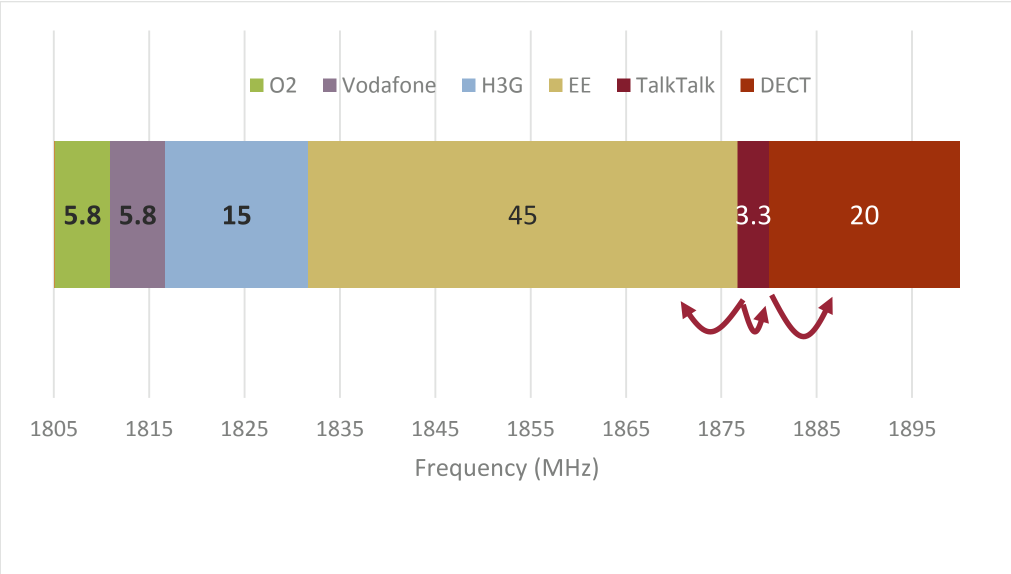
Out of Band Emissions in the DECT Guard band

A study for TalkTalk



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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.

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1. Introduction

This technical study has been commissioned by TalkTalk from Real Wireless to investigate the potential impact of deploying LTE in the frequency bands 1781.7-1785 MHz paired with 1876.7-1880 MHz.

In November 2005, Ofcom recommended [1] that the frequency bands 1781.7-1785 MHz paired with 1876.7-1880 MHz (the DECT Guard band) 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.

This decision took into consideration responses from a consultation and a technical analysis on the interference that would be caused to adjacent bands by allowing operation in these bands [2]. This technical analysis determined that it was possible to deploy "both narrowband (e.g. low power GSM) and wideband (e.g. low power cdma2000x1)" systems, but noted that in-band sharing would likely need co-ordination between the shared users of the band. Protection of adjacent bands required a power limit which was modified to a power spectral density to facilitate more flexible use of the spectrum.

Since 2005, mobile technology has evolved from 2G to advanced 4G systems, with typical expected spectral efficiencies in an urban environment rising from 0.04bps/Hz for GSM to 1.3 for LTE R8 and 2.6 for LTE R10 [3], and vastly improved ability to support high rate data services expected by consumers. Despite having slightly higher Out of Band emissions than legacy technology, the advantages of using more advanced technology in 1800 MHz spectrum was recognised by Ofcom [4] when in 2012 they granted EE's request to vary their licence in order to be able to additionally deploy other technologies in their 1800 MHz spectrum. In March of this year Ofcom initiated a consultation on relaxing these licence conditions further [5] in order to increase the maximum EIRP that can be used by MNOs by 3dB. Although this increased maximum EIRP may cause some additional interference to neighbouring uses such as DECT, or concurrent shared users, Ofcom indicate in the consultation document that they are of the view that the advantages would more than offset any negative impact of additional interference.

TalkTalk have a licence to operate [6] 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 E-UTRA (commonly referred to as LTE) band 3 [7], and represents spectrum that has equipment readily available for use in this band.

This report seeks to identify what interference impact may be caused by modifying the existing licence emission mask in order to permit equipment complying with the 3GPP LTE standards to be deployed in the CSA band. Though not directly related to the current Ofcom consultation on relaxing the maximum EIRP that can be used by existing MNOs in their 1800 MHz band, any future licence variation of the low power shared band relates to changes in the licence conditions to the band covered by E-UTRA band 3, and could be considered jointly by Ofcom.

This report is structured as follows:

- Section 2 identifies the spectrum under consideration, the existing licence limits and a proposed licence limit that could allow standard LTE equipment to be used.
- Section 3 identifies components that contribute to adjacent channel interference

- Section 4 identifies the scenarios for interference analysis and suitable parameters to calculate interference
- Section 5 presents the results of the interference assessment
- Section 6 identifies that changes that would be required to the existing licence to support the proposed licence limit in a form that may be used to seek any future licence variation.

2. Use of the CSA band

Following recommendations in Ofcom's 2005 Spectrum Framework Review: Implementation Plan [8] and the dedicated consultation [1], Ofcom released the spectrum 1781.7-1785 MHz paired with 1876.7-1880 MHz for concurrent use by low powered devices to 12 licensees.

This spectrum occupies the upper 3.3 MHz of spectrum in the paired 1800 MHz mobile band (E-UTRA band 3). At the time of spectrum release the most likely technologies that would be deployed in such a small amount of spectrum were considered to be GSM or CDMA2000 1x. Primarily based on these technologies, Ofcom undertook technical analysis of the utility of this spectrum for a range of scenarios, and established that co-ordination would, in general, be required between users of the CSA band to reduce the impact of interference. Instead of setting a maximum EIRP, Ofcom set a maximum power spectral density to facilitate flexible use of the spectrum (the limits set are 0 dBm/kHz, though a higher level of 7 dBm/kHz can be used in agreed circumstances).

2.1 Existing licence limits

In order to facilitate technology neutral licences, Ofcom defined the Out of Band limits for use in this band using a radiated power spectral density rather than a maximum EIRP. The value of the peak power spectral density is consistent with a GSM picocell radiating 23 dBm EIRP in a channel bandwidth of 200 kHz.

The existing in-band and out of band licence limits [6] for the base station transmit band are as shown in Table 1. These limits are the same as the licence limit definition, but are presented here in one table to simplify the presentation.

Table 1: The existing licence limits for the downlink frequency band 1876.7-1880 MHz, for both in-band and out-of-band emission limits.

Δf - frequency offset from lower band edge (MHz)	Maximum EIRP power spectral density (dBm/kHz) (two values are given for in-band psd – the higher only to be used with agreement and in exceptional conditions)	
-5.7 to -1.5	-74	
-1.5 to -0.9	-56	
-0.9 to -0.3	-53	
-0.3 to -0.1	$-49 + 20*(\Delta f + 0.1)$	
-0.1 to 0	$-33.6 + 153.3 * \Delta f$	
0 to 0.05	$-33 + 153.3 * \Delta f$	$-33 + 153.3 * \Delta f$
0.05 to 0.1	$-26 + 60*(\Delta f – 0.05)$	$-26 + 60*(\Delta f – 0.05)$
0.1 to 0.2	$-23 + 230*(\Delta f – 0.1)$	$-23 + 300*(\Delta f – 0.1)$
0.2 to 3.2	0	7

Δf - frequency offset from lower band edge (MHz)	Maximum EIRP power spectral density (dBm/kHz) (two values are given for in-band psd – the higher only to be used with agreement and in exceptional conditions)	
3.2 to 3.3	-23 + 230*(3.3 - Δf)	-23+300*(3.3 - Δf)
3.3 to 3.35	-23 – 60*(Δf – 3.3)	
3.35 to 3.5	-26 – 153.3*(Δf – 0.05 – 3.3)	
3.5 to 3.7	-49 – 20*(Δf – 0.2 – 3.3)	
3.7 to 4.3	-53	
4.3 to 4.9	-56	
4.9 to 9.1	-74	

The frequency bands 1781.7-1785 MHz paired with 1876.7-1880 MHz and the adjacent frequency bands and their uses are shown in Figure 1.

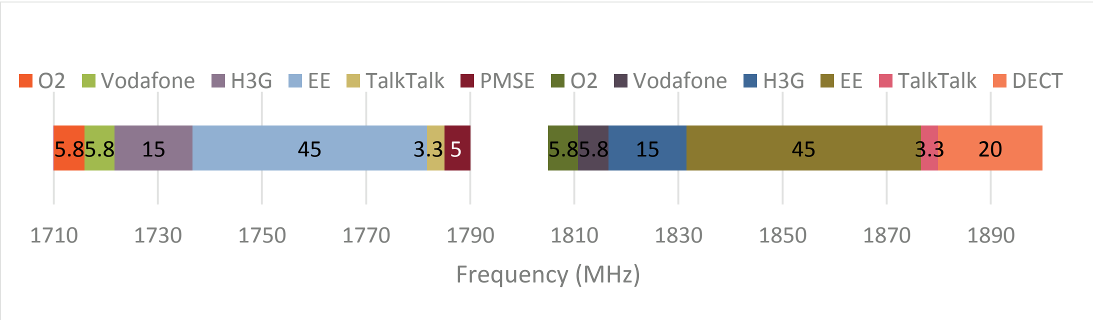

Figure 1: Uplink (left) and downlink (right) spectrum showing the TalkTalk (CSA) spectrum in the context of the surrounding assignments (the bandwidths of the different assignments are given in MHz).

As can be seen the neighbours in the uplink are mobile uplink and PMSE in the uplink band and mobile downlink and DECT TDD in the downlink band. The CSA spectrum is the uppermost 3.3 MHz of the 2x75 MHz harmonised mobile E-UTRA band 3; the remaining spectrum is assigned to the mobile network operators as shown, with a 0.1 MHz guard band at the bottom edge.

This 1800 MHz mobile spectrum has been subject to previous changes in licence conditions. EE's request to allow use of LTE and WiMAX technologies was granted after an Ofcom consultation [4]. A February 2013 consultation [9] on the liberalisation of mobile spectrum in the 900 MHz, 1800 MHz and 2100 MHz frequency bands relaxed the limits to allow all the mobile operators to deploy 4G technology in these 3 bands, and to allow an increase in the maximum base station EIRP by 3 dB for UMTS and 4G (wideband) technologies. Ofcom are currently consulting [5] on whether this relaxation of the maximum base station EIRP by 3dB should be permitted in the 1800 MHz mobile band below the CSA spectrum.

EE has been allowed to modify its ‘GSM-1800’ licence in order to be able to support LTE since Ofcom considered that this would benefit consumers (“it would further their interests by, for example, encouraging innovation, investment, and the availability and use of high speed data transfer services throughout the UK; and improve choice, price, quality of service and value for money”). Ofcom also considered the impact of any potential interference in migrating from using GSM to LTE and concluded “it is not necessary to impose any additional technical licence conditions on Everything Everywhere in order to address coexistence with those adjacent users considered by the CEPT”.

