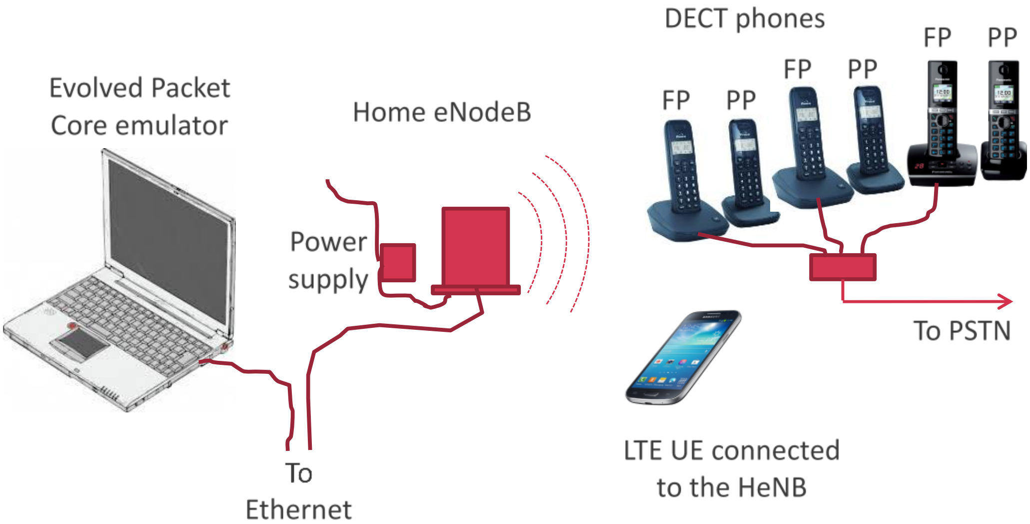
LTE Femtocell to DECT Coexistence Measurements

Real Wireless report for TalkTalk



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About Real Wireless

Real Wireless is a leading independent wireless consultancy, based in the U.K. and working internationally for enterprises, vendors, operators and regulators – indeed any organization which is serious about getting the best from wireless to the benefit of their business.

We seek to demystify wireless and help our customers get the best from it, by understanding their business needs and using our deep knowledge of wireless to create an effective wireless strategy, implementation plan and management process.

We are experts in radio propagation, international spectrum regulation, wireless infrastructures, and much more besides. We have experience working at senior levels in vendors, operators, regulators and academia.

We have specific experience in LTE, UMTS, HSPA, Wi-Fi, WiMAX, DAB, DTT, GSM, TETRA – and many more.

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Executive summary

TalkTalk commissioned Real Wireless to conduct technical studies – based on both measurement and modelling – to support a request for a variation of their 1800 MHz licence to allow standard 3GPP-compliant LTE small cells to be used within the frequency band 1781.7-1785 MHz paired with 1876.7-1880 MHz.

This report provides details of the measurement campaign to test the potential interference into adjacent Digital Enhanced Codeless Telecommunications (DECT) systems. The objective of these tests is to ensure that a fully operational Long Term Evolution (LTE) Home eNodeB does not cause significant interference to existing DECT users beyond any experienced with the existing licence limits and a Global System for Mobile communication (GSM) picocell.

We conducted the following test scenarios using LTE and GSM small cells:

1. Small cell spectrum emission tests (conducted with Arcadyan and Huawei LTE femtocells and an ip.access GSM picocell)
2. Interference from small cells to a dense network of DECT cordless telephones via voice quality, dropped call rate and call hold times comparisons (with the Arcadyan femtocell and ip.access picocell)
3. Interference from small cells to a DECT-based baby monitor (with the Arcadyan femtocell and ip.access picocell)

Our observations are as follows:

- The spectrum emission measurements show that:
  - the spectrum emissions from the tested eNodeBs from Arcadyan and Huawei meets the proposed licensing conditions but not fully comply with the existing licensing conditions.
- Interference from an Arcadyan LTE Home eNodeB (femtocell) does not:
  - cause voice quality deterioration of the DECT cordless phone system, below that experienced with the GSM picocell.
  - cause dropped calls in the DECT system, beyond those experienced with the GSM picocell.
  - make the performance of the baby monitor any worse than the GSM picocell

These findings support the case for a licence variation, which would allow the use of standard 3GPP-compliant devices without causing harmful interference to adjacent systems.

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1. Introduction

Real Wireless has been commissioned by TalkTalk to measure the spectrum characteristics of a LTE Home eNodeB operating in the DECT Guard bands[1] and the potential interference effects into DECT. This technical report explains the approach and the measurement results of the laboratory tests conducted by Real Wireless in the anechoic chamber laboratory at University of Surrey.

1.1 Purpose of the test

In November 2005, Ofcom recommended [1] that the frequency bands 1781.7-1785 MHz paired with 1876.7-1880 MHz (the DECT Guard bands) be released for use of low power concurrent shared access (CSA), subject to limits on the in-band and out of band power spectral densities and other technical licence conditions.

TalkTalk have a licence to operate [2] low power transmitters in the CSA band (1781.7-1785 MHz paired with 1876.7-1880 MHz). This frequency range is at the upper edge of the harmonised Enhanced-Universal Terrestrial Radio Access or E-UTRA (commonly referred to as Long Term Evolution or LTE) band 3 [3], and represents spectrum that has equipment readily available for use in this band.

TalkTalk has requested from Ofcom a variation on their 1800 MHz licence to allow standard 3GPP-compliant LTE small cells (i.e. femtocells or picocells) to be used within in this band. The licence variation was supported by previous Real Wireless analysis of the potential interference into adjacent systems operated by EE [4].

Ofcom indicated that analysis was sufficient to inform their thinking on the EE interactions, but that to further support their consideration of the licence variation, two additional factors need to be considered:

1. The potential interference into adjacent DECT systems
2. The potential interference to other concurrent 1800 MHz licensees

TalkTalk has requested Real Wireless to conduct technical studies – based on both measurement and modelling – to provide the necessary support for both Ofcom discussions and discussions with other Mobile200 licensees

This report provides the test results for the measurements of potential interference into adjacent DECT systems.

1.2 Scope of the test

Figure 1 shows the interference scenario we are investigating in this study.

[1] frequency bands 1781.7-1785 MHz paired with 1876.7-1880 MHz

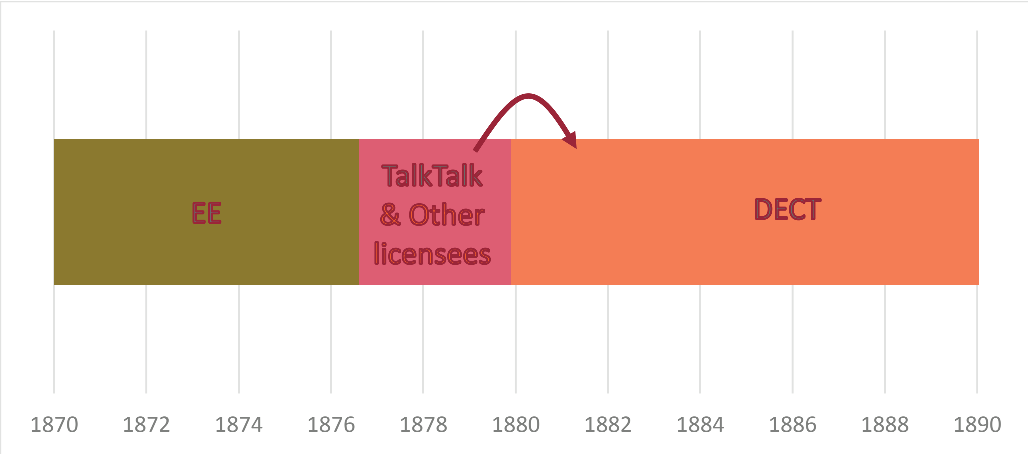


Figure 1: The interference scenario under study, showing the guard band base station transmit subband and its neighbours

As shown in Figure 2, we have two potential interference cases to examine:

1. Interference to a DECT Fixed Part (FP) receiver from a nearby TalkTalk Home eNodeB[2], when the transmitting DECT Portable Part (PP) is on cell edge
2. Interference to a DECT PP receiver from a nearby TalkTalk Home eNodeB, when the DECT PP is on cell edge

In both cases DECT frequency hopping is expected to significantly mitigate any scope for interference and will be used to temper the impact of interference which occurs when the DECT system happens to be just above 1880 MHz.

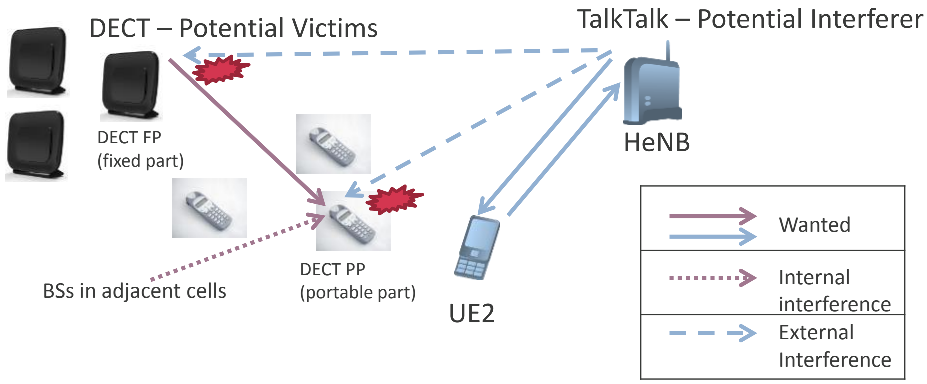


Figure 2: Potential interference scenarios in to DECT

[2] In this report "Home eNodeB" and "(LTE) femtocell" are used interchangeably.

2. Test equipment and configuration

The objective of these tests is to determine whether a fully operational, heavily loaded Home eNodeB (HeNB) causes significant interference to existing DECT users beyond any experienced with the existing licence limits and a GSM picocell. Therefore, both out of band interference tests and DECT interference tests are conducted for LTE HeNB and a GSM picocell.

Spectrum characteristics were tested with two different LTE Home eNodeBs i.e. from Arcadyan and Huawei. The network set up for the HeNBs is explained in the following section.

