European Radiocommunications Committee (ERC)
within the European Conference of Postal and Telecommunications Administrations (CEPT)

COMPATIBILITY BETWEEN CERTAIN RADIOCOMMUNICATIONS SYSTEMS OPERATING IN ADJACENT BANDS

EVALUATION OF DECT / GSM 1800 COMPATIBILITY

Naples, February 2000

EXECUTIVE SUMMARY

1.1 This report details the findings of the SE7 Project Team study into the compatibility issues between DECT and GSM 1800. This report supersedes all earlier JPT reports relating to DECT/GSM 1800.

1.2 Several interference scenarios were analysed to identify the scenarios that exhibited significant interference ranges. Compared to earlier reports DECT WLL and GSM 1800 indoor BTS scenarios have been added

Two main interference mechanisms were identified:
(i) Interference of DECT from GSM 1800 base station carrier power (blocking)
(ii) Interference of GSM mobile stations by DECT out of band emissions

For the WLL scenarios one more interference mechanisms was identified:
(iii) Interference of DECT from GSM 1800 base stations out-of-band emissions

1.3 The means for reducing the compatibility problems are given in detail below. Error correction and the possible escape mechanisms (dynamic channel selection, power control, hand over algorithms) for both systems to avoid local interference problems and the consequent reduction in capacity are also considered in the discussions leading the recommendations.

1.4 The important scenarios are when DECT and GSM operate in the same local environment. Important scenarios for the recommendations are when a GSM 1800 MS operates in the same indoor environment as a DECT indoor system, and when above rooftop DECT WLL systems and GSM macro cell systems operate in the same local outdoor environment.

From studying the critical scenarios it is observed and / or recommended that:

1.4.1 A guard band is not required, but specific restrictions should apply locally to the GSM sub-band 1878 - 1880 MHz. See Section 7.

1.4.2 Co-ordinated site engineering and system planning will be required to minimise interference from above roof -top GSM BTSs to DECT WLL systems.

1.4.3 DECT WLL applications would suffer less potential risk of range reduction due to GSM interference if installed DECT WLL equipment have improved blocking performance above minimum specification.

1.4.4 ETSI Project DECT should make sure that the provisions for DECT to detect interference from a single GSM bearer are properly defined.

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1 INTRODUCTION

The CEPT SE7 project team (PT) was set up to evaluate compatibility between certain mobile radio communications systems operating in adjacent bands

This report is a revision of the earlier reports of CEPT JPT FM10/SE7 on the compatibility of DECT/GSM 1800 and provides a detailed technical study about the coexistence between DECT and GSM 1800.

As with the past work of the PT, both practical as well as theoretical studies were carried out in an attempt to assess the potential interference with real equipment, as well as with specification values on the basis of MCL (minimum coupling loss), E-MCL (enhanced minimum coupling loss) calculations and MC (Monte Carlo) analysis.

1.1 The DECT and GSM 1800 DECT systems

DECT[1] is the term used for the Digital Enhanced Cordless Telecommunications systems. DECT carriers are defined for the band 1880-1938 MHz. located between 1880 and 1930 MHz. Spectrum is available for DECT in about 80 countries. 1880 – 1900 MHz in Europe and Australia and in several African and Asian countries (except China), 1900 – 1920 MHz in China and 1910 – 1930 MHz in several Latin American countries. During mid 1999 there were between 25 and 30 Million DECT terminals shipped worldwide.

GSM 1800[2] is the term used for the Global Mobile System 1800 located between 1710 – 1785 MHz (mobile transmit band) and between 1805 and 1880 MHz (base station transmit band).
Spectrum is available for GSM 1800 in all the European countries and in several countries in Asia, Africa and Latin American countries. In march 1999, the number of GSM users was estimated to be between 110 and 115 Million. Included in these figures, there are about 12 Million subscribers of GSM 1800 networks and 30 Million subscribers of dual–band networks.

In order to estimate the probabilities for harmful interference between DECT and GSM 1800, it is important to know how common different types of systems are, and to know their geographical distribution. To estimate which scenarios are important, below is a short description of different system applications and of the likelihood for different scenarios to occur. For a more detailed description of DECT and GSM 1800 features, provisions and expected future development see Annex 6 "Market information and system properties for DECT and GSM1800".

Indoor DECT systems, with indoor Radio Fixed Parts, RFPs, and indoor Portable Parts, PPs (office and residential applications) are the most common DECT installations. They represent the vast majority of the shipments of DECT equipment, most of them are in Western Europe. The major growth of DECT system sales are expected from residential and office applications.

Outdoor DECT systems, with below roof-top RFPs and outdoor PPs for public use (CTM) in large numbers are only found in Italy, where streets, shopping centres and public buildings are covered in 31 cities. Total number of subscribers is about 130.000 (mid-99). With the success of GSM and heavy investment in mobile telephony, there is in general a reserved attitude towards the needs for public pedestrian DECT applications. Outdoor RFPs and PPs also exist as outdoor coverage extensions (parking places etc.) of office systems. The largest is a Volvo plant with 2 sqkm area complete indoor/outdoor coverage for about 5000 subscribers.

DECT WLL Systems, with above roof-top RFPs and above roof-top CTAs (subscriber units) installations are for the time being mainly found in Eastern Europe, Asia, Latin America and Africa.

Outdoor GSM 1800 systems, with outdoor above roof-top macro base stations, BTSs, or below roof-top micro BTSs, and outdoor and indoor portable stations, MSs, is the most common application of GSM 1800. The service is available in many European countries, soon in all. There is a substantial annual increase of systems and customers.

Indoor GSM 1800 systems, with indoor micro base stations, BTSs, and indoor and indoor portable stations, MSs, have today a low penetration, but is expected to have increased penetration in the future.

[1] EN 300 175 "Digital Enhanced Cordless Telecommunications (DECT)"
[2] EN 300 577 (GSM 05.05), Dec. 1998 (Phase 2)

1.2 Evolution of DECT and GSM

For the present time **speech** is the dominant service both for DECT and GSM, but **data services** are expected to substantially increase during the next years both for DECT and GSM 1800.

The present evolutions of the DECT and GSM standards by introducing multi-step modulation options, have substantially increased the data service capabilities.

Investigation of the technology and other features of the implementations of the new modulation options show that the compatibility study in this report is relevant also for the emerging multi-step higher user bit rate of DECT and GSM applications. See Appendix 6, section 3.

1.3 The interference scenarios

Since GSM is an FDD system, DECT is a TDD system, the GSM BTS transmit band is adjacent to the DECT band and the GSM mobile transmit band is distant from the DECT band, it is seen that:

- GSM BTSs are the main interferers to DECT RFP, PP and CTA victims.
- GSM MSs are the main victims for interference from DECT RFP, PP and CTA interferers.

See the table below for a simplified overview of relevant interference scenarios.

GSM1800 **DECT** (Interferer and victim)	**Above roof-top macro BTS** (Interferer)	**Below roof-top micro BTS** (Interferer)	**Indoor micro BTS** (Interferer)	**Outdoor MS** (victim)	**Indoor MS** (victim)
Indoor system (Residential and office applications)	Case 1		Case 8		Case 2
Below roof-top outdoor system (CTM and outdoor extension of indoor systems)	Cases 3 & 4			Case 5	
Above roof-top WLL system	Cases 6 & 7				

Table 1

Some scenarios are not very likely to occur, and only some are critical. Cases 1 and 3 are the most common cases and cases 6 and 7 are the most critical. Cases with "**Below roof-top micro BTS** (Interferer)" are in this study not treated as separate cases, but are discussed as cases with low power version macro BTSs. For a more detailed definition of the different interference cases, see section 4.

A pictorial overview of the major interference scenarios, which illustrates the different compatibility cases studied by the PT, is given in Appendix 4 of this report.

1.4 Decisions on Spectrum for DECT and GSM

Council Directive of 3 June 1991 (91/287/EEC) requires an absolute protection of all carriers of DECT band: *"In accordance with the CEPT recommendation T/R22-02, DECT shall have priority over other services in the same band, and be protected in the designated band"* (91/287/EEC, page 2, §2).

The European decision on the frequency bands to be designated for the introduction of the DCS 1800 (ERC/DEC/95(03)) requires protection of GSM 1800 bands allocated to operators:
"It is recognised that the exclusive use of the frequency bands for DCS 1800 may be preferred in order not to place constraints on potential operators and such an approach is generally recommended." (ERC/DEC/95(03), page 2, §2).

1.5 Previous report

Compared to the previous report, work relating to the introduction of the WLL (wireless local loop) systems (cases 6 and 7) and indoor micro BTS GSM 1800 systems (case 8) are included in this report.

2 BACKGROUND

Each operator has a goal to have as much traffic as possible (with acceptable quality) within his allocated frequency band. The maximum possible traffic is limited (C/I limited) by the interference caused within his own band by his own generated traffic. Within the own system, he has on one hand a wish to reuse his own channels with as small geographical separation and frequency separation as possible. This would increase the number of available traffic channels per square km and would increase the traffic. But this would at the same time decrease the isolation and increase the potential interference between the channels, so that they cannot always be used for traffic. So, to maximise the traffic capacity, there is a trade off between having very large carrier spacing (in-system guard-bands) with large geographical reuse distances and to allow higher potential interference.

In most scenarios, the probability for worst case interference situations occurring is rather low. Therefore, capacity is normally optimised by allowing “unacceptable” interference cases, as long as it, by intra-cell hand over to a better channel, is possible to escape these interference occurrences. As long as this need to change channels only occurs for a few percent of the connections, also only a few % of the capacity is affected.

The same mechanisms apply between adjacent systems. As stated above, most capacity limiting interference comes from within the own system. Interference between adjacent systems will also, but to less extent, contribute to limit the maximum possible traffic capacity within each system. Again, traffic capacity for each operator is optimised, with a minimised guard-band allowing “unacceptable” interference cases, as long as it, by intra-cell hand-over to a better channel, is possible to escape these interference cases when they occur. This implies that the interference from one of the systems has to be detectable by the hand-over procedure of the other system. As long as this need to change channels only occurs for a few percent of the connections, also only a few % of the capacity is affected.

Interference may occur between any kind of radio systems operating on adjacent bands in the same geographical area.

The possibility to escape local/temporary interference by intra-cell hand-over is a most important mechanism to reduce the need for guard-bands between adjacent systems and to reduce the need for very demanding performance on receiver interference rejection (blocking) and transmitter out-of band emissions.

In the same way that base station sites and other parameters are planned within a system, it is common practise for outdoor systems that the two adjacent band operators make some co-ordination and dedicated site engineering to minimise the mutual interference potential.

An operator can not provide a reliable service if the system deployed lacks an efficient monitoring operation and maintenance, O & M, feature. It is common practice in wired and wireless telecommunications systems to monitor the traffic variations and blocking rates as part of the O&M support to an operator. This is required for timely adjustment of the infrastructure as the local traffic increases or varies, due to changed habits of the subscribers, new services visible or not visible for the operator and due to new subscribers.

Thus the need for monitoring the local traffic and service quality, and having processes for timely modification of the local infrastructure to adjust for partly unpredictable local variations, is nothing specific for radio systems. The new element for radio systems is that not only the own subscribers, but also the traffic from adjacent systems, may to some extent influence the need to adjust the infrastructure. This is not a problem as such, as long as the economic impact of adjustments due to traffic from surrounding systems is low compared other costs.

A complication with the compatibility study including DECT or GSM is that DECT and GSM has so many different application scenarios and services. Another aspect is that WLL services and office services require very low out-of-service probabilities. For instance 95 % coverage and 5 % call blocking probability, often used for mobile telephone speech systems, will not be acceptable. For WLL applications 100 % coverage of the fixed users and below 1 % blocking probability for each user is required. See section 3.3 below.

3 METHODOLOGIES

The basic methodology for addressing the problems associated with DECT - GSM 1800, was similar to the approach adopted in previous work of the project team PT SE7. That is, a dual approach was mounted by looking both at the theoretical values obtained by MCL, E-MCL and MC as laid down in the system specifications and agreed network parameters, and at the practical values obtained from tests on real equipment.

PT SE7 has compared various methods for computing the minimum frequency separation[3] between radio systems operating in adjacent frequency bands**.** This work focused upon the Minimum Coupling Loss (MCL), the Enhanced Minimum Coupling Loss (E-MCL) and the Monte Carlo (MC) method as specified by CEPT PT SE21.
The MCL method is very straightforward as it allows the engineer to determine a minimum frequency separation in a very short time by making a number of worst case assumptions.
The cost for this simplicity is a reduction in spectrum efficiency. By using worst case assumptions the minimum frequency separation obtained is significantly greater than that required in practice.
The E-MCL method is also simple to use but includes power control and network planning parameters.
The Monte Carlo method is a statistical technique, which is capable of modelling interference scenarios. The method is complex and is being discussed in several international working groups.

3.1 Minimum Coupling Loss (MCL)

The maximum permissible level of received interference power can be related to the co-channel, adjacent channel, blocking and intermodulation performance of the equipment as defined by the system standards. This, in conjunction with knowledge of the interfering transmitters power, level of spurious emissions and antenna configurations allows the MCL to be calculated. The user density of the systems can be considered to derive the required isolation for optimal operation with minimum interference. Practical measurement of a receiver's ability to reject interfering signals can also be used in this analysis.

The required isolation can be translated into an interference range through the application of an appropriate propagation model. This yields a number of interference ranges relating to the different interference mechanisms, frequency separations, transmitter powers and receiver sensitivities.

Since short-range propagation at 1800 MHz depends on the local environment, many different propagation models were discussed. Eight different propagation models were selected to represent the propagation conditions appropriate to the eight different interference scenarios studied.

3.2 Enhanced Minimum Coupling Loss (E-MCL)

The Enhanced Minimum Coupling Loss (E-MCL) method has been devised in an attempt to improve the ability of the Minimum Coupling Loss (MCL) method to model realistic scenarios. The E-MCL methodology includes

- assuming the victim receiver to have a desired signal level fixed at 10 dB above the wanted signal level used for MCL, N = 10 dB ;
- the effect of power control when it is used ;
- considering only a single interferer ;
- having a fixed frequency offset between interferer and victim for each calculation ;

The E-MCL method tackles a number of these drawbacks to provide a more meaningful result.

The victim receiver is provided with a fixed wanted signal strength margin. This represents an average for a victim who could be located anywhere in the cell. The number of dB above sensitivity is determined by the availability of the victim system. A system with a high availability will have a greater average margin than a system with a low availability. The suggested way of determining the number of dB margin for a given availability is to use a set of curves proposed by W.C.Jakes in his book ‘Microwave Mobile Communications'. The engineer is able to read from the curves by assuming a specific path loss exponent and lognormal shadowing standard deviation.

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[3] ERC Report 101 A comparison of the minimum coupling loss method, enchanced minimum coupling loss method and the Monte-Carlo simulation.

The interferers are assumed to be uniformly distributed across a circular cell system.

Each circular cell is divided into a number of concentric rings with a circle in the middle. Each ring represents an area within which all interferers transmit at the same power. The use of power control leads to interferers who are closer to the centre of the cell being able to transmit at a lower power. Interferers in the central circle will be transmitting at the lowest power allowed by the power control specification. The width of each ring is dependent upon the path loss model chosen by the user and the step size defined in the power control specification. The victim to interferer isolation requirement can be calculated for each ring within the cell (each interferer transmit power). By calculating the ratio of the number of interferers within a specific ring, to the total number of interferers within a cell, the mean victim to interferer isolation requirement can be computed.
More than a single interferer is considered in the sense of mean isolation requirements. However the interfering effect of multiple interferers is not summed and in this sense the E-MCL method is optimistic.
A fixed frequency offset is assumed by the E-MCL in the same way as the MCL. This may have consequences when interferer and victim have unwanted emission and receiver blocking masks respectively with significant steps. It may be possible to introduce variable frequency offsets in the E-MCL method but at the cost of added computation.
The path loss figures used by the E-MCL method include fading on the victims wanted signal link (assuming the curves derived by W.C.Jakes are used) but does not include fading in the victim to interferer link. This may have some effect at higher interferer densities.

The curves derived from W.C.Jakes are used to determine the parameter N that is used in the E-MCL calculations. In this report we use N =10 dB.

The results of initial E-MCL calculations indicate results that are of the same order of magnitude as those generated by the Monte Carlo method. If this remains true subsequent to further studies then the E-MCL method will provide a useful algorithm for rapid results, which are considerably more appropriate than those generated by the MCL method.

3.3 Monte Carlo Simulation

The Monte Carlo simulation is an important tool for assessment of complex communication systems.
The Monte Carlo simulations described in Appendix 5, section 5.3 of this document have been made with a statistical program for the assessment of communication systems considering different interferers. The simulations use scenarios in line with the SEAMCAT tool developed by CEPT SE21.

The probability of each interference scenario occurring depends on a number of factors. Some scenarios are much more likely to occur than others. Examples of typical high-density high link quality DECT applications for residents and homes are found in Appendix 6.
It is the highly probable scenarios that exhibit significant interference ranges that are of major concern. These have been identified and addressed in this report.

4 STUDY AND RESULTS OF THE INVESTIGATION

This section gives details of the considered interference scenarios, the propagation models used, and the interference calculations performed based on the existing ETSI specifications and on some limited practical tests performed for the PT.

4.1 Interference Scenarios

Eight different interference scenarios were studied to assess the compatibility between DECT and GSM 1800.

Case	Interferer	Victim
1	GSM 1800 base outdoors	DECT base indoors
2	DECT base indoors	GSM 1800 mobile indoors
3	GSM 1800 base outdoors	DECT base outdoors
4	GSM 1800 base outdoors	DECT mobile outdoors
5	DECT base outdoors	GSM 1800 mobile outdoors
6	GSM 1800 base outdoors	DECT WLL CTA
7	GSM 1800 base outdoors	DECT WLL BTS (& CTA)
8	GSM 1800 base indoors	DECT base indoors

Table 2

4.1.1 *Antenna gain and transmitter power levels*

Station type	Antenna Gain (dBi)	Tx power into antenna	Tx power from antenna)
GSM 1800 base outdoors (BTS)	12	42 dBm	54 dBm
GSM 1800 base indoors (BTS)	0	26 dBm	26 dBm
GSM 1800 mobile (MS)	0*	30 dBm	30 dBm
DECT base indoors (RPF)	0	24 dBm	24 dBm
DECT WLL CTA / BTS (RFP)	12	24 dBm	36 dBm
DECT mobile (PP)	0*	24 dBm	24 dBm

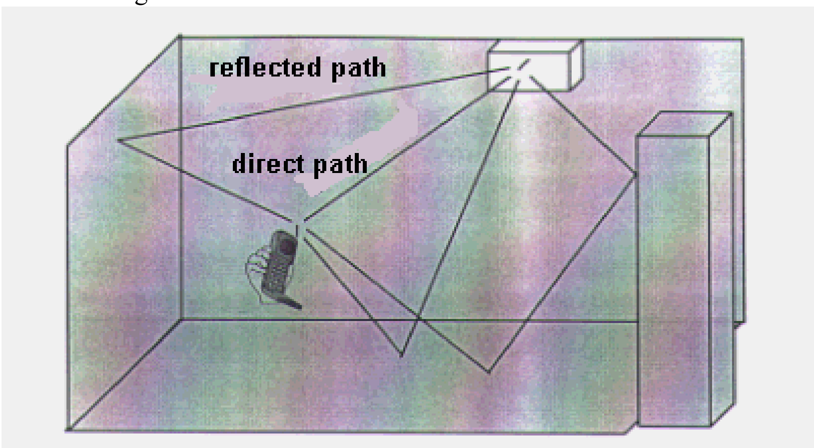
Table 3

***The typical body loss of 5 dB for mobile stations, has not been included in the calculations.**

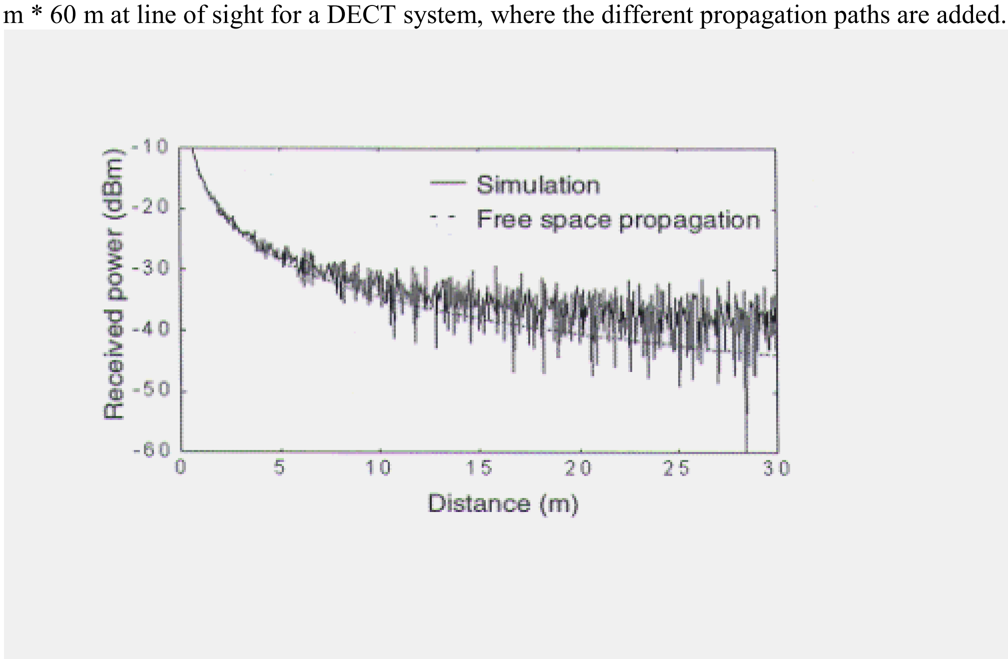
4.2 Propagation Models

For each scenario a propagation model was chosen. All propagation models are described in Appendix 3.