Real Wireless has previously conducted a study for Ofcom which identified spectrum efficiency benefits from LTE compared to legacy communications technologies [3]. Though the precise spectrum efficiencies achievable are influenced by the traffic mix and the environment, typical urban spectrum efficiencies quoted range from 0.04 bps/Hz for GSM to 1.3 for LTE R8 and 2.6 for LTE R10. The data rates achievable for an indoor LTE cell could easily exceed these values. Improved performance coupled with the increased range of services that can be supported, motivates the use of using LTE rather than the existing use of GSM in the concurrent spectrum access band.

LTE channels have greater bandwidths than the 200 kHz GSM carriers anticipated for use in the CSA band at the time of licence issue. This increased bandwidth makes it more difficult to achieve the rapid filtering roll-off at the transmitter. Indeed, the LTE specification has an increased Out of Band emission limit compared to legacy systems. This limit sets a threshold and any emissions must be less than this limit across a wide range of frequencies – typically any one transmitter has emissions (significantly) below this upper limit across the majority of the band specified. Hence we should expect leakage to be significantly less than the threshold defining the worst acceptable limit across the defined out of band emission range. Nonetheless, it is likely that LTE will have increased Out of Band emissions compared to GSM – the purpose of this report is to assess if any additional out of band limit in adopting the LTE specification compared to the existing licence limits will have a material impact on neighbouring spectrum users.

2.2 Existing licence limits compared with LTE specifications

The existing licence limits for the CSA band are defined in Table 1. The LTE base station minimum performance requirements for unwanted emission limits are defined in section 6.6 of [7], for a set of different types of base stations and channel bandwidths. The in-band and out of band emission limits for a 3 MHz carrier 34 dBm medium range base station and 24 dBm local area base station are shown in Figure 2.

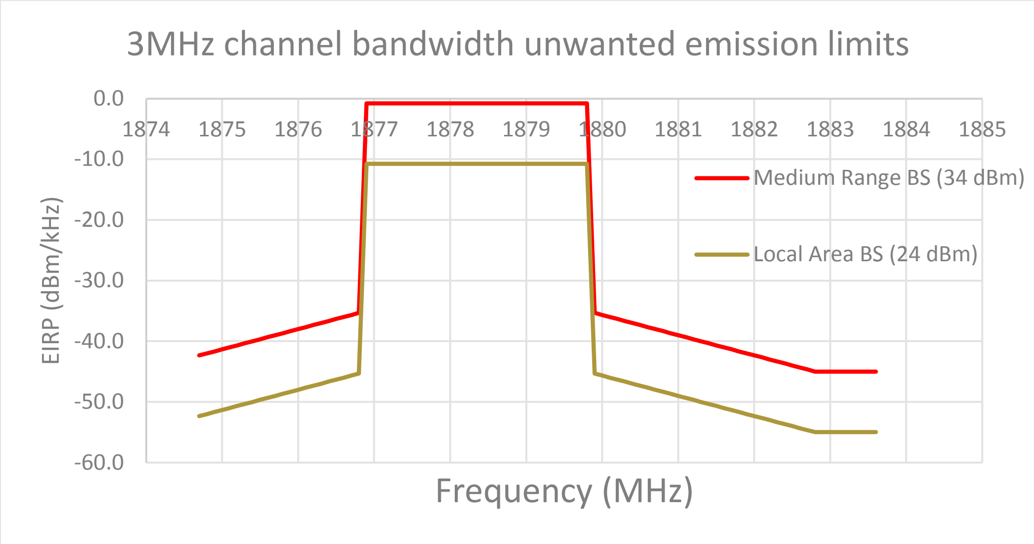

Figure 2: In-band and Out-of-band emission limits for 2 different powered base station classes with 3 MHz bandwidth carriers as defined in 3GPP specifications

The precise shape will depend upon the in-band EIRP used (the above are typical powers for each class of base station). For these typical powers, the out of band emission limit is approximately 35 dB less than the carrier power spectral density, reducing to 45 dBc more than 3 MHz away from the channel edge (the baseline level).

LTE chipset manufacturers will design equipment to achieve performance that can exceed the minimum performance requirements at all frequencies. In practice the emissions are likely to be below the minimum requirements at most frequencies and will roll-off away from the in-band channel. Setting requirements tighter than the existing LTE specifications could result in non-standard equipment needing to be deployed and would be likely to increase equipment costs and reduce supplier choice. Consistent with a CEPT report [10], Ofcom's March 2014 consultation [5] "considered the natural/realistic decay of OOB emission" and simulated lower OOB emissions than defined in the 3GPP specifications more than 4 MHz away from the in-band channel[1]. However, any one manufacturer may emit at a level up to the specification at any particular frequency and still conform to the specification even though the aggregate OOB will be lower than the limit defined by the specification. Hence, though the 3GPP specification is likely to reflect pessimistic performance for any given device, setting more conservative limits would be likely to reduce equipment choice.

It is therefore of interest to assess what the interference would be for a device whose performance is consistent with the 3GPP LTE local area base station limits and the existing licence limits (whichever is the least restrictive). These limits are shown in Figure 3 and Table 2 (which is in the same format used for Table 1).

[1] Ofcom used the values recommended in a CEPT report [10] for LTE macrocells with a OOB emission that rolls off at approximately 2.66 dB/MHz more than 4 MHz away from the in-band channel, rather than the baseline value defined in the 3GPP specifications.

Table 2: Proposed licence limits – least restrictive combination of existing licence limits and 3GPP requirements for a local area base station.

Range of frequency offset from lower band edge (MHz)	Maximum EIRP density (dBm/kHz)	
-6.2 to -3.2	-55	
-3.2 to 0	-45 + 10*(Δf-0.2)/3	
0 to 0.05	-33 + 140*Δf	-33 + 140*Δf
0.05 to 0.1	-26 + 60*(Δf – 0.05)	-26 + 60*(Δf – 0.05)
0.1 to 0.2	-23 + 230*(Δf – 0.1)	-23 + 300*(Δf – 0.1)
0.2 to 3.2	0	7
3.2 to 3.3	-23 + 230*(3.3 - Δf)	-23+300*(3.3 - Δf)
3.3 to 3.35	-23 – 60*(Δf – 3.3)	
3.35 to 3.4	-26 – 153.3*(Δf – 0.05 – 3.3)	
3.4 to 6.1	-45 – 10* (Δf – 3.1)/3	
6.1 to 9.1	-55	

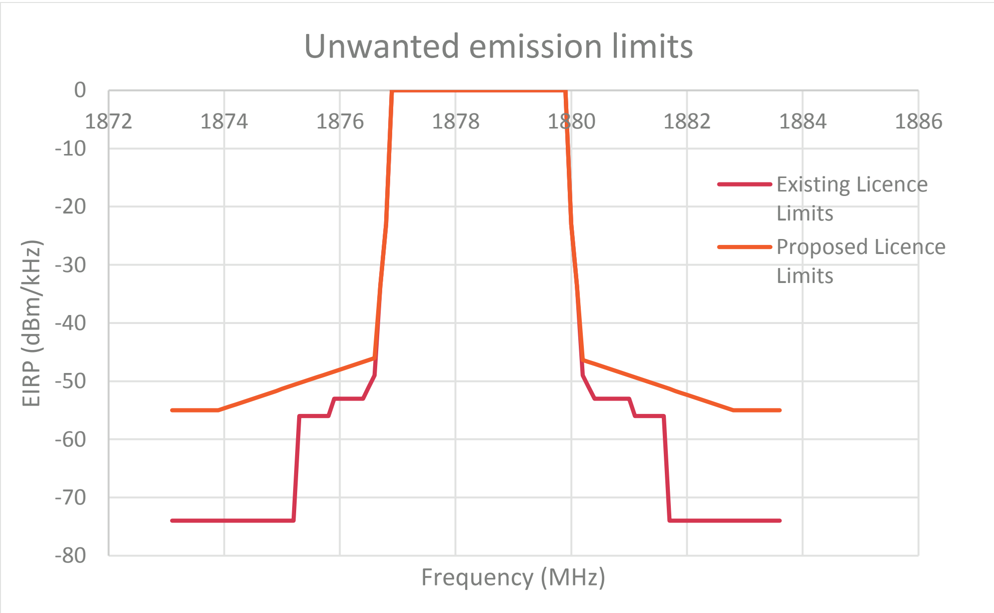

Figure 3: Proposed and existing licence limits defining the maximum in-band and out-of-band EIRP power spectral densities.

From inspection, the out of band emission of the proposed licence limits is at least 45 dB below the in-band EIRP power spectral density from the edge of the defined 3.3 MHz band edge which is normally considered an acceptable ACLR within the CEPT for co-existence studies [11] and so the interference caused by the Out of Band emissions are likely to be ‘low’. The remainder of this report will determine the additional interference owing to the increased out of band emissions (proposed versus existing).

3. Adjacent channel interference (ACI) components

The interference caused by adjacent channels is composed of two key components:

- Inband power selected: This is the interference power selected owing to imperfections in the victim receiver filter front end:
    - A proportion (the ACS, in dB) of the aggressor channel power in frequencies outside of the victim channel is incorporated into the receiver as interference noise
- Power leakage: This is the interference power leaked owing to imperfections in the aggressor transmit output stage into the victim channel:
    - A proportion (the ACLR, in dB) of the power from the aggressor outside of designated transmit channel leaks into the victim band (and cannot be filtered out)

These two components and the ACS and ACLR are shown in Figure 4.

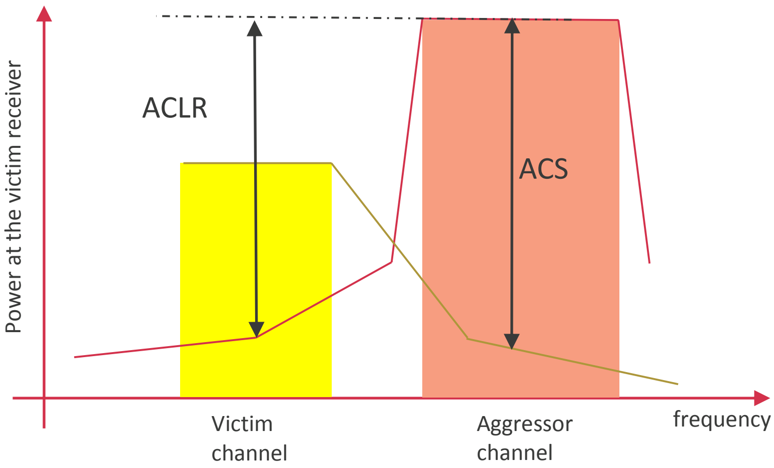

Figure 4: Interference components resulting from imperfections in victim receiver and aggressor out of band emissions

These two contributions add together to form the ACI. The lower of the two values (ACLR and ACS), dominates the combined contribution to the ACI. This ACI adds to the other noise in the receiver (thermal noise and own system interference) to make up the total noise in the receiver. One possible criterion for limiting the ACI is in terms of the noise rise it creates in the receiver – for example the ACI could be required to add less than ~X dB to the noise in the receiver and a distance Y metres, where X and Y depend upon the operating environment.

