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

COMPATIBILITY OF SRDS AT 900 MHZ WITH ADJACENT SERVICES

Marbella, February 1999

EXECUTIVE SUMMARY

This report has been compiled to examine the impact of the introduction of SRDs (Short Range Devices) in the band 868 - 870 on the services in adjacent bands (TETRA and CT2 – Cordless Telephone 2), but has not considered how these devices may be affected by other services elsewhere in the 900 MHz bands. The segmentation in sub-bands is detailed in ERC/REC 70-03, produced originally by SE24 and FM26. A maintenance group has now been created to address future modifications. One of the relevant ETSI standards for SRDs is prEN300 220.

Because of their low power and defined transmitter spectrum mask, it is possible for low power SRDs (up to 25 mW) to operate in bands adjacent to other services without causing unacceptable interference, provided that:

- SRDs up to 25 mW e.r.p. in the 868 - 870 band can coexist with CT2 in 864.1 - 868.1 MHz, provided that SRDs at 868 - 868.5 MHz are subject to a power restriction of 25 mW and have dynamic frequency allocation.

- Narrow band SRDs can coexist with TETRA but wideband SRDs need a minimum carrier separation of 500 kHz.

The implications of introducing higher power SRDs (500 mW), based upon minimum performance specifications, are given below:

- Interference to the adjacent band services (and other SRDs within the band) should be expected if very large numbers of 500 mW SRDs become widely used. The cost of 500 mW SRDs will be insufficient to adequately restrict the number of these SRDs, and wide geographical distribution (including in the domestic environment) should be expected, because it's highly likely that mass-market applications are found. Therefore it is unlikely that an immediate compatibility problem could arise, but if the potential (currently not quantifiable) future interference to the adjacent band services is to be avoided, an acceptable method of limiting the deployment of 500 mW SRDs may need to be identified before this type of SRD is permitted to operate within the 868 - 870 MHz frequency band.

- A request for an allocation for high performance and high price SRDs has been submitted to WG FM. An uncontrolled increase of production of SRDs for different applications than those envisaged at the moment could cause the unavailability of the band for those specific applications (e.g. professional telemetry).

- An uncontrolled and permanent increase of the generic pollution of this band could cause problems initially to the lower power SRDs in adjacent bands and later to the other services allocated in 900 MHz band, such as CT2 in some particular environments such as domestic applications or radio PABX, and to a lesser extent TETRA. In particular it is highly likely that social alarms and security systems within the harmonised SRD 900 MHz band could be frequently affected by uncontrolled deployment of 500 mW devices.

- In a precedent ERC report dealing with the compatibility between CT2 and CAD (Cordless Audio Devices) it has been stated that *"It is important that the 'non-shared' band (865 - 868.1 MHz), having a capacity of about 28 channels is not further interfered with by possible future new applications so as to ensure a proper call capacity / reserve for the system."* In the absence of other sources of interference a CT2 system still has 14 free channels in the presence of 500 mW SRDs at more than 6.2 m; but if the lower part of the band is made unusable by CAD, then all the CT2 capacity may be lost in presence of 500 mW SRDs at less then 70 m (free space). CT2 and CAD may occur together in domestic environment and introducing 500 mW SRDs into this environment will cause problems.

- It is recognised that, in general, a limited duty cycle can be a useful factor in the aim of limiting interference (even in the absence of specific means for evaluating the precise effect). In the current version of the ERC/REC/70-03 the definition of duty cycle is inappropriate for the purpose of considering it when producing compatibility studies.

In the case of frequency hopping applications, the duty cycle time, for adjacent band compatibility studies, has to be the total transmitter on time and not the time of a selected frequency channel (1 frequency hop).

Also it should be clarified, that it must be ensured, that the broad band noise, the switching transient and other effects of SRDs with frequency hopping are not higher than the limit for the unwanted emissions at the appropriate SRDs standards. It is recommended that SRDs intended for operating in a frequency-hopping mode be tested in that mode for type approval.

Further work would be required to:

- Ensure high channel availability for social alarms and security systems within the harmonised SRD band.
- Determine the effects of spurious emissions.
- Define the situations in which these units are to be used.
- Identify typical scenarios depending on the envisaged applications.

The SRD industry and ETSI are encouraged to draft further standards for specific SRD applications. In particular the presence of a standard for the definition of the minimum SRDs receiver performances would be useful for evaluating the impact of other services towards the SRDs. Furthermore it was not possible to take into account the mitigation effect of low duty cycles, due at this time to the lack of a precise definition in ERC/REC 70-03 and concerns were raised concerning the wide band noise that could be generated by systems using frequency hopping. It is recommended that SRDs intended for operating in a frequency-hopping mode be tested in that mode for type approval.