2.1 LTE network set up

The LTE network set up consist of:

1. Core network emulator
2. Home eNodeB
3. LTE User Equipment (UE)

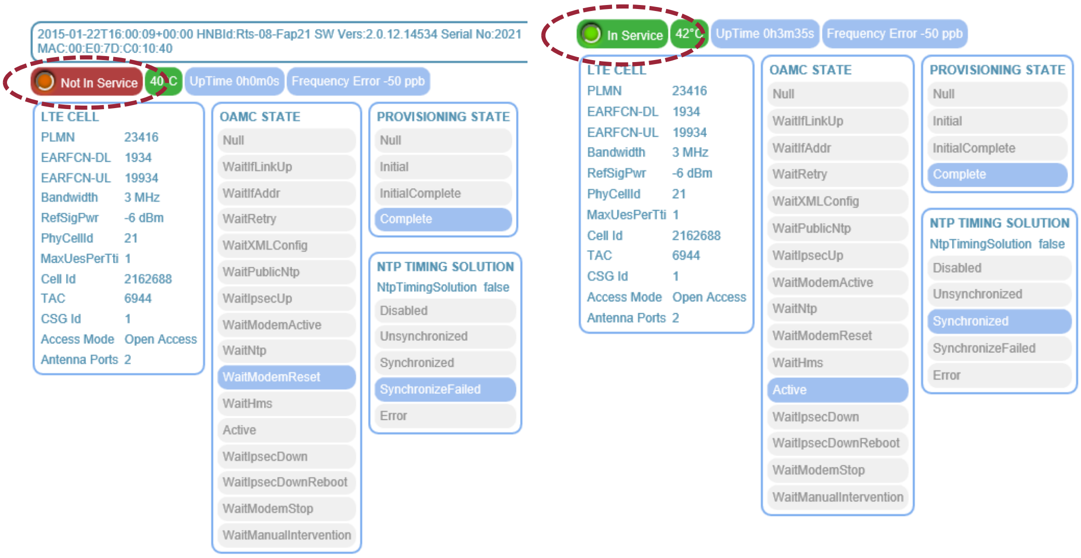
2.1.1 LTE network set up with the Arcadyan Home eNodeB

The core network emulator was installed in a Linux based laptop. The core network emulator software was provided by Node-h [5]. The Home eNodeB product we tested was manufactured by Arcadian. Figure 3 shows a photograph of the Arcadyan Home eNodeB under test. A Samsung Galaxy Mini phone was used as the UE. A TalkTalk test subscriber identity module (SIM) card was used with the Samsung UE during the tests.

Figure 3: Arcadyan LTE Home eNodeB

Once the core network software is initiated and the Home eNodeB is switched on, the status of the Home eNodeB is determined by inserting the Internet Protocol (IP) address of the Home eNodeB in an internet browser window. Figure 4 shows a screenshot from the browser window when the LTE network is “not is service“ (on the left) and when the LTE network is “in operation” (on the right).

Once the UE is switched on, it “camps on” the TalkTalk network. If the UE does not “camp on” the TalkTalk LTE network, the TalkTalk network can be searched and selected manually from the UE. The File Transfer Protocol (FTP) can be activated between the UE and the core network so that a continuous data stream is produced from the LTE network to the UE. We used “Iperf” [6], an application available in Linux, to transfer data from the LTE network to the UE.



LTE network is “not in service” LTE network is in operation

Figure 4: Status of the LTE network

Once the data transmission is initiated, the data rate can be shown on the laptop where the core network is installed. The top part of the Figure 5 shows a screenshot of the data rates observed in the laptop during the tests. The bottom part of Figure 5 shows the Samsung UE with the FTP application initiated from the UE side. During the tests, we observed a maximum down link bitrate of 18.9 Mbps (shown in Figure 5).

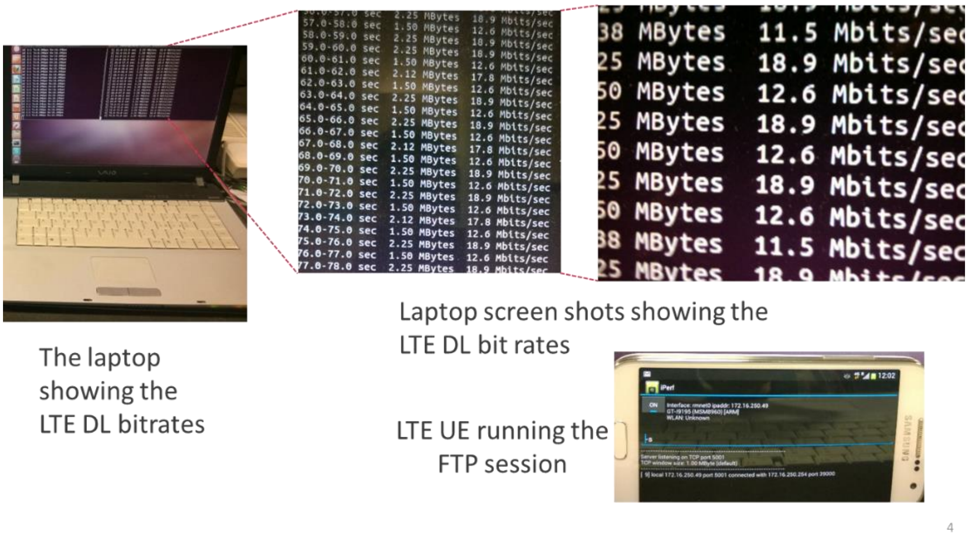


Figure 5: FTP application running on the Laptop and the UE

2.1.2 LTE network set up with the Huawei Home eNodeB

The Huawei LTE Home eNodeB was driven by a laptop with the Huawei core network. Unlike the Arcadyan network set up, the laptop with the core network was directly connected to Huawei LTE Home eNodeB laptop. Figure 6 shows a photograph of the Huawei LTE Home eNodeB.

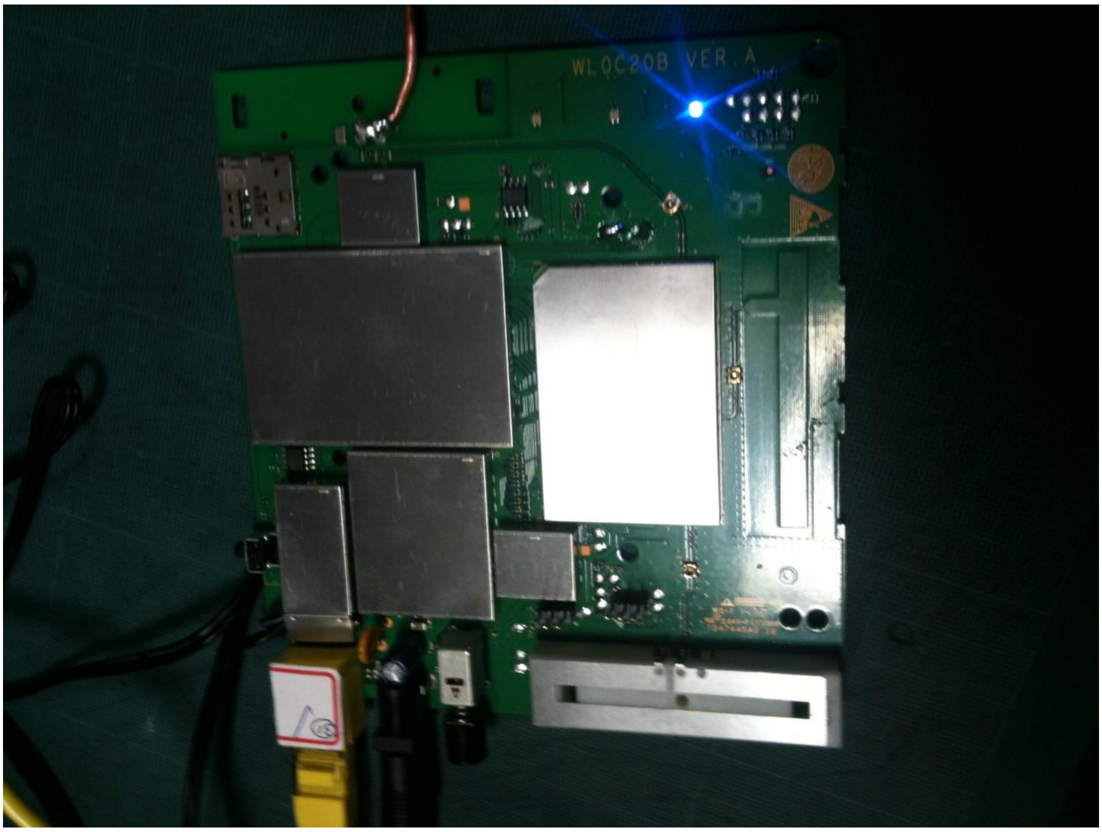


Figure 6: Huawei LTE Home eNodeB

Huawei Home eNodeB was configured such that it was transmitting its full power during the test.

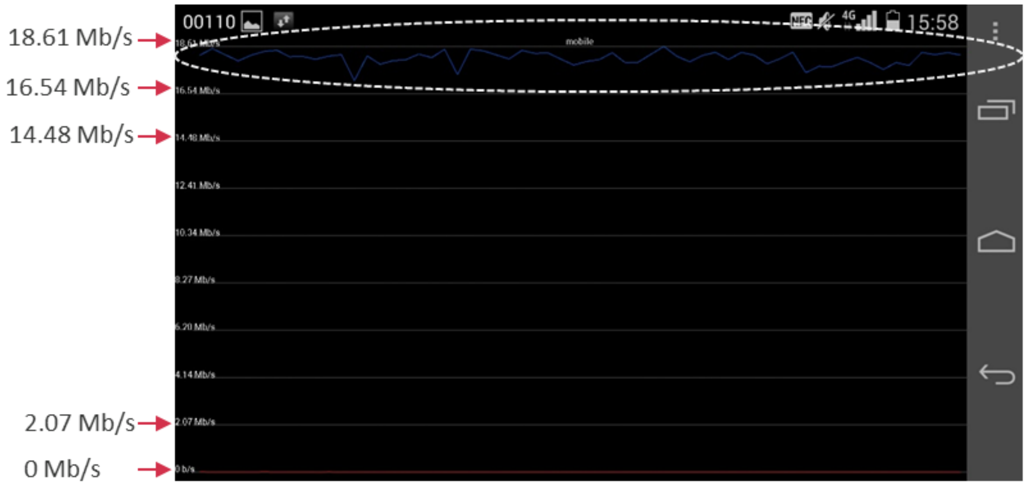


Figure 7: A screenshot showing bitrates observed in the lab with the Huawei network set up (taken from the Huawei LTE UE)

Figure 7 shows the LTE bit rates observed from the Huawei UE during the testing in the lab.