4. Scenarios and parameters for analysis

Based on the existing use of the adjacent spectrum we can identify the following key interference interactions of interest:

1. TalkTalk HeNB transmit into EE mobile receivers
2. TalkTalk HeNB transmit into DECT receivers
3. TalkTalk HeNB transmit into mobile receivers of other low-power licensees
4. TalkTalk mobile transmit into EE base station receive
5. TalkTalk mobile transmit into PMSE receivers

The first three result from interference from the base station into victim devices using the CSA spectrum; the last two result from interference from the mobile device into victim receivers.

The interference owing to uplink transmissions from standard 23 dBm LTE mobiles is not examined further here since the uplink interference is unlikely to be problematic. Whilst the aggregate interference level and probability of interference could increase with greater bandwidths and more widespread use, these are consistent with the existing licence conditions.

The first three interactions that should be considered in more detail are:

- TalkTalk base station to EE mobile
    - EE could deploy either GSM or LTE handsets in the band adjacent to the CSA spectrum
- TalkTalk base station to DECT (TDD) receivers
    - DECT receivers could be either the portable part of the fixed part. The performance of these are similar – but the fixed part could be using more simultaneous channels.
- TalkTalk base station to other in-band users sharing the CSA spectrum.

We can represent the interference cases as shown in Table 3. The CSA equipment will be a low power device and will primarily be used indoors. In these circumstances interference to devices within the home will be under the control of the CSA device owner, and mitigation actions such as maintaining a reasonable separation between aggressor and potential victim receivers should be possible.

In addition victim GSM systems (such as at the top of the spectrum used by EE in the UK) will be able to reduce the impact of interference to any one GSM channel by use of frequency hopping over a large number of channels.

Similarly, DECT systems can mitigate the impact of interference by using Dynamic Channel Selection (DCS) [12]. All DECT equipment scans the local radio environment at least every 30 seconds to select a channel and time slot to avoid interference.

Table 3: Potential aggressor system and victim receiver cases

Aggressor system	Tx conforming to existing licence limits	Tx conforming to proposed licence limits		
Victim system	EE using GSM (which can use channel hopping to avoid interference)	EE using LTE (2x10, 2x15, 2x20 MHz).	DECT (which can use DCS to avoid interfered DECT carriers)	Other inband systems (using GSM or LTE)
Victim receiver equipment type	UE /MS (LTE/GSM)	FP / PP (DECT)		
Victim receiver position (with respect to desired signal)	Edge of cell (with associated SINR target)	Median cell location (with associated SINR target)		
Victim receiver position (with respect to aggressor)	Indoor – close to HeNB	Indoor – randomly positioned	Outdoors walking past house	

In-band systems using the CSA spectrum are likely to use GSM and users of this band have a responsibility to co-ordinate their use in order to avoid interference, and will not be considered further.

In this case the interference cases of interest are to assess any interference increase when using the existing and proposed licence limits with victim receivers being GSM mobile devices, LTE mobile devices or DECT devices (FP or PP). The interesting coupling losses will be devices reasonably close (in the same building) as the aggressor base station (in which case mitigating action is under the control of the device owner) or a victim walking past the building hosting the interfering base station.

4.1 Parameters for use in the simulations

4.1.1 Aggressor EIRP and Out of Band Limits

The aggressor out of band limits will be assumed to conform to the existing and proposed licence limits defined in Table 1 and Table 2 respectively. The maximum transmit power is 35.19 dBm (which is equivalent to the maximum power spectral density of 0 dBm / kHz across a 3.3 MHz bandwidth). The licence does not allow this peak psd to be used close to the channel edge, but for simplicity, we can use this value of 35.19 dBm in the analysis.

4.1.2 Victim LTE UE parameters

The LTE UE parameters shown in Table 4 are typical and will be used. It can be seen that he highest performing ACS is 33 dB for a 10 MHz (or smaller) carrier. Using this value will maximise the negative impact of any interference from out of band and hence we will use an assumed victim bandwidth of 10 MHz to consider a ‘worst case’.

Table 4: LTE UE parameters

Parameter	Value	Units	Source
Antenna gain	0	dBi	3GPP TS36.101 – S6.1 [13]
ACS	33 (BW<=10 MHz) 30 (BW=15 MHz) 27 (BW=20 MHz)	dB	3GPP TS36.101 - Table 7.5.1-1 [13]
Noise Figure	9	dB	3GPP Report R4-092042 [14]

4.1.3 Victim GSM MS parameters

The GSM MS parameters shown in Table 5 are typical and will be used. The ACS varies according to the proximity to the aggressor and for channel offsets more than 1 channel are significantly better than the LTE ACS values shown in Table 4.

Table 5: GSM MS parameters

Parameter	Value	Units	Source
Receiver bandwidth	200	kHz	3GPP TS45.005, Section 2 [15]
Antenna gain / other losses	N/A	dBi	Use different coupling losses. Comparison is between the different OoB emission limits
Reference sensitivity	-102 (and a 8 dB noise figure)	dBm	Table 6.2-1a from 3GPP TS45.005 (above) and3GPP TR45.050 for NF [16]

Parameter	Value	Units	Source
ACS	18 dB, 1st adjacent GSM channel 50 dB, 2nd adjacent GSM channel 58 dB, 3rd adjacent GSM channel 58.7 dB, 4th to 8th GSM adjacent channel 68.7 dB, 9th to 15th GSM adjacent channel 75.7 dB, over 16th adjacent GSM channel	dB	Annex 3 and table 88 from [17]

4.1.4 DECT receiver parameters

The DECT system is a TDD system with similar receiver performance at both the fixed part and portable part of the link. DECT parameters are given in and shown in Table 6.

Table 6: DECT receiver parameters

Parameter	Value	Units	Source
Noise figure	10	dB	[18]
Receiver bandwidth	1.152	MHz	As above
Carrier Separation	1.728	MHz	As above

From [18], the ACS for different channel offsets of DECT systems is as shown in Table 7Table 7, and the DECT carrier, k, is centred on frequency F_k = 1897.344 - K*1.728 MHz.

Table 7: DECT ACS attributes as a function of DECT channel separation

DECT Channel separation (in 1.728 MHz channels)	ACS (dB)
1st adjacent	24
2nd adjacent	45
3rd adjacent	51
4th adjacent	55
5th adjacent or further	58

Hence the closest DECT carrier is separated from an LTE carrier in the CSA spectrum by 1.96 DECT carriers. For the purposes of deriving suitable ACS parameters for the different DECT carriers, we will approximate this minimum separation as 2 DECT carriers, meaning that the ACS parameters are 45 dB or better, depending upon the DECT carrier being considered.

4.1.5 Coupling losses

In this study we are interested in the impact of a change in the emissions complying with the existing licence limits to the proposed licence limits – and so the coupling loss values are unlikely to be critical. However small values of coupling loss will maximise the impact of the ACI compared to other noise contributions in the receiver, such as thermal or victim intra-system noise.

Indoors, locating the victim in the same desk as the aggressor is possible. At 1800 MHz a free space loss distance of 1.3m corresponds to a coupling loss of 40 dB, and 13m to a loss of 60 dB.

An interesting case is of someone walking past a building which hosts an indoor aggressor base station. The propagation path is depicted in Figure 5. Assuming that the victim is 'close' to the aggressor we can assume a total separation distance of 7.5m (3m to the cavity wall and 4m to the victim outside). In Ofcom's previous technical analysis of interference in the CSA spectrum [2] a value of 13 dB was used for the building penetration loss (BPL) of a cavity wall. Combining ITU-R P.1238-3 for a distance of 7.5m with the 13 dB BPL gives a path loss of 75 dB neglecting any additional fading or body loss.

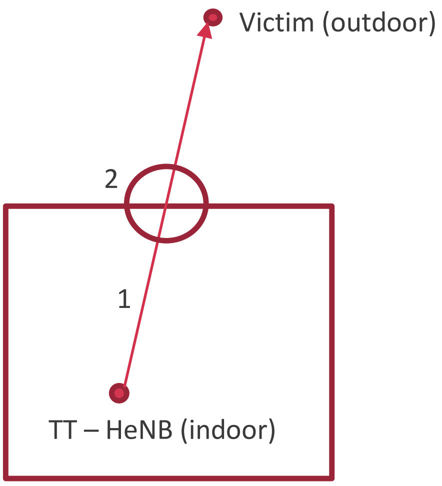

Figure 5: Example geometry of a victim walking past a house hosting the aggressor base station.

We will therefore assess the interference impact over a range of coupling losses from 40 dB to 95 dB.

5. Interference assessment

5.1 Interference Impact on LTE

The in-band power selected and power leakage ACI components per LTE resource block in a victim LTE receiver with a coupling loss of 95 dB as a function of the frequency offset is shown in Figure 6. The ACI is dominated by the ACS and the in-band power selected is 14-24 dB more than the ACI due to Out of Band emissions. Figure 7 shows the results for a coupling loss of 40 dB, demonstrating that the noise contributions increase, but their relative strength is insensitive to the value of the coupling loss used.

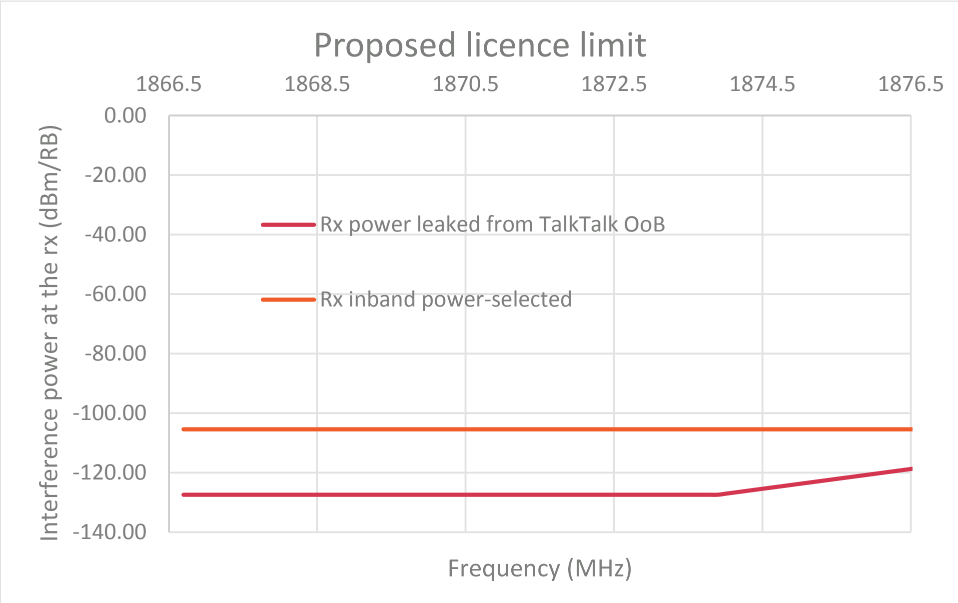

Figure 6: LTE - ACI interference components for the proposed licence limit with a coupling loss of 95 dB.