This report has not examined the effect of 500 mW SRDs on the other SRDs operating within the band. Harmful interference is possible and further work should be carried out within WG SE.

SRD manufacturers should be aware of adjacent services (CT2, TETRA and other SRDs) when specifying and designing systems.

This report has not examined the effect of 500 mW SRDs on the other SRDs operating within the band. Harmful interference is possible and further work should be carried out within WG SE.

INDEX TABLE

COMPATIBILITY OF SRDS AT 900 MHZ WITH ADJACENT SERVICES

1 INTRODUCTION

Producers and users of SRDs have indicated a need for spectrum in the 900 MHz region. The main requirement is for professional telemetry purposes but there is also demand for 'low cost' equipment for less critical applications.

Short Range Devices (SRDs) are low power transmitting devices for which an end user license is not needed. They are used in domestic circumstances for remote control, e.g. garage door openers, car key fobs, and also for professional telemetry, e.g., instrumentation and process control. Another large use is for alarms, e.g.. Social alarms and security systems.

The use of SRDs is deregulated and no central records are kept of their numbers and locations. Very large numbers are in use and existing allocations for SRDs are becoming crowded. There are no guaranteed clear channels or time slots for SRDs and no agreed formats for transmissions. Mutual interference occurs but its effects are reduced because of the low duty cycles often employed and the short ranges of the transmissions. The level of mutual interference acceptable depends on the nature of the applications.

There are some obstacles, which are making it difficult to make compatibility analysis on SRDs. The receivers of SRDs and the bandwidth are not specified, so the calculations can only be made based on the acceptance of some parameters for SRDs.

The SRD applications and their quality (e.g. transmitter, receiver, operation area, number of equipment, location, modulation, multiplex access techniques, etc.) are diverse and different. For example a medical implant has generally different qualities than a container identification system or a garage door opener.

The previous name for SRDs, Low Power Devices (LPDs) included in most European countries equipment with a maximum output power of 10 mW e.r.p. Because of their low power it was assumed, that LPDs would not interfere with other radio services up to now. Under certain circumstances these LPDs didn't need to be licensed and regulated. The LPDs were operating mainly at ISM frequencies and without charge, there was no demand for the customers of the equipment for protection. But the number of LPDs had been not so high.

Some of the characteristics of LPDs are not applying to SRDs and the number of SRDs had been increased the last years. New applications brought new problems, e.g. the interference of garage door openers due to permanently active unwanted emissions from wireless headphones at the 433 ISM (Industrial Scientific and Medical) applications band. The additional relief of the licensing (e.g. no receiver parameters had been created) and also the increase of e.r.p. output power for SRDs to a maximum limit of 500 mW made it questionable to speak about low power application. During this time the number of devices and applications have grown, operating without licensing and with free circulation and use on a European basis.

With SRDs it is assumed that most of them are aimed at low cost mass-produced equipment. This means, that in high population density areas thousands of equipment/km² are coming in operation with varying quality and technical design (mobile, fixed, different modulations, duty cycles...). The probability of SRD transmissions is now therefore very high.

2 STUDY

Equipment Regulations

SRDs have to meet type approval requirements before being marketed. The generally adopted specification is prEN 300 220. This specifies certain requirements for spurious emissions, etc. To make a complete technical specification, further restrictions on operating frequency and radiated power need to be added. It is noted that prEN 300 220 sets limits on the transmitter spectrum but does not specify the signalling protocols or modulation techniques. It is intended that the SRD bands will be available for emerging technologies and also for derivatives of existing technologies, including for instance, CT2, DECT, GSM etc.

In order to produce a complete study including the analysis of the possible interference produced by services using adjacent bands to SRDs, the receiver characteristics of SRDs would be needed. Neither prEN 300 220 nor the individual national requirements specify receiver selectivity parameters or overall system performance levels for general applications. This is left as a matter between the purchaser and the manufacturer. Different SRDs will have different susceptibilities to interference, depending on their intended application and price. It is not therefore possible to calculate the general effect of adjacent channel transmitters on a typical SRD system by reference to existing harmonised specifications.

At present, individual countries set their own limits for these parameters, and sometimes also for permitted uses and configurations. Working Group FM has produced the ERC/REC 70-03 on SRDs that proposes harmonised parameters for SRDs in several bands, depending on the type of service envisaged. A maintenance group is charged of all possible modifications to the recommendation under the guidance of WG FM and WG SE. The ERC/REC 70-03 relating the use of SRDs recommends following specific frequency arrangements for the band 868 - 870 MHz.