The most critical propagation conditions are for indoor scenarios. Several propagation paths between the transmitter and the receiver are caused by reflections and scattering. The signals are constructively or destructively superimposed at the receiver. This effect is called fading.



The next picture shows the simulated receiver power in accordance with the distance between transmitter and receiver for a room with 60 m * 60 m at line of sight for a DECT system, where the different propagation paths are added.



For case 1 the GSM 1800 base station is assumed to be located on a rooftop.

To take account of all of the possible locations of the DECT base station many different propagation models were discussed, and three were agreed to be used.

In the worst case, the DECT receiver may be located within line of sight to the GSM 1800 base station.
Here "Model A" is assumed to be representative for distances < 200 m. See Appendix 3.

In the general case, more complicated propagation conditions apply. Here "Model B" is assumed to be representative. See Appendix 3.

When the DECT base station is located at ground level, "Model C" is assumed to be representative.

Case 2 "Model D" was chosen.

Case 3 "Model E" has been used.

Case 4 "Model E" has been used

Case 5 "Model F" was adopted.

Case 6 "Model F" was adopted.

Case 7 "Free space" was adopted. The model is relevant for distances up to 0.5 - 2 km depending on antenna highs of the GSM and DECT WLL base stations.

Case 8 "Model D" is chosen.

The theoretical calculations were based on the ETSI specifications (ETS 300 175-2 for DECT and GSM 05.05 for GSM 1800), the relevant parts of which are summarised in Appendices 1 and 2.

It should be recognised that these specifications primarily are intended to assure good intra system performance, and all parameters are not appropriate to be directly applied in inter system compatibility calculations (e.g. blocking levels, receiver IM generation), since different interfering signals are used. Therefore, the parameters of the specifications have, where needed, been translated into corresponding requirements appropriate for the interference calculations. See Appendices 1 and 2 and section 4.3 below.

4.3 Interference mechanisms

The potential interference mechanisms are:

- spurious emissions,
- receiver blocking,
- receiver interference performance,
- out of band emissions (including transients in some case),
- the generation of intermodulation products

These mechanisms are evaluate below to decide which are dominant

- Spurious emissions

The required isolation values due to spurious emissions are generally higher, than those for out-of-band emissions. But these levels should not be treated as a continuous noise floor. The spurious signals will appear at a few unknown specific frequencies, and therefore these problems may be solved by the Dynamic Channel Selection, DCS, in DECT and by intra cell hand over in GSM 1800. Spurious emissions do normally not cause a dominant interference mechanism, and are not used for the calculations in this report.

- Receiver interference and blocking

Receiver interference relates to receiver co-channel interference performance (C/I) and to the receiver attenuation of interference on the adjacent channels.

The receiver interference specification mainly relates to interference occurring within the own band. When out-of-band emissions from an interfering system on an adjacent band fall into the own band, it is the interference on the co-channel that normally dominates. Thus the co-channel interference performance, C/I, is an important parameter.

The blocking requirements for DECT and GSM exclude the band of 3-4 adjacent channel separations closest to the band edge. GSM excludes 1800 to 1880.4 MHz (600 kHz from the last carrier), and DECT excludes 1875.8 to 1880 MHz. There is no problem with the GSM blocking specification, since no DECT carriers exist within 1800 to 1880.4 MHz.

But GSM carriers fall within the band 1875.8 to 1880 MHz, and therefore information from the interference requirements on DECT receiver attenuation on the adjacent channels has to be used to extend the DECT blocking requirements to include the whole band below 1800 MHz. The last GSM carrier is on frequency 1879.8 MHz. This extension has been made in Appendix 1 table 4A. Receiver interference and blocking requirements are translated into one consistent blocking requirement covering the whole GSM band.

Blocking from GSM 1800 BTS transmissions is the dominant interference mechanisms to DECT receivers.

It is very important to be aware that the concept of blocking does not mean that the DECT receiver is going into saturation. DECT receivers can typically withstand interfering levels of –5 dBm to 0 dBm with a constant ratio between wanted signal and interfering signal for a constant performance. Thus required isolation due to blocking will be reduced with the same amount that the wanted signal level is increased beyond the level used for the blocking specification
(-80 dBm).

- Co-channel interference due to out-of-band emissions from an interfering system

The dominant interference mechanisms to GSM 1800 is co-channel interference from DECT out-of band emissions into GSM 1800 MS receive channels.

- Co-channel interference due to transients emissions from an interfering system

Switching transients do also provide out-of-band emissions, but do normally not cause a dominant interference mechanism.

DECT emissions due to transients are not needed to be considered at all. They are very short (1micro second) with very low average power content, and are efficiently masked by the GSM1800 receiver error correction capability.

The impact of GSM 1800 BTS emissions due to transients need to be analysed even if they only affect a few bits in a DECT frame. They are not very short compared to a DECT bit length, and the instant peak level is relevant since many of the DECT services do not implement error correction. Estimated worst case values of out-of-band emissions based on the GSM transient specification are found in table 3C of section 1.4 of Appendix 2.

Measurement made on a typical GSM macro BTS do however show that transients do not exceed the peak power of other out-of-band emissions (like emissions due to modulation) when received in a 1 MHz wide filter typical DECT.
See section 4.5.

Thus emission due to transients is not a dominant interference mechanism.

- Intermodulation (IM)

Since the probability of IM interference is low, these problems may also be solved by intra cell hand over in GSM 1800 and by the Dynamic Channel Selection in DECT. Receiver IM does normally not cause a dominant interference mechanism, and is not used for the calculations in this report.

4.4 Interference calculations

The power levels and antenna gains used in this compatibility study are shown in section 4.1 above.
For complete calculations of MCL, E-MCL and MC methods, see Appendix 5.

The MCL (minimum coupling loss) method was used to find the most critical interference scenarios. After this in a second step some of the critical interference scenarios were calculated again with E-MCL and MC. The results of the different methods are compared (see Appendix 5).

Both GSM and DECT use Time Division Multiple Access, TDMA, which implies that the number of active transmit slots on a carrier can vary from 0 to all being active. For all interference calculations in this document, MCL, E-MCL and MC, the transmit power during the active part of the time-slots has been used. Therefore there is no difference in the transmit power or in the results if one or all slots are active. Thus the results of the calculations are relevant for the case where all slots are active on the interfering carrier.
In reality, for many cases, normally only a low number of timeslots are active per carrier. For instance, a DECT telepoint or residential BTS normally has one carrier with one active transmission and 9 carriers with no transmissions. The same is true for a DECT speech handset when it is active. A DECT office (speech only) BTS with 5 Erlang average traffic/BTS, typically has 5 carriers with one active time-slot each and 5 carriers with no active time-slots.
DECT and GSM will cause asynchronous interference to each other due to different frame cycle times. One single GSM time-slot will always interfere with any specific DECT time slot at least every 60 ms (every 6^{th} DECT time frame). Thus a DECT transmission will be interfered about 16 times per second, which of course will make it useless. In fact, every one of the 24 time-slot positions on a DECT carrier will be interfered at least every 6^{th} frame. (About 25 % of the slots will be interfered twice every 60 ms.) Thus all time-slots of a carrier will become useless, no matter if 1 or 8 GSM transmissions (time-slots) are active on the interfering GSM carrier.
For interference from DECT to GSM, the situation is different. The GSM standard error correction capability can correct for interference from up to 2 active DECT time-slots. This is very important when interpreting the results of the calculations of this report.

4.4.1 GSM 1800 BTS interferes with DECT WLL systems, BTSs and CTAs, Case7

The GSM1800 above rooftop BTS interferes with DECT above roof top BTS receivers due to blocking and out of band emissions. This case 7 is a critical scenario.
The cell sizes of GSM and DECT WLL are similar, typically 500 m to 5 km, smaller sizes in urban areas and larger in sub-urban and rural areas. Some efforts in co-ordinated BTS site engineering are normally to be expected. In some countries, it might not be envisaged to deploy dense GSM and DECT WLL networks in the same area. However, in cases where both systems are deployed in dense urban areas, it is not realistic to expect to be able to co-ordinate with a minimum distance between DECT WLL and GSM sites below 100 to 200 m. Therefore the observations derived from this chapter are such that the minimum separation distance between the victim and the interferer can go down to about 100m.

4.4.1.1 Calculation results for case 7

The DECT base stations are relatively few, and each base station has after installation a well-known position with a few more or less deterministic interference sources, the closest GSM BTS's. Furthermore, the GSM base station is typically transmitting all the time with at least one time slot active on each carrier, and a DECT WLL base station is typically receiving all the time.

Because of this deterministic nature of the interference scenario case 7, Monte Carlo simulations are not relevant. Therefore MCL and MSD have been used for the calculations in the table below.

Since both the GSM and DECT base stations are normally elevated above rooftop, some sectors of each DECT BTS will be in line of sight with the closest GSM BTS. Thus the free space propagation model applied for case 7 is relevant for distances up to 500-2000 m depending on the antenna height.

The MCL analysis from table 2 and table 4 of Appendix 5, section 5.1 for Case 7 is summarised below in table 4. In the headings of columns of table 4, "GSM <1875 MHz, No DECT capacity reduction" implies, that with the indicated minimum separation distance and GSM carrier positions <1875 MHz, none of the DECT carriers F0 – F9 are affected. "GSM in 1875 – 1879.8 MHz. Capacity reduction in DECT carriers F7 – F9" implies, that with the same minimum separation distances as in the previous column and GSM carrier positions within 1875 – 1879.8 MHz, carriers F0 – F6 will not be affected, but carriers F7 – F9 will not be usable except for CTAs with high wanted signal level close to the DECT base station. This will result in a capacity reduction of the DECT WLL system. Compare with Case 7 of Table 2 of Appendix 5, section 5.1. Two additional rows have been added for MSD 100 m and 200 m.

GSM 1800 BTS EIRP	Required Isolation	Minimum Separation Distance, MSD	
		GSM <1875 MHz No DECT capacity reduction	GSM in 1875 – 1879.8 MHz Capacity reduction in DECT carriers F7 – F9
54 dBm	99 dB (blocking)	1122 m	1122 m
54 dBm	86 dB (out-of-band)	251 m	251 m
(36 dBm)	84 dB (bl.)	200 m	200 m
(33 dBm)	78 dB (bl.)	100 m	100 m
30 dBm	75 dB (bl.)	71 m	71 m

Table 4

In the calculations above, the GSM 1800 BTS and the DECT WLL BTS are assumed to be in direct alignment. This is the worst case, which will not apply to all BTS in the real deployment, due to varying antenna heights and tilting.

The table above shows that to reach the required 100 m separation distance (with –80 dBm DECT wanted signal level):

he required isolation due to blocking has to be reduced by 21 dB,

and

the required isolation due to out-of-band emissions has to be reduced by 8 dB

It is impossible to solve this by required reduction of the GSM BTS below 54 dBm within the whole GSM band. Therefore the above reduction of required isolation have to be met by other means. Reduction to maximum 33 dBm EIRP could be required in the band 1878 – 1879.8 MHz not to cause capacity reduction on carriers F7-F9 in areas where it is not possible to separate the GSM and DECT WLL BTSs equipments by more than a few hundreds of metres (see section 4.4.1.2 below on the use of external filters on DECT WLL BTS).

Therefore DECT WLL will have to withstand 54 dBm interference at least from the band 1805 – 1878 MHz. This will need about 20 dB less required isolation within the band 1805 – 1878 MHz to reach the wanted MSD of about 100 m.

4.4.1.2 Local site engineering with local external filters between BTS transmitters and antennas

It is possible and common practice when needed, in the site engineering process to deploy external filters between the BTS transmitters and the antennas of those sectors that are blocked. Such filters at the DECT WLL BTS could add 10 dB, 20 dB or more to the DECT blocking performance, but with substantial difficulties for GSM frequencies above 1878 MHz supposing the filter is only marginally affecting the DECT carriers. There are two ways to solve this difficulty.

a) Reduction of the GSM 1800 BTS power to maximum 33 dBm EIRP in the band 1878 – 1879.8 MHz.
(100m MSD in the table above requires power reduction to 33 dBm.). But it will at the same time increase the number of GSM 1800 BTS, leading to a more difficult choice of proper BTS siting.

b) Put the filter cut-off frequency 2 MHz further inside the DECT band to fully attenuate GSM carriers up to 1879.8 MHz, but will at the same time reduce the DECT WLL system capacity with about 10 %.

How much additional attenuation is required for the external filters depends on how much better the DECT WLL BTS is compared to the blocking specification, and on the minimum sensitivity used for the deployment (the margin N used in E-MCL).

Similarly, it is possible, and common practice when needed, in the site engineering process to deploy external filters between the GSM 1800 BTS transmitters and the antennas of those sectors that are interfering DECT BTS due to too high out-of-band emissions from the GSM 1800 BTS. Such filters could add 10 dB, 20 dB or more attenuation to the GSM out-of band emissions within the DECT band, but with difficulties for GSM frequencies above 1878 MHz unless the filter is allowed to attenuate GSM frequencies above 1878 MHz.

There are two ways to solve this difficulty.

a) Put the filter cut-off frequency inside the GSM band whereby GSM carriers above 1878 MHz will be attenuated, and the GSM 1800 BTS cell radius will be reduced by 50 % in this band. This will at the same time increase the number of GSM 1800 BTS, leading to a more difficult choice of proper BTS siting.

b) Put the filter cut-off frequency at the GSM band edge so that no GSM carrier is attenuated, whereby one or two DECT carriers will still be affected by the GSM emissions and the DECT WLL system capacity will be reduced by about 10 %.

How much additional attenuation is required for the external filters depends on how much better the GSM BTS is compared to the out-of-band specification, and on the minimum sensitivity used for the DECT deployment (the margin N used in E-MCL).

4.4.1.3 The number of sites that may need site engineering

The number of BTS sites that will require dedicated site engineering depend on the required isolation (see the table above) and on how dense the GSM BTS network is. For example, suppose that the required separation distance will be about 320 m due to DECT blocking performance being B dB better than the specification and/or installation was made with wanted signal having a margin N added to the –80 dBm. N + B >= 10 dB. Suppose also that the average radius of the GSM cells is 1 km. Supposing uncoordinated installation of the two systems, in average 10 % of the DECT WLL BTS will appear within 320 m from a GSM base station. Thus about 10% of the sites would require dedicated site engineering. We could also suppose that in average only ½ of the sectors of each site is affected. Thus in this example 5 % of the BTS radios and BTS sectors will require site engineering. With relevant differences in antenna heights and tilting, the number of affected sectors could be further reduced.

4.4.1.4 Means to reduce the Required Isolation

The extra 20 dB reduction in required isolation for 54 dBm EIRP due to blocking can for example be provided alternatively by:

- 10 dB better actual blocking performance and 10 dB external filter, or
- 10 dB larger sensitivity margin N (-70 dBm sensitivity) and10 dB external filter, or
- 10 dB better actual blocking performance and 10 dB larger sensitivity margin N.

Note : The blocking performance of actual DECT equipment may typically be in the order of 6 to 10 dB better than the specification. The blocking performance close to the DECT band (up to 20 MHz separation or more from the band edge) is dominated by the IF-filter performance. See section 4.5.

The extra 8 dB reduction in required isolation for 54 dBm due to out-of-band emissions can for example be provided alternatively by:

- 8 dB actual GSM better out-of-band emissions performance*, or
- 8 dB larger DECT sensitivity margin N (-70 dBm sensitivity), or
- 8 dB external GSM BTS filter

*Note: 8 dB actual better GSM out-of-band emissions performance implies that in section 1.2, Appendix 2, the –80 dB figure for out-of-band emissions in Table 2 instead shall be –88dB. Measurements on typical GSM Macro BTS show out-of-band emissions 2-14 dB lower than specified. See section 4.5.

Table 5 below gives an example on combination of different means to reach the 100 m minimum separation distance, MSD.

Different means for 100 m Minimum Separation Distance, MSD		Different alternatives					
		a	b	c	d	e	F
54 dBm EIRP BCCH below 1878 MHz		Yes	Yes	Yes	Yes	Yes	Yes
Carriers within 1878 – 1879.8 MHz have EIRP below 33 dBm		Yes/ No*	Yes/ No*	Yes/ No*	Yes/ No*	Yes/ No*	Yes/ No*
DECT minimum wanted signal level	[dBm]	-80	-80	-80	-80	-70	-70
DECT blocking performance above specification	[dB]	0	20	20	10	0	10
DECT external filter extra attenuation	[dB]	20	-	-	10	10	-
GSM out-of-band emission performance above specification	[dB]	0	0	8	8	0	0
GSM external filter extra attenuation	[dB]	8	8	-	-	-	-
Obtained isolation / Minimum separation distance, MSD	[dB]/ [m]	78/ 100	78/ 100	78/ 100	78/ 100	78/ 100	78/ 100

Table 5

Table: Different means for obtaining 100 m Minimum Separation Distance, MSD, for above roof-top DECT WLL BTS and GSM 54 dBm EIRP BTS. This corresponds to 78 dB required isolation.
*If "No", about 10 % capacity loss may be expected for the DECT WLL system and if "Yes", 50% cells radius decrease may be expected for the GSM 1800 BTS.

4.4.1.5 Requirements on DECT to detect interference from a GSM single bearer and requirements on GSM with implemented frequency hopping

The different solutions of the above table 5 assume that the interference can be detected, so that DECT can make intra-cell hand over to a better, less interfered channel, avoiding the need for a guard band.

Interference from a single non-frequency hopping bearer occurs every 6th DECT frame. DECT will be able to make handover, if the handover process is triggered by a "leaking bucket" setting where for instance a correct frame produces 1 step up and an error frame produces 8 steps down. This is feasible to be implemented in DECT, although not currently specified. See section 4.5 Practical Tests.

Frequency hopping is becoming more and more common. One GSM frequency hopping single bearer (time-slot) will interfere with a specific DECT time slot only every 48th DECT frame (2 times per second). This may give a DECT speech connection a bad quality, but the interference occurs too seldom for the DECT hand over process to initiate hand over.

One solution to help the DECT hand over process to detect the interference and make a successful handover is to always have the highest GSM carrier in use adequately loaded by always having at least one time slot active in each frame. This is however very complicated and it is expected to be hard to get commitment from ETSI Project SMG to properly standardise and implement such a feature. Therefore no action is recommended in this respect.

