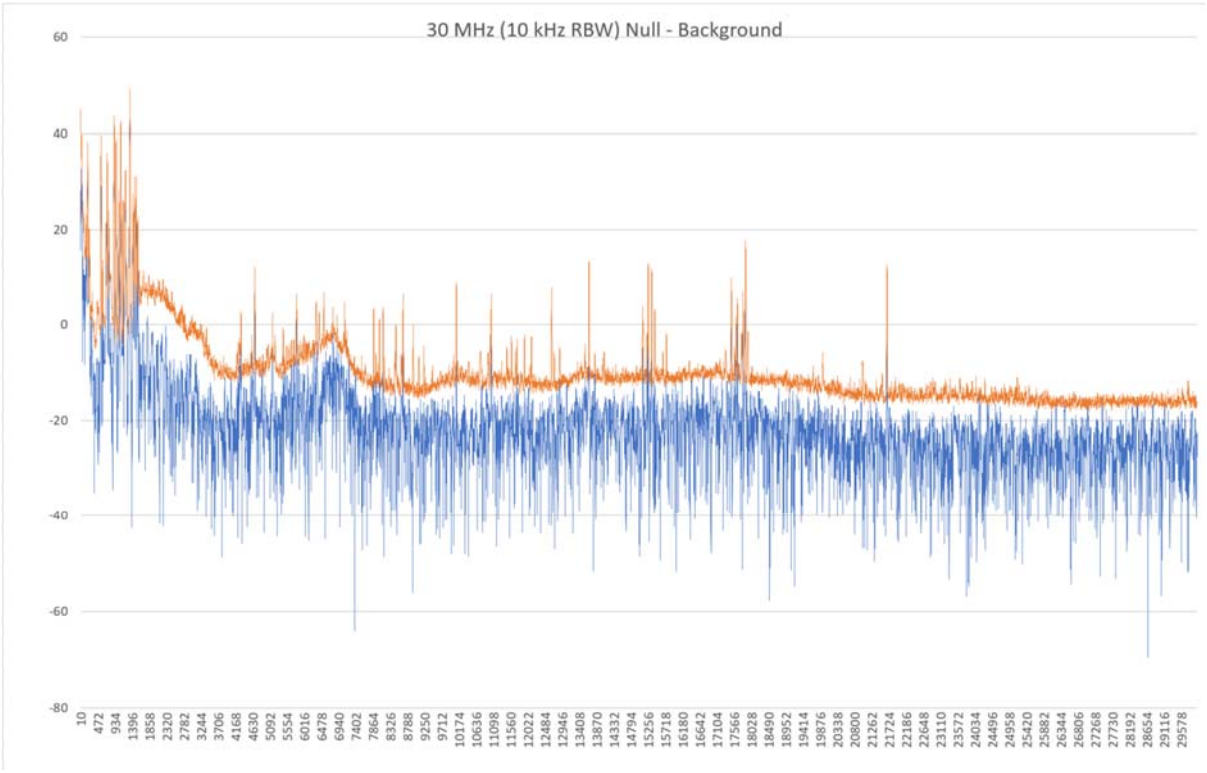
Plot 11



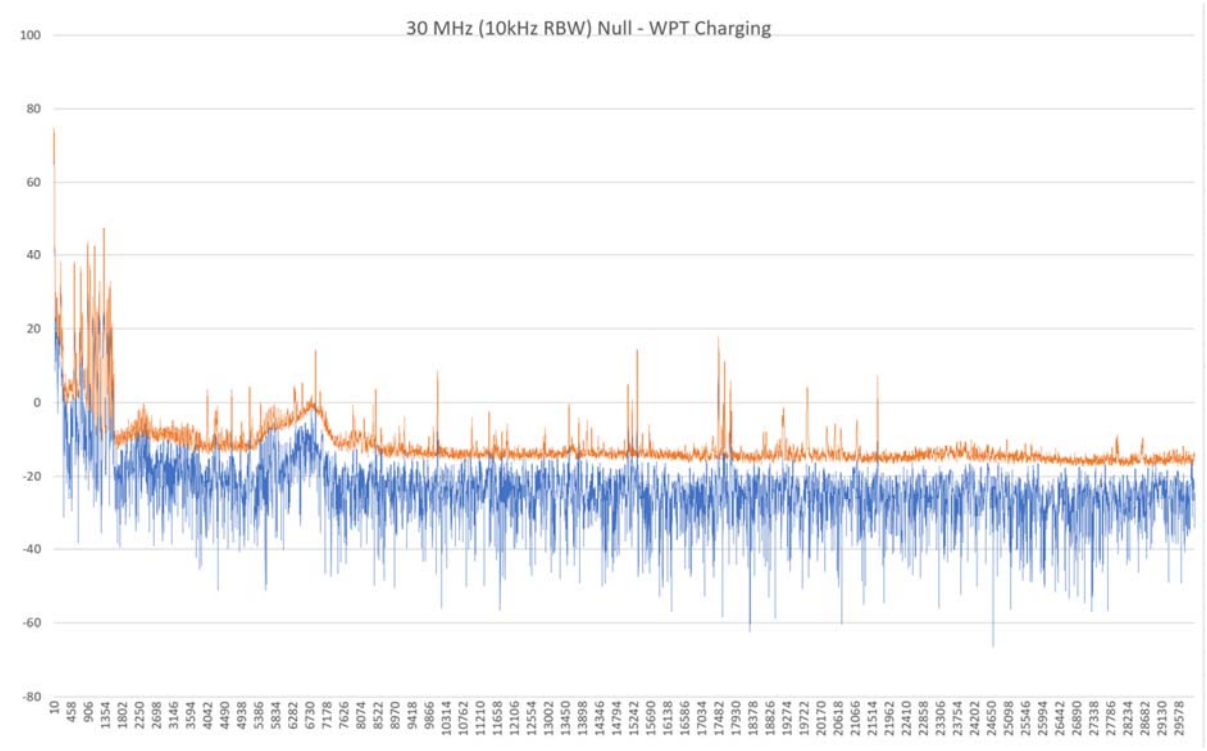
Plot 12

3.4 130 MHz (RBW = 10 kHz)