Ref 70-03	Frequency Band, MHz	Power e.r.p., mW	Channel spacing, kHz	Duty cycles[1] Footnote 1	Applications	Relevant ETSI standards and CEPT recommendations
1f	868 -868.6	25	25 Footnote[2, 3, 4]	Low < 1.0 %	N.S.	*
7a	868.6-868.7	10	25	Very Low < 0.1%	Alarms in general	**
1g	868.7-869.2	25	25[3,4]	Very Low < 0.1 %	N.S.	*
7d	869.2-869.25	10	25	Very Low < 0.1%	Social alarms	**
7b	869.25-869.3	10	25	Very Low < 0.1%	Alarms in general	**
1h	869.3-869.4	t.b.d.	25	t.b.d.	N.S.	*
1I	869.4-869.65	500	25[5]	High < 10 %	N.S.	*
7c	869.65-869.7	25	25	High < 10 %	Alarms in general	**
1k	869.7-870.0	5	25, 50[3]	Very High Up to 100%	N.S.	*

Table 1

Footnotes of table 1:
N.S = Not Specified.

SRD Special Applications
Special applications are those for which some protection may be appropriate, even in absence of mechanisms like licensing and administration. Examples are social alarms and wireless security systems, for which large numbers of devices each with extremely low (<1:1000) duty cycles can be foreseen. A small number of channels should be set aside for such purposes. It is important that these systems have high channel availability and therefore further work is necessary to ensure compatibility with;

- other co-channel systems,
- systems in other adjacent SRD channels,
- other systems outside or overlaying the SRD band.

[1] the average time period of a full cycle is up to 1 hour.
[2] To avoid mutual interference between CT2 and SRDs below 868.5 MHz, these SRDs should avoid using a dedicated frequency channel and instead use a technology that allows automatic channel selection of a free channel within the band.
[3] the frequency band may also be used for wideband data (frequency varying transmitters)
[4] the frequency band may also be used spread spectrum technology with a maximum bandwidth of around 100 kHz
[5] the whole frequency band may also be used as 1 channel for high speed data transmission.
* prEN 300 220, prEN 300 330, prEN 300 440; T/R 01-04, T/R 20-03
** prEN 300 220; ERC/DEC/(97)06

SRDs with emitted power up to 500 mW
As the 868 - 870 MHz draft Band Plan places 500 mW SRDs approximately 500 kHz from the nearest band edge, the most likely interference mechanism to adjacent band services will be blocking (assuming good quality SRD transmitters), and the magnitude of the compatibility problem will largely be dictated by the number and geographical distribution of 500 mW SRD usage. In assessing the likely numbers and geographical distribution, the SE7 project team considered the following arguments;

a) That the 868 - 870 MHz SRD band is designed for high quality, high performance, channelised SRDs. 500 mW SRDs will only be used for highly specialised applications that justify the high cost e.g. professional telemetry, and this will limit the number and geographical location in which this type of high power SRD will be used.

b) That if 500 mW SRD use doesn't become widespread, the magnitude of the compatibility problem should not be critical to the other services within the 900 MHz band (providing that the 500 mW SRDs are kept approximately 500 kHz from the nearest band edge as is proposed).

c) That there is nothing in prEN 300-220 that precludes the manufacture of low cost 500 mW SRDs and, as these SRDs will be deregulated, it is highly likely that a mass market application will be found and very large numbers should be expected in most locations, including the domestic environment. There are no restrictions for the use of SRDs and they can be used anywhere (mobile and fixed). The SRDs with 500 mW e.r.p can cover not only short ranges (considering free-space path loss, at 1 km the received power is still around -64.5 dBm, or -78.5 at 5 km, high figures compared to receivers' sensitivities). If they are used at exposed locations the coverage areas of those "high" power SRDs can be up to kilometres if a high quality receiver is used. They can interfere with other systems in the 900 MHz range through blocking over a wide area and frequency range, if there is no control on their deployment by mechanisms such as licensing or frequency planning.

The uncertainty regarding the likely numbers and distribution of 500 mW SRDs has made an accurate assessment of the compatibility problem impossible. Following considerable debate however, the SE7 project team concludes;

- that interference to the adjacent band services (and other SRDs within the band) should be expected if very large numbers of 500 mW SRDs become widely used.

- that problems might arise with the introduction of SRDs with an output power of 500 mW if there is free circulation and use, because national regulations for the required regulated frequency planning cannot be achieved and they may be not observed.