2.1.3 End to end network set up used for testing

The block diagram of the test set up is shown in Figure 8. A photograph of the actual test setups are shown in Figure 9 (Arcadyan Home eNodeB) and Figure 10 (Huawei Home eNodeB).

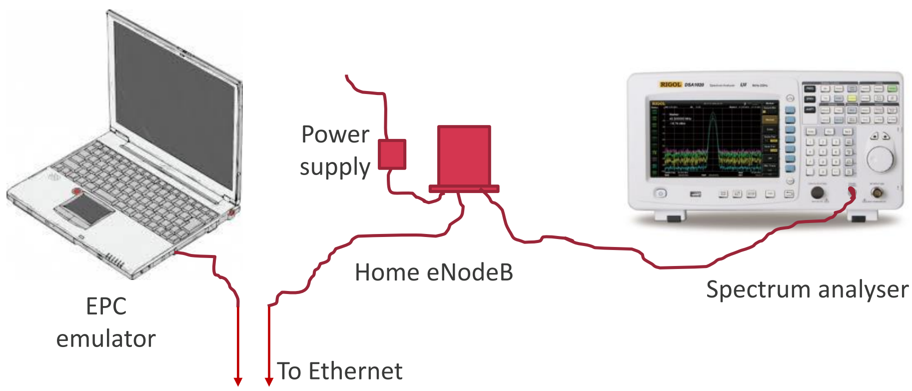


Figure 8: LTE network setup

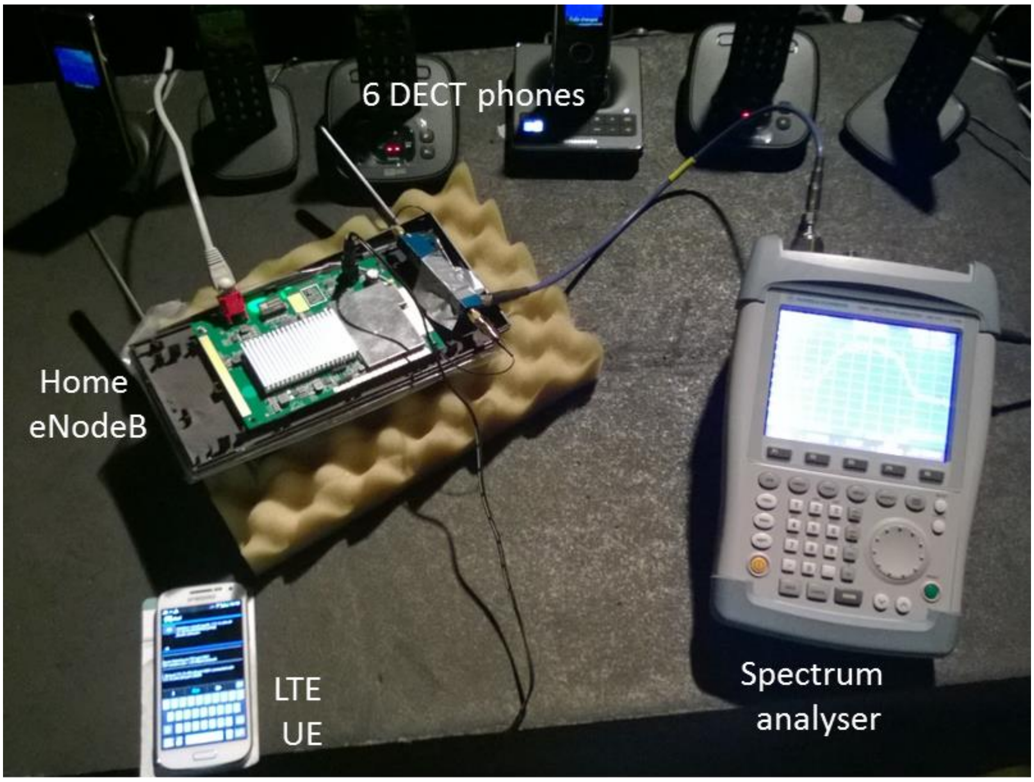


Figure 9: A photograph of the Arcadyan test set up used in the lab

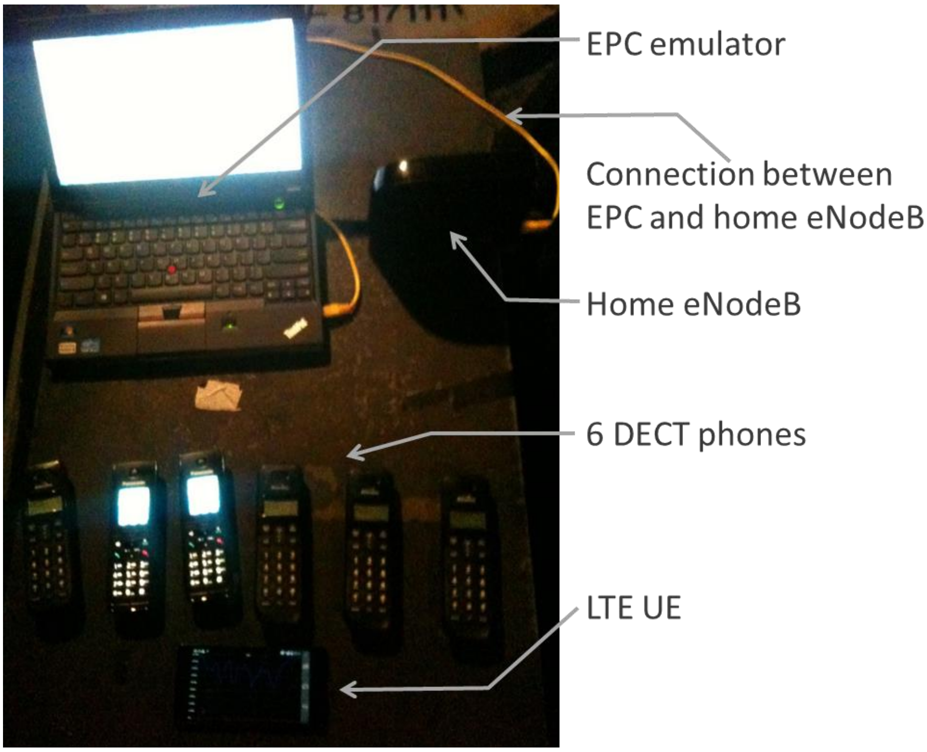


Figure 10: A photograph of the Huawei test set up used in the lab

2.2 GSM network set up

Similar to the LTE network set up, the GSM network set up consisted of:

1. Core network emulator
2. Base station transceiver subsystem (BTS)
3. GSM UEs (Nokia 6500 and Nokia E71 models)

GSM core network emulator was run on a Windows laptop. We used an ip.access GSM picocell with the core network emulator software provided by Quortus [7]. Figure 11 shows a photograph of the GSM picocell used for testing. Nokia 6500 and E71 models were used as the UEs (see Figure 12). A TalkTalk test SIM card was used with Nokia UEs during the tests.

Figure 11: GSM picocell used for testing

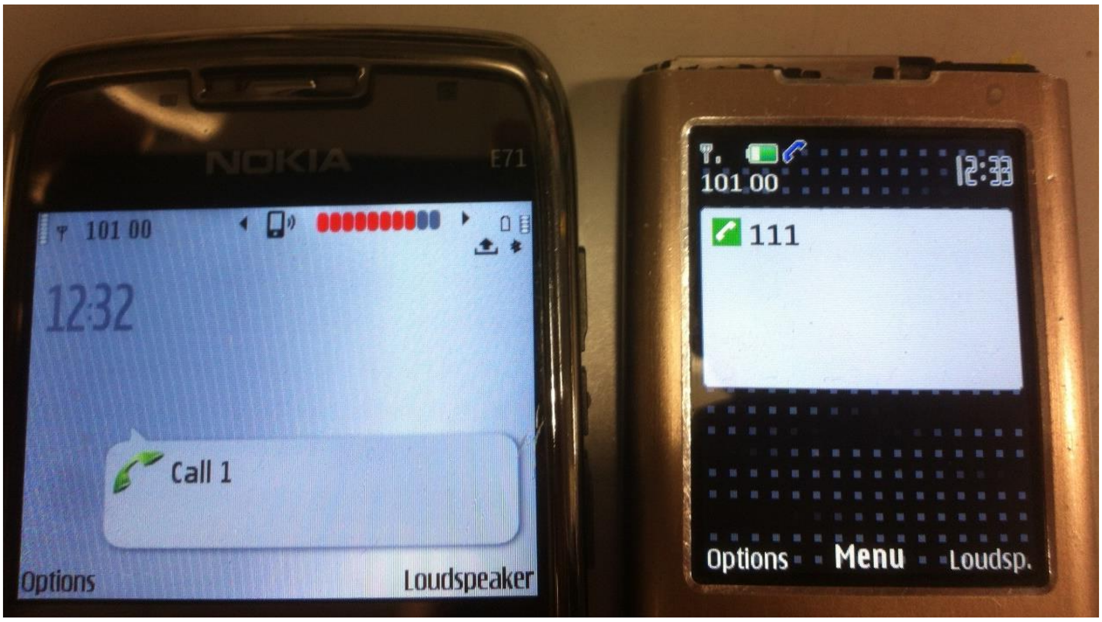


Figure 12: GSM UEs used for testing

We used a directional coupler to connect the spectrum analyser to the antenna port. The block diagram of the connection set up is shown in Figure 13.