However when further analysing this problem it is found that the frequency hopping in it self may not be a major cause to harmful interference, **provided that handover due to a single non-frequency hopping bearer is properly implemented**. There are several reasons for this; the non-hopping BCCH channel is always present, transmissions on several carriers are normally detectable, the DECT transmission does not always use carrier F9, the subjective effect of occasional errors can be minimised by special processing in the DECT speech codec, for DECT packet data services occasional errors are taken care of by retransmissions, carrier F9 could in worst case be locally disabled.

The conclusion is that frequency hopping in this report is not treated as a special case for special actions. The counter measures for non-hopping interference are thus regarded relevant also when frequency hopping is implemented.

However, if the possibility exists not to allocate locally the upper part of the GSM 1800 band (1878 – 1880 MHz), this would generally improve coexistence and would also reduce the probability for harmful non-detectable frequency hopping interference (at GSM low traffic hours) to DECT WLL applications.

4.4.1.6 Requirements on GSM BCCH broadcast channel

The GSM BCCH broadcast channel is fixed and cannot make handover. Therefore the BCCH channel should be given a channel at least 2 MHz from the DECT band edge, below 1878 MHz, so that it can be received without interference by any GSM MS.

4.4.1.7 Case 7 is also relevant for a limited number of DECT WLL CTAs

The GSM 1800 above roof top BTS interferes also to the WLL CTAs (subscriber units) receivers due to blocking and out of band emissions. CTAs are often in line-of-sight of the DECT WLL BTS. They are however not installed as high up as the BTS and have directional antennas (about 60 – 80 degree opening angle) and are often mounted on an external wall. Thus there will always be some CTAs (may be 10% of the CTAs) that also will be in direct line of sight to a close-by GSM BTS, where the free space propagation model and CASE 7 applies also for those CTAs.

If the assumptions of section 4.4.1.3 are used, and if the CTA has 12 dBi antenna gain, and if case 7 is relevant for 10 % of the CTAs, then 1 % of the subscriber sites will require some kind of site engineering. Note that for a mobile system outage between 1 and 5 % are very acceptable because the subscribers are mobile. But in a WLL system the subscribers are fixed and the outage has to be brought to 0 % by site engineering for each subscriber.

But the majority of the CTAs are not in line-of-sight of the closest GSM BTS. This case is covered in section 4.4.2 below. This case 6, where propagation model F is used, is also an important scenario.

Thus case 7 is relevant for some of the CTAs, but for the majority of CTAs and for estimation of the average impact on CTAs case 6 below, where also Monte Carlo simulations have been applied, is more relevant.

4.4.1.8 Proposal for requirements on the two operators for co-ordination of above roof-top system installations

There are at least three cases to consider; the DECT WLL is already installed, the GSM 1800 system is already installed and no GSM system nor DECT WLL system is installed. The solutions envisaged for each of these cases will vary depending on the national regulatory position regarding the relative development of one or the other system in the considered area.

DECT WLL will not cause harmful interference to the GSM system, provided that the following conditions for GSM intra-cell handover, which normally are feasible, have initially been taken into account in the network engineering (see section 4.4.6):

- The GSM BTS normally have at least 2 carriers per sector, whereby it should be avoided to have more than one carriers within the frequency band 1878 – 1880 MHz. If there is a single carrier in a sector, this carrier shall not be within the band 1878 – 1880 MHz.
- The GSM 1800 BCCH control channel should not operate within the band 1878 – 1880 MHz.

However, implementing such requirements can be impracticable for an existing network which has its whole network based on a specific reuse pattern, uses specific sub-bands for BCCH, micro-cells and where hopping sequences are a key element of the network architecture.

But the GSM system may cause harmful interference to the DECT WLL subscribers unless the system installations are properly co-ordinated.

In all cases, DECT has to be able to detect and escape via intra-cell hand over interference from a single GSM bearer:

DECT has to be able to process a successful hand over when the up-link or the down-link is interfered as seldom as every 6^{th} frame.

4.4.1.8.1 The DECT WLL system is already installed

- Co-ordinated site engineering and system planning will be required by the GSM operator to minimise interference between the new above roof-top GSM BTS and the DECT WLL system(s).
- To help the co-ordination process, the GSM operator should supply information on the actual GSM out-of-band peak hold emission levels received in a 1MHz bandwidth. The DECT operator should supply information on the actual DECT site positions, BTS EIRP, blocking performance and actual wanted signal receive levels.
- The GSM operator shall aim at getting his BTS sites at the intersection of DECT WLL cells. (This will minimise interference to DECT WLL subscriber units, CTAs, since all close by line-of- sight CTAs will then have its directional gain antenna directed away from the GSM BTS.)
- The general requirements stated in 5.4.1.8 should apply
- If the GSM operator also have indoor BTSs and/or below roof-top BTSs, the carriers closest to the DECT band should be used for these systems and not for the above roof-top macro cell BTSs.
- Some GSM BTS sectors may require dedicated site engineering, e.g. external filters to suppress out-of-band emissions if they are high and/or plan to reduce the power of carriers within 1878 – 1880 MHz or not to use these carriers locally where DECT maximum traffic capacity is required.
- Some DECT WLL BTS sectors and some CTAs may still require dedicated site engineering, e.g. by adding external filters.

4.4.1.8.2 The GSM 1800 system is already installed

- Co-ordinated site engineering and system planning will be required by the DECT operator to minimise interference between the above roof-top GSM BTSs and the new DECT WLL system(s).
- To help the co-ordination process, the DECT operator should supply information on the actual DECT blocking performance and actual wanted signal receive levels planned to be used, and the estimated traffic peak for his station.
- The GSM operator should supply information on the actual GSM site positions, carriers in use, BTS EIRP, out-of band peak hold emissions levels received in a 1MHz bandwidth.
- The DECT operator shall aim at getting the intersection of DECT WLL cells where GSM BTS sites are. (This will minimise interference to DECT WLL subscriber units, CTAs, since all close by line-of- sight CTAs will then have its directional gain antenna directed away from the GSM BTS)
- The DECT operator should plan to use a wanted signal level high enough to ensure reasonably low interference potential from the GSM system. The demand on high wanted signal level (smaller cells) is reduced if installed DECT WLL equipment have improved blocking performance above minimum specification.
- Some DECT WLL BTS sectors and some CTAs may require dedicated site engineering, e.g. by adding external filters.
- The general requirements stated in section 4.4.1.8 should apply. If the GSM operator also have indoor BTSs and/or below roof-top BTSs, the carriers closest to the DECT band should be replanned if possible to be used for these systems and not for the above roof-top macro cell BTSs.
- Exceptionally, some GSM BTS sectors may still require dedicated site engineering, e.g. external filters to suppress out-of-band emissions if they are high and/or may plan to reduce the power of carriers within 1878 – 1880 MHz or not to use these carriers locally where DECT capacity is affected too much

4.4.1.8.3 No GSM system and no DECT WLL system is installed

If both systems are intended to use adjacent channels in the same dense areas, the regulator should advise the operators that they will need to co-ordinate their networks and that in some specific cases it might have to implement some means of reducing interference. See the section above.

4.4.2 GSM 1800 BTS interferes with DECT WLL CTAs, Cases 6.

The GSM1800 BTS interferes with DECT CTA receivers due to DECT blocking. This scenario describes a possible interference path between a GSM1800 BTS installed on the roof of a high building and DECT-WLL receiver antenna installed outside a building.

The required isolation with MCL for this case is compared with the results for the same scenario calculated with E-MCL and MC. The parameters are given in Appendix 5.2 and 5.3. The results are in table 6:

GSM 1800 BTS 54 dBm EIRP on carrier	MSD with MCL	MSD with E-MCL average	MSD with E-MCL maximum	Blocking probability with MC*
1879,8 MHz	760 m	347 m	439 m	21 %
1878.4 MHz	334 m	152 m	193 m	3 %
1876.6 MHz	240 m	109 m	139 m	1 %
1805 - 1875 MHz	182 m	83 m	106 m	<1 %

Table 6

Table: Blocking probability and separation distances for DECT carrier F9 case 6.

* Considering the assumptions made for the MC analysis (see Appendix 5.3), the blocking probabilities given in this column are related to the specific case where the GSM 1800 carrier is blocked at the frequency given in the corresponding row and the DECT is blocked on the F9 carrier without taking into account of the escape mechanisms of DECT. In order to give a more realistic meaning to this simulation, we can derive from these values the maximum average capacity reduction for all DECT carriers. Maximum average capacity reduction means average capacity reduction when capacity reduction occurs, that is when the full capacity of DECT is needed. In this case, this leads to a maximum average capacity reduction value for DECT of 2.1+0.3+0.1=2.5%.

The calculations above have been made for DECT carrier F9, but the results for carriers F8, F7 etc. are easily derived by shifting the results in the tables above one line up for F8, two lines up for F7 etc.

This case would also benefit from improved performance. It does however relate to the same system as case 7 above. We can foresee that the case 7 will provide 10 dB better actual blocking performance and/or 10 dB larger sensitivity margin N, which will give the wanted performance improvement. **From this point of view case 7 is the critical case.**

Note: The Monte Carlo simulation for this case is not very accurate. It supposes that the DECT CTA antennas are 12 dBi omni-directional elevated 10 m, while they in reality have 60-80 degrees opening angle and are often mounted on external walls. On the other hand the modified Urban Hata propagation model has been used, which gives higher attenuation than would be expected for a WLL scenario. So the selection of a too optimistic propagation model, and not including the interference reduction due to the antenna directivities , will counteract each other to give a result of this Monte Carlo simulation that may be reasonable.

4.4.3 GSM1800 above roof-top BTS interferes with a private cordless telephone DECT FP in a neigh-bouring building. Case 1.

For Case 1 A, see the table below, the DECT building is in the direct beam of the GSM BTS. Cases 1B and 1C apply for the majority of DECT residential and office systems. Case 1 A is more critical than cases 1B and 1C.

GSM 1800 BTS 54 dBm EIRP on carrier	MSD with MCL	Average MSD with E-MCL	maximum MSD with E-MCL N = 10 dB	maximum MSD with E-MCL N = 26 dB	Blocking probability with MC*
1879,8 MHz	1000 m	206 m	374 m	50 m	28 %
1878.4 MHz	178 m	36 m	67 m	9 m	3 %
1876.6 MHz	89 m	18 m	33 m	4.5 m	1 %
1805 – 1875 MHz	50 m	10 m	19 m	2.5 m	<1 %

Table 7

Table: Blocking probability and separation distances for DECT carrier F9 case 1A.

* Considering the assumptions made for the MC analysis (see Appendix 5.3), the blocking probabilities given in this column are related to the specific case where the GSM 1800 carrier is blocked at the frequency given in the corresponding row and the DECT is blocked on the F9 carrier without taking into account of the escape mechanisms of DECT. In order to give a more realistic meaning to this simulation, we can derive from these values the maximum average capacity reduction for all DECT carriers. In this case, this leads to a maximum average capacity reduction value for DECT of 2.8+0.3+0.1=3.2%.

In reality, distances will hardly ever be below 20-30 m from a 54 dBm EIRP GSM macro BTS. Further more, DECT office system are normally installed with a high wanted signal margin (N >=10 dB) and therefore the E-MCL values are relevant. Thus DECT carriers F0 to F7 will always be available. For low capacity systems this is no problem. High capacity DECT systems may have higher margins N due to the small cell sizes used to get the high capacity. See Appendix 1 section 2.5 the Note, where extreme but not unrealistic high capacity systems with N = 26 dB and 38 dB are described. Here the row for N = 26 dB in the table above applies.

The Monte Carlo simulations do not use the propagation model A but the modified Hata urban model. It is supposed that the blocking probability figures are useful in spite of this. The maximum average capacity reduction of 3.2% can be compensated by installing DECT office base stations 2 % closed to each other.

The conclusion is that CASE 1 is not a critical scenario, since DECT will always have carriers that are not interfered, and the potential probability for serious capacity reduction is very low.

But this conclusion, again as for case 7, assumes that the interference can be detected, so that DECT can make intra-cell handover to a better, less interfered channel, else a large guard band will be required.

4.4.4 DECT FP with 12 dBi gain antenna installed outdoors for a service like telepoint or DECT for WLL. DECT FP interferes with a GSM 1800 MS. Case 5, model F.

GSM MS receiver on carrier	MSD with MCL	Maximum MSD with E-MCL N = 10 dB	Maximum MSD with E-MCL N= 10 dB DECT FP 2 dBi
1879,8 MHz	183 m	106 m	50 m
1878.4 MHz	50 m	23 m	11 m
1876.6 MHz	22 m	10 m	3 m
1805 - 1875 MHz	18 m	9 m	3 m

Table 8
Table: Interference to GSM MS. Separation distances with DECT carrier F9 case 5.

The column with 2 dBi corresponds to the large FIDO telepoint/CTM system in Italy, which have about 2 dBi antennas.

When having more than one carrier in a sector, typical for GSM macrocell systems, GSM can in most cases avoid this interference with limited impact on capacity by making intra-cell handover. When only one carrier operates in the sector, the upper GSM channels should not be used.

GSM can in many cases avoid this interference with limited impact on capacity due to the GSM error correction, which can correct for up to two interfering DECT time slots per frame. Interference from DECT telepoint base stations, residential base stations, DECT handsets and CTAs and typically meet this criteria. A highly loaded WLL base station often not, but GSM MS will not come very close to a WLL above roof-top base station.

The GSM BCCH broadcast channel is fixed and cannot make handover. Therefore the BCCH channel should be given a channel at least 2 MHz from the DECT band edge, below 1878 MHz, so that it can be received without interference by any GSM MS when there is a DECT BTS nearby .

The ability by GSM error correction to avoid the impact of all interference of low capacity DECT case 5 applications is verified by the measurements. No interference could be measured. **Thus Case 5 is not a critical scenario**.

4.4.5 GSM above roof-top BTS interferes with DECT FP outdoors at street level. Case 3 model E,

GSM 1800 BTS 54 dBm EIRP on carrier	MSD with MCL	MSD with E-MCL average	MSD with E-MCL maximum	Blocking probability with MC*
1879,8 MHz	398 m	129 m	197 m	21 %
1878.4 MHz	130 m	40 m	62 m	3 %
1876.6 MHz	63 m	26 m	40 m	1 %
1805 - 1875 MHz	35 m	17 m	27 m	<1 %

Table 9
Table: Separation distances and blocking probability for DECT carrier F9 case 3.

* Considering the assumptions made for the MC analysis (see Appendix 5.3), the blocking probabilities given in this column are related to the specific case where the GSM 1800 carrier is blocked at the frequency given in the corresponding row and the DECT is blocked on the F9 carrier without taking into account of the escape mechanisms of DECT. In order to give a more realistic meaning to this simulation, we can derive from these values the maximum average capacity reduction for all DECT carriers. In this case, this leads to a maximum average capacity reduction value for DECT of 2.1+0.3+0.1=2.5%.

The Monte Carlo simulation figures are made with the modified Hata urban model instead of model E. Model E would give lower probabilities. Therefore the figures above are on the high side.

The critical mechanism here is the blocking performance of DECT.

The calculations above have been made for DECT carrier F9, but the results for carriers F8, F7 etc. are easily derived by shifting the results in the tables above one line up for F8, two lines up for F7 etc.

The DECT victim is typically a DECT telepoint/CTM BTS. It could also be a below roof-top installed DECT WLL base station. In reality, distances will hardly ever be below 30-40 m from a 54 dBm EIRP GSM macro BTS. Thus DECT carriers F0 to F6 will always be available. For low capacity systems this gives no capacity reduction. For high capacity DECT systems the Monte Carlo simulation show an average capacity reduction for all 10 carriers of only 2.5 %.

The conclusion is that CASE 3 is not a critical scenario, since DECT will always have carriers that are not interfered, and the potential probability for serious capacity reduction is very low.

But this conclusion again as for case above assumes that the interference can be detected, so that DECT can make intra-cell handover to a better, less interfered channel, else a guard band will be required.

4.4.6 DECT indoor system interferes with GSM 1800 MS in indoor usage. Case 2, model D.

GSM MS on carrier	MSD with MCL	Maximum MSD with E-MCL N = 10 dB	Maximum MSD with E-MCL N = 20 dB	Maximum MSD with E-MCL N = 30 dB
1879,8 MHz	53 m	30 m	17 m	9 m
1878.4 MHz	17 m	10 m	3 m	1 m
1876.6 MHz	9 m	3 m	1 m	-
1805 - 1875 MHz	6 m	2m	-	-

Table 10
Table: Interference to GSM MS. Separation distances with DECT carrier F9 case 2.

E-MCL includes N, but does in this not include power control because DECT does not have power control.

This case applies to both a GSM MS locked to a GSM outdoor system (the most obvious and common case) and to GSM locked to a an indoor micro BTS described in Case 8.

GSM MS can in many cases avoid this interference with limited impact on capacity due to the GSM error correction, which can correct for up to two interfering DECT time slots per frame. Interference from the DECT MS meet this criteria, but not always a highly loaded DECT office BTS. The solution to this depends on which system the MS is locked to.

4.4.6.1 Locked to an outdoor GSM BTS

The solution for an outdoor system is to provide handover to a less interfered carrier. The outdoor GSM BTSs normally have at least 2 carriers per sector, whereby only one of these carriers should be within the frequency band 1878 – 1880 MHz. If there is a single carrier in an outdoor BTS sector, this carrier shall not be within the band 1878 – 1880 MHz.

The GSM BCCH broadcast channel is fixed and cannot make handover. Therefore the BCCH channel should be given a channel at least 2 MHz from the DECT band edge, below 1878 MHz, so that it can be received without interference by any GSM MS when there is a DECT BTS nearby.

The maximum E-MCL value with N = 10 dB could be used for our analysis. MSD above 3-5 m from a DECT office base station can not be accepted. Out-of band emissions of DECT actual equipment is typically 5-10 dB better than the specification and the probability is not very high that a GSM MS will be called when very close to the DECT BTS and at the same time at the range limit.

The conclusion is that with the above proposed provisions, the probability of harmful interference to GSM MS locked to outdoor BTS is very small. **This case is not critical.**

4.4.6.2 Locked to an indoor GSM micro BTS

When having more than one carrier in a BTS sector, GSM can, as for the outdoor systems, avoid interference on carriers close to the DECT band with limited impact on capacity by making intra-cell handover to the other carrier. But a micro indoor BTS may not always have more than 1 carrier (per sector).

The probability to have a DECT indoor system and a GSM indoor system in the same indoor location is very low. But it may happen, e.g. in a shopping centre or a large exhibition centre. This case will thus apply only to a very, very small fraction of all GSM and DECT calls.
It is thus not economically justifiable to prevent potential harmful interference for these few cases by implementing a general guard band. Instead it is feasible to prevent potential harmful interference for these few cases by proper planning of the system installation.

An adequate installation margin N should be added to the minimum operational wanted signal level of the GSM indoor system. N could be in the order of 20 dB or 30 dB, which is a feasible non-controversial restriction. N = 30 dB would still give a GSM (26 dBm trx, model D) indoor cell radius beyond 80m, which is much more than required for indoor high capacity installations. The indoor capacity requirements will force base stations to be installed with much closer separation distances than 160 m.

Thus the maximum E-MCL value with N = 30 dB or more could be used for our analysis. MSD above 3-5 m from a DECT office base station cannot be accepted. Out-of band emissions of DECT actual equipment are typically 5-10 dB better than the specification. N = 30 dB and DECT out-of-band emissions 7 dB better than the specification giver 4 m MSD. It is thus very feasible to plan the deployment of an indoor GSM system to avoid harmful interference from a DECT system in the same indoor location, also when the GSM micro BTS only has one carrier. **This case is not critical**.

The ability by GSM error correction to avoid the impact of all interference of low capacity DECT case 2 applications is verified by measurements.

4.4.7 Indoor GSM 1800 micro BTS in interferes with DECT indoor system. Case 8 model D.

GSM 1800 BTS 26 dBm EIRP on carrier	MSD with MCL	Maximum MSD with E-MCL N =10 dB	Maximum MSD with E-MCL N = 20 dB	Maximum MSD with E-MCL N = 30 dB
1879,8 MHz	47 m	27 m	15 m	11 m
1878.4 MHz	20 m	11 m	4 m	2 m
1876.6 MHz	14 m	6 m	2 m	1 m
1805 - 1875 MHz	11 m	4 m	1 m	<1 m

Table 11
Table: Separation distances and blocking probability for DECT carrier F9 case 8.