- that the cost of 500 mW SRDs will be insufficient to adequately restrict the number of these SRDs, and wide geographical distribution (including in the domestic environment) should be expected if mass market applications are found.

- that there is unlikely to be an immediate compatibility problem but if the potential (currently not quantifiable) future interference to the adjacent band services is to be avoided, an acceptable method of restricting the number and location of 500 mW SRDs may need to be identified before this type of SRD is permitted to operate within the 868 - 870 MHz frequency band.

- that WG FM has demanded an allocation for high performance and high price SRDs for a limited market. The practical implication is that it will be possible for the administrations to deal with the number of demands for obtaining licenses. On the contrary, if no licence is required, the likely scenario is that of an uncontrolled increase of production of SRDs for different applications than those envisaged at the moment. This could cause an uncontrollable and permanent increase of the generic pollution of this band, causing problems to the lower power SRDs in adjacent bands and later to the other services allocated in 900 MHz band, such as CT2 and to a lesser extent TETRA.

Wireless Microphones
Wireless microphones used for public entertainment and broadcasting purposes need to be administered to ensure clear channels. Such wireless microphones should not be confused with SRDs and need a different treatment in the administration of spectrum and have been shown to be incompatible with SRDs in this band.

Cordless Audio Devices
Cordless Audio Devices can operate in a de-regulated environment but only for domestic and non-critical applications. These wideband constant carrier devices are considered incompatible with SRDs operating between 868 - 870 MHz. An ERC report has been previously produced dealing with such devices. Therefore, the ERC has designated the band 863 - 865 MHz for such applications.

Compatibility considerations
The four main interference scenarios have been defined as:
1. SRDs are interfering CT2 systems
2. SRDs are interfering TETRA BS
3. TETRA MS are interfering SRDs
4. CT2 systems are interfering SRDs.

Due to the considerations proposed in the chapter above dealing with 'Equipment Regulations' on the absence of sufficient information on SRDs receivers the study covers only the first two scenarios.

Two interfering mechanisms have to be considered: adjacent channel interference and blocking.

Adjacent channel interference occurs when the wanted and unwanted signals are close in frequency and the filtering in the receiver does not suppress the unwanted signal enough. In cases where the unwanted signal is wideband, the co-channel component of the unwanted signal should be considered separately.

Blocking occurs when the unwanted signal is strong enough to induce an increase of the noise at the detector stage due to the fact that the noise of the local oscillator is convoluted with the unwanted signal or due to the fact that the unwanted signal is strong enough to drive some of the receiver circuits into non linear operation. Even though the receiver filtering prevents the unwanted signal from reaching the detector stages, the receiver is de-sensitised because the front end stages are affected. The technical term for this de-sensitisation effect is "blocking". While adjacent channel effects depend on the relative levels of the wanted and unwanted signals, blocking occurs at a specific level of unwanted signal, regardless of wanted signal level.

The receiver parameters provided in the relevant ETSI standards for TETRA and CT2 have been used in this study in order to evaluate the possibility of interference. A minimum coupling loss (MCL) calculation has been produced and the results are included in annex 1.

Impact of duty cycle
In general, when assessing interference to other systems the duration of the transmission has to be considered. SRDs with higher duty cycles therefore present a greater interference probability. Duty cycles should therefore be kept as short as possible. This should present no problems for most SRDs applications. The victim receiver characteristics and requirements, together with the burst length of the interferer, determine the impact in terms of perceived interference. For example at digital mobile radio system special error correcting mechanisms and interleaving functions are able to deal with one interfered timeslot. An interference of more than one timeslot can cause interruption. As an example, a GSM timeslot has a duration of 577µs and a TETRA timeslot has 15 ms.

In general, whenever the burst length is shorter than the receiver time slot, a low duty cycle can be considered as a mitigation factor (especially due to averaging effect), always difficult to quantify. In particular in this case it is not possible to evaluate the effect of the duty cycles used in ERC/REC 70-03 in compatibility studies. The proposed value of 1 hour for the averaging period for the evaluation of a duty cycle seems not to be adequate. As an example, 10 % of 1 hour means 6 minutes and this value has to be considered as a continuous transmission for compatibility studies on mobile radio services.

In any case, due to the unlicensed nature of SRDs, it is expected that a great number of such devices should be able to operate satisfactory together over a certain area without any co-ordination. It could be expected that many SRDs will employ short transmission times and/or low duty cycles, because this is one way for them to function. In this case the devices work in different "time slots", without any specific access mechanism. Nevertheless, for the purpose of increasing compatibility with adjacent services, the parameters of both interferer and victim (burst length and victim receiver time slot) are relevant.