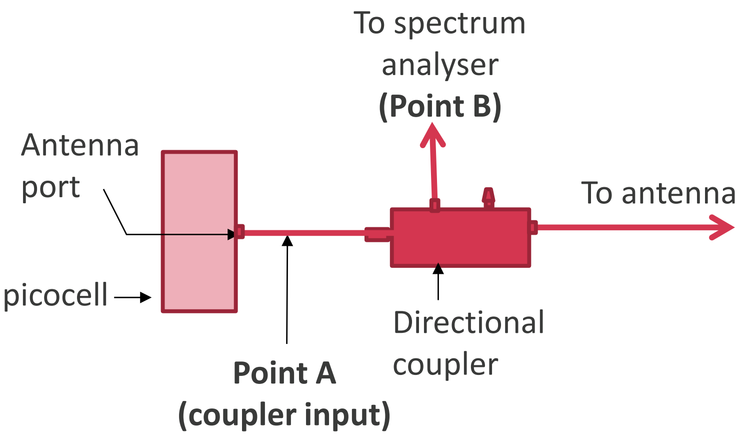


Figure 13: Connection setup used to connect the spectrum analyser to the antenna port

Figure 14: Directional coupler

A DCS2020 directional coupler (shown in Figure 14) [8] is used during the tests. The DCS2020 from TRM Microwave is a directional coupler with an operating frequency range of 1000 to 12400 MHz. It has a coupling factor of 20 dB with coupling variation of 0.75 dB.

The spectrum analyser model used for the tests is Rohde and Schwarz FSH03 [9]. The FSH03 can be used for measurements up to an upper frequency limit of 3 GHz. It comes as standard with an adjustable preamplifier, making it suitable for measuring very small signals.
A photograph of the complete set up in the laboratory is shown in Figure 9. To avoid external interference effects, the whole test set up was located in an anechoic chamber.

A photograph of the complete test set up is shown in Figure 15.

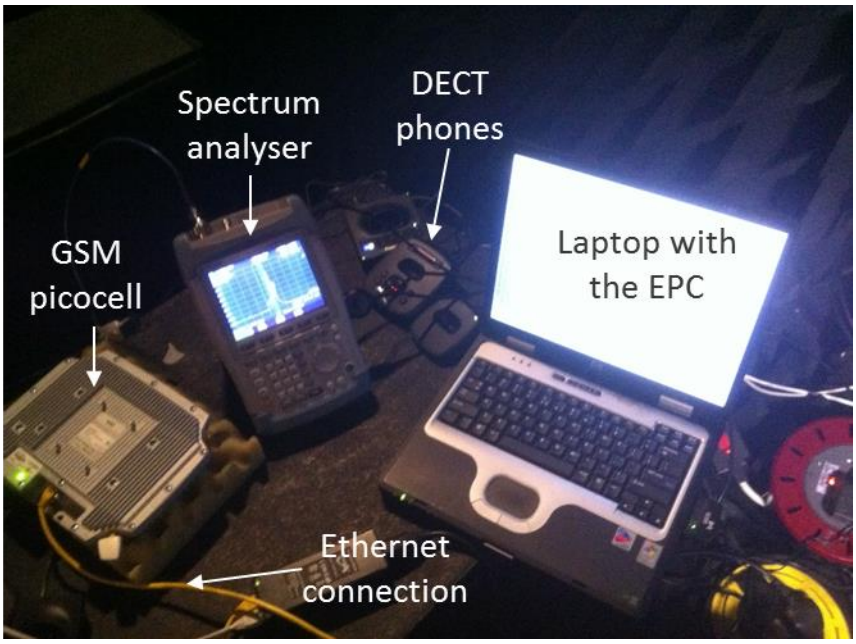


Figure 15: A photograph of the GSM test set up

3. Test scenarios

Three different test scenarios were carried out during the measurements:

1. Spectrum emission test
2. DECT interference test
3. Baby monitor interference test

3.1 Spectrum emission test

The purpose of this test scenario is to test the spectrum characteristics of two LTE Home eNodeB products from Arcadyan and Huawei. We compare the spectrum emissions generated by the LTE Home eNodeB with the spectrum emissions generated by a GSM picocell operating in the same band.

As shown in Figure 16, the Evolved Packet Core (EPC) network emulator and GSM core network emulator generate traffic for the Home eNodeB and GSM picocell to represent a fully operational Home eNodeB and picocell respectively. Once the Home eNodeB and picocell is functional and loaded with traffic, a spectrum analyser is used to measure the spectrum characteristics.

The Home eNodeB power emissions are measured at the full power level and at two different reduced power levels i.e. 2 dB and 10 dB lower than the maximum power level.

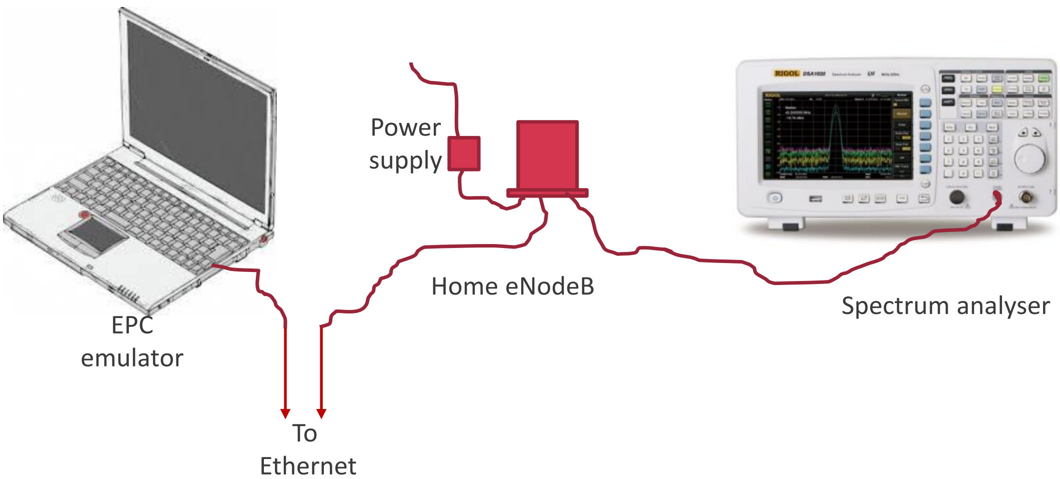


Figure 16: Home eNodeB test set up

3.2 DECT interference test

The objective of this test scenario is to ensure that a fully operational Home eNodeB does not cause significant interference to existing DECT users beyond any experienced with the existing licence limits and a GSM picocell.

3.2.1 GSM test set up

Firstly, we conduct the tests with a GSM picocell operating in the same frequency band. The equipment setup is shown in Figure 18. A core network emulator is used to emulate the traffic to GSM picocell so that the picocell is operated in conditions similar to a GSM picocell in commercial operation. Two GSM phones with TalkTalk test sim cards were used to communicate with the GSM picocell. In addition, six DECT phones were used to emulate the operational DECT environment. Six DECT phones could represent a scenario with a high density DECT usage in an apartment complex where four surrounding flats, one flat above and one flat below, all uses DECT phones. During the measurements, all six DECT phones were made to be operational and carrying voice simultaneously. We used the following DECT phone models for the tests.

1. PANASONIC KX-TG8564EB cordless phone Quad Handsets
2. Two pairs of Binatone Veva 1700 twin cordless phone

Figure 17 shows the pictures of the DECT phone models used during the tests.

Binatone Veva 1700 twin codeless phones (2 pairs used)

PANASONIC KX-TG8564EB cordless phones

Figure 17: DECT phones used during the tests

Firstly a voice call was activated between the two GSM phones to load the picocell. We then dialled the DECT phones using another external landline and all six DECT phones were connected to the external call. A set of standard speech samples was then played to the external telephone, located outside the chamber call using a computer. The speech samples were loud enough to hear from six DECT phones located inside the chamber. Voice quality testing was carried out using one of the DECT phones inside the chamber. Tests were conducted while the GSM voice call is in progress Firstly, the test was conducted with the GSM picocell switched “off” to establish the quality of the DECT network. Subsequently, the tests were repeated with the GSM picocell is “on”.

Since the GSM picocells are currently in operation within the existing licence limit the measurement results from this test case provides a baseline for comparison.

As recommended by ITU, [10] the following scale was used to evaluate the opinion of the voice quality:

1. Bad
2. Poor
3. Fair
4. Good
5. Excellent

We used 10 sample test vectors in [11]. Each speech sample was repeated at least 25 times to get a more reliable set of measurement results. Further, to emulate a worst case scenario for the DECT network, the FP of the DECT is located as far as possible to the PP of the DECT network.

The GSM test set up is shown in Figure 18.

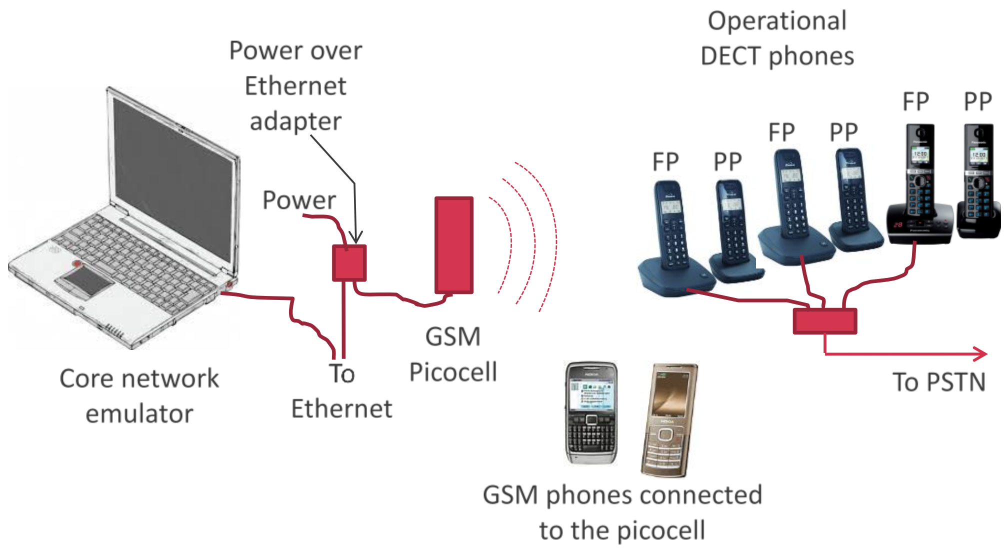


Figure 18: Equipment setup for GSM picocell spectrum characteristics measurement

The received speech samples were recorded and stored as audio files to allow offline evaluation and comparison.