The critical mechanism here is the blocking performance of DECT.

The calculations above have been made for DECT carrier F9, but the results for carriers F8, F7 etc. are easily derived by shifting the results in the tables above one line up for F8, two lines up for F7 etc.

This case is only relevant if DECT and GSM indoor systems are installed in the same area in the same building. This is not a very likely scenario, but it happens, for example in large exhibition halls and fairs. For this specific case MSD of a few (3-4) m may be required. This is solved by limiting the GSM BTS EIRP and installing the DECT system with a relatively large margin N. See further explanation for cases 1 and 2 above.

- GSM micro BTS transmit power should be limited to 30-33 dBm EIRP when installed indoor in the same location as a DECT system. (This maximum BTS power level is already typical for indoor GSM installations, which is 26 dBm EIRP. Thus this is a feasible non-controversial restriction.)

- An adequate installation margin N should be added to the minimum operational wanted signal level of the DECT system. N could be in the order of 20 dB or more, which is a feasible non-controversial restriction. N = 20 dB would still allow DECT cell radius beyond 40 m, which is much more than required for indoor high capacity installations. The indoor capacity requirements will force base stations to be installed with much closer separation distances that 80 m.

The conclusion, as for Case 1, is that Case 8 is not a critical scenario, since with proper installation DECT will always have carriers that are not interfered, and the potential probability for serious capacity reduction is very low.

But this conclusion again as for case above assumes that the interference from GSM can be detected by DECT, so that DECT can make intra-cell handover to a better, less interfered channel, else a guard band will be required. Note that generally, indoor GSM 1800 BTS use only one carrier per BTS and thus frequency hopping for indoor GSM 1800 BTS is not used.

4.4.8 Effects of power reduction for the GSM 1800 BTS on the interference to DECT

A reduction of the GSM 1800 transmit power can help to further reduce the probability for interference from GSM 1800 to DECT carriers F9 and F8. Below are some more results from the Monte Carlo simulations where the effect of reduced GSM BTS power is shown.

4.4.8.1 Monte Carlo Simulations for DECT CT as victim (Case 4)

GSM 1800 BTS on carrier	**BTS EIRP 54 dBm**	**BTS EIRP 47 dBm**	**BTS EIRP 37 dBm**	**BTS EIRP 33 dBm**	**BTS EIRP 27 dBm**
1879,8 MHz	28 %	11 %	3 %	1 %	< 1%
1878.4 MHz	3 %	1 %	<1 %	< 1%	< 1%
1876.6 MHz	1%	<1 %	< 1 %	< 1%	< 1%
1805 - 1875 MHz	<1 %	<1 %	< 1 %	< 1%	< 1%
Maximum average capacity reduction for all DECT carriers	3.2 %	1.2 %	0.3 %	0.1 %	<0.1 %

Tabel 12

Table: Blocking probability for DECT carrier F9 and maximum average capacity reduction Case 4 derived by Monte Carlo simulations

Considering the assumptions made for the MC analysis (see Appendix 5.3), the blocking probabilities given in the rows 2 to 5 in this table are related to the specific case where the GSM 1800 carrier is blocked at the frequency given in the corresponding row and the DECT is blocked on the F9 carrier without taking into account of the escape mechanisms of DECT. In order to give a more realistic meaning to this simulation, the maximum average capacity reduction for all DECT carriers has been derived and is given in the last row.

The calculations above have been made for DECT carrier F9, but the results for carriers F8, F7 etc. are easily derived by shifting the results in the tables above one line up for F8, two lines up for F7 etc. See the table above .

4.4.8.2 Monte Carlo Simulations for DECT WLL as victim (Case 6)

GSM 1800 BTS on carrier	BTS EIRP 54 dBm	BTS EIRP 47 dBm	BTS EIRP 37 dBm	BTS EIRP 33 dBm	BTS EIRP 27 dBm
1879,8 MHz	21 %	10 %	3 %	<2 %	<1 %
1878.4 MHz	3 %	1 %	<1 %	<1 %	<1 %
1876.6 MHz	1 %	<1 %	<1 %	<1 %	<1 %
1805 - 1875 MHz	<1 %	<1 %	<1 %	<1 %	<1 %
Maximum average capacity reduction for all DECT carriers	2.5 %	1.1 %	0.3 %	0.1 %	<0.1 %

Table 13

Table: Blocking probability for DECT carrier F9 and maximum average capacity reduction Case 6 derived by Monte Carlo simulations

This results are only valid for a maximum radius of ≤ 2000 m for the WLL system.
Considering the assumptions made for the MC analysis (see Appendix 5.3), the blocking probabilities given in the rows 2 to 5 in this table are related to the specific case where the GSM 1800 carrier is blocked at the frequency given in the corresponding row and the DECT is blocked on the F9 carrier without taking into account of the escape mechanisms of DECT. In order to give a more realistic meaning to this simulation, the maximum average capacity reduction for all DECT carriers has been derived and is given in the last row.

The calculations above have been made for DECT carrier F9, but the results for carriers F8, F7 etc. are easily derived by shifting the results in the tables above one line up for F8, two lines up for F7 etc. See the table above .

5 PRACTICAL TESTS

Limited practical tests have been conducted on some GSM and DECT equipment.

Laboratory tests have been made on residential DECT equipment simulating real indoor conditions. Also, information from earlier field tests has been provided. The following observations were noted:

- DECT does not interfere with GSM 1800 MS for the tested scenarios. The tests specifically confirm the results of the analysis made that GSM, due to its error correction capabilities, is not interfered by up to two DECT transmissions even with very small (10 cm) separation distances to a GSM MS.

- The tested DECT residential equipment had 6 to 10 dB better interference (blocking) performance than required by the specification.

Measurements on a typical GSM macro BTS have been made on GSM switching transients;

- Transients did not exceed the peak power of other out-of-band emissions (like emissions due to modulation and wideband noise) when received in a 1 MHz wide filter typical for DECT.

Although the GSM specification does not adequately cover this interference case, the practical tests indicate that switching transients are not a dominant interference mechanism to DECT.

- Furthermore the measured GSM device had out-of-band emissions 2-14 dB lower than those values used in Appendix 2 Table 2A.

This supports the conclusion that blocking is the dominant interference mechanism to DECT systems.

Measurements made on specific DECT (GAP) equipment showed that the speech path was very robust towards asynchronous interference, did also lack ability to detect interference from a single GSM bearer and make handover when the speech quality became too low. An investigation shows that other DECT equipments will perform proper handover when interfered by a single GSM bearer. The handover “threshold” for DECT equipment varies from manufacturer to manufacturer.

- As a conclusion, ETSI Project DECT should make sure that provisions are properly defined for DECT to detect interference from a single GSM bearer and to provide the required handover.

- Furthermore the measured DECT device had blocking performance 6 to 17 dB better than those values used in Appendix 1 Table 4A.

This supports the statement in section 4.4.1.4 that the blocking performance of actual DECT equipment could be 6 to 10 dB better than specified. (The blocking performance for frequencies up to 20 MHz separation or more from the DECT band edge is dominated by the IF-filter performance.)

6 MEANS TO IMPROVE THE COMPATIBILITY

Interference may occur between any kind of radio systems operating on adjacent bands in the same geographical area. From the analysis and discussions above we find that means to improve compatibility between DECT and GSM 1800 may be:
- inherent in the system properties ;
- related to improved performance of equipment ;
- related to parameters used when planning the deployment ;
- related to local site engineering.

6.1 Inherent system properties

The possibility to escape local/temporary interference by **intra-cell handover to an other carrier** is the most important mechanism to reduce the need for guard-bands between adjacent systems and to reduce the need for very demanding performance on receiver interference rejection (blocking) and transmitter out-of band emissions.

This intra-cell handover feature is inherent in GSM if the BTS has at least 2 carriers per sector, and if the BCCH signalling can be received by the GSM MS. For some scenarios with potential interference (see section 4.4), the following measures should be applied :

- The BCCH carrier should be below 1878 MHz,
- When having several carriers in each sector, at least one traffic carrier should be below 1878 MHz.

This intra-cell handover feature is also inherent in DECT through Instant Dynamic Channel Selection. But this assumes that the interference can be detected, so that DECT can make intra-cell handover to a better, less interfered channel (see section 4.4.1.5).

6.2 Improved performance

Actual equipment may have performance superior to the specification. Improved performance on DECT blocking and GSM BTS out-of-band emissions would improve compatibility and ease co-ordination between DECT above roof-top WLL installations and GSM 1800 Macro BTS installations.

6.3 Planning the deployment

Planning deployment with relevant margins on the wanted signal level (smaller cell radius) is always helpful for the self-protection of the system. Since the cost for indoor base station sites is only a fraction of the costs for outdoor sites, this is easier to do for indoor systems. The cost penalty will be higher for outdoor systems.

High capacity systems are normally interference limited and not range limited, and are therefore forced to use smaller cells and will thus automatically have a margin on the minimum wanted signal which increases the protection.

If the GSM operator intends to have indoor BTSs and/or below roof-top BTSs, the carriers closest to the DECT band could beneficially be planned to be used for these systems and not for the above roof-top macro cell BTSs.

GSM macro BTSs have about 18 dB higher peak power and 25 dB higher spectrum power density than DECT WLL. This unbalance is to disadvantage of DECT.

Planning with reduced transmitter power for GSM 1800 Macro BTSs reduces the potential interference to an adjacent DECT WLL system. This technique leads to a reduced GSM 1800 cell radius, which requires more sites to maintain the same coverage and the link quality. Furthermore, the reduction applies to all carriers within the cell.

6.4 Local site engineering

It is common practise for outdoor mobile telephone systems that the two operators using adjacent frequencies make some co-ordination and dedicated site engineering to minimise the mutual interference potential. This includes means like selection/exclusion of carriers, power adjustment, antenna configuration, adding extra BTS and adding external filtering. How much site engineering is required does not depend on the specification, but on the actual performance of the installed equipment, which may be better than that required by the standards.

6.5 Further considerations

Interference may occur between any kind of radio systems operating on adjacent bands in the same geographical area. It is normal practice that the newcomer has a responsibility to plan his system to minimise interference to the adjacent system already in operation, but both operators have to co-operate to solve emerging local unacceptable interference situations.

As explained here above, there are several means, which could be used to avoid interference cases to occur.

It is very important to note that the different means provided to facilitate sharing can be constraining for the system they are applied to. Due to the high complexity of a radio network engineering, even little constrains on the way an operator should use its frequencies can be impracticable, especially if it is an existing network (excessive cost, degradation of the quality of service/coverage are unavoidable issues). Therefore, the application of constraints should only be taken at a national level, in the very specific cases where it is relevant . Such an approach would not unduly constrain either operator and would facilitate efficient use of the spectrum.

7 CONCLUSIONS

This Report identifies and investigates the critical scenarios where interference can occur between DECT and GSM 1800 systems.

The problem of compatibility in adjacent bands between DECT and GSM 1800 is alleviated by properties inherent in these systems: DCS algorithm for DECT and intra-cell hand-over for GSM 1800 which both enable in most cases to avoid local/temporary interference by moving to an other carrier when interference has been detected. However, it has to be ensured that this escape process is possible, i.e. that the interfered system is capable of detecting the interfering signal and provide a successful handover.

- **DECT has very low probability to cause harmful interference to GSM 1800 systems.**

- **A guard band is not required to protect DECT from GSM 1800 interference, but measures are proposed to facilitate the coexistence when the GSM sub-band 1878-1880 MHz is used.**

It is very important to note that the different means provided to facilitate sharing could be constraining for the system they are applied to. Due to the high complexity of a radio network engineering, even little constrains on the way an operator should use its frequencies can be impracticable, especially if it is an existing network.

As the potential interference problems will appear in specific situations, it would not be economically justifiable to prevent potential harmful interference for these few cases by implementing general measures to a whole network. Therefore, the application of constraints should only be taken at a national level, in the very specific cases where it is relevant. Such an approach will not unduly constrain either operator and would facilitate efficient use of the spectrum.

7.1 Interference from DECT to GSM 1800

The potential victims are only the GSM 1800 mobile stations. The probability that DECT will cause harmful interference to GSM 1800 is very low in particular due to the GSM error correction capability.
Moreover, GSM can escape temporary interference close to the DECT band edge by intra-cell handover, if this escape can be made to another carrier more distant from the DECT band.

Interference to GSM 1800 mobile stations can occur in cases where a GSM 1800 mobile indoor is connected to an outdoor GSM 1800 BTS and is close to an indoor DECT system. In cases where it is estimated that the probability of such interference is high enough to require specific measures, the distribution of the GSM carriers to the different base stations which would be affected could be planned locally as proposed below in section 7.1.1 and 7.1.2. This proposed planning does normally not reduce the traffic capacity of the GSM system, but will provide escapes for the few instances when harmful interference could occur to the GSM mobile stations.

For the case when the mobile station is connected to an indoor GSM system, the typical short cell radius will provide a relevant margin for self-protection, and does not need further recommendations. See section 4.4.6.2

7.1.1 Position of the GSM BCCH control channel

The GSM 1800 BCCH control channel should not operate within the band 1878 – 1880 MHz for outdoor GSM BTSs.

7.1.2 GSM escape from DECT interference by intra-cell handover

GSM can escape temporary interference close to the DECT band edge by intra-cell handover, if this escape is made to another carrier more distant from the DECT band. This provision is of importance mainly for systems with GSM systems outdoor BTSs. GSM outdoor macro cells systems normally have at least 2 carriers per sector. At least one of these carriers should be below the frequency band 1878 – 1880 MHz.

7.2 Interference from GSM 1800 to DECT

The important scenarios for the recommendations are when DECT and GSM operate in the same local environment. There are two relevant cases:

GSM and DECT systems operate both in the same residence, office or exhibition hall
Above rooftop DECT WLL systems and GSM macro cell systems operate in the same outdoor environment.

For both these cases, the potential interference comes from GSM base stations interfering with the DECT base stations and DECT subscriber stations (mobiles and CTAs for WLL).

Whenever needed, it is important to apply proper system planning, co-ordination and site engineering to ensure that potential local interference to all DECT carriers is avoided. See proposed feasible recommendations in section 7.2.1 for DECT WLL applications.

For the indoor case, the typical short cell radius will provide a relevant margin for self-protection, and does not need further recommendations. See section 4.4.7.

7.2.1 Above roof-top DECT WLL systems and GSM 1800 macro cell systems in the same local area

The critical case occurs when the BTSs and subscriber units (CTAs) are in proximity of a GSM BTS and the antennas are in alignment.

Blocking is the main cause of interference to DECT from GSM 1800 BTS. DECT WLL applications would suffer less potential risk of range reduction, if installed DECT WLL equipment have blocking performance above minimum specification.

Site co-ordination and system planning has to be done properly. Above roof-top DECT WLL base stations and above roof-top GSM 1800 base stations should be geographically separated as much as possible. Wherever possible, the GSM BTS sites should occur at the intersection of DECT WLL cells. This is important to minimize interference probability for the DECT BTS and for the DECT WLL subscriber units (which have a directional antenna).

A guard band is not required, but where the possibility exists not to allocate in the same local area the upper part of the GSM 1800 band (1878 – 1880 MHz), this would simplify the coexistence, especially in areas where high traffic densities DECT above roof-top WLL systems already are installed. This would also reduce the probability for harmful non-detectable interference (at GSM low traffic hours) to DECT, if GSM frequency hopping were used (see section 4.4.1.5).

There may be cases where separation distances between DECT and GSM BTS down to 100 m have to be accepted. These cases mainly occur in urban areas where high traffic is expected for both systems. This corresponds typically to about 20 dB improved interference protection requirement. Depending on the configuration and the eventual precedence of one or the other system, some of the precautions listed below may need to be taken:

- Using DECT equipment that exceeds the minimum blocking requirement.

Note: Performance of installed equipment is expected to typically exceed the DECT minimum blocking requirement by about 10 dB.

- Planning the DECT system with an adequate installation margin N added to the minimum operational wanted signal level.
- Local site engineering and system planing, e.g. local change/removal of carriers, local external filtering and local change of antenna configuration including height differentiation and proper tilting.
- The GSM operator could avoid using the upper part of the band (1878-1880 MHz) especially with power > 33 dBm on its macro-cell sites (this means using these channels for indoor or micro cells),

7.3 Requirements to detect asynchronous interference from a single GSM connection

DECT should be able to detect and escape via intra-cell handover interference from a single GSM bearer, which implies that:

- DECT should be able to process a successful handover when the up-link or the down-link is interfered as seldom as every 6th frame.

This requirement is of prime importance for DECT WLL systems.

It is recommended that ETSI Project DECT make a study on the possibility to properly define the provisions for DECT to detect the interference and to process handover when interfered by a single GSM bearer.

Specific requirements on GSM to facilitate DECT detection of GSM is discussed in section 4.4.1.5.

APPENDIX 1

SYSTEM PARAMETERS FOR DECT

The following is a summary of the parameters given in prTBR 6 (February. 1999) and information from ETSI Technical Report ETR 310.

Frequency band: 1880 - 1900 MHz, ten RF carriers:

F_9 = 1881.792 MHz, F_8 = 1883.520 MHz, ... , F_1 = 1895.616 MHz, F_0 = 1897.344 MHz

Maximum transmitted power: 24 dBm (250 mW)
Maximum antenna gain: 12 dBi
Modulation: GFSK (η=0,5) => GMSK

1 TRANSMITTER:

1.1 Unwanted RF power radiation:

Emissions due to modulation: see table 1

Emissions on RF channel "Y"	Maximum power level	Maximum power level	Frequency offset	GSM 1800 channel frequency
1. Y=M±1	160 µW	-8 dBm	ΔF=+/ **-1.728 MHz**	1879.8 MHz
2. Y=M±2	1 µW	-30 dBm	ΔF=+/ **-3.456 MHz**	1878.4 MHz
3. Y=M±3	40 nW	-44 dBm	ΔF=+/ **-5.184 MHz**	1876.6 MHz
4. Y>M±3	20 nW	-47 dBm	any other channel	< 1875.6 MHz

Table 1: Out-of-band emissions for F_9 =1881.792 MHz

"M" is the EUT transmitting channel (carrier) and "Y" is a legal DECT channel other than the EUT transmit channel. Type approval tests must be performed for DECT RF channels c=0, 5 and 9 (including the band edges).

The analysing system shall be operated under the following conditions:
- resolution bandwidth: *100 kHz;*
- video bandwidth: *greater than resolution bandwidth;*
- peak hold: *on;*
- filtering type: *synchronously tuned;*
- power integration: *over 1 MHz bandwidth.*

Note: DECT emissions due to transients are not needed to be considered. They are very short (1micro second) with very low average power content, and are efficiently masked by the GSM1800 receiver error correction capability.

1.1.1 Application for interference to GSM 1800

The DECT standard does not provide a power spectrum mask (measured in a very narrow bandwidth) as the GSM standard does (see Appendix 2 section 1.2). Therefore the DECT adjacent channel measurements in table 1 have to be converted into a modulation mask. The principle is shown in figure 1 below. Due to the steep slop of the DECT modulation emission power spectrum density, the actual power into the narrow GSM1800 channels in the middle of the DECT adjacent channels, will be (besides the -7 dB for bandwidth translation) considerably less than stated in table 1.

Due to the steep slope of the DECT modulation emission power spectrum density, and because the integration filters are not as ideal as the shaded boxes in figure 1, the dominant power into the DECT adjacent channel filter comes from the spectrum mask power density at very upper edge of the shaded 1 MHz boxes. Therefore it is relevant to use the upper (blue) slope line in figure 1 for an approximate estimate of the DECT power spectrum due to modulation. (As seen from the lower (red) slope line, emissions from measured spectrum mask of DECT equipment are even 5-8 dB less.)
Following the upper (blue) line of figure 1, we get the following power related to 1 MHz band width in the middle of the DECT adjacent channels, M+1: -14 dBm, M+2: -34 dBm, M+3: -45 dBm, >M+3: -47 dBm. Table 1A below shows the power in the middle of the DECT adjacent channels corrected to the 200 kHz integration bandwidth used for the GSM receive filter. The conversion from 1 MHz to 200 kHz corresponds to –7 dB power in the GSM receiver.

