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Time Division Duplex (TDD) in Point-to-Multipoint (P-MP)
Fixed Wireless Access (FWA) systems;
Characteristics and network applications

Reference

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Transmission and Multiplexing (TM).

Introduction

Time Division Duplex (TDD) is a duplexing technique used in digital telecommunication systems. The potential of TDD is often overlooked by regulators for multipoint fixed wireless access services, particularly in bands traditionally occupied by FDD systems.

Historically, point-to-point telecommunications systems and mobile telecommunications systems have used a Frequency Division Duplexing (FDD) technique, as TDD systems were unsuited to analogue transport. In Europe, the Fixed Service frequency bands have been largely harmonized by CEPT around a paired spectrum configuration allowing Frequency Division Duplex (FDD). It has been argued that TDD should have more prominence in CEPT's thinking on point-to-multipoint systems and that TDD systems can be effectively deployed within paired spectrum mainly exploited by FDD systems. CEPT is clarifying the position on TDD operation in such bands and has drafted guidelines on frequency allocation and deployment. Further work is in hand within CEPT on coexistence issues of unlike FWA systems in certain Fixed Service bands including the coexistence of systems with unlike duplex methods.

ETSI WG-TM4 is responsible for proposing the equipment standards for P-MP fixed wireless access systems and these standards are "coexistence standards" (as opposed to "interoperability standards"). Compliance with coexistence standards does not ensure interoperability of equipments from different suppliers and such standards do not specify a Common Air Interface. Nor even does compliance with the standards alone ensure coexistence with other compliant systems which depends upon the proper management of the spectrum assignments. These standards seek to specify those parameters which allow Regulators to assign frequencies in such a way as to ensure that the effect of interference between neighbouring systems in neighbouring frequencies do not exceed acceptable levels.

Within ETSI, questions have been raised about the coexistence of TDD and FDD systems in the same band. Questions have also been raised about whether additional parameters should be specified in equipment standards which allow TDD techniques or whether the existing P-MP standard are applicable to TDD and FDD systems. It has been suggested that some changes may be required to the current P-MP standards to permit TDD operation and the present document seeks to identify any such changes. Such issues are addressed in the present document but with the goal of determining the extent of any changes needed to TM4 coexistence standards to allow for TDD operation.

1 Scope

The present document discusses the issues on the application of Time Division Duplex (TDD) in the Fixed Service bands for Fixed Wireless Access (FWA) Point-to-Multipoint (P-MP) applications. It examines the advantages and disadvantages of applying TDD techniques to such systems, and it discusses the differences between traditional Frequency Division Duplex (FDD) methods and TDD methods as far as these impact the P-MP standards produced by ETSI WG-TM4.

It reviews some of the related work being undertaken by other ETSI bodies and by CEPT in particular, that concerning the deployment of TDD systems in the same Fixed Service bands as FDD systems are deployed. It gives guidance on any additional parameters definitions, precautions or other changes required to TM4 P-MP standards that might be necessary to clarify the use of TDD techniques.

The terms of reference for the study were:

Taking due consideration of the ongoing studies in WG-TM4 (namely, TM-04069), ERC/WGSE and ERM, in particular of compatibility issues between FDD and TDD systems deployed in the same geographical area using the same frequency band allocated by the CEPT for P-MP fixed systems, produce a Technical Report which:

- describes and gives background on the selection, modification or addition of technical parameters relevant to the usage of TDD arrangements in FWA applications;
- is intended to provide the preliminary draft of generic wording for ENs for P-MP systems using TDD.

Close liaison with WGSE (PT SE-19), TC-ERM (WG ERM/RM) and EP DECT is required.

2 References

For the purposes of this Technical Report (TR) the following references apply:

[1] SRSP-303.4: "Technical Requirements for Fixed Wireless Access Systems Operating in the Band 3 400 - 3 700 MHz".

[2] MII (1998) No.649: "Document of the Ministry of Information Industry, China, Notification on Management Rules of 1,9 GHz Band".