During the tests we have also measured the following key performance indicators (KPIs) of the DECT system:

- Call set up success rate (%)
- Call hold time in the form of the proportion of 2 minute duration calls

To minimise the impact of interference effects from the external networks, the whole set up will be placed within an anechoic chamber.

3.2.2 LTE test set up

Once the GSM tests were completed, the GSM picocell and GSM phones were replaced with a Home eNodeB and a LTE phone with a TalkTalk SIM. The same experimental steps (with the Home eNode B switched “off” and “on”) were carried out once again with the Home eNodeB.

Similar to the previous tests, each test was nrepeated at least 25 times to increase the confidence of the outcome.

The LTE test set up is shown in Figure 19.

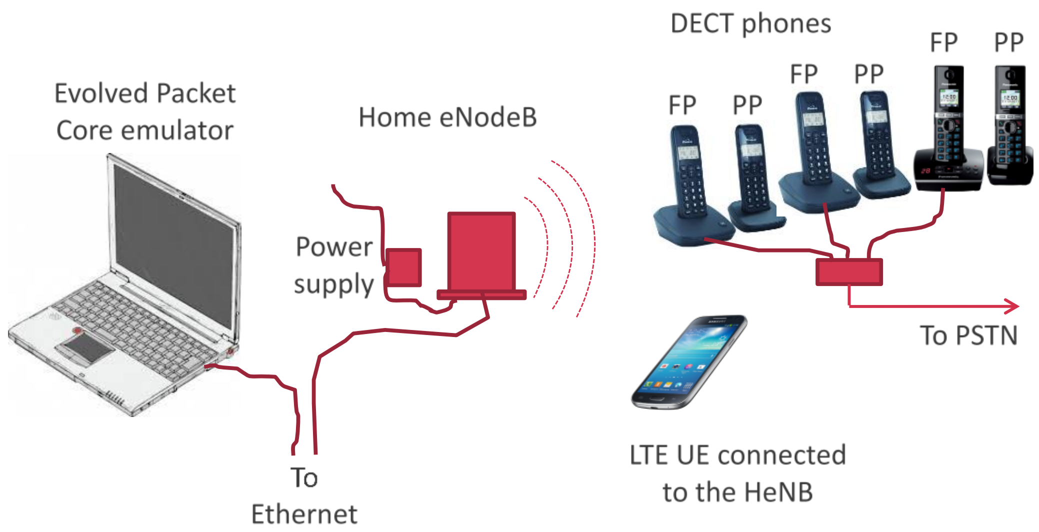


Figure 19: LTE test set up for DECT interference measurements

3.3 Baby monitor interference test

The purpose of this test is to ensure the performance of baby monitors equipped with 1.8 GHz DECT technology is not affected by the LTE Home eNodeB. We used a Motorola MBP8 Digital Audio baby monitor (see Figure 20) for our tests [12].

Figure 20: Motorola's MBP8 baby monitor units used for testing

The test set up to test the baby monitor performance is shown in Figure 20.

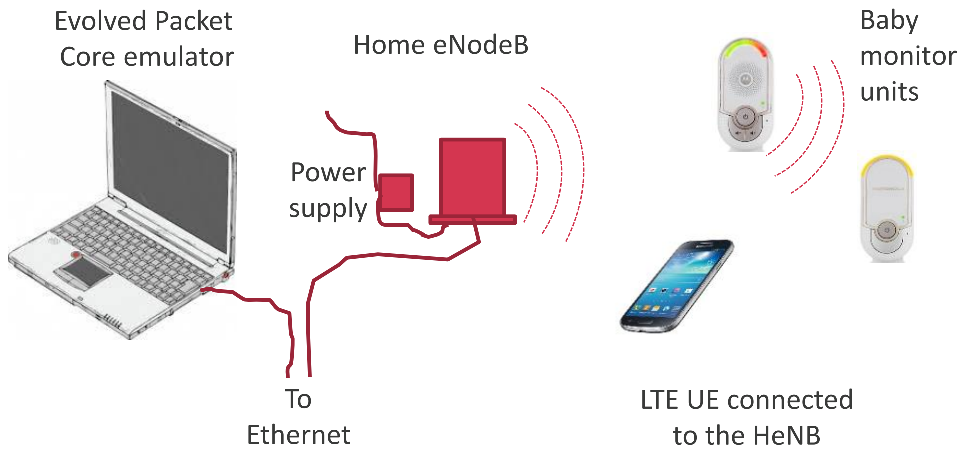


Figure 21 : Test set up for the baby monitor performance testing

4. Test results

4.1 Spectrum characteristics

4.1.1 LTE spectrum characteristics for Arcadyan Home eNodeB

The centre frequency of the 3 MHz LTE carrier was set at the middle of the TalkTalk band i.e. 1.8784 GHz. The parameter set used for the spectrum analyser is shown in Table 1.

Parameter	Value	Unit
Centre Frequency	1878.4	MHz
Span	20	MHz
Frequency Offset	0	Hz
Resolution Bandwidth	1	kHz
Video Bandwidth	1	MHz
Sweep time	0.5	seconds
Reference Level	0	dBm
Reference Offset	0	dBm
Reference Range	10	dB/div

Table 1: Spectrum analyser parameter settings with Arcadyan Home eNodeB

A sample screenshot taken from the spectrum analyser is shown in Figure 22

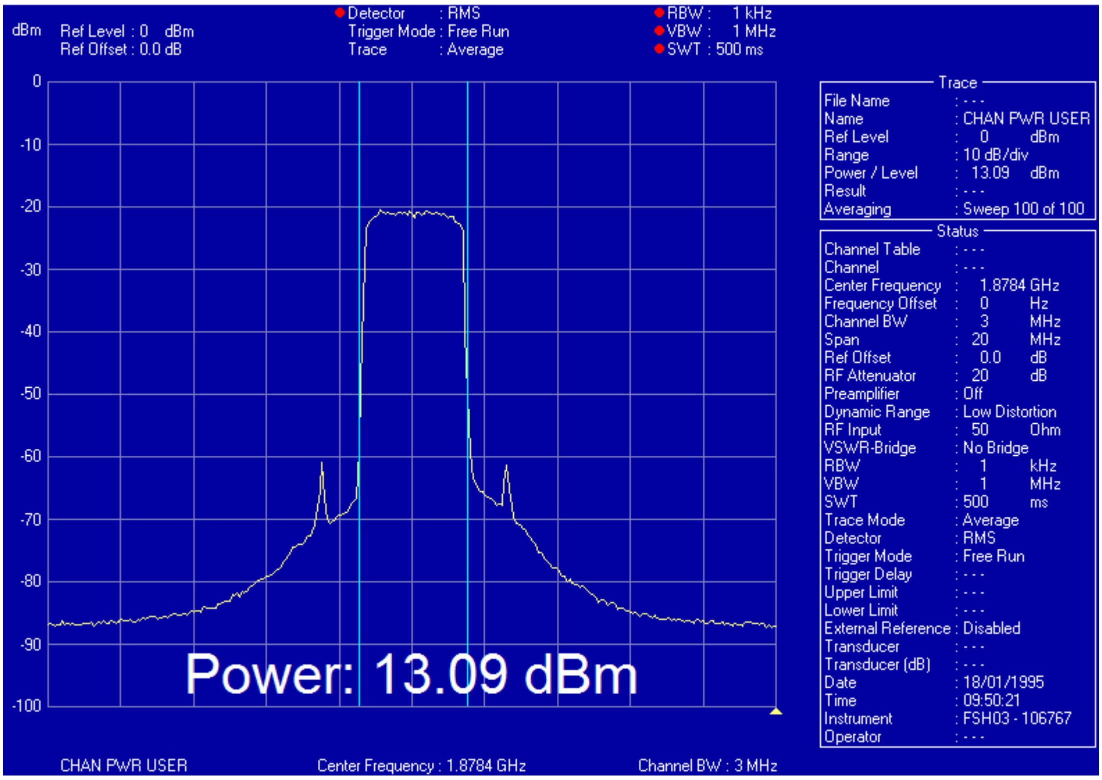


Figure 22: Screenshot taken from the spectrum analyser with Arcadyan Home eNodeB

We conducted measurements while LTE Home eNodeB is in operation, i.e. in the presence of live data transmission, to represent a realistic operational conditions. A summary of the calculations based on the measurements are shown in Table 2.

Power settings	Measurement number	Integrated power over 3 MHz (dBm)	Measured power at the antenna port (measured power + cable loss) dBm	Expected power at the antenna port (dBm)	EIRP per antenna (dBm/3MHz)	Total EIRP (dBm/3MHz)	EIRP (dBm/kHz)
Max power from the device (RS=-6)	1	13.0	13.4	13.6	15.4	18.4	-16.4
	2	13.0	13.4	13.6	15.4	18.4	-16.4
	3	13.0	13.4	13.6	15.4	18.4	-16.4
	4	13.0	13.4	13.6	15.4	18.4	-16.4
	5	13.0	13.4	13.6	15.4	18.4	-16.3
	6	13.0	13.4	13.6	15.4	18.4	-16.4
	7	13.0	13.4	13.6	15.4	18.4	-16.4
	8	13.0	13.4	13.6	15.4	18.4	-16.3
	9	13.0	13.4	13.6	15.4	18.4	-16.3
	10	13.1	13.5	13.6	15.5	18.5	-16.3
Max power - 2dB (RS=-8)	1	11.2	11.6	11.6	13.6	16.6	-18.1
	2	11.3	11.7	11.6	13.7	16.7	-18.1
	3	11.3	11.7	11.6	13.7	16.7	-18.1
	4	11.3	11.7	11.6	13.7	16.7	-18.1
	5	11.3	11.7	11.6	13.7	16.7	-18.1
	6	11.3	11.7	11.6	13.7	16.7	-18.1
	7	11.3	11.7	11.6	13.7	16.7	-18.1
	8	11.3	11.7	11.6	13.7	16.7	-18.1
	9	11.2	11.6	11.6	13.6	16.6	-18.2
	10	11.2	11.6	11.6	13.6	16.6	-18.2
Max power - 10dB (RS=-16)	1	3.3	3.7	3.6	5.7	8.7	-26.1
	2	3.3	3.7	3.6	5.7	8.7	-26.1
	3	3.3	3.7	3.6	5.7	8.7	-26.1
	4	3.2	3.6	3.6	5.6	8.6	-26.1
	5	3.2	3.6	3.6	5.6	8.6	-26.1
	6	3.2	3.6	3.6	5.6	8.6	-26.1
	7	3.2	3.6	3.6	5.6	8.6	-26.1
	8	3.2	3.6	3.6	5.6	8.6	-26.2
	9	3.2	3.6	3.6	5.6	8.6	-26.2
	10	3.2	3.6	3.6	5.6	8.6	-26.1

Table 2: Summary of the LTE measurements with Arcadyan Home eNodeB

The parameters used for the calculation of the EIRP is shown in Table 3.