The power levels in table 1A have been used for out-of-band emissions in GSM 1800 channels from DECT carriers F9 to F7.

Out-of-band emissions due to DECT modulation in GSM frequency channels	**Maximum power level into the 200 kHz GSM1800 channel from DECT TX 24 dBm (36 dBm) carriers F9, F8 and F7**		
	DECT carrier F9 1881.792 MHz	**DECT carrier F8 1883.520 MHz**	**DECT carrier F7 1885.248 MHz**
1879.8 MHz	-14 –7 = -21 dBm (-9 dBm)	-34 –7 = -41 dBm (-29 dBm)	-45 –7 = -52 dBm (-40 dBm)
1878.4 MHz	-34 –7 = -41 dBm (-29 dBm)	-45 –7 = -52 dBm (-40 dBm)	-47 –7 = -54 dBm (-42 dBm)
1876.6 MHz	-45 –7 = -52 dBm (-40 dBm)	-47 –7 = -54 dBm (-42 dBm)	-47 –7 = -54 dBm (-42 dBm)
< 1875.6 MHz	-47 –7 = -54 dBm (-42 dBm)	-47 –7 = -54 dBm (-42 dBm)	-47 –7 = -54 dBm (-42 dBm)

Table 1A: Out-of-band emissions in GSM 1800 channels from DECT carriers F9, F8 and F7.
Values within parenthesis are for outdoor DECT base stations and CTAs (DECT WLL fixed subscriber units).
The maximum power level from DECT carriers F0 to F6 is –52 dBm (-40 dBm).

Power levels for GSM1800 frequencies between those indicated in table 1A, should be derived by linear interpolation in the dBm scale. The figure 1 below has been used for the power estimates of table 1A.

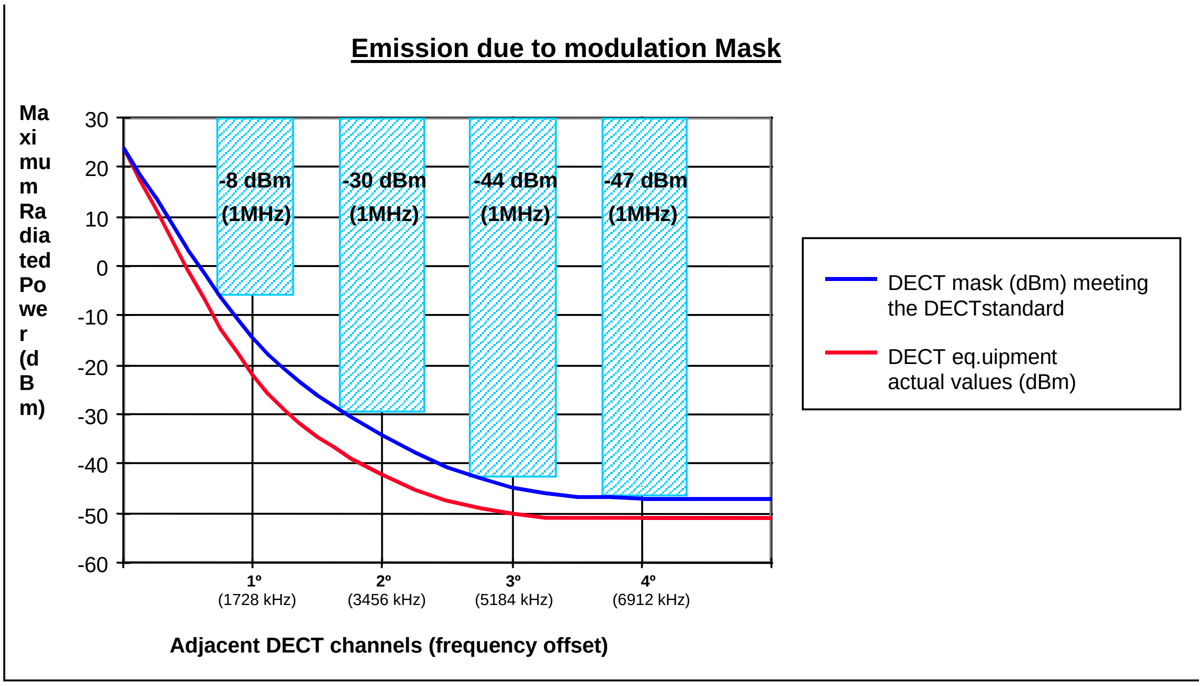


Figure 1: Approximation of the DECT modulation mask according to the DECT standard and compared to the actual DECT equipment values. DECT EIRP 24 dBm.

1.2 Spurious emissions when allocated a transmit channel

The spurious emissions shall not be greater than -30 dBm (250 nW) at frequencies below 1 GHz and -36 dBm (1 µW) at frequencies above 1 GHz.

The analysing system shall be operated under the following conditions:

Frequency offset from edge of band	**Resolution Bandwidth**	**Frequency range** (GSM MS receive band)
0 - 2 MHz	30 kHz	1878 - 1880 MHz
2 - 5 MHz	30 kHz	1875 - 1878 MHz
5 - 10 MHz	100 kHz	1870 - 1875 MHz
10 - 20 MHz	300 kHz	1860 - 1870 MHz
Peak hold: on;	Averaging: none	

Table 2: Spurious emissions, method of measurement

2 RECEIVER:

2.1 Radio receiver sensitivity

The radio receiver sensibility is -83 dBm (for Bit Error Ratio, BER = 0.001)

2.2 Radio receiver interference performance

The ability of DECT equipment **to continue** receiving in the presence of an interfering signal on the same or different DECT RF channel.

Wanted signal level: -73dBm

Interferer on RF channel	**Interfering signal strength**	**C/I**	**Frequency Range (MHz)**	**Frequency at GSM band edge (MHz)**	**GSM channel frequency**
Y=M=F_9	-83 dBm	10 dB	ΔF= 0	1881.792	outside
Y=M +/- 1	-60 dBm	-13 dB	ΔF =+/**- 1.728**	1880.064	1879.8 MHz
Y=M +/- 2	-39 dBm	-34 dB	ΔF =+/**- 3.456**	1878.336	1878.4 MHz
Y=M +/- 3	-33 dBm	-40 dB	ΔF =+/**- 5.184**	1876.606	1876.6 MHz

Table 3: Interfering signals and frequencies for channel "M"=F_9

The RF carriers "Y" shall include the three nominal DECT RF carrier positions immediately outside each edge of the DECT band.

2.2.1 Application to interference from GSM 1800

See section 2.3.1 below on a modified consistent blocking requirement including the receiver interference performance requirements of table 3 above.

For calculating the co-channel interference to DECT from GSM out-of-band emissions, the wanted DECT signal level of –80 dBm is used. The maximum interference level into the DECT receiver is set to –80 dBm minus the required 10dB C/I (from table 3 above), which equals –90 dBm.

2.3 Radio receiver blocking:

Wanted signal with a level set to -80 dBm.

Frequency (f)	Continuous wave interferer level	Comments
25 MHz ≤ f ≤ 1780 MHz	-23 dBm	GSM MS transmitter band
1780 ≤ f ≤ **1875 MHz**	-33 dBm	GSM BTS transmitter band
$\|f-F_C\|$ > 6 MHz	-43 dBm	GSM BTS transmitter band
1905 MHz < f ≤ 2000 MHz	-33 dBm	not relevant
2000 MHz <f ≤ 12.75 GHz	-23 dBm	not relevant

Table 4: Blocking requirements

F_C is DECT RF channel (carrier) for wanted signal: c = 0,1, ... ,9.

Notes: - The frequency range 1875 - 1880 MHz is not included in this requirement (for DECT channel F_9).

2.3.1 Application of interference from GSM 1800 to DECT receiver interference performance and blocking

The blocking requirements for the frequency range 1875 - 1880 MHz is not fully included in Table 4 for the DECT carriers F9, F8 and F7. It is the DECT receiver IF filters that provides the required attenuation to meet both the receiver interference performance of table 3 and the blocking requirements close to the band edge of table 4. The RF filter has very limited impact at 1875 MHz. Therefore is it necessary to have one consistent blocking requirement, derived from the combined requirements of tables 3 and 4. This consistent requirement is found in table 4A. When relating to interference into the DECT adjacent channels, the three GSM 1800 channels from tables 1 and 1A above have been used. The interfering signal strengths of table 3 have (by subtracting 7 dB) been translated to a wanted signal of –80 dBm as for the blocking requirements of table 4. Furthermore, since the adjacent power in table 3 has been measured in a 1 MHz wide filter, and since the filter slope is very steep, a technique similar to that showed in figure 1 of Appendix 1 has to be used to estimate the power in a narrow 200 kHz GSM receiver frequency in the middle of the DECT adjacent channels. In this way the maximum interference levels to meet the combined translated requirements of tables 3 and 4 are first estimated for DECT carrier F9 closest to the band edge. Since it is the IF filters that provides the required attenuation, the levels for carriers F8, F7 etc. are easily derived by shifting the levels of the F9 column one line up for F8, two lines up for F7 etc.

This leads to the following consistent blocking requirements covering the whole GSM 1800 band, which have been used within this study. Values within parenthesis in table 4A are the C/I values of the wanted signal level (–80 dBm) relative to the interferer.

Interfering GSM 1800 TX frequency	Maximum GSM 1800 interferer power level for DECT receiver on carrier			
	F9 1881.792 MHz	**F8 1883.520 MHz**	**F7 1885.248 MHz**	**F0 – F6**
1879.8 MHz	-59 dBm (-21 dB C/I)	-44 dBm (-36 dB C/I)	-38 dBm (-42 dB C/I)	-33 dBm (-47 dB C/I)
1878.4 MHz	-44 dBm (-36 dB C/I)	-38 dBm (-42 dB C/I)	-33 dBm (-47 dB C/I)	-33 dBm (-47 dB C/I)
1876.6 MHz	-38 dBm (-42 dB C/I)	-33 dBm (-47 dB C/I)	-33 dBm (-47 dB C/I)	-33 dBm (-47 dB C/I)
1805 - 1875 MHz	-33 dBm (-47 dB C/I)	-33dBm (-47 dB C/I)	-33 dBm (-47 dB C/I)	-33 dBm (-47 dB C/I)
<1785 MHz	-23 dBm (-57 dB C/I)	-23 dBm (-57 dB C/I)	-23 dBm (-57 dB C/I)	-23 dBm (-57 dB C/I)

Table 4A: Blocking requirements for a wanted signal level of –80 dBm. Power levels for GSM 1800 frequencies between those indicated in table 4A, should be derived by linear interpolation in the dBm scale

Blocking from GSM 1800 BTS transmissions is the dominant interference mechanisms to DECT receivers. BTS EIRP of 54 dBm for outdoor installations and 30 dBm for indoor installations are used for the calculations. It is possible to limit the calculations to the F9 column, since relevant estimates for the other DECT carriers can be made from the results for F9.

2.4 Receiver intermodulation performance

A modulated DECT-like carrier and a continuous-wave carrier shall be received together with a -80 dBm wanted signal. The interfering signals are in every case located in the DECT band.
In TBR 6 there is no information about interfering signals on carrier positions immediately outside each edge of the DECT band.

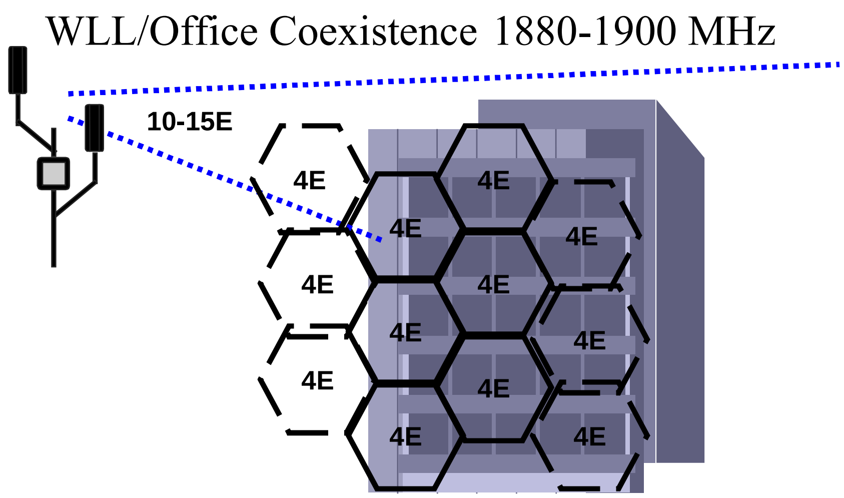
2.5 Coexistence of DECT WLL and Office applications on a common spectrum

The following is an expansion of information available in ETR 310 "Traffic capacity and spectrum requirements for multi-system and multi-service DECT applications co-existing in a common frequency band.

Coexistence between Public and Private Systems, all Dynamic Channel Selection, DCS, is no new idea. It is implemented and proven by the DECT standard. The figure below gives a simple example illustrating that a WLL application does not interfere more (in fact less) than two office systems do.

A high density DECT base with 6-sector antenna arrangement with 60 E total traffic, could typically radiate the wall of a high building with 10-15 E average traffic.

The Private systems have been designed to cover very large buildings by many rows of cells in three dimensions. The figure below illustrates that the interference from a nearby FWA DECT base does not interfere more than an other row of internal cells does, which the private system anyhow is designed to coexist with. In fact simulations show that only about half the DECT spectrum is required to support a very large office (many rows of cells) with
10.000 E / sqkm /floor with about 20 m base station separation.



WLL interferes less than another row of Office cells does. WLL site with 6 sector antenae arragement with totally 60E as an example.

Furthermore, suppose that the indoor base station separation is 20 m close to the radiated wall. Thus the maximum range is 10 m. Using Model D, this corresponds to a path loss of 58 dB. With 24 dBm EIRP, the wanted signal will be 24 dBm –58 dB = -34 dBm. With 8 dB fading margin and 10 dB C/I, a WLL interfering signal below – 34dBm – 8dB -10dB = -52 dBm will not at all interfere with the office system. Supposing 36 dBm EIRP and model A for the WLL system, the separation distance for no interference at all becomes as short as 56 m.

The conclusion is that adding DECT WLL applications to DECT office applications does not cause major capacity limitations.

Note: For the office case above, the allowed interfering signal is –52 dBm instead of –90 dBm being used for the MSD calculations with MCL. See section 2.2.1 above (of Appendix 1). This corresponds to calculations of maximum MSD for E-MCL with a margin N = 38 dB. With 40 m office base separation instead of 20 m would give a radius of 20 m instead of 10m and N will decrease to N = 26 dB.

APPENDIX 2

SYSTEM PARAMETERS FOR GSM 1800

The following is a summary of the parameters given in technical standard
ETS 300 577 (GSM 05.05), Dec. 1998 (Phase 2).

Frequency bands:	1710.0 - 1785.0 MHz	(uplink)	MS transmit, BTS receive;
	805.0 - 1880.0 MHz	(downlink)	BTS transmit, MS receive;

Modulation: GMSK (η = 0.3)
Maximum antenna gain: 18 dBi for BTS

1 TRANSMITTER CHARACTERISTICS

1.1 Transmitter power classes:

Note: BCCH channels without power control.

Power class	**MS** **GSM 1800 Nominal Maximum output power**	**BTS** **Maximum output power**	**GSM 1800 micro BTS** **TRX power class**	**Maximum output power**
1	1 W (30 dBm)	20 - (<40) W	M1	27 - 32 dBm (0.5 - 1.6 W)
2	0.25 W (24 dBm)	10 - (<20) W	M2	22 - 27 dBm (0.16 -0.5 W)
3	4 W (36 dBm)	5 - (10) W	M3	17 - 22 dBm (0.05 - 0.16 W)
4		2.5 - (<5) W		

Table 1: DCS transmitter power classes

1.2 Output RF spectrum

Power level (dBm)	**Measurement bandwidth for frequency separation from the central frequency**									
	30 kHz						100 kHz MS and normal BTS		100 kHz Micro BTS	
	100	200	250	400	≥600 to < 1200	≥1200 to <1800	≥1800 to <6000	≥6000	≥1800	
≥43	+0.5	-30	-33	-60	-70	-73	-75	-80		
42	**+0.5**	**-30**	**-33**	**-60**	**-69**	**-72**	**-74**	**-80**		
41	+0.5	-30	-33	-60	-68	-71	-73	-80		
39	+0.5	-30	-33	-60	-66	-69	-71	-80		**BTS**
37	+0.5	-30	-33	-60	-64	-67	-69	-80		
35	+0.5	-30	-33	-60	-62	-65	-67	-80	-76	
≤33	**+0.5**	**-30**	**-33**	**-60**	**-60**	**-63**	-65	-80	**-76**	
≥36	+0.5	-30	-33	-60	-60	-60	-71	-79		
34	+0.5	-30	-33	-60	-60	-60	-69	-77		
32	+0.5	-30	-33	-60	-60	-60	-67	-75		**MS**
30	**+0.5**	**-30**	**-33**	**-60**	**-60**	**-60**	**-65**	**-73**		
28	+0.5	-30	-33	-60	-60	-60	-63	-71		
26	+0.5	-30	-33	-60	-60	-60	-61	-69		
≤24	+0.5		-33	-60	-60	-60	-59	-67		

Table 2: Spectrum due to the modulation and wideband noise

1.2.1 Application of interference to DECT from GSM 1800 out-of-band emissions

In practice it is only the columns of table 2 for frequency separation >1800 kHz that apply. Here the measurement bandwidth is 100 kHz, and thus 10 dB power has to be added to convert into the DECT receiver bandwidth of 1 MHz. This is shown in the table 2A, having the same three GSM 1800 carrier frequencies earlier used. From table 2 we use the BTS power 42 dBm (this line has been added to the GSM specification by interpolation) and 30 dBm for MS. 12 dB shall be added for the BTS for antenna gain including antenna feeder loss to get 54 dBm EIRP. Example for carrier F9 for the BTS; At 1879.8 MHz, 42 dBm – 74 dB + 10dB +12 dB = -10 dBm. At <1875.3 MHz, 42 dBm – 80 dB + 10dB +12 dB = -16 dBm. For carriers 1878.4 and 1876.6 the levels are derived by interpolation.

GSM 1800 BTS (12 dB antenna gain) 54 dBm EIRP on carrier	**Maximum GSM 1800 interfering power level into DECT receiver on carrier**			
	F9 1881.792 MHz	**F8 1883.520 MHz**	**F7 1885.248 MHz**	**F0 to F6**
1879,8 MHz	-10 dBm	-13 dBm	-15 dBm	-16 dBm
1878.4 MHz	-13 dBm	-15 dBm	-16 dBm	-16 dBm
1876.6 MHz	-15 dBm	-16 dBm	-16 dBm	-16 dBm
<1875,3 MHz	-16 dBm	-16 dBm	-16 dBm	-16 dBm

Table 2A: Out-of-band emissions from an GSM outdoor 54 dBm EIRP BTS into a DECT receiver with 0 dBi antenna

GSM 1800 transmitter on carriers	**GSM 1800 interfering power into DECT receiver on carrier F0 to F9**
Micro BTS 30 dBm EIRP, 1805 – 1879.8 MHz	30 dBm – 76 dB + 10 dB = -36 dBm*
MS 30 dBm EIRP, 1710 – 1785 MHz	–66 dBm*

Table 2B: Out-of-band GSM 1800 emissions from a 30 dBm micro BTS and a 30 dB MS into a DECT receiver with 0 dBi antenna. * From spurious emissions requirements, see section 1.3.1 Note

The interference levels of tables 2A and 2B have been used as out-of band emission levels for the calculations in this document. (They are not dominant interference mechanisms). In the GSM specification “spectrum due to modulation and wideband noise”, Table 2 above, applies to the entire relevant transmit band and only up to 2 MHz outside either side. In this study the application is extended up to 20 MHz above 1880 MHz, since there is no reason why these emissions should be higher outside than inside the GSM band.