[3] NPRM FCC 98-337: "Amendment of the Commission's Rules with Regard to the 3 650- 3 700 MHz Government Transfer Band".

[4] Doc. 8-1/INFO/1: "UMTS Forum Report on UMTS/IMT-2000 Spectrum Requirements".

[5] ETSI EN 301 055: "Fixed Radio Systems; Point-to-multipoint equipment; Direct Sequence Code Division Multiple Access (DS-CDMA); Point-to-multipoint digital radio systems in frequency bands in the range 1GHz to 3 GHz".

[6] ETSI EN 301 179: "Fixed Radio Systems; Point-to-multipoint equipment; Frequency Hopping Code Division Multiple Access (FH-CDMA); Point-to-multipoint DRRS in the bands within the range 1 GHz to 3 GHz".

[7] ETSI EN 301 080: "Fixed Radio Systems; Point-to-multipoint equipment; Frequency Division Multiple Access (FDMA); Point-to-multipoint digital radio systems in frequency bands in the range 3 GHz to 11 GHz".

[8] ETSI EN 301 213-1: "Fixed Radio Systems; Point-to-multipoint equipment; Point-to-multipoint digital radio systems in frequency bands in the range 24,25 GHz to 29,5 GHz using different access methods; Part 1: Basic parameters".

[9] ETSI EN 301 460-1: "Fixed Radio Systems; Point-to-multipoint equipment; Part 1: Point-to-multipoint digital radio systems below 1 GHz - Common parameters".

[10] ETSI EN 301 253: "Fixed Radio Systems; Point-to-multipoint equipment; Frequency Hopping Code Division Multiple Access (FH-CDMA); Point-to-multipoint digital radio systems in frequency bands in the range 3 GHz to 11 GHz".

[11] ETSI EN 301 021: "Fixed Radio Systems; Point-to-multipoint equipment; Time Division Multiple Access (TDMA); Point-to-multipoint digital radio systems in frequency bands in the range 3 GHz to 11 GHz".

[12] ERC Report 097: "Fixed Wireless Access (FWA) spectrum engineering and frequency management guidelines (qualitative)".

[13] ETSI TR 101 853: "Fixed Radio Systems; Point-to-point and point-to-multipoint equipment; Rules for the
co-existence of point-to-point and point-to-multipoint systems using different access methods in the same frequency band".

[14] ERC Report 99: "The Analysis of the coexistence of two FWA cells in the 24,5 - 26,5 GHz and 27,5 - 29,5 GHz bands".

[15] ETSI TR 101 370: "Digital Enhanced Cordless Telecommunications (DECT); Implementing DECT Fixed Wireless Access (FWA) in an arbitrary spectrum allocation".

[16] CITEL: OEA/Ser.L/XVII.4.3, PCC.III/doc.935/97 Report of PCC III Interference Experts Group on "Incompatibility issues between FWA and PCS systems", September 1997.

[17] CITEL: OEA/Ser.L/XVII.4.3, PCC.III-doc.1077/98 Comments on PCC-III-935/97 by Interference Experts Group, September 1998.

[18] ITU-T [9B/100] draft new Recommendation ITU-T F [9B/100] on frequency band plans for fixed wireless access (FWA) systems in the range 3 400 - 3 800 MHz.

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

fixed wireless access: defined by the ITU as a wireless access application in which the location of the end user terminal and network access point to connect to the end user are fixed. However, throughout the present document the term is restricted to fixed point-to-multipoint radio systems

time division duplex: duplex technique where the traffic in each direction carried on two way telecommunications link is carried on a single carrier radio frequency, in discrete time intervals each dedicated to traffic in one direction

frequency division duplex: duplex technique where the traffic in each direction of a two-way telecommunications link is carried on two different carriers frequencies each dedicated to the traffic in one direction

forward link: path direction from Central Station to Terminal Station, also termed "Down-link"

reverse link: path direction from Terminal Station to Central Station, also termed "Up-link"

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

CEPT	Conférence Européenne des Postes et Télécommunications
CCS	Central Controller Station
CRS	Central Radio Station
CS	Central Station
DECT	Digital Enhanced Cordless Telephone
ETSI	European Telecommunications Standards Institute