Parameter	Value	Unit	Notes
Cable loss	0.4	dB	Measurements from UniS
Antenna gain	2	dBi	Information from node-h
power split between antennas	3	dB	Assumption

Table 3: Parameters used for the calculation of EIRP with Arcadyan Home eNodeB

According the measurements we are within the 0.2 dB of the expected power rated by the manufacturer.

Details	Parameter set 1	Parameter set 2	Parameter set 3	Unit	Notes
Number of resource elements (REs)	12				
Number of resource blocks (RBs)	15				Number of RBs in 3 MHz
Reference signal power	-6	-8	-16	dBm	Parameter available to change the power settings
Total power	**16.6**	**14.6**	**6.6**	**dBm**	**RS power+ 10log(12*15)**
Total power per antenna (power into the antenna port)	**13.6**	**11.6**	**3.6**	**dBm**	
Antenna gain	2			dBi	
EIRP	**18.6**	**16.6**	**6.6**	**dBm**	**Total power + Antenna gain**

Table 4: Power level calculations for the Arcadyan Home eNodeB

Table 4 shows the power level calculations for the LTE Home eNodeB for different reference signal (RS) power levels. The maximum RS power setting allowed in the device is -6 dBm which corresponds to a total EIRP of 19 dBm.

Figure 23 compares the spectrum emissions measured in the lab with the technical licensing conditions (TLC) set by Ofcom for the TalkTalk band. As shown in Figure 23, the spectrum emissions from the tested eNodeB meet the proposed licensing conditions although the out of band emissions do not meet the existing licensing conditions which were developed based on GSM technology.

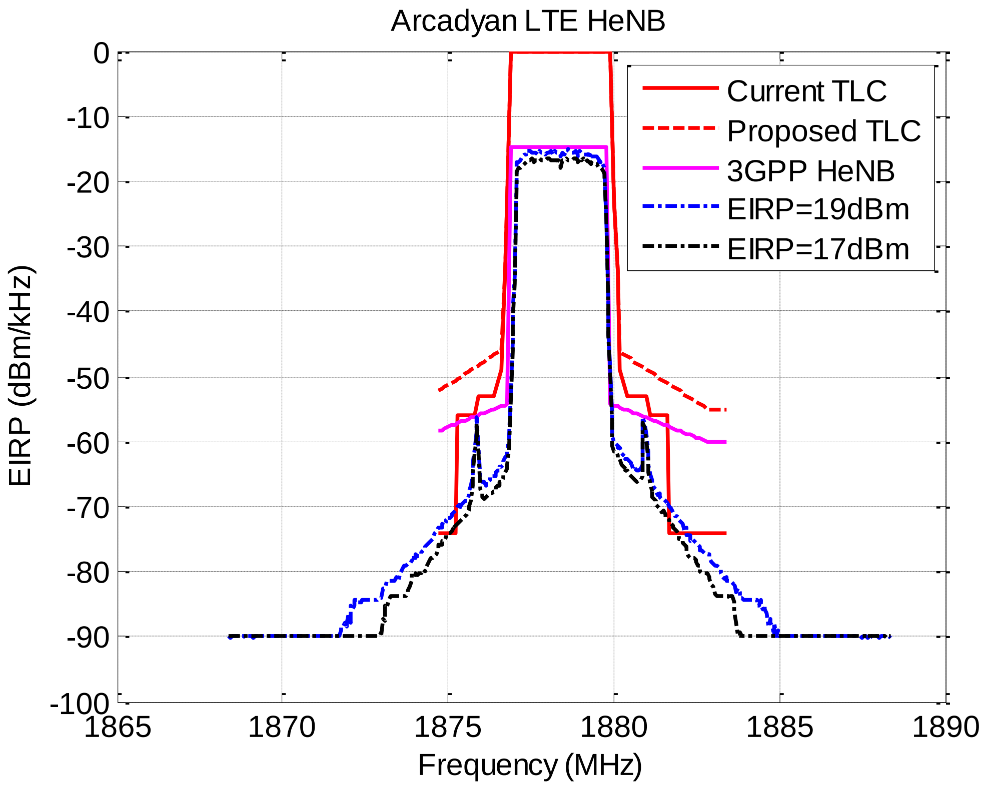


Figure 23: Comparison of spectrum emissions for LTE with Arcadyan Home eNodeB

4.1.2 LTE spectrum characteristics for Huawei Home eNodeB

Similar to the measurements with the Arcadyan Home eNodeB, the centre frequency of the 3 MHz LTE carrier in the Huawei Home eNodeB was set at the middle of the TalkTalk band i.e. 1.8784 GHz. The parameter set used for the spectrum analyser is shown in Table 1.

Parameter	Value	Unit
Centre Frequency	1878.4	MHz
Span	20	MHz
Frequency Offset	0	Hz
Resolution Bandwidth	1	kHz
Video Bandwidth	1	MHz
Sweep time	0.5	seconds
Reference Level	0	dBm
Reference Offset	0	dBm
Reference Range	10	dB/div

Table 5: Spectrum analyser parameter settings with Huawei Home eNodeB

A sample screenshot taken from the spectrum analyser is shown in Figure 24.

Figure 24: Screenshot taken from the spectrum analyser with Huawei Home eNodeB

A summary of the calculations based on the measurements is shown in Table 6.

Power settings	Measurement number	Integrated power over 3 MHz (dBm)	Measured power at the antenna port including cable loss dBm	Expected power at the antenna port (dBm)	EIRP per antenna (dBm/3MHz)	Total EIRP (dBm/3MHz)	EIRP (dBm/kHz)
Max power from the device	1	14.1	14.8	17	17.8	20.8	-14.0
	2	13.9	14.6	17	17.6	20.6	-14.2
	3	13.9	14.6	17	17.6	20.6	-14.2
	4	13.9	14.6	17	17.6	20.6	-14.2
	5	13.8	14.5	17	17.5	20.5	-14.3
	6	13.8	14.5	17	17.5	20.5	-14.3
	7	13.8	14.5	17	17.5	20.5	-14.3
	8	14.0	14.7	17	17.7	20.7	-14.1
	9	14.1	14.8	17	17.8	20.8	-14.0
	10	14.1	14.8	17	17.8	20.8	-14.0
Max power - 2dB	1	11.1	11.8	15	14.8	17.8	-17.0
	2	11.1	11.8	15	14.8	17.8	-17.0
	3	11.0	11.7	15	14.7	17.7	-17.0
	4	11.0	11.7	15	14.7	17.7	-17.1
	5	11.0	11.7	15	14.7	17.7	-17.1
Max power - 10dB	1	3.5	4.2	7	7.2	10.2	-24.6
	2	3.4	4.1	7	7.1	10.1	-24.7
	3	3.4	4.1	7	7.1	10.1	-24.7
	4	3.4	4.1	7	7.1	10.1	-24.7
	5	3.4	4.1	7	7.1	10.1	-24.7

Table 6: Summary of the LTE measurements with Huawei Home eNodeB

Parameters used for the calculation of the EIRP is shown in Table 3.

Parameter	Value	Unit	Notes
Cable loss	0.7	dB	Measurements by University of Surrey
Antenna gain	3	dBi	Information from Huawei
power split between antennas	3	dB	Assumption

Table 7: Parameters used for the calculation of EIRP with Huawei Home eNodeB

During the measurements (presented in Table 6) we observed that the measured power was approximately 2.4 dB lower than the expected power when the Home eNodeB is transmitting with its maximum power. The power reduction was approximately 3 dB at lower transmitted power levels. The potential reasons for the variation in the measured power are:

- Loss in the connector: The RF cable was carefully soldered into the LTE Home eNodeB circuit board. Although the connection was stable, there is a possibility of a small amount of power leaking at the point of soldering.
- Variations in the transmitted power: there is a possibility of the Home eNodeB not transmitting its full power continuously.

According to the 3GPP base station conformance testing requirements, the maximum power measured for each antenna for band 3 should be within +/- 2.7 dB of the manufacture's rated power [13]. Therefore, requirement is that the maximum power measured from the spectrum analyser should be within 14.3 dBm and 19.7 dBm. As shown in Table 6, the measured power lies within the requirement specified by 3GPP.