Measuring Loop in Null Position

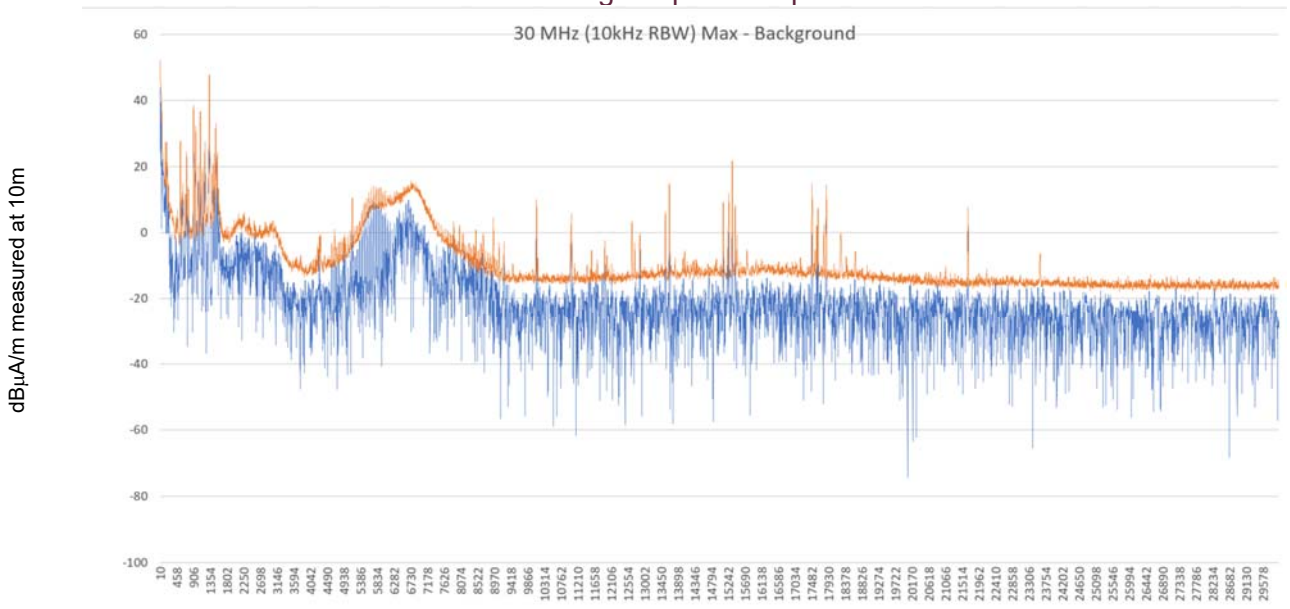


Plot 13

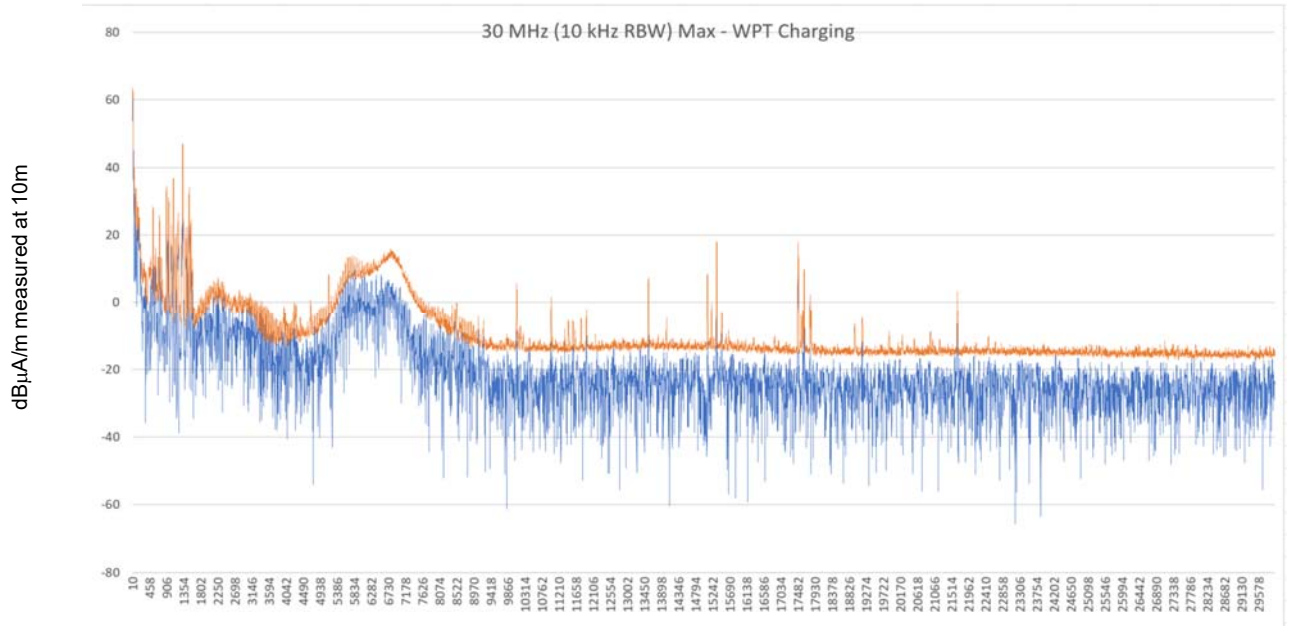


Plot 14

Measuring Loop in Max position



Plot 15



Plot 16

Note:- in this single final measurement (Plot 16 - 30 MHz span, RBW 10 kHz, in the max orientation) there is little difference between the Background and the Charging plots. The measurement team were told by the bus driver that the charging had automatically ceased at this point, as the bus had achieved full charge. As such, this final result is likely to be unrepresentative.

4 Conclusions

The results detailed in this section apply only to the tests made at that time, using the test equipment detailed. They do not indicate that on another date an identical set of results may be achieved, due to changes in local environmental conditions or other factors which may or may not have an effect on the measurement results obtained at that future time.

In all cases the harmonics measured are much lower than the limits set out in EN 303 417 v1.1.1 dated September 2017. However, the fundamental 20 kHz signal is seen at or about the H-field strength limit of 72 dBµA/m measured at 10 m.

It is of particular interest that the largest signals were seen when the loop antenna was oriented in the Null direction to the charging plates. In this null direction, the loop was aligned in the direction of both the Docklands Light Railway (DLR) and London Underground Jubilee line. Figure 5 indicates the proximity of these two rail systems to the bus station. Further, the WPT Power Supply Unit (PSU) was diagonal (11m East by 10 m North). IPT Technology have also indicated that there is a PLT connection to the PSU.

It is not possible to conclude why the Null orientation measurements gave such a result, but it could be due to a number of factors including, the WPT's PSU EMC emissions, the PLT connection to the PSU or unrelated EMC emissions from the two railway systems that are in close proximity to the bus station.

However, in the orientation of maximum gain to the charging plates, the measured emissions remain within the limits set out in EN 303 417 v1.1.1 in all conditions.