1.3 Spurious emissions

Frequency offset from edge of the band	**Measurement bandwidth**
2 MHz ≤ Δf ≤ 5 MHz	30 kHz
5 MHz ≤ Δf ≤ 10 MHz	100 kHz
10 MHz ≤ Δf ≤ 20 MHz	300 kHz

Table 3A: Measurement conditions for spurious emissions related to offset from the band edge

The power shall be no more than -30 dBm in the frequency range 1 - 12.75 GHz.

Notes:
- in case of co-sited GSM 900 and GSM 1800 BTS, the spurious emissions shall be no more than -47 dBm for the GSM BTS in the band 1805 - 1880 MHz (filter and video bandwidth of 100 kHz)
- when allocated a channel, the power emitted by the MS in the band 1805 - 1880 MHz shall be no more than -71 dBm.

Frequency offset from transmit carrier	**Measurement bandwidth**
> 1.8 MHz	30 kHz
> 6 MHz	100 kHz

Table 3B: Measurement conditions for spurious emissions related to offset from the carrier

The power shall be no more than -36 dBm.

1.3.1 Application of interference to DECT from GSM 1800 spurious emissions

The requirements of table 3A are the only formal GSM requirements on out-of-band emissions more than 2 MHz from the transmit band edge. Table 3 B only applies within the GSM transmit band. The required isolation values due to spurious emissions of table 3A and 3B are generally higher than those for out-of-band emissions used for BTSs in tables 2A and 2B (see note on MS below). But these levels should not be treated as a continuous noise floor. The spurious signals will appear at a few unknown specific frequencies, and therefore these problems may be solved by the Dynamic Channel Selection, DCS, in DECT. Spurious emissions do normally not cause a dominant interference mechanism, and are not used for the calculations in this report.

Note: The requirements Table 3A on MS at 1880 MHz is –71 dBm measured in 300 kHz bandwidth. This corresponds to –66 dBm in 1 MHz. This is a stricter limit than derived from emissions due to modulation and wideband noise of table 2. Therefore –66 dBm has been used for the MS in table 2B above.

1.4 Transients

GSM 1800 BTS emissions due to transients may need to be considered even if they only affect a few bits in a DECT frame. They are not very short compared to a DECT bit length, and the instant peak level is relevant since many of the DECT services do not implement error correction.

The GSM 1800 BTS transient requirement are not specified for frequencies separated > 1.8 MHz from the GSM transmit carrier. Relevant for interference to DECT is only requirements for frequencies separated > 1.8 MHz from the GSM carrier. Therefore the specific requirements specified for the GSM transients cannot be used. The requirements on spurious in section 1.3 above can however be used. The spurious emissions are measured over the whole GSM time frame with a peak hold setting. Thus the effect of transients are included in these measurements.

1.4.1 Application of interference to DECT from GSM 1800 transient emissions

The requirements from tables 3A and 3B are used below to estimate the peak power of transients. These requirements relate to measurements after narrow filters (30, 100 and 300 kHz bandwidth) which suppress the peak power of sharp transients. Therefore the peak power has be related to to corresponding levels that would occur after reception in a DECT 1 MHz wide receive filter. Suppose that the transients are the very dominating contribution to the measured peak power spurious levels. Then, theoretically in worst case, the conversion factors are 30, 15 and 10 dB for respectively 30, 100 and 300 kHz measurement bandwidths. This corresponds to 6 dB increased peak power per doubling of the bandwidth. See table 3C below. Linear interpolation has been applied for frequency offsets between frequencies defined in tables 3A and B. Example, GSM carrier 1879.8 MHz and F9 gives 2 MHz carrier separation, thus table 3B with –36 dBm for 30 kHz bandwidth applies. Thus the power into a DECT receiver will be –36 dBm +12 dB (GSM BTS antenna gain) + 30 dB (conversion from 30 kHz to 1 MHz) = 6 dBm.

GSM 1800 BTS (12 dBi antenna gain) 54 dBm EIRP on carrier	**Maximum GSM 1800 interfering power level into DECT receiver on carrier**			
	F9 1881.792 MHz	**F8 1883.520 MHz**	**F7 1885.248 MHz**	**F0 to F6**
1879,8 MHz	6 dBm	1 dBm	3 dBm	8 dBm
1878.4 MHz	1 dBm	3 dBm	-5 dBm	
1876.6 MHz	3 dBm	-5 dBm	-6 dBm	
<1875,3 MHz	-5 dBm	-6 dBm	-7 dBm	

Table 3C: Transient emissions from a GSM outdoor 54 dBm EIRP BTS into a DECT receiver with 0 dBi antenna

The theoretical worst case estimates of transient peak power into a 1 MHz receiver are 8 to 16 dB higher than the out-of-band emissions levels of Table 2A. This shows that transients could be a potential source to interference to DECT. Therefore measurements have been made on typical GSM 1800 equipment, which showed that transients do not dominate out-of-band peak hold measurements. Therefore possible emissions due to transients have not been considered as an important interference mechanism in this report.

2 RECEIVER CHARACTERISTICS

2.1 Blocking characteristics and spurious response

The blocking characteristics of the receiver are specified separately for in-band and out-of-band performance. A useful signal at frequency f_0, 3 dB above the reference sensitivity level combined with a continuous, static sine wave signal (f) yields the maximum interfering power levels shown in table 4.

Frequency in band (1785 - 1920 MHz)	**GSM 1800 MS**	**Frequency (MHz)** out-of-band	**GSM 1800 MS**
* 600 kHz ≤ $\lvert f-f_0 \rvert$ <800 kHz	-43 dBm	0.1 - 1705	0 dBm
800 kHz ≤ $\lvert f-f_0 \rvert$ <1.6 MHz	-43 dBm	>1705 - >1785	-12 dBm
1.6 MHz ≤ $\lvert f-f_0 \rvert$ <3 MHz	-33 dBm	>1920 - 1980	-12 dBm
3 MHz ≤ $\lvert f-f_0 \rvert$	-26 dBm	>1980 - 12,750	0 dBm

Table 4: Blocking requirements for GSM 1800 MS receiver. * Frequencies in the range ±600 kHz are excluded

For spurious response the level of the continuous interfering signal shall be -43 dBm.

2.1.1 Application of interference from DECT to GSM 1800 MS blocking

Only separation distances >1.6 MHz are relevant. See table 4A below. The GSM 1800 MS receiver has 200 kHz bandwidth.

Interfering DECT transmit carrier	**Maximum power level into interfered GSM 1800 MS receive carrier**	
	1879.8 MHz	**<=1878.4 MHz**
F9 1881.792 MHz	-33 dBm	-26 dBm
F0 to F8	-26 dBm	-26 dBm

Table 4A: Blocking requirements for GSM 1800 MS receiver related to relevant DECT carriers

2.2 AM suppression characteristics

AM suppression is a measure of the ability of the receiver to receive a modulated wanted signal in the presence of an unwanted TDMA modulated signal.

The following signals are simultaneously input into the receiver:
- a useful signal, 3 dB above reference sensitivity level
- a GSM TDMA signal with a level at -29 dBm (6 MHz separated from wanted signal)

2.3 Reference interference level

The reference interference ratio, for DCS MS, shall be:

Reference interference ratio		**Interference levels [dBm]** class 1 or 2 MS	class 3 MS
wanted signal 20 dB above sensitivity level		-80 dBm	-82 dBm
co-channel	C/Ic: 9 dB	-89 dBm	-91 dBm
adjacent (200 kHz)	C/Ia1: -9 dB	-71 dBm	-73 dBm
adjacent (400 kHz)	C/Ia2: -41 dB	-39 dBm	-41 dBm
adjacent (600 kHz)	C/Ia3: -49 dB	-31 dBm	-33 dBm

Table 5: Reference interference level requirements

Note: The reference sensitivity level is –102 dBm.

2.3.1 Application of interference from DECT out-of-band emissions into the GSM 1800 MS receive channel

The dominant interference mechanisms to GSM 1800 is DECT out-of band emissions (table 1A of Appendix 1) into a GSM 1800 MS receive channel. It is the co-channel interference that dominates, because the adjacent channel attenuation of table 5 above increases much faster as a function of the frequency separation than the attenuation of DECT out-of-band emissions in table 1A of Appendix 1 does. Maximum allowed co-channel power level of –108 dBm has been used in the calculations. This level is derived from a wanted signal level of –99 dBm (reference sensitivity + 3 dB) and a C/I requirement of 9 dB from table 5.

APPENDIX 3

PROPAGATION MODELS

Free space model

This model assumes free space propagation for all distances $L=38+20*log(d)$. This can be expressed with the following equation:

$$La= 38 +20*log(d)$$

Model A

This model assumes free space propagation for all distances $L=38+20*log(d)$, plus an additional 15 dB to account for building attenuation. This can be expressed with the following equation:

$$La=53+20*log(d)$$

Model B

This model assumes free space propagation for distances below 10 m, and a 4th power law for greater distances, plus an additional 15 dB to account for building attenuation. This can be expressed with the following equations:

$$Lb=53 +20*log(d),\ d<10m$$
$$Lb=73 +40*(logd-1)\ ,\ d> 10m$$

Model C

The COST obstruction model is described in Doc FM1O/SE7(92)22. An extension is made by linear extrapolation for distances below the range of the model. 15 dB has been added to account for building attenuation. The following equations can be used:

$$Lc=8\ 3 +20*\ logd,\ 0 < d< 130\ m$$
$$Lc=61.6+30*logd,130<d<300\ m$$
$$Lc=36 +40*logd,\ 300<d<6000\ m$$

Model D

This model assumes free space propagation for distances below 10 m, and a 4th power law for greater distances. This can be expressed with the following equations:

$$Ld=38 +20*logd,\ d< 10\ m$$
$$Ld=58 +40*(logd-1)\ ,\ d> 10\ m$$

Model E

The COST obstruction model is described in Doc FM1O/SE7(92)22. An extension is made by linear extrapolation for distances below the range of the model. The following equations can be used:

$$Le=6\ 8 +2\ 0*log(d),\ 0 < d< 130\ m$$
$$Le=46\ .6+30*log(d),\ 130<d<300\ m$$
$$Le=21+40*log(d),\ 300<d<6000\ m$$

Model F

This propagation model is an interpolation between free-space loss at 10 m, free-space + 10 dB loss at 100 m, and values from CCIR Report 567-4 at 1 km and 10 km. The CCIR values have been increased by 6 dB to take account of the higher frequency. The antenna heights are 30 m and 1.5 m. The following equations can be used to calculate the propagation loss [dB]:

$$Lf=3\ 8 +20*log(d),\ d<\ 10\ m$$
$$Lf=58+30*(logd-1)\ ,\ 10<d<100m$$
$$Lf=88+42\ (logd-2),\ l00<d<l000m$$
$$Lf=130+38\ (logd-3)\ ,\ l000<d<l0.000\ m$$

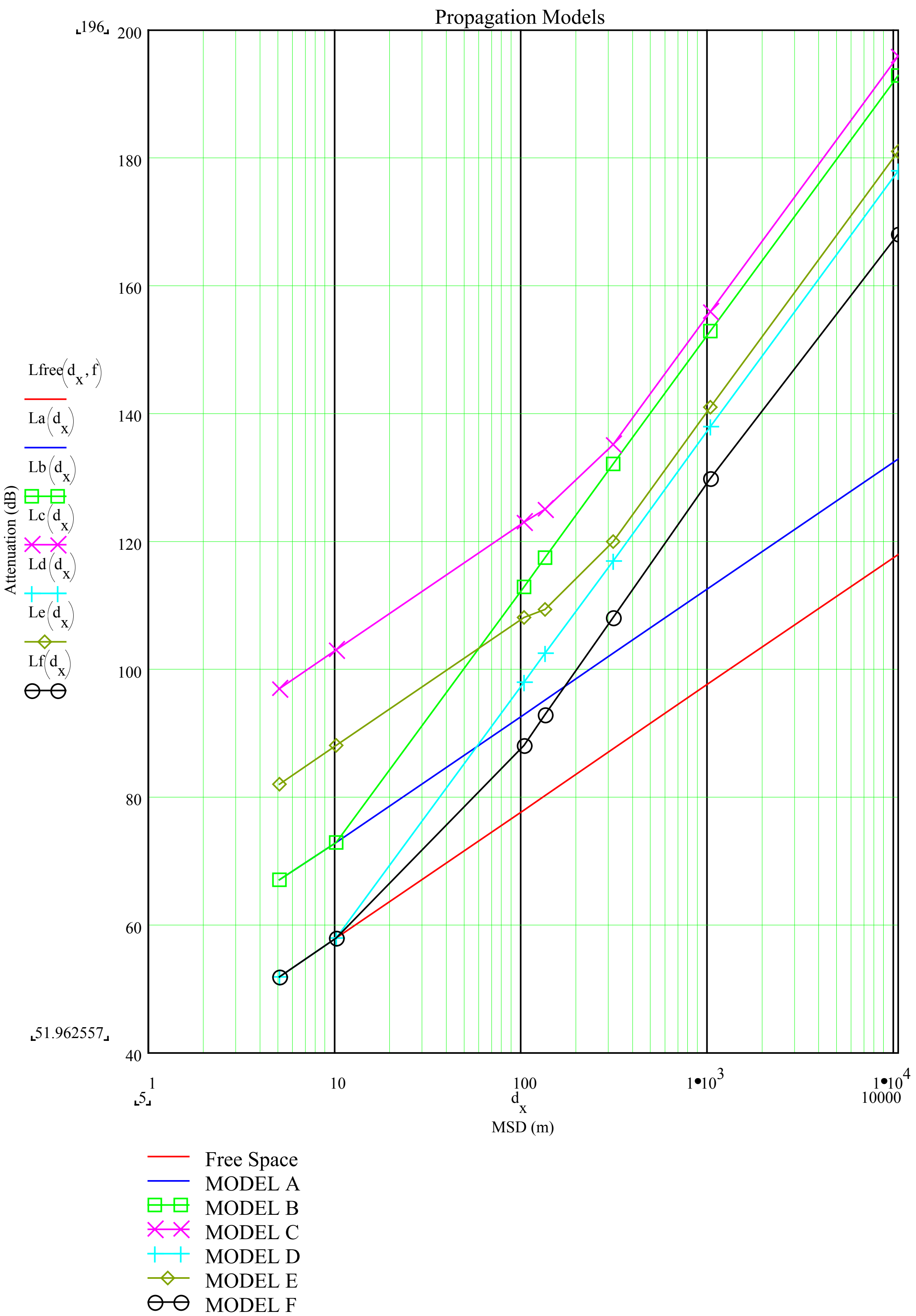
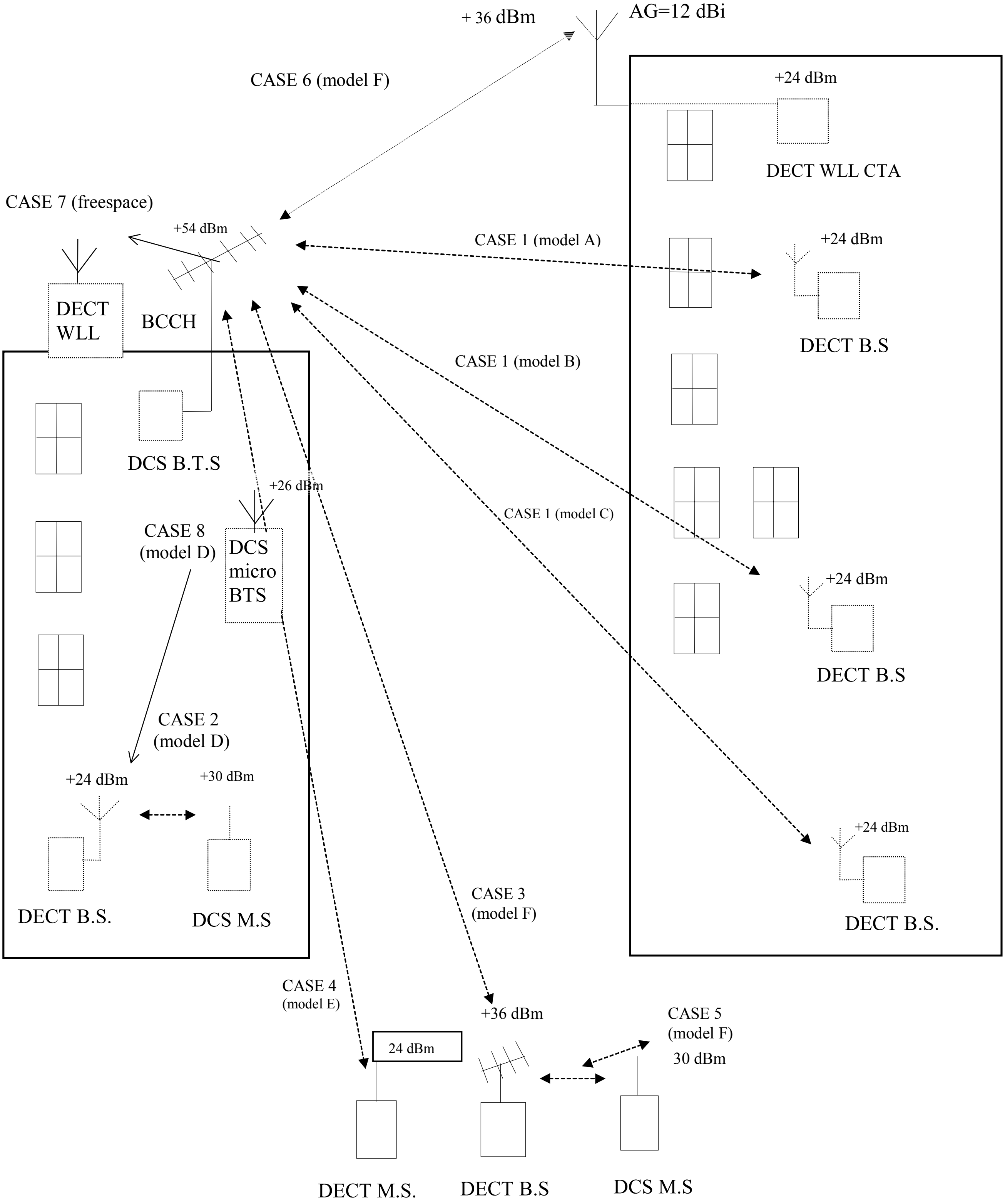


Figure 1: Comparison of the considered propagation models

APPENDIX 4

OVERVIEW OF COMPATIBILITY CASES



APPENDIX 5

COMPATIBILITY CALCULATIONS

5.1 Overview of Minimum Separation Distance and Isolation using Minimum Coupling Loss Method

The victim receiver is assumed to be continuously operating 3 dB above reference sensitivity. Fading is not taken into account.

1 THE EQUATION FOR UNWANTED EMISSIONS ANALYSIS IS:

$$\text{Isolation} = P_{INT}+dB_{BW}+MC_{INT}+G_{VICT}+G_{INT}-(S_{VICT}-C/I_{VICT})+dB_{INT}$$

Where:

P_{INT}	is the maximum transmit power of the interferer,
dB_{BW}	is the bandwidth conversion factor between interferer and victim,
MC_{INT}	is the multiple carrier margin for when the interferer is a base site and has more than a single carrier being transmitted,
G_{VICT}	is the gain of the victim antenna (incl. cable loss),
G_{INT}	is the gain of the interferer antenna (incl. cable loss),
S_{VICT}	is the sensitivity of the victim,
C/I_{VICT}	is the protection ratio of the victim,
dB_{INT}	is the power of the wideband noise at the frequency offset being considered relative to the interferer's carrier power.

Note: For example table 1A of Appendix 1 have already included P_{INT}, dB_{BW}, G_{INT} and dB_{INT} in the values.

2 THE RECEIVER BLOCKING ANALYSIS EQUATION IS:

$$\text{Isolation} = P_{INT}+ MC_{INT}+G_{VICT}+G_{INT}-dB_{VICT}$$

Where:

P_{INT}	is the maximum transmit power of the interferer,
MC_{INT}	is the multiple carrier margin for when the interferer is a base site and has more than a single carrier being transmitted,
G_{VICT}	is the gain of the victim antenna (incl. cable loss),
G_{INT}	is the gain of the interferer antenna (incl. cable loss),
dB_{VICT}	is the blocking performance of the victim receiver, the frequency offset being considered.

3 GENERAL ASSUMPTIONS:

RF parameters from Appendix 1 and Appendix 2 are used as input parameters.