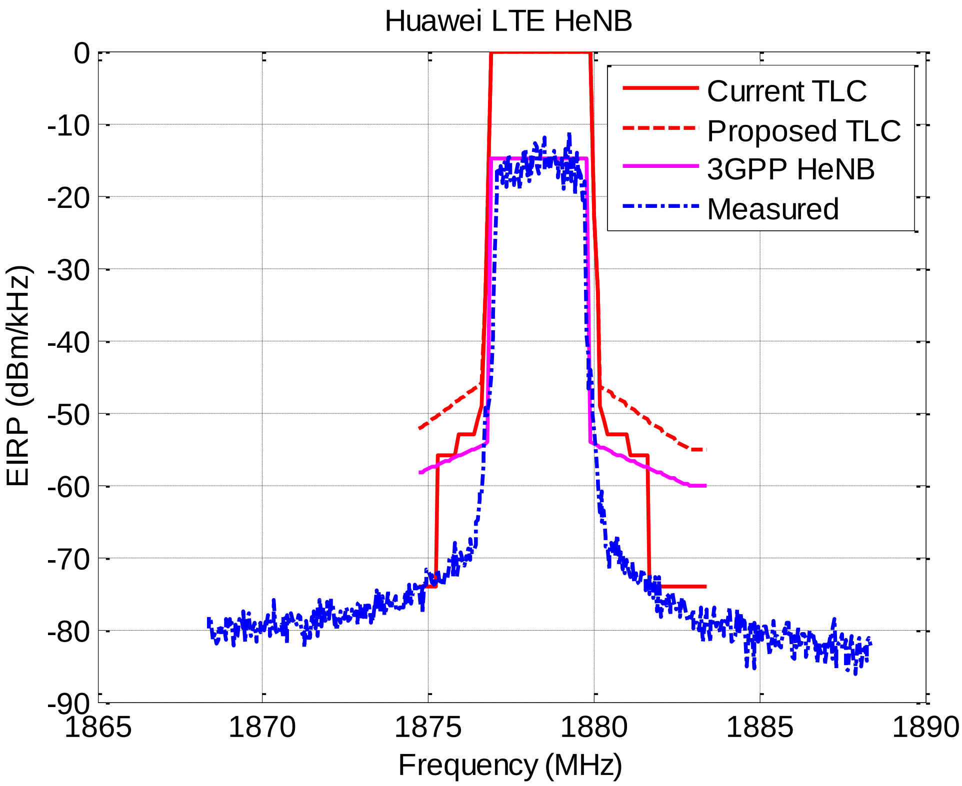


Figure 25: Comparison of spectrum emissions for LTE with Huawei Home eNodeB

Figure 25 shows the comparison of spectrum emissions measured in the lab with the TLC set by Ofcom for the TalkTalk band. As shown in Figure 23, the spectrum emissions from the tested eNodeB meets the proposed licensing conditions although the out of band emissions do not meet the existing licensing conditions.

4.1.3 GSM spectrum characteristics

The TalkTalk frequency band (1781.7-1785 MHz paired with 1876.7-1880 MHz) is sub-divided into sixteen 200 kHz bands. Radio channel assignments for GSM technology operating in this band are specified in [14]. The preferred channel numbers and the power classes are shown in 7.1 and 7.2 respectively. The closest GSM carrier to the DECT allocation has an Absolute Radio Frequency Channel Number (ARFCN) of 885. This carrier has preferred antenna class A with a maximum permitted power level of 3 dBm (Table 14 and Table 15). Further, the carrier with ARFCN 882 has a preferred antenna class C (with the maximum permitted power level of 23 dBm), D (with the maximum permitted power level of 30 dBm), or U (with the maximum permitted power level of 23 dBm). We tested both these carriers i.e. ARFCN 882 and 885 with the power levels 3 dBm and 23 dBm during our tests. In summary, the tested GSM carriers and their specifications are shown in Table 8.

ARFCN	UL frequency	DL frequency	Description [14]
882	1784.2	1879.2	An antenna operating at a power level of at most 23 dBm (0 dBm/kHz)
885	1784.8	1879.8	An antenna operating at a power level of at most 3 dBm (-20 dBm/kHz)

Table 8: Tested GSM carriers and their specifications

Similar to the LTE spectrum measurements, we conducted GSM measurements while GSM picocell is in operation, i.e. in the presence of an active voice call, to represent a realistic operational conditions.

Figure 28 shows a screenshot taken from the spectrum analyser.

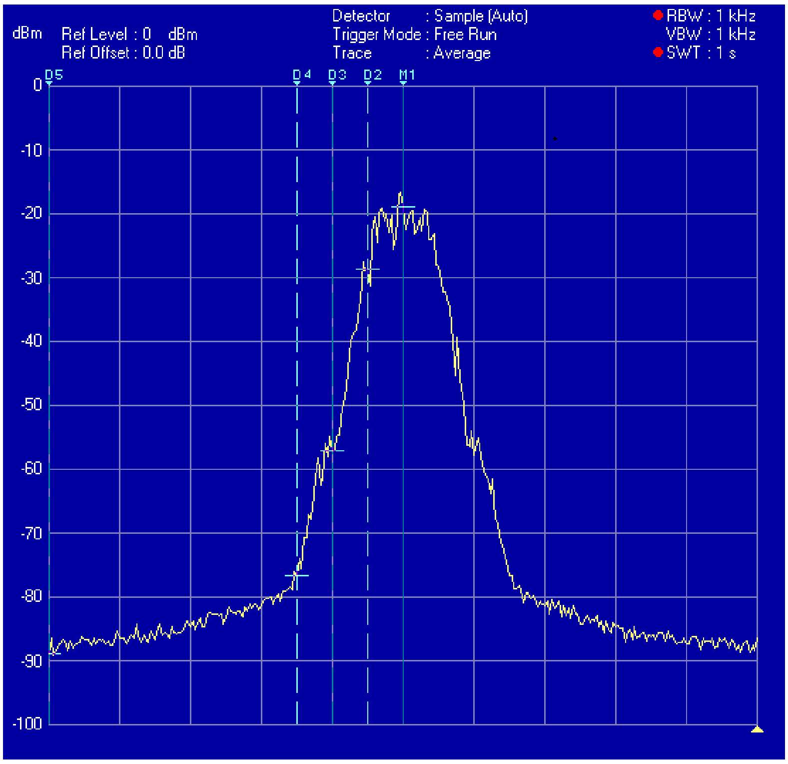


Figure 26: Screenshot taken from the spectrum analyser

A block diagram of the measurement points is shown in Figure 13.

A summary of the calculations based on the measurements is shown in Table 9.

Transmitted power setting	Measurement number	Integrated power over 200 kHz at point B (dBm)	BW (kHz)	Integrated Power into the coupler, at point A (dBm)	Total EIRP (dBm)
23 dBm	1	2.1	200	22.6	22.6
	2	2.1	200	22.6	22.6
	3	2.0	200	22.4	22.4
	4	2.0	200	22.5	22.5
	5	2.4	200	22.9	22.9
	6	2.6	200	23.0	23.0
3 dBm	1	-18.5	200	2.0	2.0
	2	-18.5	200	2.0	2.0
	3	-17.3	200	3.2	3.2
	4	-18.7	200	1.8	1.8

Table 9: Summary of the GSM measurements

Parameters used for the calculation of the EIRP is shown in Table 10.

Parameter	Value	Unit	Notes
Coupler loss	20.5	dB	Measurements by the University of Surrey (see 6.2)
Coupling variation (+/-)	0.75	dB	[15]
Antenna gain	0	dBi	Information from Quortus

Table 10: Parameters used for the calculation of EIRP

According to the measurements, we observed maximum of 0.6 dB and 1.2 dB variation at the coupler input with high power and low power settings respectively. This could be due to:

- Variations in the transmitted power: Although we have maintained an active voice call far away from the picocell, there is a possibility of variations in the transmitted power from the picocell.
- The variations in the coupler: according to the product specifications, the coupling variation could be +/- 0.75 dB (see Table 3).

Figure 27 shows the comparison of spectrum emissions measured in the lab with the technical licensing conditions (TLC) set by Ofcom for the TalkTalk band.

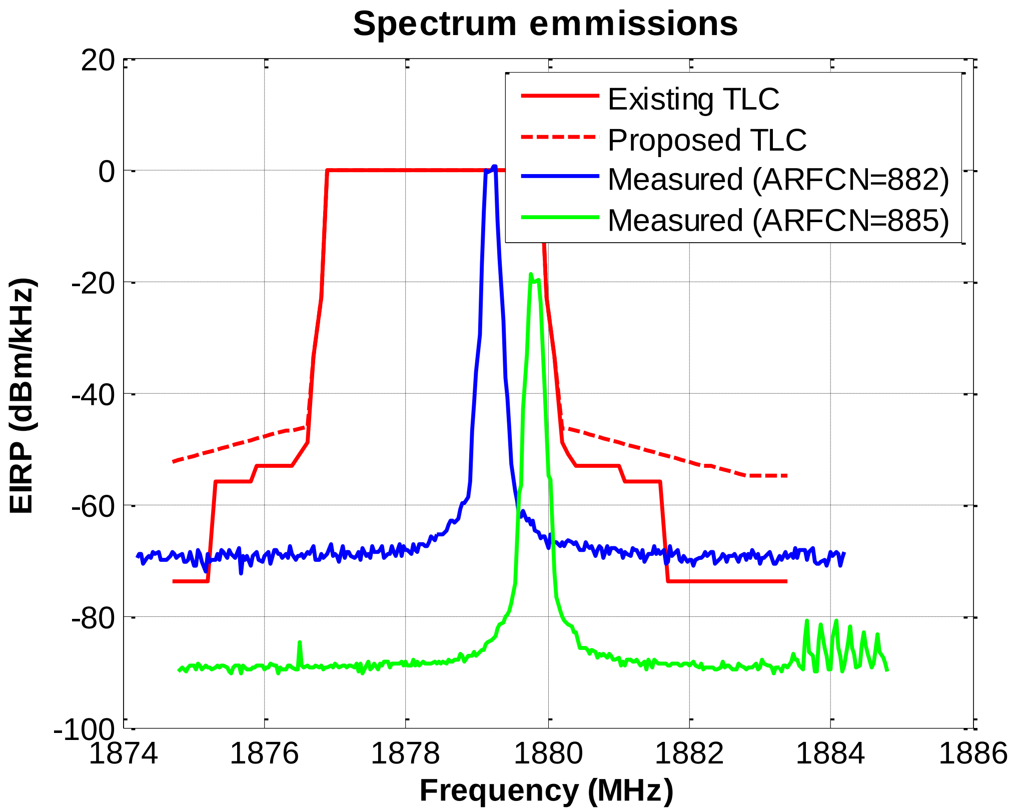


Figure 27: Comparison of spectrum emissions

We used a directional coupler to avoid excessive power in to the spectrum analyser and to measure the spectrum emissions while picocell is in active mode i.e. live voice call. However, we observed that the OOB measurements are limited by the noise floor due to the 20 dB loss in the signal with the directional coupler.