Frequency Hopping
For the study of frequency hopping of SRD applications it is important to clarify the difference between the total transmission time and the time slot for one frequency hop. For adjacent band compatibility studies, the duty cycle time has to be the total transmitter on-time and not the time of a selected frequency channel (1 frequency hop).

Also it should be ensured, that the broad band noise, the switching transient and other effects of SRDs with frequency hopping are not higher than the limit for the unwanted emissions at the appropriate standard.
It is recommended that SRDs intended for operating in a frequency hopping mode are tested in that mode for type approval.

Compatibility with CT2
In some countries the band 864.1 to 868.1 is designated for CT2 telephony for domestic or PABX applications. CT2 receivers are susceptible to signals immediately adjacent to the nominal 868.1 MHz band edge and energy from CT2 transmissions spreads beyond 868.1 MHz. Compatibility problems arise in both directions if SRDs are operated down to 868.1 MHz. For fixed frequency SRDs, a frequency separation is required. To avoid mutual interference between CT2 and SRDs it is recommended that SRDs below 868.5 MHz should avoid using a dedicated frequency channel and instead use a technology that allows automatic channel selection of a free channel within the band (note 3 under table 1). CT2 already has this capability. Furthermore SRDs operating at this end of the band should be restricted in power to 25 mW and in duty cycle to less than 1.0%.

It is noted that the technical conditions of SAP (Services Ancillary to Program making) are comparable with those of SRDs and that an ERC report dealing with SAP reached the following conclusions«*In attempting to establish the minimum frequency separation required between CT2 and SAP some limited technical measurements were undertaken.*
The results obtained from these tests indicate that it is possible to locate low power SAP services, consisting of regulated (i.e. frequency planned) SAP services having a power output of 50 mW or less, adjacent to CT2 services without the need for larger frequency separations".

The results of the calculations given in annex 1 show that, in the presence of higher power SRD-units with a power of up to 0.5 W, in the absence of other sources of interference a CT2 system still has 14 free channels in the presence of 500 mW SRD at more than 6.2 m; but if the lower part of the band is made unusable by CAD, then all the CT2 capacity may be lost in presence of 500 mW SRD at less then 70 m (free space). CT2 and CAD may occur together in domestic environment and introducing 500 mW SRDs into this environment will cause problems.

Compatibility with TETRA
The band above 870 MHz is intended for use by TETRA (MS transmit - BS receive). TETRA receivers are specified to work with a TETRA signal in the adjacent channel (+25 kHz channel spacing) at a level 45 dB higher than the wanted signal (prETS 300 394-1 7.2.4.2). Therefore the probability of interference to TETRA, from SRDs close to the band edge, is considered to be low.

A practical study has been conducted to test the immunity of existing representative SRD receivers to (adjacent) TETRA transmissions at 400 MHz (similar results are expected at 900 MHz). Two general types of SRDs were tested: telemetry units, which operate in 25 kHz channels and lower cost units intended for un-channelised bands (200 kHz).

The tests showed that the 25 kHz systems may be operated immediately adjacent to the TETRA allocation. The wider bandwidth units however, will require a frequency separation of 500 kHz. If allowance is to be made for poor frequency stability, this frequency separation needs to be increased to 800 kHz.

The probability of interference to TETRA from SRDs is therefore considered to be low. *"Interference from TETRA to SRDs is possible, but cannot be quantified".*

3 CONCLUSIONS

Because of their low power and defined transmitter spectrum mask, it is possible for SRDs up to 25 mW to operate in bands adjacent to other services without causing unacceptable interference.

Based upon minimum performance specifications it is concluded that:

- SRDs in the 868 - 870 MHz band can coexist with CT2 in 864.1 - 868.1 MHz, provided that SRDs at 868 - 868.5 MHz are subject to a power restriction of 25 mW and have dynamic frequency allocation.
- Narrow band SRDs can coexist with TETRA but wideband SRDs need a minimum carrier separation of 500 kHz.

Further work is required to ensure high channel availability for social alarms and security systems within the harmonised SRD band. Narrow band SRDs can coexist with TETRA, if they comply with the receiver limits embodied within prEN 300 220 part 2 *and with a restricted power to 25 mW.*

The recent allocation to the Cordless Audio Devices of the band 863 - 865 MHz has dramatically reduced the capacity of CT2 in the most common domestic environment. That's why in a precedent ERC report dealing with the compatibility between CT2 and CAD it has been stated that *"It is important that the 'non-shared' band (865 - 868.1 MHz), having a capacity of about 28 channels is not further interfered with by possible future new applications so as to ensure a proper call capacity / reserve for the system"*. In the absence of other sources of interference a CT2 system still has 14 free channels in the presence of 500 mW SRD at more than 6.2 m; but if the lower part of the band is made unusable by CAD, then all the CT2 capacity may be lost in presence of 500 mW SRD at less then 70 m (free space). CT2 and CAD may occur together in domestic environment and introducing 500 mW SRDs into this environment will cause problems.