The GSM BTS sends a BCCH carrier without power control in the upper part of the GSM band.

GSM transmit and receive carriers 1879.8, 1878.4, 1876.6 MHz and below 1875 MHz have been used. These carrier positions correspond to the 1st, 2^{nd,} 3rd and >=4th adjacent carrier to the DECT carrier F9 = 1881.792 MHz.

Due to this choice of GSM carriers, calculations can be made for DECT transceivers active on carrier F9, and relevant estimates for the other DECT carriers can be made from the results for F9.Spurious emissions from DECT and GSM are disregarded, due to the fact that they occur on an unknown but limited number of occurrences, and DECT can escape them by Dynamic Channel Selection and GSM by handover.
Minimum separation distances are corresponding to the propagation models in Appendix 3.

3.1 Dominant interference mechanism to DECT receivers

The dominant interference mechanisms to DECT receivers is the blocking from GSM 1800 BTS transmissions, Table 4A of Appendix 1. (See section 4.3 below.) BTS EIRP of 54 dBm is used, except for indoor BTS. It is possible to limit the calculations to the impact on DECT carrier F9, since relevant estimates for the other DECT carriers can be made from the results for F9.

3.2 Dominant interference mechanism to GSM 1800 receivers

The dominant interference mechanisms to GSM 1800 is co-channel interference from DECT out-of band emissions into GSM 1800 MS receive channels, Table 1A of Appendix 1. A maximum allowed co-channel interfering power level into the 200 kHz GSM 1800 MS receiver of –106 dBm, see Appendix 2 section 2.3.1, has been used for the calculations.

4 DECT RECEIVER IS THE VICTIM

4.1 Blocking of DECT due to interference from above roof-top GSM BTS with 54 dBm EIRP

Table 4A of Appendix 1 is used for carrier F9. Example, for GSM carrier 1879.8 MHz the maximum interference level on carrier F9 is –59 dBm. Since the GSM BTS EIRP is 54 dBm, the required isolation is 113 dB for cases 1 and 4 and 125 dB for cases 3, 6 and 7, where the DECT receive antenna has 12 dBi gain.

Minimum Separation Distance, MSD, and Required Isolation for DECT carrier F9								
GSM 1800 BTS 54 dBm EIRP on carrier	CASE 1 model A		CASE 1 model B		CASE 1 model C		CASE 4 model E	
	m	dB	m	dB	m	dB	m	dB
1879,8 MHz	1000	113	100	113	32	113	178	113
1878.4 MHz	178	98	42	98	5.6	98	32	98
1876.6 MHz	89	92	30	92	-	92	16	92
1805 - 1875 MHz	50	87	22	87	-	87	9	87

Table 1: Minimum Separation Distance, MSD, and Required Isolation due to blocking of DECT receiver

Minimum Separation Distance, MSD, and Required Isolation for DECT carrier F9								
GSM 1800 BTS 54 dBm EIRP on carrier	CASE 3 model E		CASE 6 model F		CASE 7 model Free Space		CASE “7 with 30 dBm BTS EIRP”* model Free Space	
	m	dB	m	dB	m	dB	m	dB
1879,8 MHz	398	125	760	125	>2000**	125	1 412	101
1878.4 MHz	130	110	334	110	>2000**	110	258	86
1876.6 MHz	63	104	240	104	1 995	104	126	80
1805 - 1875 MHz	35	99	182	99	1122	99	71	75

Table 2: Minimum Separation Distance, MSD, and Required Isolation due to blocking of DECT receiver

* This is not one of the defined cases. It is a check for Case “7” of the impact of having 30 dBm instead of 54 dBm BTS EIRP.

** The model is not relevant for > 2 km distance.

4.2 Blocking of DECT due to interference from indoor GSM Micro BTS and GSM MS with 30 dBm EIRP

Table 4A of Appendix 1 is used for carrier F9. Example, for GSM carrier 1879.8 MHz the maximum interference level on carrier F9 is –59 dBm. Since the GSM micro BTS EIRP is 30 dBm, the required isolation is 89 dB for case 8. Example, for MS on GSM carrier <1785 MHz the maximum interference level on carrier F9 (and any carrier) is –23 dBm. Since the GSM MS EIRP is 30 dBm, the required isolation is 53 dB for case 2 and 65 dB for case 5, where the DECT receive antenna has 12 dBi gain.

Minimum Separation Distance, MSD, and Required Isolation for DECT carrier F9								
GSM 1800 30 dBm EIRP on carrier	CASE 8 model D		CASE 2 model D		CASE 5 model F		CASE "5 with 30 dBm EIRP BTS on street"** model F	
	M	dB	m	dB	m	dB	m	dB
BTS 1879,8 MHz	60(47)*	89(85)*	NA	NA	NA	NA	193	101
BTS 1878.4 MHz	25(14)*	74(70)*	NA	NA	NA	NA	86	86
BTS 1876.6 MHz	18(20)*	68(64)*	NA	NA	NA	NA	52	80
BTS 1805 - 1875 MHz	13(11)*	63(59)*	NA	NA	NA	NA	35	75
MS 1710 – 1785 MHz	6	53	6	53	17	65	17	65

Table 3: Minimum Separation Distance, MSD, and Required Isolation due to blocking of DECT receiver
NA means not applicable.
* Values within parenthesis ( ) are for indoor BTS with 26 dBm EIRP (0 dBi antenna).
** This case with street mounted micro BTS does not occur in Appendix 4.

4.3 Check of statement on dominant interference mechanism

It has been stated that interference due to blocking from GSM BTSs is the dominant mechanism for interference to DECT. In the table below the required minimum isolation due to blocking are compared to the isolation required by GSM out-of-band emissions according to tables 2A and 2B from Appendix 2. The maximum interference level into the DECT receiver –90 dBm according to section 2.2.1 of Appendix 1. Example, CASE 1 and BTS frequency 1879.8 MHz table 2A of Appendix 2 gives a maximum power level into carrier F9 of –10 dBm. No DECT receiver antenna gain gives thus a required isolation of 90 – 10 = 80 dB.

Minimum Required Isolation [dB] for DECT carrier F9								
GSM 1800 TX carrier	CASES 1 and 4 54 dBm BTS EIRP 0 dBi DECT antenna		CASES 3, 6 and 7 54 dBm BTS EIRP 12 dBi DECT antenna		CASES 2 30 dBm MS and CASE 8 with 30 dBm BTS EIRP 0 dBi DECT antenna		CASE 5 30 dBm MS and CASE "7 with 30 dBm BTS EIRP" 12 dBi DECT antenna	
	Out-of-band emissions	Blocking	Out-of-band emissions	Blocking	Out-of-band emissions	Blocking	Out-of-band emissions	Blocking
BTS 1879,8 MHz	80	113	92	125	54	89	66	101
BTS 1878.4 MHz	77	98	89	110	54	74	66	96
BTS 1876.6 MHz	75	92	87	104	54	68	66	80
BTS 1805 - 1875 MHz	74	87	86	99	54	63	66	75
MS 1710 – 1785 MHz					24	53	36	65

Table 4: Minimum Required Isolation due to GSM out-of-band emissions and blocking of DECT receiver
* Indicate emissions due to transients derived from table 3C in Appendix 2.

As seen from the table above, the required isolations are generally larger due to blocking than due to out-of-band emissions for BTSs. Thus blocking of DECT receiver from GSM BTS is the dominant interference mechanism.

5 GSM RECEIVER IS THE VICTIM

5.1 Co-channel interference of GSM MS due to interference from DECT out-of-band emissions

Table 1A of Appendix 1 is used DECT for out-of-band emission levels for carrier F9. Maximum allowed co-channel interfering power level into the 200 kHz GSM 1800 MS receiver is –108 dBm, see Appendix 2 section 2.3.1. Example, for GSM receiver carrier 1879.8 MHz the maximum interference level from a DECT 24 dBm EIRP TX on carrier F9 is –21 dBm into a 200 kHz wide GSM MS receiver. Thus the required isolation is 108 – 21 = 87 dB.

Minimum Separation Distance, MSD, and Required Isolation for DECT TX on carrier F9								
GSM 1800 receiver on carrier	CASE 2 model D		CASE 5 model F		CASE 6* model F		CASE 7* model Free Space	
	m	dB	m	dB	m	dB	m	dB
MS 1879,8 MHz	53	87	183	99	-	-	-	-
MS 1878.4 MHz	17	67	50	79	-	-	-	-
MS 1876.6 MHz	9	56	22	68	-	-	-	-
MS 1805 - 1875 MHz	6	54	18	66	-	-	-	-
BTS 12 dBi antenna 1710 – 1785 MHz*	-	-	-	-	46*	78*	100*	78*

Table 5: **Minimum Separation Distance, MSD, and Required Isolation due to co-channel interference of DECT out-of-band emissions into GSM 1800 MS receiver. * These calculations are for GSM BTS where another 12 dB has been added for the GSM receiver antenna gain.**

6 SUMMARY

The calculations above have been made for DECT carrier F9, but the levels for carriers F8, F7 etc. are easily derived by shifting the levels in the tables above one line up for F8, two lines up for F7 etc.

For most interference cases the interference to large DECT systems only affect one or two carriers and only part of the system (e.g. parts close to one window side of a building). Suppose that carrier F9 is interfered 100% of the time in 30 % of the system. This corresponds to 3 % capacity decrease, which is compensated by installing the DECT base stations 1.5 % closer to each other, since the DECT system capacity is proportional to the DECT base station density. (The same result is obtained if F9 and F8 were interfered 50 % of the time in 30 % of the system.) Due to the dynamic channel selection procedure (were all cells and systems share the same total number of traffic channels), many small (residential single cell) systems may be regarded as one large system where only part of it is interfered. Thus the conclusion on limited impact on capacity also applies to small systems.

1. DECT as victim:
   The dominating interference mechanism is blocking.
   The upper 1875 – 1880 MHz part of the GSM band is most critical, but for carriers F9 to F7 with decreasing influence.
   DECT can avoid this interference with limited impact on capacity due to the DECT dynamic channel selection, and for indoor office systems with the typical large installation margins on the wanted signal level. See discussions in section 5.4 of this report.
   This statement is however not true for Cases 6 and 7, where specific counter measures are required, due to the 1 km MSD. See discussions in section 5.4 of this report.

2. GSM as victim:
   The dominating interference mechanism is out-of-band DECT emissions..
   The upper 1875 – 1880 MHz part of the GSM band is most critical, but for carriers F9 to F7 with decreasing influence.
   When having more than one carrier in a sector, GSM can in most cases avoid this interference with limited impact on capacity by making intra-cell handover.
   GSM can in many cases avoid this interference with limited impact on capacity due to the GSM error correction, which can correct for up to two interfering DECT time slots per frame. Interference from DECT handset and CTAs and residential, telepoint and many office base stations meet this criteria.
   The GSM BCCH broadcast channel is fixed and cannot make handover. Therefore the BCCH channel should be given a channel at least 2 MHz from the DECT band edge, below 1878 MHz. This restriction does not apply for indoor office systems with the typical large installation margins on the wanted signal level.

3. It is very important that interference can be detected, so that both DECT and GSM can make intra-cell handover to a better, less interfered channel, else large guard bands may be required. This implies that DECT must be able to detect and react on asynchronous interference from a single GSM bearer. If GSM uses frequency hopping (BCCH is never hopping), the interference may occur less frequent (at GSM low traffic hours) than for non-frequency hopping GSM systems. See discussions in section 5.4.1.5.

4. The E-MCL and Monte Carlo simulations below will add a relevant statistical component to some of the above cases.

5.2 E-MCL calculation for radio compatibility between DECT and GSM 1800

1 POWER CONTROL

In this investigation power control is only used at the interfering GSM 1800 system. The power control algorithm is described in GSM 0505.
For the interference scenarios where DECT systems are the interferer, no power control is used. Therefore the calculations of these scenarios are based only on the MCL method and not on the E-MCL method.

2 AVAILABILITY OF COVERAGE

2.1. Interfering system

As far as the interfering system is concerned, the parameter « availability of coverage » is introduced when the maximum power of the disturbing transmitters is determined as a function of the cell radius R0 of the interfering system.
For example, in the case of GSM 1800, if the maximum BTS power equals 43 dBm, the cell size (downlink) is set to 38 km² (R0 = 3.5 km). This means that the link margin is 9 dB at the border of a cell.

2.2. Victim system

The « quality of coverage » parameter can also be introduced in the MCL approach.
To do so, the rule mentioned above can be modified as « the victim receiver is assumed to be operating N (instead of 3) dB above its reference sensitivity ».
If N > 3 that means that the wanted transmitter powers are supposedly increased by N dB with respect to the previous situation, all others parameters being maintained equal, this also means that the victim links margins (without interference) are increased by N dB which results in an improvement of the quality of coverage within the victim system.

3 CRITICAL INTERFERENCE MECHANISMS

3.1 Blocking of DECT receivers

The following conditions apply:

R0 = 3.5 km, giving the area SC = 38 sqkm.
N = 10 dB, leading to 10 dB less required maximum isolation than in table 1 and 2 of Appendix 5.1

The table below shows this new maximum isolation, average separation distance and the maximum separation distance for DECT carrier F9.

Average and Maximum Separation Distance [m] for DECT carrier F9 and N = 10 dB									
GSM 1800 BTS on carrier	**Isolation (maximum)**	CASE 1 model A		CASE 1 model B		CASE 1 model C		CASE 4 model E	
		Aver.	Max.	Aver.	Max.	Aver.	Max.	Aver.	Max.
1879,8 MHz	**103 dB**	206	374	41	56	16	24	51	78
1878.4 MHz	**88 dB**	36	67	17	24	5	7	16	24
1876.6 MHz	**82 dB**	18	33	12	17	3	5	10	15
1805 - 1875 MHz	**77 dB**	10	19	8	13		-	7	10

Table 1: Average and Maximum Separation Distance [m] for DECT carrier F9 and N = 10 dB

Average and Maximum Separation Distance [m] for DECT carrier F9 and N = 10 dB					
GSM 1800 BTS on carrier	**Isolation (maximum)**	CASE 3 model E		CASE 6 model F	
		Aver.	Max.	Aver.	Max.
1879,8 MHz	**115 dB**	129	197	328	450
1878.4 MHz	**100 dB**	41	62	144	198
1876.6 MHz	**94 dB**	26	40	104	142
1805 - 1875 MHz	**89 dB**	17	27	79	108

Table 2: Average and Maximum Separation Distance [m] for DECT carrier F9 and N = 10 dB

The calculations above have been made for DECT carrier F9, but the levels for carriers F8, F7 etc. are easily derived by shifting the levels in the tables above one line up for F8, two lines up for F7 etc.

3.1 Co-channel interference of GSM MS due to interference from DECT out-of-band emissions

The following conditions apply:
N = 10 dB, leading to 10 dB less required maximum isolation than in table 5 of Appendix 5.1

The table below shows this new isolation and the maximum separation distance, since no power control is applied to DECT.

Separation Distance and Required Isolation for DECT TX on carrier F9 with N = 10 dB						
GSM 1800 receiver on carrier	CASE 2 model D	CASE 5 model F		CASE 5 with only 2 dBi* BTS antenna		
	m	DB	m	dB	m	dB
1879,8 MHz	30	77	106	89	50	79
1878.4 MHz	10	57	23	69	11	59
1876.6 MHz	3	46	10	58	3	48
1805 - 1875 MHz	-	44	9	56	3	46

Table 3: Separation Distance [m] for DECT TX carrier F9 and N = 10 dB.
***Typical for the Italian FIDO telepoint**

The calculations above have been made for DECT carrier F9, but the levels for carriers F8, F7 etc. are easily derived by shifting the levels in the tables above one line up for F8, two lines up for F7 etc.

4 CONCLUSION

The most critical interference mechanism is blocking performance in DECT WLL systems, when the antenna of these systems is outdoors on the roof of buildings and there is a LOS between the WLL antenna and the GSM 1800 BTS above roof top elevated transmitter antenna, case 6. Note: Case 7 is not treated in this section.

5.3 Monte Carlo Simulation between DECT and GSM 1800

Simulations are an important tool for the assessment of complex communication systems.
The simulations described in this document were carried out with a statistical programme for the assessment of communication systems considering different interferers.
All the simulations were based on the same principle. A simulation consisted of an adjusted number of momentary records (events). The parameters of the momentary records were scrambled in accordance with the random variable (e.g. location, density of users, distances between transmitters, ...). Each event was scrambled independently. The interference probability was calculated with:

$$\text{interference probability} = \frac{\Sigma \text{interfered events}}{\Sigma \text{ events}}$$

The higher the number of events, the more reliable the result, but also the simulation time increases.

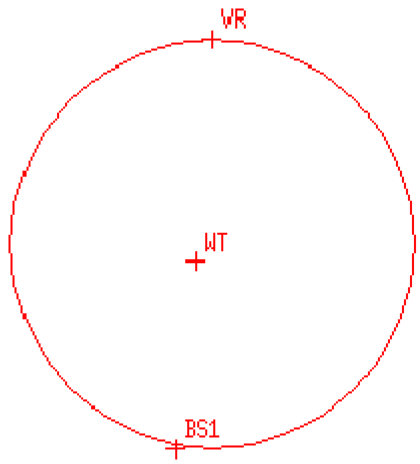
1 Blocking of DECT receivers, Case `4

Simulations for DECT CT:
WT: DECT FP transmitter
VR: Area of DECT PP receiver
Radius of DECT system: 140 m

BTS1: GSM 1800 base station
DCS BTS height: 30 m
DCS BTS Ptx: 42 dBm
Antenna gain of DCS BTS: 12 dB
DECT height: 1.5 m
Propagation model: modified Hata urban model

Distance DCS BTS edge to DECT cell 15 m.
Number of iterations = 10,000

Scenario:



Results:

GSM 1800 BTS on carrier	BTS EIRP 54 dBm	BTS EIRP 47 dBm	BTS EIRP 37 dBm	BTS EIRP 33 dBm	BTS EIRP 27 dBm
1879,8 MHz	28 %	11 %	3 %	1 %	<1 %
1878.4 MHz	3 %	1 %	<1 %	<1 %	<1 %
1876.6 MHz	1 %	<1 %	<1 %	<1 %	<1 %
1805 - 1875 MHz	<1 %	<1 %	<1 %	<1 %	<1 %

Table 1: Blocking probability for DECT carrier F9 case 3 derived by Monte Carlo simulations

The calculations above have been made for DECT carrier F9, but the levels for carriers F8, F7 etc. are easily derived by shifting the levels in the tables above one line up for F8, two lines up for F7 etc.

1.1 Conclusions for simulation of DECT CT (Case 4)

See discussions and conclusions in section 5.4 in the main body of this report.

2 Blocking of DECT WLL CTA receivers, Case 6
:

Simulations for DECT WLL CTA

WT: DECT FP transmitter
VR: area of DECT WLL CTA receiver
BTS1: GSM 1800 base station

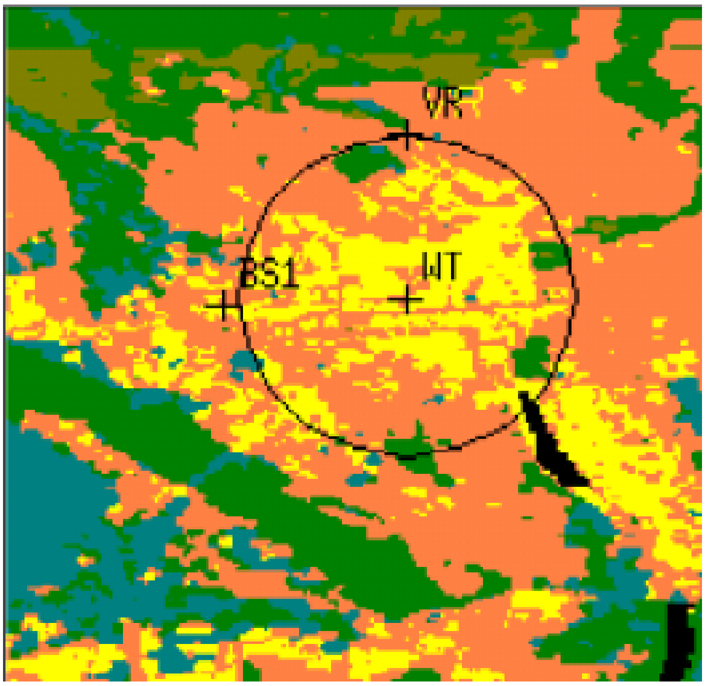
DCS BTS height: 30 m
DCS BTS Ptx: 42 dBm
Antenna gain of DCS BTS: 12 dB
Antenna gain of DECT transmitter/receiver: 12 dB
DECT CTA height: 10 m
Radius of DECT system: 2000 m

Propagation model: modified Hata urban model

Distance DCS BTS edge to DECT cell: 100 m.