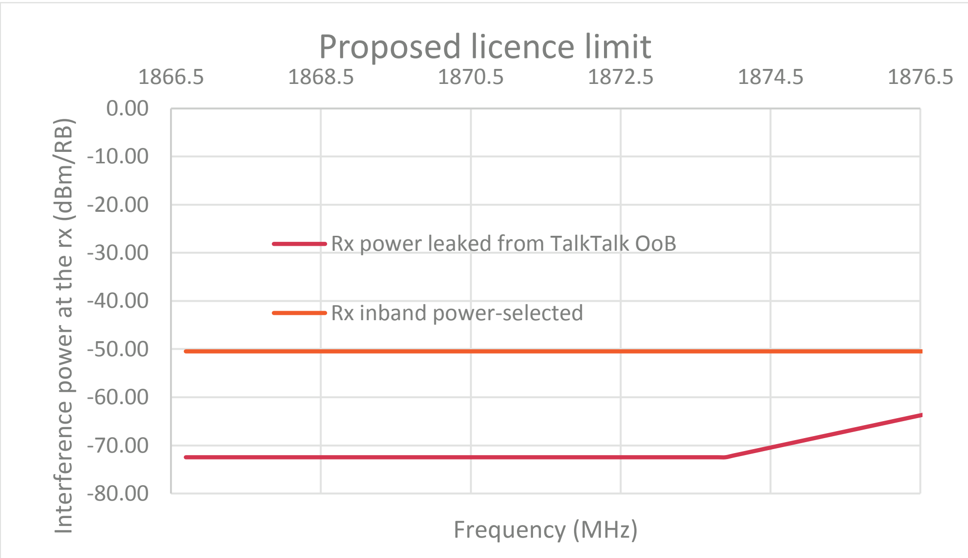

Figure 7: LTE - ACI interference components for the proposed licence limit with a coupling loss of 40 dB

In Figure 8, the noise floor per resource block is calculated in three different cases:

- The black line shows the total noise floor when the noise power and the cochannel interference are taken into consideration.
- The orange and green lines show the total noise floor when the noise power and all interference components (including ACI) are taken into consideration for proposed and existing licence limit, respectively.

We conclude from the figure that the licence limit case performance is very close to the proposed licence limit. The difference between the existing and proposed limits is less than 0.09 dB for MCL of 95 dB. Hence, although he proposed licence limits has higher OOB emissions than the existing licence limit, these have a negligible impact on the ACI of an LTE victim, since the ACI is dominated by the LTE receiver ACS.

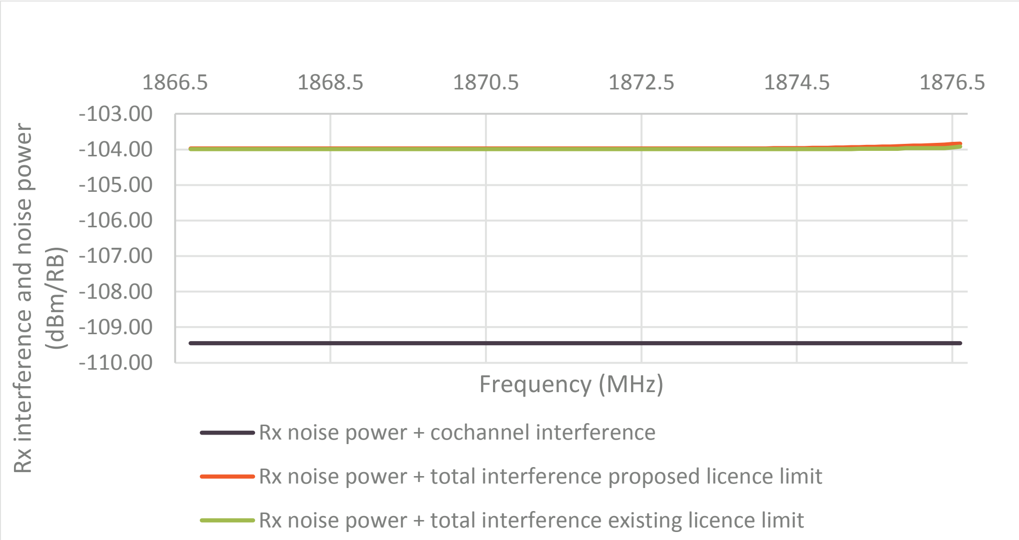

Figure 8: LTE - Noise power and ACI components per LTE resource block for a coupling loss of 95 dB (note that the proposed and existing licence limits lie on top of each other over most of the range)

When LTE is the adjacent victim, the interference caused can be summarised as:

- The ACI is dominated by the ACS of the victim's receiver, since LTE ACS is less than the ACLR corresponding to the proposed licence limits, the increased OOB emission limits of the proposed licence have little impact.
- Changing from existing to proposed limits increases the ACI by small fractions of a dB, e.g. ranging from 0.02 dB to 0.09 dB depending on the proximity to the band edge.
- The difference between existing and proposed limits is insensitive to the coupling loss values assumed.

5.2 Interference Impact on GSM

EE could use GSM in their spectrum adjacent to the CSA band. For the purposes of understanding the impact on different GSM channels as the frequency gap between the GSM carriers and the CSA band increases, we have defined channel numbers as shown in Figure 9. The GSM channel number 1 is the closest to the edge of LTE TalkTalk licensed band. In this case, the bandwidth separating the centre of the closest channel and the LTE lower channel edge is 100 kHz, i.e. there is no guard gap between the edge of channel 1 and the edge of the 3.3 MHz CSA band.

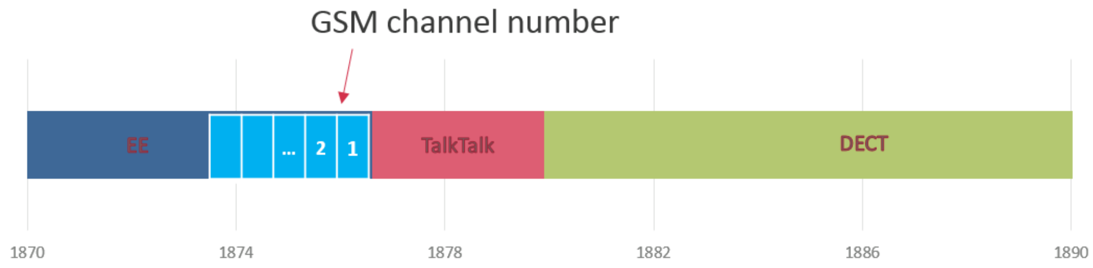

Figure 9: GSM channel number convention used to display the results

Figure 10 shows the ACI components with a MCL or 95 dB. It is clear that the ACS dominates the ACI for channel #1, but the OoB emissions dominate for higher GSM channels.

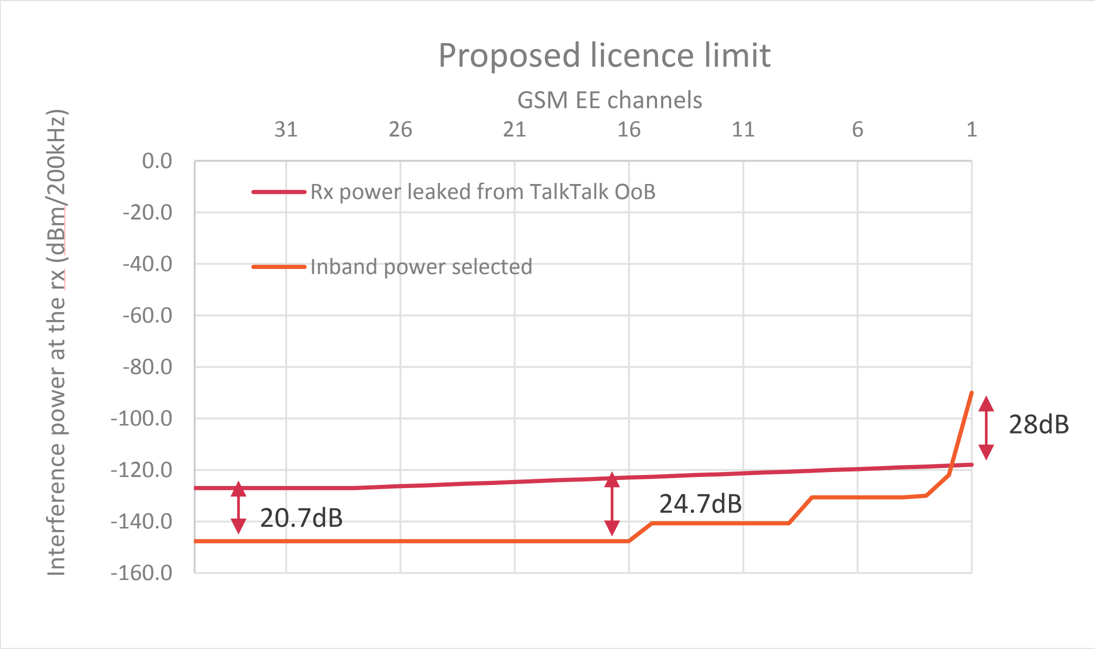

Figure 10: GSM - ACI interference components per GSM channel for the proposed licence limit with a coupling loss of 95 dB

These results are insensitive to coupling loss values used as illustrated in Figure 11 where a coupling loss of 40 dB was used, though the absolute power in the victim receiver changes.