Avoiding Interference due to blocking caused by SRDs with a power of 500 mW to adjacent TETRA-BS-Stations requires a Minimum Separation Distance of 12 m, or 42 m if in the TETRA main beam. If TETRA BS antennas are located on masts, such interference is very unlikely.

This report has not examined the effect of 500 mW SRDs on the other SRDs operating within the band. Harmful interference is possible and further work should be carried out within WG SE.

Unless SRDs with an output power higher than 25 mW in this frequency band are regulated and frequency planned, it is very likely that problems may arise. In particular with the introduction of the SRDs with an output power of 500 mW problems are expected if there is free circulation and use of them.

Interference caused to SRDs by TETRA or CT2 cannot be predicted fully because of the diverse nature of SRDs.

CT2 requires a power restriction and a frequency separation for SRDs at the ends of the band.

The SRD industry and ETSI are encouraged to draft further standards for specific SRD applications in particular for what concerns the minimum receiver performances.

SRD manufacturers should be aware of adjacent services (CT2, TETRA and other SRDs) when specifying and designing systems.

Annex 1

ANNEX 1: THEORETICAL STUDY

Compatibility with CT2

CT2 system is defined in ETSI standard ETS 300 131. The relevant part of the CT2 specification is paragraph 4.6.3.1, and particularly Table 1 (see below), which contains the maximum permitted level of interference produced by an unmodulated interfering signal that doesn't affect the CT2 receiver considering both blocking and adjacent channel interference, depending on the frequency. The operative range of CT2 equipment is 864.1 to 868.1 MHz and the table was produced taking into consideration the possible presence of other services in adjacent bands. The levels are proposed in the form (I/C) in the relevant band 860 - 872 MHz. When using the figures in the table in calculations of absolute interference levels, then the sensitivity of +40 dBμV/m should be considered and the wanted signal level should be taken [3]5 dB higher than the sensitivity.

It has been noted that the standard doesn't propose the conceptual difference between adjacent channel interference and blocking, but the values in the first three lines correspond to this last effect (because they present a fixed value). Nevertheless, if the values in following lines are not respected all the band is not available . In fact the values in these lines correspond to figures of adjacent channel rejection capability for the closer CT2 channel and they force the respect of the blocking condition for the more spaced channels. In the following, the original Table 1 of paragraph 4.6.3.1 in the ETS 300 131 is presented.

Frequency Range(s)	Extreme conditions	Nominal conditions
25 MHz to 800 MHz	120 dBμV/m	123 dBμV/m
800 MHz to 850 MHz 890 MHz to 4 GHz	117 dBμV/m	120 dBμV/m
850 MHz to 860 MHz 872 MHz to 890 MHz	110 dBμV/m	113 dBμV/m
860 MHz to 863 MHz 869 MHz to 872 MHz	45 dBc	48 dBc
863 MHz to fc - 300 kHz fc+300 kHz to 869 MHz	35 dBc	38 dBc
fc-300 kHz to fc - 200 kHz fc+200 kHz to fc + 300 kHz	30 dBc	33 dBc
fc-200 kHz to fc-100 kHz fc+100 kHz to fc+200 kHz	20 dBc	20 dBc
fc-100 kHz to fc+100 kHz	-20 dBc	-20 dBc

Table 1: Table 1 of ETS 300 131 (paragraph 4.6.3.1)

This table can be used in the following way: we make the hypothesis that the figures in the table are those needed by CT2 system in order to protect all the band. That means that the values are referred in particular to the protection of the channels that are closer to the SRD band. If we consider that in particular the protection of the last CT2 channel is envisaged (central frequency of 868.05 MHz), we can deduce a mask that corresponds to the needed protection for each channel (it is not perfectly true that the receiver performances are the same for all the channels, but it is the most likely way to consider the figures in the table). The receiver mask of the channel at the upper edge of the band (fc = 868.05 MHz) can be obtained from the table 1, considering the I/C mask and the figures relative to blocking, whenever they represent a more stringent criteria. That is summarised in the following table:

fc-100 kHz to fc+100 kHz	-20 dBc
fc-200 kHz to fc-100 kHz fc+100 kHz to fc+200 kHz	20 dBc
fc-300 kHz to fc - 200 kHz fc+200 kHz to fc + 300 kHz	33 dBc
fc-950 kHz to fc -300 kHz fc+300 kHz to fc+950 kHz	38 dBc
fc-3950 kHz to fc-950 kHz fc+950 kHz to fc+3950 kHz	48 dBc
In all the band, up to f_c + 21.95 MHz, whenever this figure is higher than the resulting tolerable I (from I/C)	113 dB V/m → -20 dBm