4.2 Call statistics with GSM picocell and LTE Home eNodeB

This section provides a description of the call statistics measurements we conducted with GSM picocell and LTE Home eNodeB.

Call statistics measurements were performed with the GSM picocell and Arcadyan LTE Home enodeB while the picocell and the Home eNodeB were transmitting their maximum allowable power.

Table 11 shows the summary of the tests conducted and the observations.

Test	Description	Condition	Observations
Call set up success rate test for LTE Home eNodeB	25 calls from a DECT phone to an external landline	LTE HeNB “off”	No failures
	25 calls from a DECT phone to an external landline	LTE HeNB “on”	No failures
	25 calls from an external landline to a DECT phone	LTE HeNB “off”	No failures
	25 calls from an external landline to a DECT phone	LTE HeNB “on”	No failures
Call set up success rate test for GSM picocell	25 calls from a DECT phone to an external landline	GSM picocell “off”	No failures
	25 calls from a DECT phone to an external landline	GSM picocell “on”	No failures
	25 calls from an external landline to a DECT phone	GSM picocell “off”	No failures
	25 calls from an external landline to a DECT phone	GSM picocell “on”	No failures
Call hold time test for LTE Home eNodeB	25 calls from an external landline to a DECT phone, each call is held for 2 mins	LTE HeNB “on”	No failures
Call hold time test for GSM picocell	25 calls from an external landline to a DECT phone, each call is held for 2 mins	GSM picocell “on”	No failures

Table 11: Summary of call test statistics

Conclusion: Interference from GSM picocell or LTE Home eNodeB did not cause dropped calls on the tested DECT system.

4.3 Voice quality tests

We conducted voice quality tests using the test set up explained in the section 3.2. One of the Panasonic KX-TG8564EB cordless phones was used for voice quality testing.

Following is a summary of the observations and the conclusion of the voice quality tests:

- The phone number of the DECT phones was dialled using a fixed telephone connected to the PSTN line located outside the, 10 standard utterances spoken by a US male speaker [11] were repeatedly played 25 times to a land phone located outside the chamber. DECT systems with 6 phones located.
- Voice quality was marked for each of the utterance based on 1 to 5 scale (1 = Excellent, 5 = Bad) with:
    - LTE HeNB “on” and “off”

- GSM picocell “on” and “off”
- **Results:**
  - Overall voice quality of the system was average.
  - No noticeable differences were found among these 4 settings i.e. LTE HeNB “on” and “off” and GSM picocell “on” and “off”
  - 98% of the samples were marked as 3: Fair and the remaining 2% was marked as 2: Good.
- **Conclusion:** Interference from LTE Home eNodeB does not cause voice quality deterioration of the DECT system, any worse than the GSM picocell.

4.4 Baby monitor interference test

Baby monitors use DECT technology to transfer messages between the two baby monitor units. The purpose of this test was to test if there is any noticeable impact on the baby monitor, when the LTE Home eNodeB is switched on.

We used the test set up explained in section 3.3 for the tests conducted using the baby monitor. The baby monitor units were plugged and switched on while LTE Home eNodeB was in the active mode i.e. engaged in an FTP session. Following this, the noise made at the transmitter unit was observed from the baby monitor receiver unit. A similar test was conducted with an active voice call in the GSM picocell to use a baseline comparison.

We observed that there was no noticeable difference in the sound heard from the baby monitor receiver when LTE Home eNodeB is “on” compared to the sound heard from the baby monitor receiver unit when the LTE Home eNodeB is “off”. Similar observation was found with the GSM picocell.

Therefore we conclude that the Interference from LTE HeNB does not make the performance of the baby monitor any worse than the GSM picocell.

5. Summary

In summary we conducted measurements on the spectrum characteristics of an LTE Home eNodeB operating in the DECT Guard bands and the carried out tests to investigate the potential interference effects into DECT system operating in the adjacent band. In this report we explained the approach and the measurement results of the laboratory tests conducted by Real Wireless in the anechoic chamber laboratory at University of Surrey.

Our observations are as follows:

- The spectrum emission measurements show that:
  - the spectrum emissions from the tested eNodeBs from Arcadyan and Huawei meets the proposed licensing conditions but not fully comply with the existing licensing conditions.
- Interference from an Arcadyan LTE Home eNodeB (femtocell) does not:
  - cause voice quality deterioration of the DECT cordless phone system, below that experienced with the GSM picocell.
  - cause dropped calls in the DECT system, beyond those experienced with the GSM picocell.
  - make the performance of the baby monitor any worse than the GSM picocell

These findings support the case for a licence variation, which would allow the use of standard 3GPP-compliant devices without causing harmful interference to adjacent systems.

6. Annex A: Directional coupler specifications

This section provides the product specifications and the coupler loss measurements of the directional coupler used in during the tests.

6.1 Product specification

Product specifications for the directional coupler is show in Table 12 [8].

Parameter	Value
Frequency Range GHz	1 - 12.4
Nominal Coupling (±.5 dB)	20
Coupling Variation (± dB)	0.75
Directivity (dB Min.)	12
VSWR Main (Max.)	1.25:1
VSWR Out (Max.)	1.30:1
Insertion Loss (dB Max.)	1
Power Incident Avg. (Watts)	50
Power Reflected Avg. (Watts)	50
Power Peak (kW)	3

Table 12: Parameters of the directional coupler

6.2 Coupler loss measurements

The directional coupler loss measured the various frequencies is shown in Table 13. These measurements were conducted by the researchers at the University of Surrey on the 9th of January 2015. From these values, the coupler loss at the centre frequency of the TalkTalk band i.e. 1878.35 MHz was deduced to be -20.4634 dB.

Freq in MHz	s31 (coupling) in dB
1854	-20.4808
1858.25	-20.4468
1862.5	-20.3092
1866.75	-20.4603
1871	-20.4339
1875.25	-20.3978
1879.5	-20.4789
1883.75	-20.4452
1888	-20.5321
1892.25	-20.4962
1896.5	-20.4771
1900.75	-20.5725

Table 13: The directional coupler loss measured at different frequencies

Figure 28 shows the coupling and insertion loss measurements suing the directional coupler used for the tests. The s21 is the insertion loss, this is how much loss there will be on the signal when it is transmitted from the eNodeB or picocell. The measured insertion loss is less than 2dB. s31 is the amount of coupling. This is reasonably constant for the band of interest in this test. We used these values to correct against the signal we measured for calibration purposes.

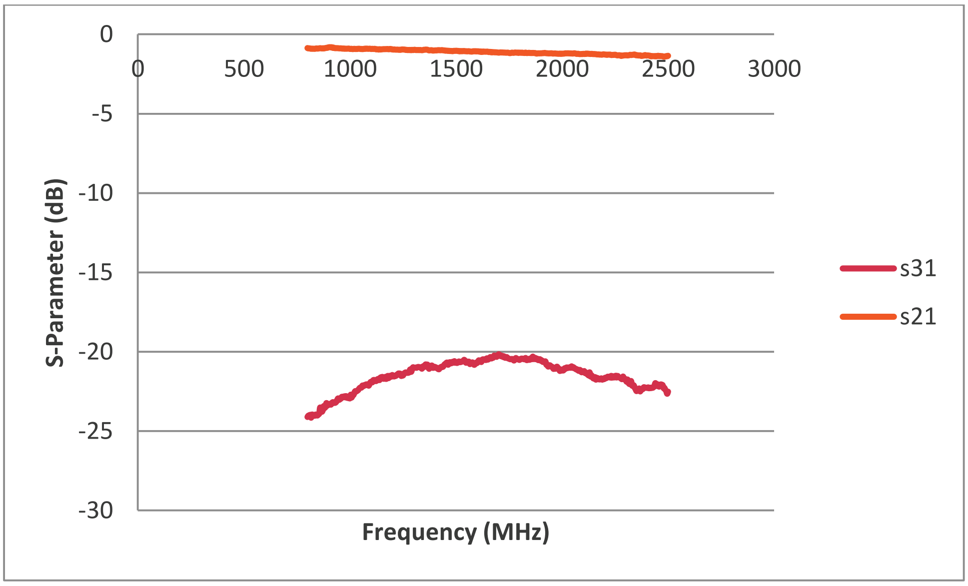


Figure 28: Coupling loss measurements

7. Annex B: Frequency band information

7.1 Radio channel assignments for GSM technology

The Radio channel assignments for GSM technology are shown in Table 14 [14].

Uplink (MHz)	Downlink (MHz)	Mobile200 CN	ARFCN	Permitted Classes	Preferred CNs for each Class
1781.8	1876.8	1	870	A	A
1782.0	1877.0	2	871	A,C,D,U	
1782.2	1877.2	3	872	A,C,D,U	
1782.4	1877.4	4	873	C,D,U	C,D,U
1782.6	1877.6	5	874	C,D,U	C,D,U
1782.8	1877.8	6	875	C,D,U	C,D,U
1783.0	1878.0	7	876	C,D,U	C,D,U
1783.2	1878.2	8	877	C,D,U	C,D,U
1783.4	1878.4	9	878	C,D,U	C,D,U
1783.6	1878.6	10	879	C,D,U	C,D,U
1783.8	1878.8	11	880	C,D,U	C,D,U
1784.0	1879.0	12	881	C,D,U	C,D,U
1784.2	1879.2	13	882	C,D,U	C,D,U
1784.4	1879.4	14	883	A,C,D,U	
1784.6	1879.6	15	884	A,C,D,U	
1784.8	1879.8	16	885	A	A

Table 14: Radio channel assignments for GSM technology

7.2 Classes of GSM antennas

Classes of GSM antennas are shown in Table 15 [14].

Class	Maximum Permitted Power Level (dBm)	Registered in Coordination Database	Static Frequency Allocation	Permitted Mobile200 CNs	Preferred Mobile200 CNs
A	3	No	Not mandated	1 to 3 & 14 to 16	1 & 16
B	Reserved for possible future applications				
C	23	Yes	Yes	2 to 15	4 to 13
D	30	Yes	Yes	2 to 15	4 to 13
U	23	No	Yes	2 to 15	4 to 13

Table 15: Classes of GSM antennas

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