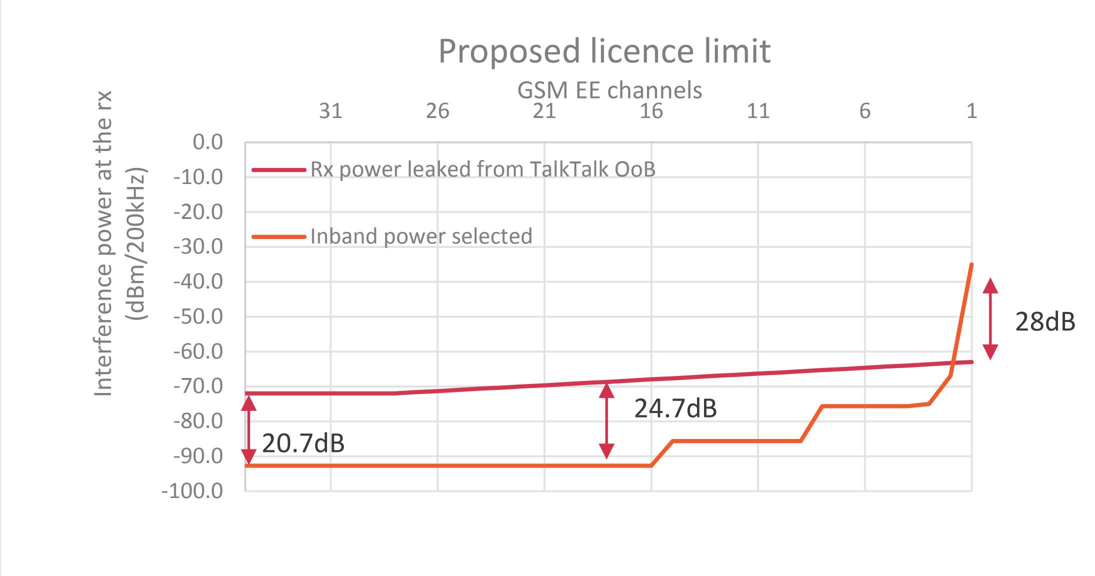

Figure 11: GSM - ACI interference components per GSM channel for the proposed licence limit with a coupling loss of 40 dB

Figure 12 shows these ACI components in the context of the receiver noise floor for a Coupling Loss of 95 dB. The noise floor/GSM channel is calculated in three different cases:

- The black line shows the total noise floor when the noise power and the co-channel interference are taken into consideration.
- The orange and green lines show the total noise floor when the noise power and total interferences are taken into consideration for proposed and existing licence limit, respectively.

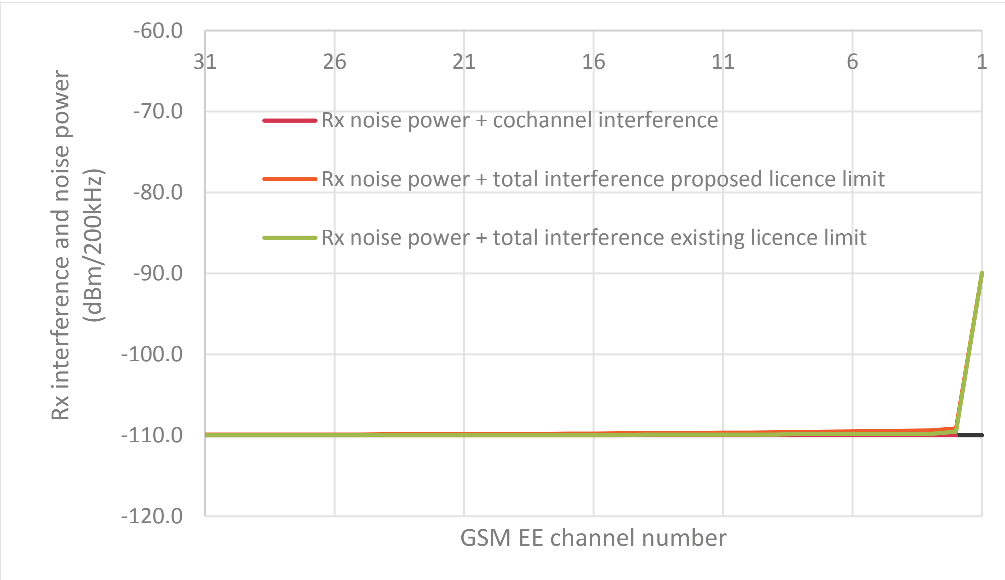

Figure 12: GSM - Noise power and ACI components per GSM channel for a coupling loss of 95 dB (note that the curves lie on top of each other over most of the range)

For a coupling loss of 95 dB, the difference between ACI components for the existing and proposed licence limits is less than 0.3 dB.

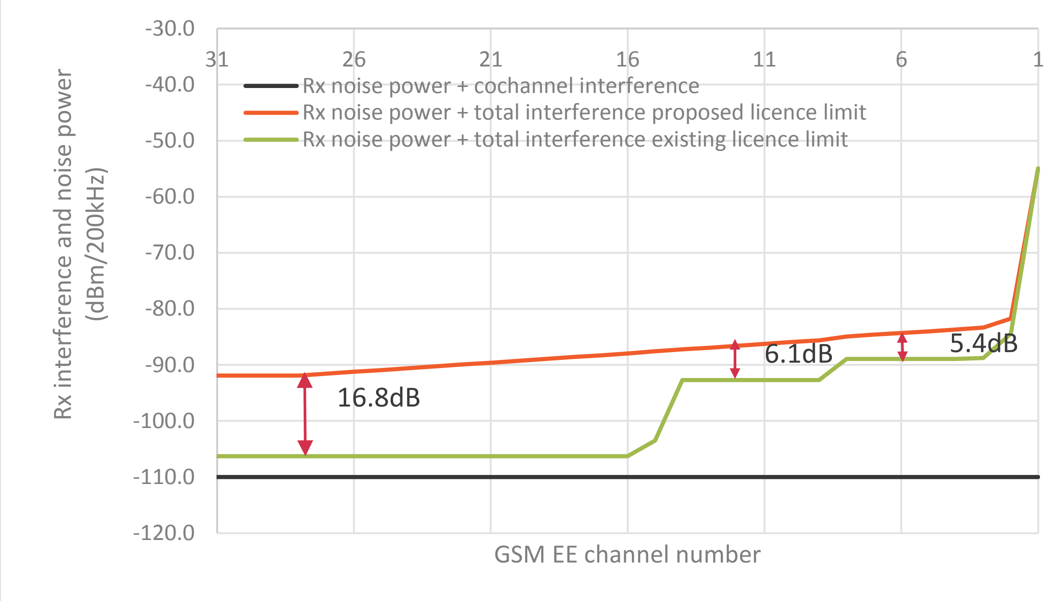

Figure 13: GSM - Noise power and ACI components per GSM channel for a coupling loss of 60 dB

Figure 13 shows these ACI components in the context of the receiver noise floor for a coupling loss of 60 dB and Figure 14 shows the results for a coupling loss of 40 dB.

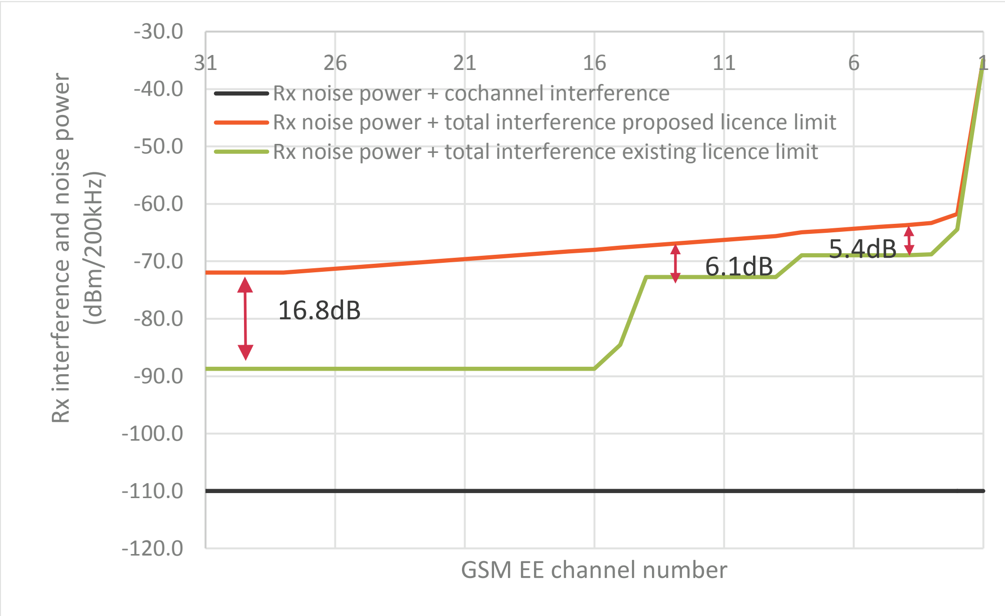

Figure 14: GSM – Noise power and ACI components per GSM channel for a coupling loss of 60 dB

As shown in the figures, for these low coupling loss cases, the proposed licence limits would add between 5.4 and 16.8 dB additional interference compared to the existing licence limit. It should, however, be noted that the interference contribution to the noise components with the existing licence limit is already large for these low coupling loss cases.

The noise rise at the victim receiver above the thermal noise floor using the existing and proposed licence limits for coupling losses of 95, 60 and 40 dB are shown in Figure 15, Figure 16 and Figure 17 respectively.

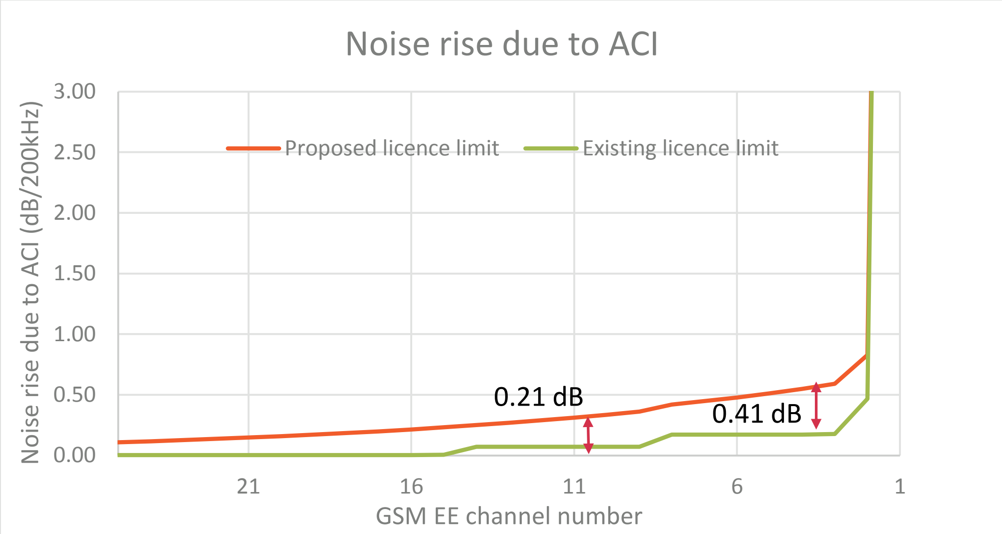

Figure 15: GSM - Noise rise above thermal noise floor due to ACI with a coupling loss of 95 dB with existing and proposed licence limits