Table 2: Receiver mask applicable to each channel

Transmitted power for uplink and downlink is 10 mW. A figure of 2.2 dBi can be used for the gain (suggested in the ETS). Sensitivity S of the mobiles is indicated as 40 dBµV/m. If we consider the following generic formulas:

$$P = \frac{E^2}{120\pi} A_{eq}$$

and

$$A_{eq} = G \frac{\lambda^2}{4\pi}$$

we can convert S into a power of -94 dBm. The same formulas have been used also for evaluating the value in dBm (-21 dBm) related to the value of 113 dBµV/m in the table of the standard.

For an unmodulated interfering signal transmitting in the band 868 - 869 MHz, the maximum permitted (I/C) is set to 38 dBc and in the band 869 - 870 MHz it is set to 48 dBc. Using these values and the proposed maximum emitted power of SRDs in the band 868 - 870 MHz, we can evaluate the necessary isolation with the MCL method. The isolation required to avoid interference or blocking can be expressed in dB as a function of the SRD power Pi using the following formula:

$$I_{w_i}(dB) = P_I(dBm) - (S(dBm) + 5dB) + (C/I)_{w_i}(dB)$$

The values obtained are presented in next table. In the second column, the isolation is converted into a separation distance using a free space propagation model. SE7 members are conscious that this model is not fully adapted for describing realistic scenarios, but present the results to give an idea of the risk of interference. The value of distance can be derived by inverting the formula:

L(dB) = 31.2 + 20Log d(m)

Here's the table of the results (in the first column the reference as in the table in ERC/REC 70-03 is given):

	f	P(mW)	(I/C)1	d1	(I/C)2	d2	N free channels	(I/C)3	d3	N free channels
1k	869.75	5	48 dBc	6.9	113 dBµV/m	0.6	17			
7a	868.65	10	38 dBc	30.9	48 dBc	9.8	36	113 dBµ V/m	0.9	6
7b	869.25	10	48 dBc	9.8	113 dBµV/m	0.9	12			
7d	869.25	10	48 dBc	9.8	113 dBµV/m	0.9	12			
1f	868.35	25	38 dBc	49	48 dBc	15.5	33	113 dBµ V/m	1.4	3
1g	868.75	25	38 dBc	49	48 dBc	15.5	37	113 dBµ V/m	1.4	7
7c	869.65	25	48 dBc	15.5	113 dBµV/m	1.4	16			
1i	869.45	500	48 dBc	69.2	113 dBµV/m	6.2	14			

Table 3: Results (distances in metres)

The precedent table has to be read in the following way
Each line corresponds to one kind of interferer as listed in ERC/REC 70-03. For each interferer, several significant distances are calculated, each of them being the minimal separation distance under which a certain number of CT2 channels are not available. As an example, if we consider a signal of type 1f, with central frequency of 868.75 and maximum emitted power of 14 dBm, if the distance between the CT2 device and the interferer is less than 1.4 m (last considered distance, last part of the table) no channels are available. If the distance is between 1.4 m (d3) and 15.5 m (d2), 7 channels are available. If the distance is between 15.5 m (d2) and 49 m (d1), 37 channels are available. If finally the distance is more than 49 m, all the channels are available.

The following table proposes the same results in a different way:

	P(mW)	Limits (m)	N free channels	limits (m)	N free channels	limits (m)	N free channels	limits (m)	N free channels
1k	5	d <0.6	0	0.6< d <6.9	17	d > 6.9	40		
7a	10	d < 0.9	0	0.9< d <9.8	6	9.8< d < 30.9	36	d > 30.9	40
7b	10	d< 0.9	0	0.9< d <9.8	12	d > 9.8	40		
7d	10	d < 0.9	0	0.9< d <9.8	12	d > 9.8	40		
1f	25	d < 1.4	0	1.4< d <15.5	3	15.5< d <49	33	d > 49	40
1g	25	d < 1.4	0	1.4< d <15.5	7	15.5< d <49	37	d > 49	40
7c	25	d < 1.4	0	1.4< d <15.5	16	d > 15.5	40		
1i	500	d < 6.2	0	6.2< d <69.2	14	d > 69.2	40		

Table 4: Results (distances in metres)

Three considerations have to be made.