5 Measurement Equipment

Equipment	Model	Serial No.	Cal due	Certificate No.
Signal Analyser	R&S FSW	101574	01/02/17	1400-54075
30cm loop Antenna	HLA6120	1172	16/05/17	2016050007-1
I/P signal isolator	ADB-18NMF-1	987517	-	-
10m cable	Chase	-	-	-

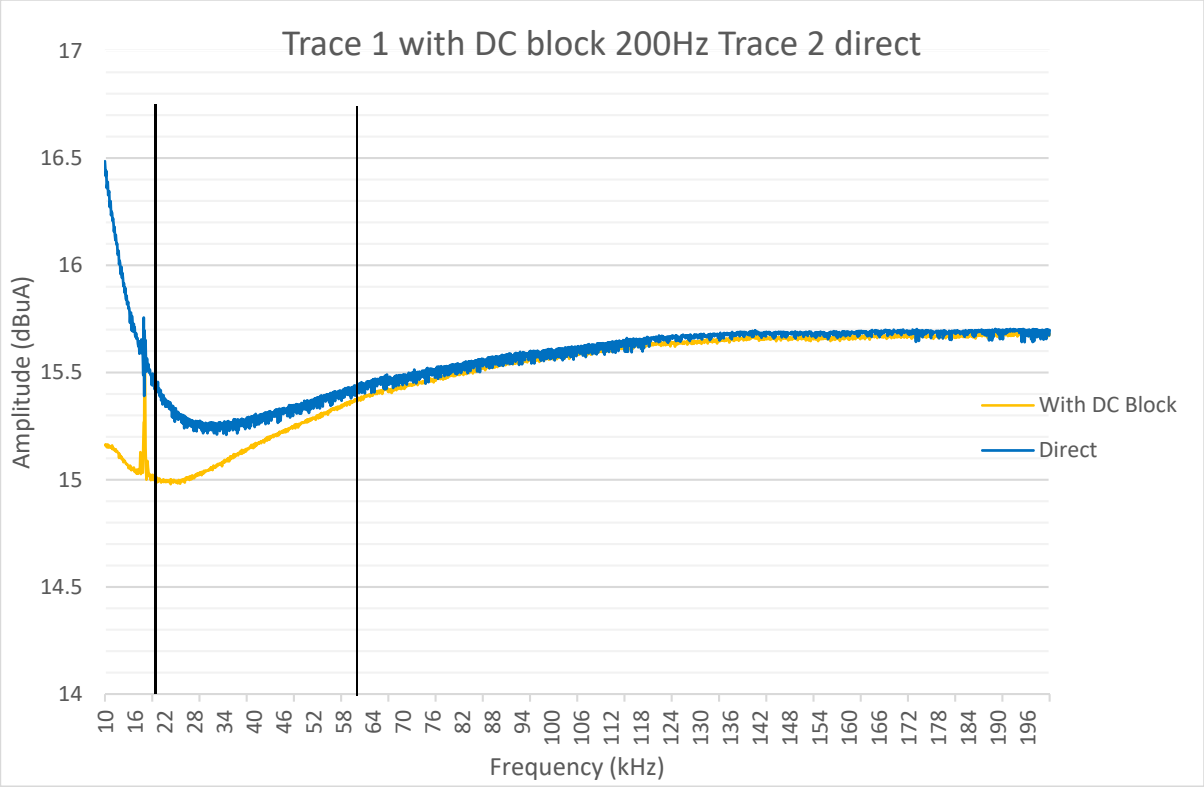
Table 4: Equipment details (including calibration status)

6 Glossary

a.g.l.	above ground level
ANFP	Access Network Frequency Plan
BW	Bandwidth
CEPT	European Conference of Postal and Telecommunications Administrations
CISPR	International Special Committee on Radio Interference (*English*)
EMC *or* emc	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ETSI	European Telecommunications Standards Institute
EUT	Equipment Under Test
FS	Field Strength measured in dBμV/m
NGA	Next Generation Access
Ofcom	Office of Communications
RBW	Resolution Bandwidth
RF	Radio Frequency
VDSL	Very high bit rate DSL
WCS	Wireless Charging System
λ	Wavelength
kHz	kilohertz
MHz	Megahertz
GHz	Gigahertz
μV	microvolt
mV	millivolt
mV/m	millivolts per metre
dB	decibel
dBμV/m	decibels above 1 microvolt per metre (see FS above)
dBm	decibels relative to 1 milliwatt
dBW	decibels relative to 1 Watt
m	metres
cm	centimetre
C	Centigrade
F	Fahrenheit
s	seconds

Table 5

7 Annex



Plot 17: Characterisation of ADB-18NMF-1 input isolator

Correction at 20 kHz = 0.42 dB
Correction at 60 kHz ~ 0 dB

Convert dBuA to dBµV:

dBµV = dBuA + 20 log (Z) *Where Z = 50Ω*

dBµV = dBuA + 20 log (50)

dBµV = dBuA + 33.98 dBµV

Convert dBµV to dBuA/m (H):

H = dBµV + *K (dB(s/m)) dBuA/m

*Where: *K = Magnetic Antenna Factor (MAF) from NPL calibration document*

End of Report