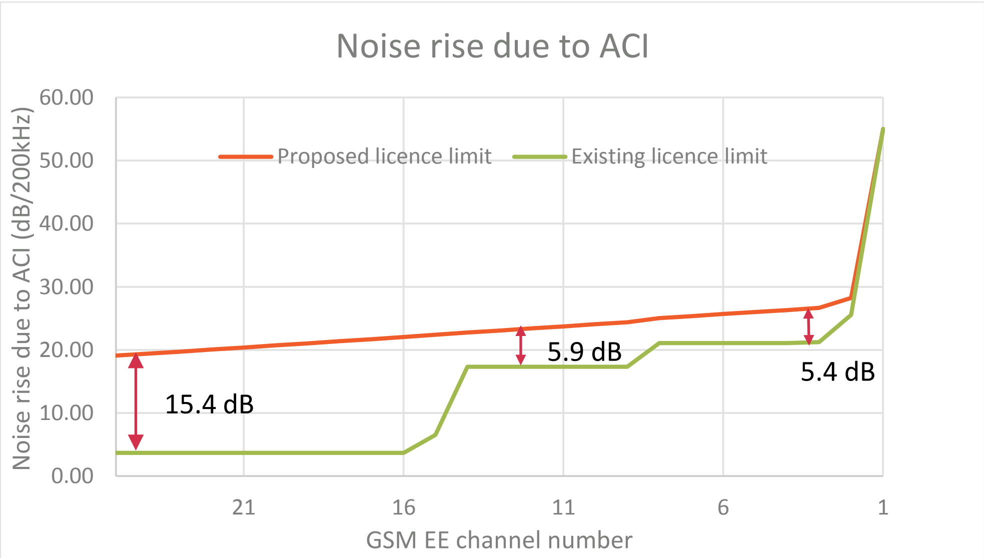

Figure 16: GSM - Noise rise above thermal noise floor due to ACI with a coupling loss of 60 dB with existing and proposed licence limits

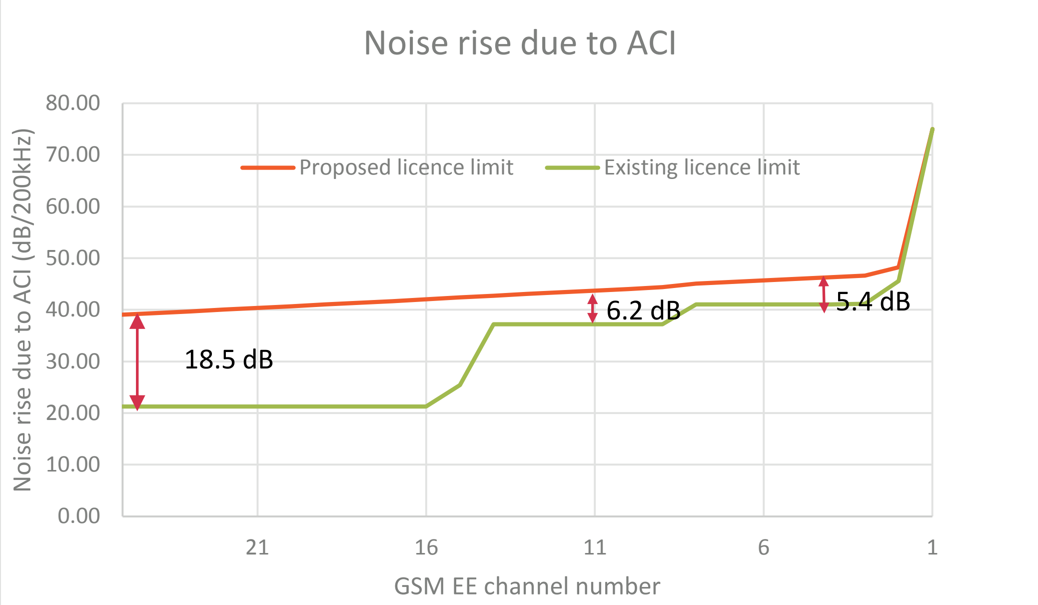

Figure 17: GSM - Noise rise above thermal noise floor due to ACI with a coupling loss of 40 dB with existing and proposed licence limits

Operating effectively in an environment with this raised level of noise would require either the desired signal level to be raised or the noise level to be reduced. In practice, these low coupling losses are likely to occur inside the building hosting the aggressor and where the victim-aggressor isolation can be controlled. In the case of only 40 dB coupling loss, gaining a further 20 dB isolation by increasing the victim-aggressor separation distance and/or providing screening is readily achievable. The more interesting case is where the victim is walking past a building hosting the aggressor. In this case a representative coupling loss was shown in section 4.1.5 to be approximately 75 dB. For a coupling loss of 75 dB, using the existing licence limits caused a noise rise of 4.33 dB in channel 14. Using the proposed licence limits required the coupling loss to be raised to 80.4 dB to achieve the equivalent noise rise - corresponding to a separation distance rising from 7.5m to 11.7m (in free space). In practice a user walking past a building hosting an aggressor would be subject to increased interference for the time required to cover the additional 4.2m – likely to be a few seconds.

Assuming GSM is used in the EE band, the difference between the proposed and existing licence limits can be summarised as:

- When the GSM channel is close (e.g. channel 1) to the edge of TalkTalk licensed band, the ACS dominates the ACI and the OoB has limited effect. Therefore, the difference between the proposed and existing licence limits is small.
- When the GSM channel is more than 300 kHz away from the TalkTalk channel edge, the OoB dominates the ACI and the proposed license limit will cause more interference than the existing licence limit.
- The ACI is likely to be small (<0.5 dB) where the coupling losses are of the order of 95 dB, or more; for low values of coupling loss the interference environment is likely to be under the control of the victim who can increase the isolation between aggressor and victim.
- In the case of an intermediate path loss, and a victim unable to control the interference environment, the separation distance to achieve an equivalent ACI to

the existing limit has to be increased by 4.2m (56%), which could degrade reception for a short period of time.

5.3 Interference impact on DECT

The 10 DECT carriers (designated C0 to C9) are located immediately above the TalkTalk downlink spectrum separated by guard bands from the CSA spectrum and from each other as shown in Figure 18.

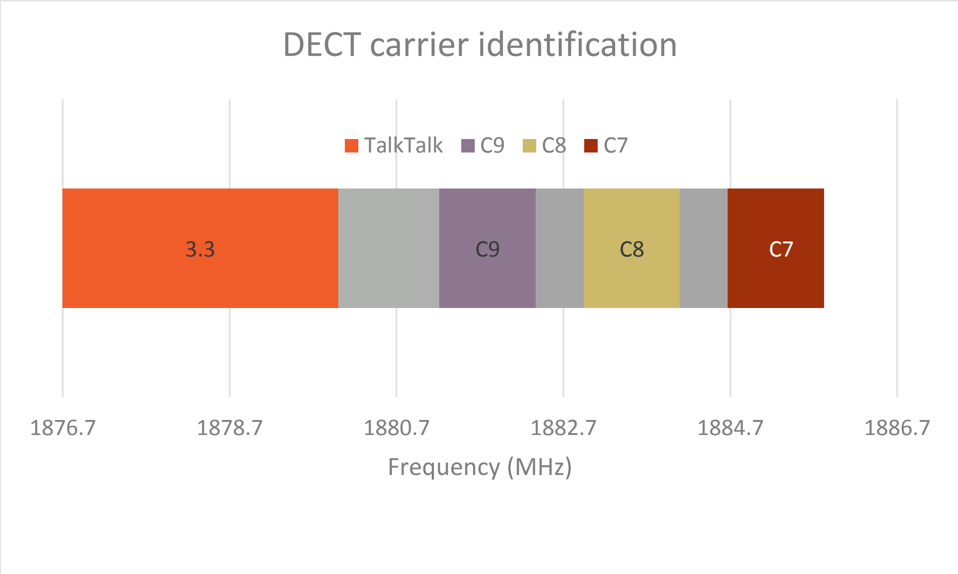

Figure 18: DECT carrier designation adjacent to TalkTalk CSA spectrum

Figure 19 shows the ACI components with a coupling loss of 95 dB using the proposed licence limits. It is clear that the ACS dominates the ACI for DECT channels 9 and 8. The ACS and ACLR components are broadly similar in DECT channel 7 and the out of band emissions are generally 3 dB higher for the other DECT channels.

As with the previous technologies considered the relative contribution of the different ACI components will apply at different coupling losses, but reduced coupling loss will increase the absolute interference power in the victim receiver.

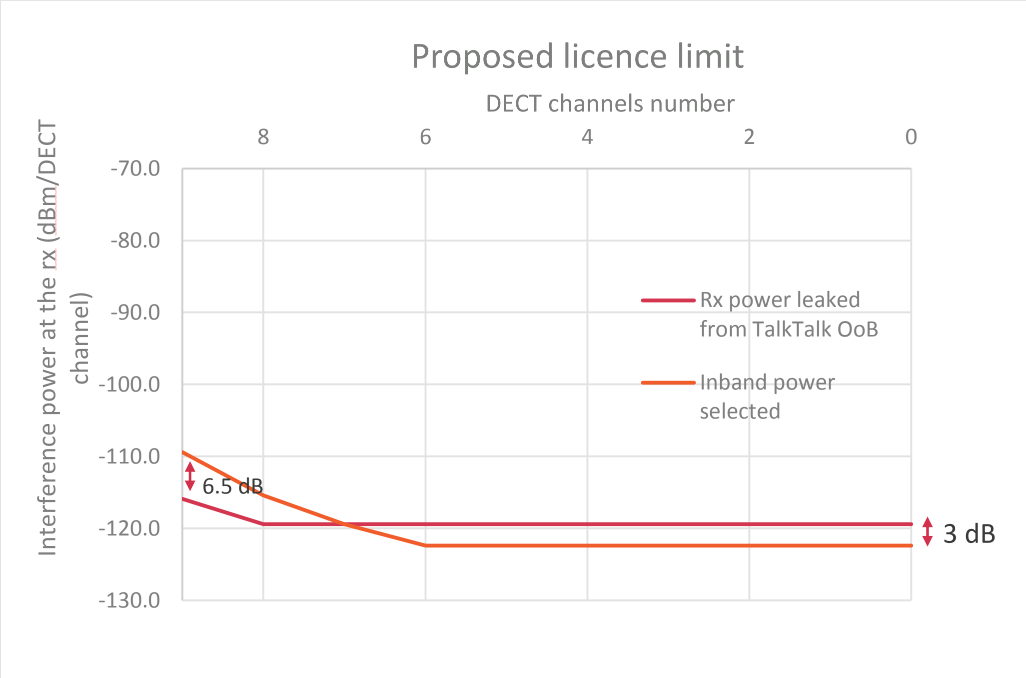

Figure 19: DECT – ACI interference components per DECT carrier for the proposed licence limit with a coupling loss of 95 dB

Figure 20 shows the ACI components in the context of the receiver noise floor for a coupling loss of 95 dB. The noise floor/DECT channel is calculated in three different cases:

- The black line shows the total noise floor when the noise power and the co-channel interference are taken into consideration.
- The orange and green lines show the total noise floor when the noise power and total interferences are taken into consideration for proposed and existing licence limit, respectively. The difference between the proposed and existing limits is 0.1 dB.