- It should be noted that these calculations are based on a CT2 system operating 5 dB above its sensitivity.
- Each calculated distance is the needed distance from the CT2 device to the SRD. But the cumulative effect of more than one SRD can interfere at the same time due to the natural deployment scenario of an unlicensed mass market.

All the free channels are in the lower part of the band. That means that if the lower part of the band is free from interference the CT2 equipment can work. It has to be noted that the part of the band 863 - 864 MHz is allocated in Europe to cordless audio devices (CAD) and that in WG SE report SE(97)31annex 7 dealing with the compatibility between CT2 and CAD it has been stated that "*It is important that the 'non-shared' band (865 - 868.1 MHz), having a capacity of about 28 channels is not further interfered with by possible future new applications so as to ensure a proper call capacity / reserve for the system.*". Looking at the table above, it is showed that in the absence of other sources of interference a CT2 system still has 14 free channels in the presence of 500 mW SRD at more than 6.2 m; but if the lower part of the band is made unusable by CAD, then all the CT2 capacity may be lost in presence of 500 mW SRD at less then 70 m (free space). CT2 and CAD may occur together in domestic environment and introducing 500 mW SRDs into this environment will cause problems.

Another type of calculation can be produced. We can imagine that a communication occurs; CT2 is at a certain distance Dct2 from its base, the SRD is at a distance Dint. Maybe the CT2 terminal is far from working at the sensitivity limit, but the interferer is closer to CT2 base than the terminal. In this case blocking can occur. We can try to calculate the ratio between the two distances that gives the limit of CT2 being able to communicate.
In this case, if we consider very simply the useful power Pct2, the interfering power Pint, the free space path loss of both devices, Lct2 and Lint and a value of I/C of 38 dBc or 48 dBc depending on the frequency, we can write (all values in dB/dBm):

$$Pct2 - Lct2 >= Pint - Lint - I/C;$$

after some rearranging we can deduce following relationship:

$$\frac{D_{CT2}}{D_{INT}} \leq 10^{(-P_{INT}+(I/C)+P_{CT2})/20}$$

Using this formula, we obtain the following table:

SRD power (mW)	Necessary Dct2/Dint
5	355
10	79 (7a); 251 (7b, 7d)
25	50 (1f); 158 (1g, 7c)
500	35

Table 5: Results for CT2, alternative approach

The two tables above may look different, but they reflect different aspects of the same problem. In both cases there is the limitation of using free space propagation which strictly is not applicable to large distances or to indoor environments. The first calculation is more classical, but may be considered as pessimistic. The second one is not a standard calculation, but it seems that this method can represent the real effect of introducing SRDs in the band adjacent to CT2. The considerations at the end of the first calculation are obviously still valid.

Compatibility with TETRA

A similar analysis can be completed for TETRA and SRDs. The TETRA BS receive band extends from 870 - 876 MHz i.e. adjacent to the SRD band. The blocking level of the Tetra BS depends on the frequency separation as shown in the table below. If the interfering SRD falls within the main beam of the TETRA antenna, a greater separation is required. The table shows separation distances for 0 dBi gain, representing the general case, and 11 dBi, representing the main beam.

	SRD power (mW)	Frequency separation (nearest TETRA channel, kHz)	ISOLATION (dB) (TETRA blocking level)	Distance in TETRA side lobes (m)	Distance (main beam, m)
7b	10	725	46 (-25 dBm)	1.5	5.5
7c	25	325	55 (-30 dBm)	4.3	15.4
1i	500	375	68 (-30 dBm)	11.8	42

Table 6: Results for Tetra

The isolations and distances are significantly greater than the CT2 case. A second analysis may be completed as was done for the CT2 scenario which calculates the ratio of TETRA MS to TETRA BS separation to SRD to TETRA BS separation. The TETRA MS is assumed to be 1 Watt and the C/I = -60 dBc. The 5 mW SRD can be in the adjacent channel and a C/I value of –45 dB is used. Free space propagation is assumed. The results are shown in the table below.

SRD power (mW)	Necessary Dtetra/Dint
5	2.5×10^3
10	10.00×10^3
25	6.31×10^3
500	1.41×10^3

Table 7: Results for TETRA, alternative approach

These ratios are much greater the CT2 case because of the greater signal strength of the wanted signal and greater dBc figure for the power allowed in the adjacent channel.