Number of iterations = 10,000

Scenario:



Results:

GSM 1800 BTS on carrier	BTS EIRP 54 dBm	BTS EIRP 47 dBm	BTS EIRP 37 dBm	BTS EIRP 27 dBm	BTS EIRP 17 dBm
1879,8 MHz	21 %	10 %	3 %	<1 %	<1 %
1878.4 MHz	3 %	1 %	<1 %	<1 %	<1 %
1876.6 MHz	1 %	<1 %	<1 %	<1 %	<1 %
1805 - 1875 MHz	<1 %	<1 %	<1 %	<1 %	<1 %

Table 2: Blocking probability for DECT carrier F9 case 6 derived by Monte Carlo simulations

The calculations above have been made for DECT carrier F9, but the levels for carriers F8, F7 etc. are easily derived by shifting the levels in the tables above one line up for F8, two lines up for F7 etc.

2.1 Conclusions for simulation of DECT WLL CTA (Case 6)

See discussions and conclusions in section 4.4 in the main body of this report.

APPENDIX 6

MARKET INFORMATION AND SYSTEM PROPERTIES FOR DECT AND GSM1800

1 DECT SYSTEMS

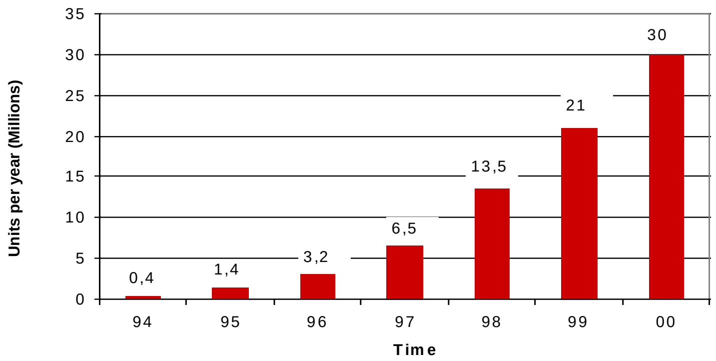
DECT is the term used for the Digital Enhanced Cordless Telecommunications systems. DECT carriers are defined for the band 1880-1938 MHz. located between 1880 and 1930 MHz. Spectrum is available for DECT in about 80 countries. 1880 – 1900 MHz in Europe and Australia and in several African and Asian countries (except China), 1900 – 1920 MHz in China and 1910 – 1930 MHz in several Latin American countries. There are mid-99 between 25 and 30 Million DECT terminals shipped world-wide. See the DECT Forum market history and forecast diagram below.
The majority DECT shipments are in residential and small business applications in Europe. DECT has proved to be cost effective for the low-end consumer market, having potential for further cost reductions.

The DECT Dynamic Channel Selection and quick hand-over procedures have also proved to be efficient and reliable for large office/industrial indoor/outdoor installations with 4000-5000 users per installation.

A large number of public DECT WLL commercial installations are in operation all over the world, mainly addressing the "teledensity" market in developing countries. In Europe, most systems are in Eastern Europe.

Public pedestrian DECT systems have had a slow development. There is one large public system operating since early 1998 in Italy. The system provides a high quality speech service and seamless coverage of streets, other public places and shopping mould in 31 cities with more than 130.000 subscribers (mid-99). With the success of GSM and heavy investment in mobile telephony, there is in general a reserved attitude towards the needs for public pedestrian DECT applications.

DECT Worldwide(source DECT Forum): Market forecast



In Western Europe, the major contribution to the growth of DECT systems and handsets are expected from residential and office applications.

The use of DECT for data transmission is foreseen to be substantially increased in the following environments:
- private homes (e.g. heating control, door opener, intercom)
- Business applications (cordless PABX's,…)
- Wireless Local Loop (WLL) e.g. Internet Access

and for some other specific applications like:

- Wireless modems.
- mobile counter systems (e.g. at restaurants and stores, paying with credit cards)
- storage
- wireless return channel for set-top boxes (return channel)
- DECT based alarm systems.

Examples for the above services and the required resources are shown in the table below:

	Service	**Required DECT Resources**
POTS	Speech	1 full slot (duplex)
Modem	data 1.2 - 4.8 kbit/s (9.6 kbit/s max.) data 56 kbit/s (V.90)	1 full slot (duplex), via 32 kbit/s ADPCM link 1 double slot (duplex), via protected 64 kbit/s PCM link
ISDN	ISDN D-channel (signalling or user data)	1 full slot (duplex)
	B+D* 3.1 kHz audio, speech	1 full slot (duplex), transcoder 64 kbit/s PCM 32 kbit/s ADPCM
	B+D* unrestricted 64 kbit/s	1 double slot (duplex)
	2B+D* two times 3.1 kHz audio, speech	2 full slots (duplex)
	2B+D* 3.1 kHz audio, speech and unrestricted 64 kbit/s	1 full slot and 1 double slot (duplex)
	2B+D two times unrestricted 64 kbit/s	2 full slots (duplex)
Data (packet, protected)	(24 kbit/s, 24 kbit/s)	1 full slot Duplex Position
	asymmetric (72 kbit/s, 24 kbit/s)	2 full slot Duplex Positions
	asymmetric (120 kbit/s, 24 kbit/~)	3 full slot Duplex Positions
	asymmetric (264 kbit/s, 24 kbit/s)	6 full slot Duplex Positions
	asymmetric (552 kbit/s, 24 kbit/s)	6 full slot Duplex Positions

* only for signalling

Table 1

The DECT specifications (ETS 300 175-2, TBR 6) provide in Europe for ten wide band channels in the frequency band 1880 - 1900 MHz (centre frequencies defined by f = 1897.344 MHz-c * 1728 kHz, where c= 0,1,.,.,9).

Council Directive of 3 June 1991 (91/287/EEC) requires an absolute protection of all carriers of DECT band: ***"In accordance with the CEPT recommendation T/R22-02, DECT shall have priority over other services in the same band, and be protected in the designated band"*** (91/287/EEC, page 2, §2).

The following should also be considered:

- The majority of private base stations (CT's) will be equipped with only one transceiver unit,
- multiple time slots are used for data transmission and ISDN,
- there are different user densities in normal environments and "hot spots",
- DECT user density will increase in the next few years.

DECT is distinguished by its efficient use of the frequencies through dynamic channel selection. The channel is always chosen by the DECT PP. It monitors all channels periodically and writes the channels in a list, ordered after the RSSI value (see table below). The DECT PP tries to establish a connection on the best channel of this list, if it requires a new channel. Since the channel selection always fits the actual situation with regard to user density and propagation conditions, the channels are selected dynamically.

The channels in the DECT standard are described in the table below:

RSSI	δRSSI	Band	Comment
> max dBm	∞	Busy	busy, don't try
	≤ 6 dB	b(n)	
	≤ 6 dB	b(4)	Possible
	≤ 6 dB	b(3)	Candidates
	≤ 6 dB	b(2)	
	≤ 6 dB	b(1)	
< max dBm	≤ -93 dBm	Quiet	quiet, always allowed

Table 2

RSSI: *Radio Signal Strength Indicator*
max dBm: *upper limit, not specified*
min dBm: *lower limit, ≤ -93 dBm*

Because of the TDD mode of DECT, it is sufficient to measure only the downlink channels for symmetric duplex connections.

The channel table of the DECT PP includes a list of all measured channels. One example is shown in the table below.

Status	Timeslot	frequency (channel number)	Quality
1	2	2	Quiet
2	4	2	Quiet
3	0	3	b(1)
4	1	1	b(1)
5	6	2	b(2)
.....	.....	.....	.....

Table 3

The channel table is regularly updated. The optimum channel selection is achieved automatically, since every DECT PP chooses the channel with the minimum interference at this moment.

Therefore the DCS algorithm allows for simple network planning. The number of usable frequencies can be reduced in the case of emissions from adjacent services. This is studied in this document. The basic important requirements of the DECT DCS algorithm are well defined in the DECT ETSI standard. The specific implementation of the DCS algorithm to meet these minimum requirements is left to the manufacturers discretion. The DECT standard does however not include requirements specifically to detect asynchronous interference like that from GSM 1800.

ETSI made simulations for the maximum traffic capacity before the introduction of the DECT systems in ETR 042. The following parameters are used by ETSI for the different scenarios:

For cordless telephones:

- suburban area with 4000 users/km^2
- normal distribution of the houses
- 10 x 10 m for each house
- every house stands centrally in a 16 x16 m garden
- the area includes 961 houses (490 m x 490 m)
- 1 DECT FP randomly positioned in every house
- 1 DECT PP at every DECT FP
- the DECT FP's are unsynchronised
- average transmission time 100 s (1.7 min)
- time between connections 2000 s (33 min)

⇨ 50 mErlangs/user,
⇨ 50 mErlangs*4000 users/km^2=200 Erlangs/km^2

- ⇨ 4000 users/km² => average distance of 16 m between DECT PP, therefore the one or two GSM 1800 BS in this area (1 km²) will have close-by DECT equipment.

For DECT PABX's:

- office building 60 m * 60 m * 9 m
- all users are static;
- all 120 full duplex physical channels are available 3 floors without internal walls
- 20 m² service area per DECT PP
- => 180 DECT PP / floor
- ⇨ 540 DECT PP in the whole building (100 % cordless penetration)
- ⇨ 200 m Erlangs/user gives 36 E per floor, which gives 36/(0.06*0.06)=10000 Erlangs/km²/floor. (Each floor has 9 FP with 4 E each)
- ⇨ 10000 users/km²/floor => average distance of 10 m between DECT PP, therefore the one or two GSM 1800 BS in this area (1 km²) will have some close-by DECT equipment.

For both scenarios ETSI defined the following Grade of Service (GoS):

$$GoS = \frac{\text{Number of blocked calls} + 10 \times \text{number of interrupted calls}}{\text{Number of calls}}$$

The DECT standard demands GoS ≤ 1%. For scenario 1 simulations showed that in the case of DECT a GoS of 1% can be achieved at a maximum range of 300 m from the DECT FP.

The above ETSI scenarios show typical high-density high link quality DECT applications.

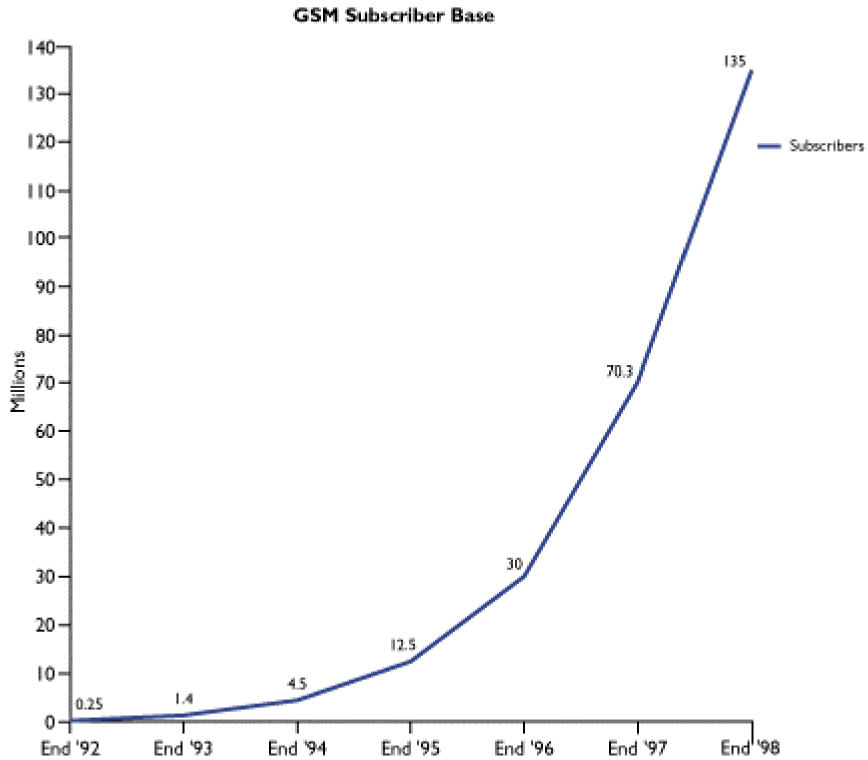
2 GSM 1800 SYSTEMS

GSM 1800 is the term used for the Global Mobile System 1800 located between 1710 – 1785 and between 1805 and 1880 MHz.
Spectrum is available for GSM 1800 in all the European countries and in several countries in Asia , Africa and Latin American countries. In march 1999, the number of GSM users was estimated to be between 110 and 115 Million. Included in these figures, there are about 12 Million subscribers of GSM 1800 networks and 30 Million subscribers of dual–band networks.
The majority GSM subscribers are in residential and rural areas all over Europe. GSM has proved to be low cost for public customer, having potential for further cost reductions.

The GSM 1800 private networks would also be efficient and reliable for large office/industrial indoor/outdoor installations. This kind of network allow the possibilities for the customer to use seamlessly private and public networks with the same terminal.

There is no GSM WLL commercial installation in operation all over Europe.

Public pedestrian GSM 1800 systems have had a high development. There is four large public systems operating since early 1996 in UK, two in Germany and three in France. The system provides a high quality speech and data services and seamless coverage of all the countries mentioned above. All other CEPT members will introduce GSM 1800 system in their countries. The GSM 900 operators now also solve their increasing traffic problem by using GSM 1800 channels in their network, and consequently, most of the GSM phones now available have dual-band capabilities.



(Source GSM association 1998 Annual Report)

The use of GSM for data transmission is foreseen to increase in private and business applications. (Internet, paying with credit card, bank access, car stolen alarm, travel ticket…).

The required resource for transmission data in GSM 1800 will increase rapidly in the next few years (Introducing the GPRS for internet and data services). For the time being the need for one operator in a high residential area is about 15 MHz, only for speech application. It is commonly admitted that the need in the same area, for speech and data application should be 25 MHz.

The European decision on the frequency bands to be designated for the introduction of the DCS 1800 (ERC/DEC/95(03)) requires protection of GSM 1800 bands allocated to operators:
"It is recognised that the exclusive use of the frequency bands for DCS 1800 may be preferred in order not to place constraints on potential operators and such an approach is generally recommended." (ERC/DEC/95(03), page 2, §2).

According to CEPT Recommendation T/R 22-07, Administrations were required to preferentially start the frequency attributions for operators in the upper part of the GSM 1800 band. This is due to the fact that in most countries, the GSM 1800 band is shared with Fixed Service systems which are progressively refarmed in other bands when possible.

Thus, in some countries, the channels adjacent to the DECT band have been licensed to operators and they can be extensively used, especially in dense urban areas. However, the use of the GSM 1800 band is very different throughout CEPT. Some countries have already allocated an important part of the spectrum and will need even more due to the increasing traffic in both GSM 900 and 1800 networks. Some other countries have not allowed any GSM 1800 license yet and have lower needs which enables them to have more flexibility in identifying the sub-bands they might use for GSM 1800.

The following should also be considered:
- The majority of base stations will be equipped with two or four transceiver unit,
- there are different user densities in normal environments and "hot spots",
- GSM 1800 user density will increase in the next few years.

For the GSM 1800 it is sufficient to measure RX-QUAL to know the quality of the communication. The RX-QUAL is a GSM Measurement code depending on the Bit Error Rate as described in the table bellow:

RX-QUAL i (signal quality level i)	BER (values range)	Representative value
0	BER < 0.2 %	0.14 %
1	0.2 % < BER < 0.4 %	0.28 %
2	0.4 % < BER < 0.8 %	0.57 %
3	0.8 % < BER < 1.6 %	1.13 %
4	1.6 % < BER < 3.2 %	2.26 %
5	3.2 % < BER < 6.4 %	4.53 %
6	6.4 % < BER < 12.8 %	9.05 %
7	12.8 % < BER	18.10 %

Table 4

If RX-QUAL is equal to 0 the quality of communication is good and if RX-QUAL is equal to 7 the quality is bad. If RX-QUAL is higher or equal to 4 we consider that the communication is corrupted.

GSM 1800 is the standard ETS 300 577, (GSM 05.05 version 4.22.2 December 1998) developed by ETSI for Digital Cellular Systems for use between 1710 to 1785 MHz (mobile transmit) and 1805 to 1880 MHz (base station transmit). It is used for macro cells and micro cells. Different parts of the band can be allocated to GSM services on a national basis. ERC Decision (95)-03 expressed the need to free at least 2 x 20 MHz in the upper part of the band, and that in long term this band would be extended to 2 x 50 MHz.

(RF aspects of the GSM 1800 specification are based on the GSM 900 specification. The carrier frequencies are defined by
$f_l(n)=1710.2+0.2(n-512)$ MHz, $512 \leq n \leq 885$; $f_u(n) = f_l(n) + 95$ MHz).

3 EVOLUTION OF DECT AND GSM 1800

3.1 Evolutions of DECT

DECT systems are proposed as a member of IMT 2000. One of the major characteristics of IMT 2000 or UMTS is a variable bit rate up to 2 Mbit/s, but not in all environments:
- minimum 384 kbit/s for wide area coverage
- local, indoor up to 2 Mbit/s.

The DECT standard include in the option for combinations of time slots for one transmission and backwards compatible 4- and 8-step modulations for increasing the data rates. The multiple time slots used for data transmission decrease the capacity of the DECT speech transmission. The multistep modulation is introduced either in the A- and B-fields or only in the B-fields of the DECT transmission. With this technique it will be possible to achieve DECT user data rates up to 2 Mbit/s. Broadcast and control signalling (A-field) can remain unchanged, whereby backwards compatible high bit rate DECT equipment is provided.

With 4-step modulation, the bit and symbol error probability remain practically unchanged, due mainly to the use of a better performing digital demodulator instead of the typical limiter-discriminator used in two level modulation schemes.

Thus the study in this report is relevant also for the emerging multi-step high user bit rate DECT applications.

3.2 Evolution of GSM 1800

Since the beginning of its development, the GSM standard has been continuously upgraded in order to provide enhanced performance and new service capabilities. The world-wide success of GSM and the increasing customer demand have led to evolutions as GPRS (up to 115 kb/s) and EDGE (384 kb/s).

The implementation of these evolutions (GPRS introduction is planned by most operators in the year 2000) will benefit from the already existing network infrastructure, which will allow, in a very short period, to offer new services to the GSM subscribers. These services will be available in large mobility and international roaming conditions as well as in private or domestic (CTS) applications, which are a natural trend for GSM applications.

Looking one step further, the arise of the new services offered by these GSM evolutions will be a key factor for the introduction of third generation systems. The main ETSI initiative in this field is the development of the UTRA (WCDMA) standard, which is led by the 3GPP at a world-wide level. The UTRA radio interface is designed in order to provide interoperability with GSM networks, which will remain essential for providing a sufficient capacity for personal communications systems.

GPRS is not a change in the radio interface specification. It will essentially lead to a different use of the time slots in order to provide packet data. The carrier loading will be different than with the current circuit switched speech service, but the assumptions of this report will remain valid.

EDGE corresponds to radio and modulation characteristics, which are different from those used in this report. In EDGE the 200 kHz carrier spacing remains, but a set of multi-step RF modulation capabilities have been added. The multi-step modulations require higher C/I than the basic GSM 2-step modulation. This implies that all links with a quality higher than required for the 2-step modulation, can increase their throughput by switching to one of the multi-step modulations. Should the link quality go down, the modulation of the link falls back to the 2-step modulation. Because of this fall back mode, the assumptions of this report will remain valid also for this evolution.

Thus the study in this report is relevant also for the emerging multi-step high user bit rate GSM applications.