Figure 21 and Figure 22 show the interference and noise components for coupling losses of 60 dB and 40 dB respectively.

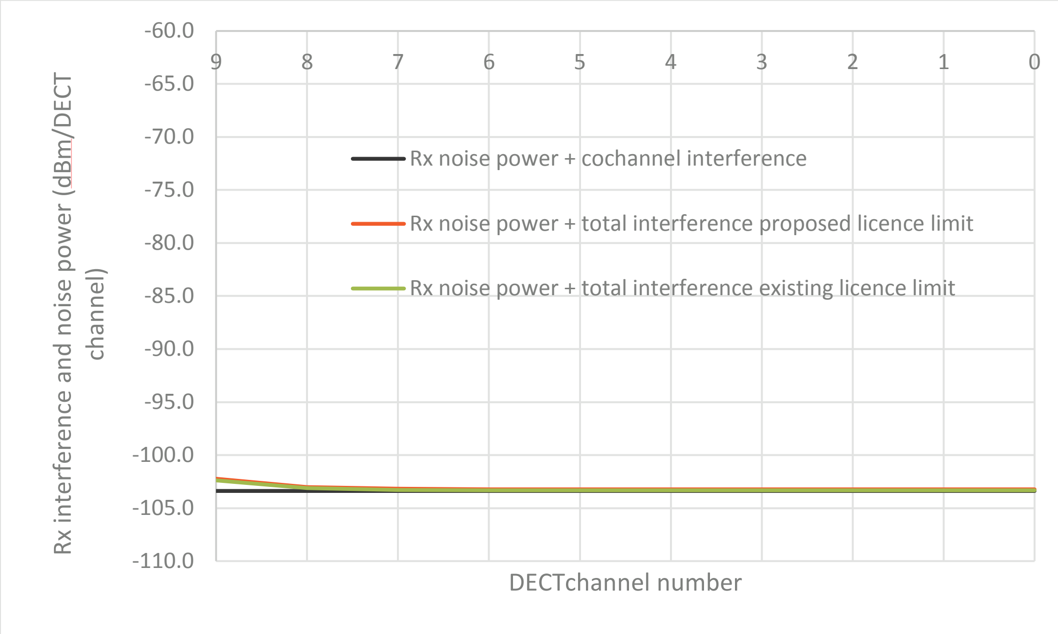

Figure 20: DECT - Noise power and ACI components per DECT channel for a coupling loss of 95 dB (note that the curves lie on top of each other over most of the range)

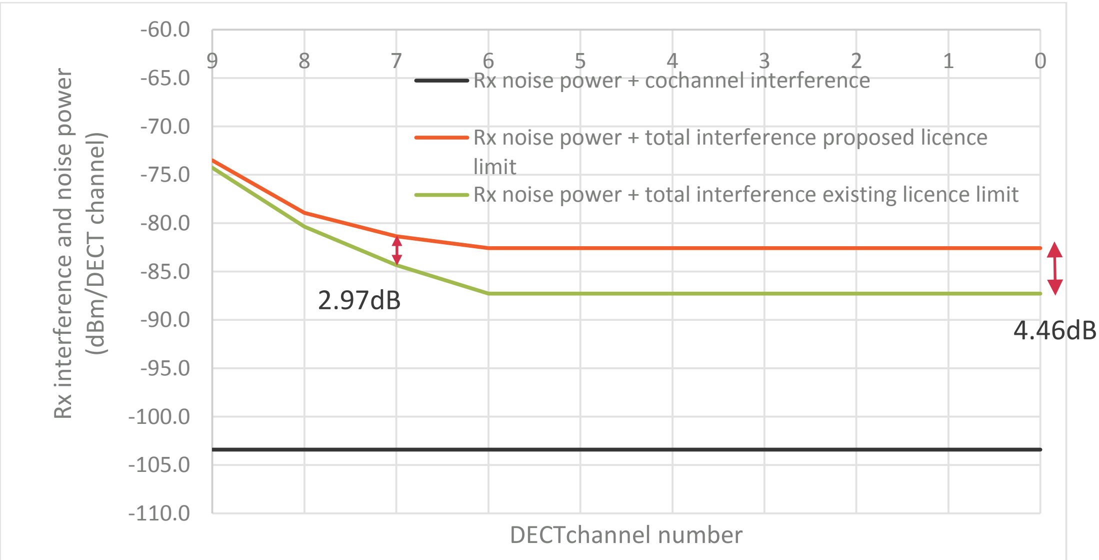

Figure 21: DECT - Noise power and ACI components per DECT channel for a coupling loss of 60 dB

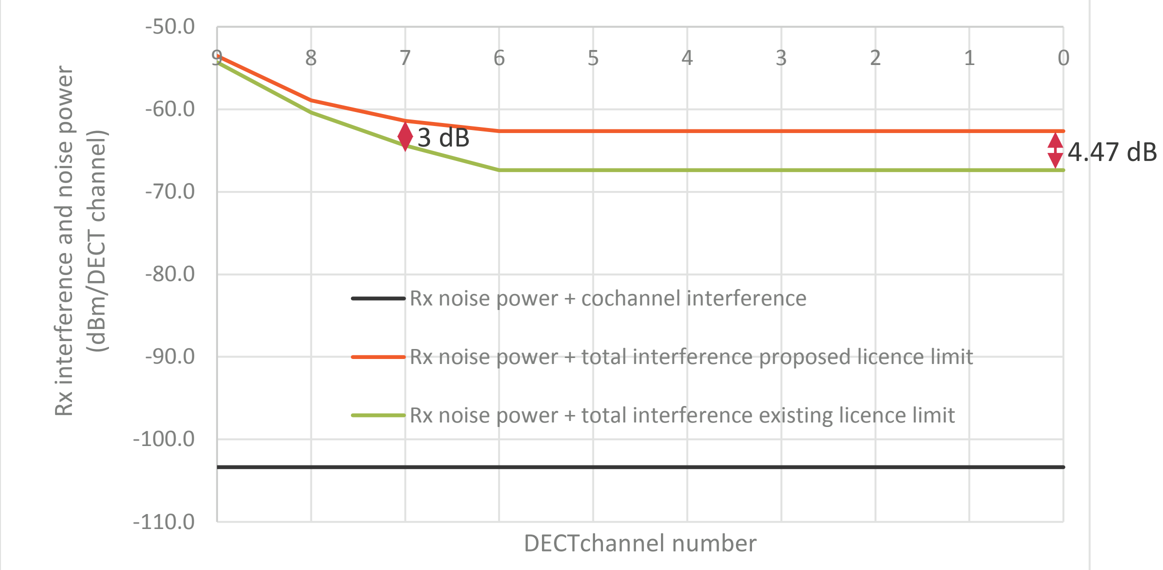

Figure 22: DECT - Noise power and ACI components per DECT channel for a coupling loss of 40 dB

For a coupling loss of 95 dB, the difference between ACI components for the existing and proposed licence limits is less than 0.3 dB.

As shown in the figures, for these low coupling loss cases, the proposed licence limits would add up to 4.5dB additional interference compared to the existing licence limit. Similar to the GSM case, it should be noted that the interference contribution to the noise components with the existing licence limit is already large for these low coupling loss cases.

The noise rise at the victim receiver above the thermal noise floor using the existing and proposed licence limits for coupling losses of 95, 60 and 40 dB are shown in Figure 23, Figure 24 and Figure 25 respectively.

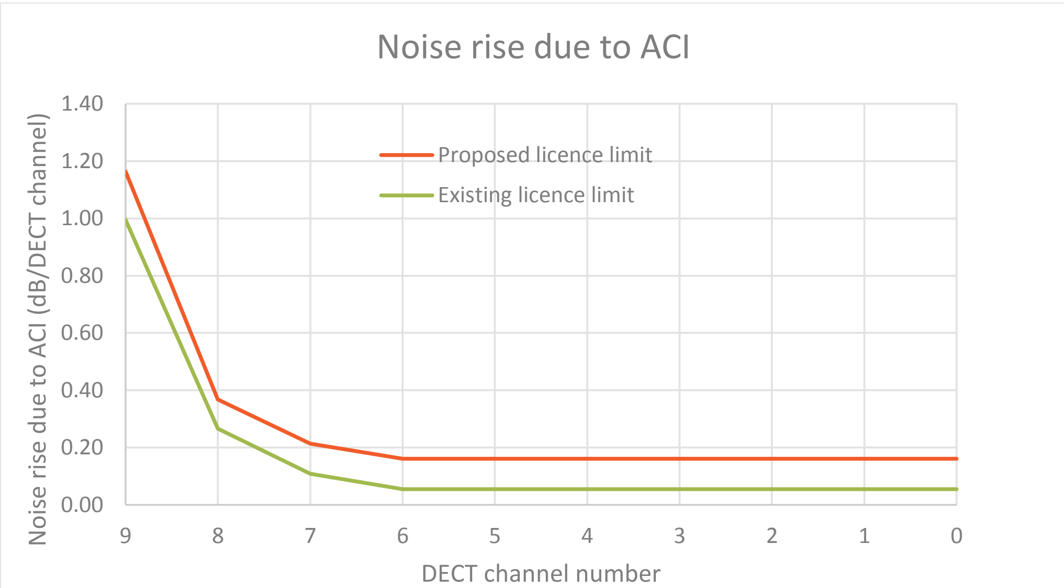

Figure 23: DECT - Noise rise above thermal noise floor due to ACI with a coupling loss of 95 dB with existing and proposed licence limits

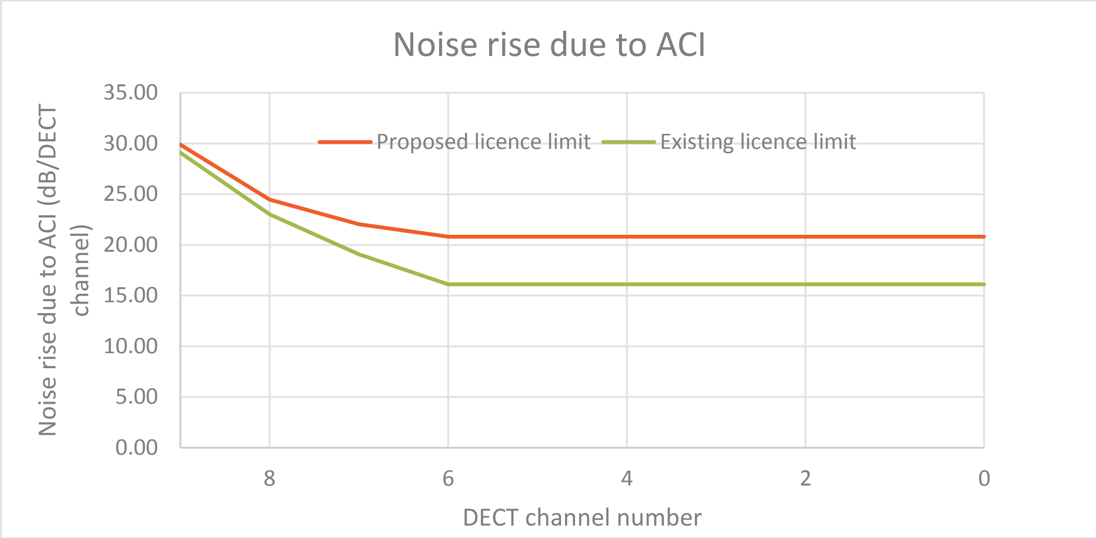

Figure 24: DECT - Noise rise above thermal noise floor due to ACI with a coupling loss of 60 dB with existing and proposed licence limits

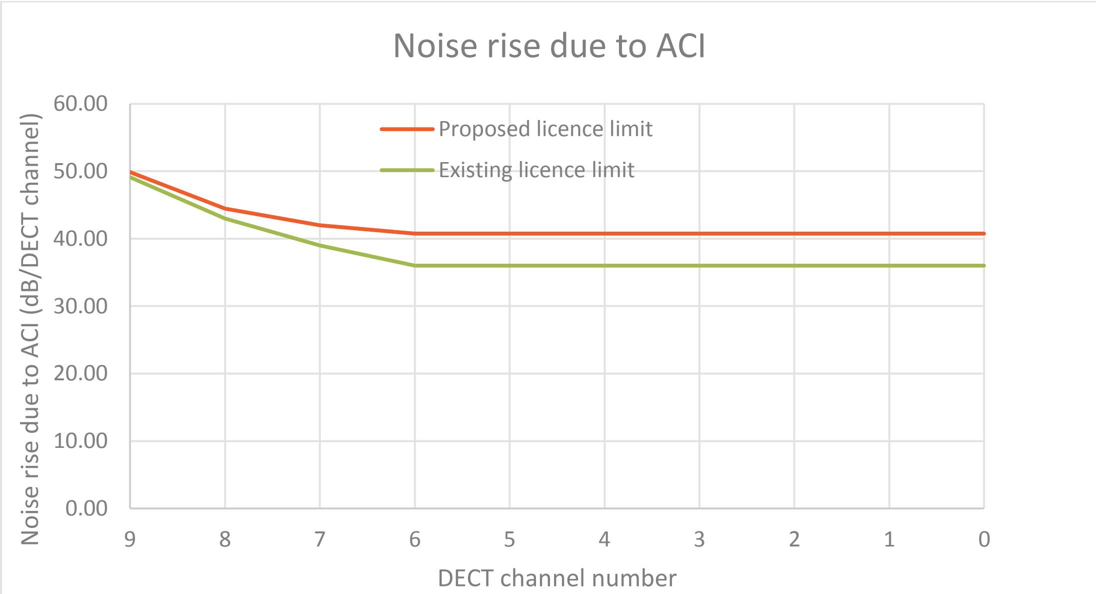

Figure 25: DECT - Noise rise above thermal noise floor due to ACI with a coupling loss of 40 dB with existing and proposed licence limits

Similar to the GSM case considered previously, operating in close proximity to an aggressor base station would require the desired signal level to be increased or the noise level to be reduced. Similar mitigation steps could be taken as to the GSM case in these low coupling loss environments.

Analogous to the GSM case, we can consider the increased separation to maintain a constant level of ACI for a 75 dB coupling loss (this could be a DECT receiver in an adjacent house). The increased ACI using the existing licence limit is 3.5 dB, and to maintain this level of interference using the proposed licence limits would require the separation distance to increase from 7.5m to 11.1m, or to have shielding capable of attenuating the interference by 4.7 dB.

For DECT, the difference between the proposed and existing licence limits can be summarised as:

- When the DECT channel is close, the ACI is dominated by the ACS performance of the DECT receiver. Therefore the difference between the proposed and existing licence limits is small.
- For DECT channels 0 to 6, the out of band emission contribution is 3 dB more with the proposed licence limit than the existing licence limit.
- The ACI is likely to be negligible where the coupling losses are of the order of 95 dB, or more; for low values of coupling loss the interference environment is likely to be under the control of the victim who can increase the isolation between aggressor and victim.
- In the case of an intermediate path loss, and a victim unable to control the interference environment, the separation distance to achieve an equivalent ACI to the existing limit has to be increased by 3.6m (48%) or shield to reduce the interference by 4.7 dB.

5.4 Impact summary

The above analysis assumed that the Out of Band emissions would be at the limit defined by either the existing or proposed licence limits. In practice the out of band limits would be less than this. The proposed licence limits have greater out of band limits than the existing licence limits – this issue is whether this has a material impact upon the ACI of potential victim systems.

The above interference assessment has demonstrated:

- Where the victim system is LTE, changing to the proposed licence limits will have a very small (0.02 dB to 0.09 dB) impact on ACI, because the ACI is dominated by the LTE ACS performance and not the adjacent channel out of band emissions.
- Where the victim system is GSM, the impact of adopting the proposed licence limits would depend upon the operating environment:
    - If the separation distance between the GSM carrier and the adjacent channel is less than 300 kHz, the poor GSM ACS dominates the interference.
    - For coupling losses of the order of 95 dB (or more) the interference impact is also small (<0.5 dB); for low values of coupling loss the interference environment is likely to be under the control of the victim who can increase the isolation between aggressor and victim.
    - In the case of an intermediate path loss, and a victim unable to control the interference environment, the separation distance to achieve an equivalent ACI to the existing limit has to be increased by 4.2m (56%), which could degrade reception for a short period of time.
- Where the victim system is DECT, the impact of adopting the proposed licence limits (like the GSM case) depends upon the operating environment:

- When the DECT channel is close, the ACI is dominated by the ACS performance of the DECT receiver. Therefore the difference between the proposed and existing licence limits is small
- For DECT channels 0 to 6, the out of band emission contribution is 3 dB more with the proposed licence limit than the existing licence limit
- The ACI owing to Out of band emissions is small (<0.2 dB) where the coupling losses are of the order of 95 dB, or more; for low values of coupling loss the interference environment is likely to be under the control of the victim who can increase the isolation between aggressor and victim.
- In the case of an intermediate path loss, and a victim unable to control the interference environment, the separation distance to achieve an equivalent ACI to the existing limit has to be increased by 3.6m (48%) or shield to reduce the interference by 4.7 dB

These results have therefore demonstrated that, where the interference environment cannot be controlled by the potential victim, the proposed licence limits can require increased separation by several metres or approximately 5 dB more isolation to provide the same level of interference impact as the existing licence limits. This small interference impact should be weighed against the benefits of deploying a modern, spectrally efficient technology in the CSA band.

6. Technical changes to TalkTalk's licence limits

The changes to the existing licence limits in order to achieve the same limits as the proposed licence, are shown in Table 8.

Table 8: Proposed Licence Limits, and the changes required to the existing licence limits to conform to the proposed licence limits.

Range of frequency offset from lower band edge (MHz)	Maximum EIRP density (dBm/kHz)	
~~-5.7 to -1.5~~	~~-74~~	
~~-1.5 to -0.9~~	~~-56~~	
~~-0.9 to -0.3~~	~~-53~~	
~~-0.3 to -0.1~~ -6.2 to -3.2	~~-49 + 20*(Δf + 0.1)~~ -55	
~~-0.1 to 0~~ -3.2 to 0	~~-33.6 + 153.3* Δf~~ -45 + 10*(Δf-0.2)/3	
0 to 0.05	-33 + 153.3 * Δf	-33 + 153.3 * Δf
0.05 to 0.1	-26 + 60*(Δf – 0.05)	-26 + 60*(Δf – 0.05)
0.1 to 0.2	-23 + 230*(Δf – 0.1)	-23 + 300*(Δf – 0.1)
0.2 to 3.2	0	7
3.2 to 3.3	-23 + 230*(3.3 - Δf)	-23+300*(3.3 - Δf)
3.3 to 3.35	-23 – 60*(Δf – 3.3)	
~~3.35 to 3.5~~ 3.35 to 3.4	-26 – 153.3*(Δf – 0.05 – 3.3)	
~~3.5 to 3.7~~ 3.4 to 6.1	~~-49 – 20*(Δf – 0.2 – 3.3)~~ -45 – 10* (Δf – 3.1)/3	
~~3.7 to 4.3~~ 6.1 to 9.1	~~-53~~ -55	
~~4.3 to 4.9~~	~~-56~~	
~~4.9 to 9.1~~	~~-74~~	

Applying the above limits to the existing licence would require changes to two tables that define the downlink licence maximum EIPR density below the band and above the licenced band. Note that no changes are proposed for the in-band licence limits. The particular changes that would be required are shown in Table 9 and Table 10.

Table 9: Specific changes required to the existing licence limits to conform to the proposed licence limits for out of band limits below the downlink channel

Permitted frequency band 1876.7 – 1880.0 MHz	
Frequency range as measured from the lower frequency of the frequency band	Maximum mean EIRP density dBm/kHz
0.0 to ~~-0.1~~ -3.2 MHz	~~33.6 + 153.3* Δf~~ -45 + 10*(Δf - 0.2) / 3
~~-0.1 to -0.3~~ -3.2 to -6.2 MHz	~~-49 + 20*(Δf + 0.1)~~ -55
~~-0.3 to -0.9 MHz~~	~~-53~~
~~-0.9 to -1.5 MHz~~	~~-56~~
~~-1.5 to -5.7 MHz~~	~~-74~~

Table 10: Specific changes required to the existing licence limits to conform to the proposed licence limits for out of band limits above the downlink channel

Permitted frequency band 1876.7 – 1880.0 MHz	
Frequency range as measured from the higher frequency of the frequency band	Maximum mean EIRP density dBm/kHz
0.0 to 0.05 MHz	-23 – 60 * Δf
0.05 to ~~0.2~~ 0.1 MHz	-26 – 153.3 * (Δf – 0.05)
~~0.2 to 0.4~~ 0.1 to 2.8 MHz	~~-49 + 20*(Δf + 0.1)~~ -45 – 10* (Δf – 0.2)/3
~~0.4 to 1.0~~ 2.8 to 5.8 MHz	~~-53~~ -55
~~1.0 to 1.6 MHz~~	~~-56~~
~~1.6 to 5.8 MHz~~	~~-74~~

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