FDD	Frequency Division Duplex
FWA	Fixed Wireless Access
ITU	International Telecommunications Union
P-MP	Point-to-MultiPoint
P-P	Point-to-Point
RS	Repeater Station
Rx	Receive, receiver
TDD	Time Division Duplex
TS	Terminal Station
TX	Transmit, Transmitter
UMTS	Universal Mobile Telecommunications System

3a Executive Summary

Clause 4 of the present document reviews the attributes of Time Division Duplex (as opposed to Frequency Division Duplex) in the context of in Fixed Wireless Access systems. Whilst identifying several positive features of TDD, it recognizes that FDD claims benefits in simplifying frequency management.

Clause 5 discusses deployment issues of Fixed Wireless Access systems, which are influenced by typical FWA regulatory regimes, in contrast to point-to-point and Cellular Mobile systems. It is recognized that such differences are important when analysing the interference scenarios.

Clause 6 summarizes work from several sources, addressing inter-system interference between different TDD systems and between TDD and FDD FWA systems. These pieces of work arrive at apparently different conclusions on the impact of the chosen duplex method on the severity of interference. However, such variations stem mainly from the different assumptions on deployment issues. It is concluded that it is not at all easy to make general statements about the impact of duplex method on interference and, in appropriate circumstances, TDD FWA systems can coexist with other TDD systems or with FDD systems in adjacent frequencies without undue interference.

Clause 7 addresses the question of "selection, modification or addition parameters" needed to be specified in Standards for TDD FWA, over those specified in similar standards for FDD FWA systems. It concludes that so long as capacity is defined in terms of gross bit rate and provided that TDD is not explicitly precluded by specifying explicit transmit-receive frequency separation, no further parameters need to be specified in coexistence equipment standards of the kind prepared by ETSI WG TM4.

Clause 8 draws conclusions from the work. It points out that there are non-trivial interference issues with FWA systems operating in adjacent frequencies whatever duplex methods are used. There are additional interference couplings when at least one system used TDD but the significance of these additional couplings relative to the other interference depends upon deployment and other assumptions.

Finally seven specific recommendations are made concerning the way ahead for TDD in TM4 P-MP systems. In particular, it is recommended:

1) not to change equipment standards to trespass into deployment, frequency management or spectrum management matters in respect of specific TDD issues;

2) to avoid, as far as possible, the creation of separate versions of standards for FDD and TDD equipment;

3) to allow standards to remain silent on duplex method, and to make clarifying statements where transmit-receive spacing is mentioned if TDD is also permitted;

4) to confirm specific changes made to EN 301 021 [11] in anticipation of the present document (and to propose similar modifications to any other standards which make explicit reference to duplex method);

5) to adopt specific explanatory wording where it is felt insufficient to remain silent on duplex method;

6) to specify traffic capacity in P-MP standards in terms of "gross bit rate" so as to be equally appropriate to TDD and FDD systems;

7) not to specify additional parameters specifically for TDD variants of TM4 standards.

4 Time Division Duplexing in Fixed Wireless Access Systems

4.1 Fixed Wireless Access Systems

ETSI WG TM4 is developing a substantial number of standards for a class of systems which provide duplex telecommunications services to several terminal stations (TS) from a central radio station (CRS) which in turn is connected to a switch or other telecommunications network node. Separate Standards have been, or are being, developed for various Fixed Services bands in the ranges: below 1 GHz, 1 GHz to 3 GHz, 3 GHz to 11 GHz, and 24 GHz to 28 GHz for various access methods including Time Division Multiple Access, Frequency Division Multiple Access, Direct Sequence - Code Division Multiple Access and Frequency Hopping - Code Division Multiple Access. See, for example, EN 301 055 [5], EN 301 179 [6], EN 301 055 [5], EN 301 080 [7], EN 301 213-1 [8], EN 301 460-1 [9], EN 301 253 [10], EN 301 021 [11].

In general, P-MP FWA systems adhere, in principle, to the typical architecture shown in figure 1.

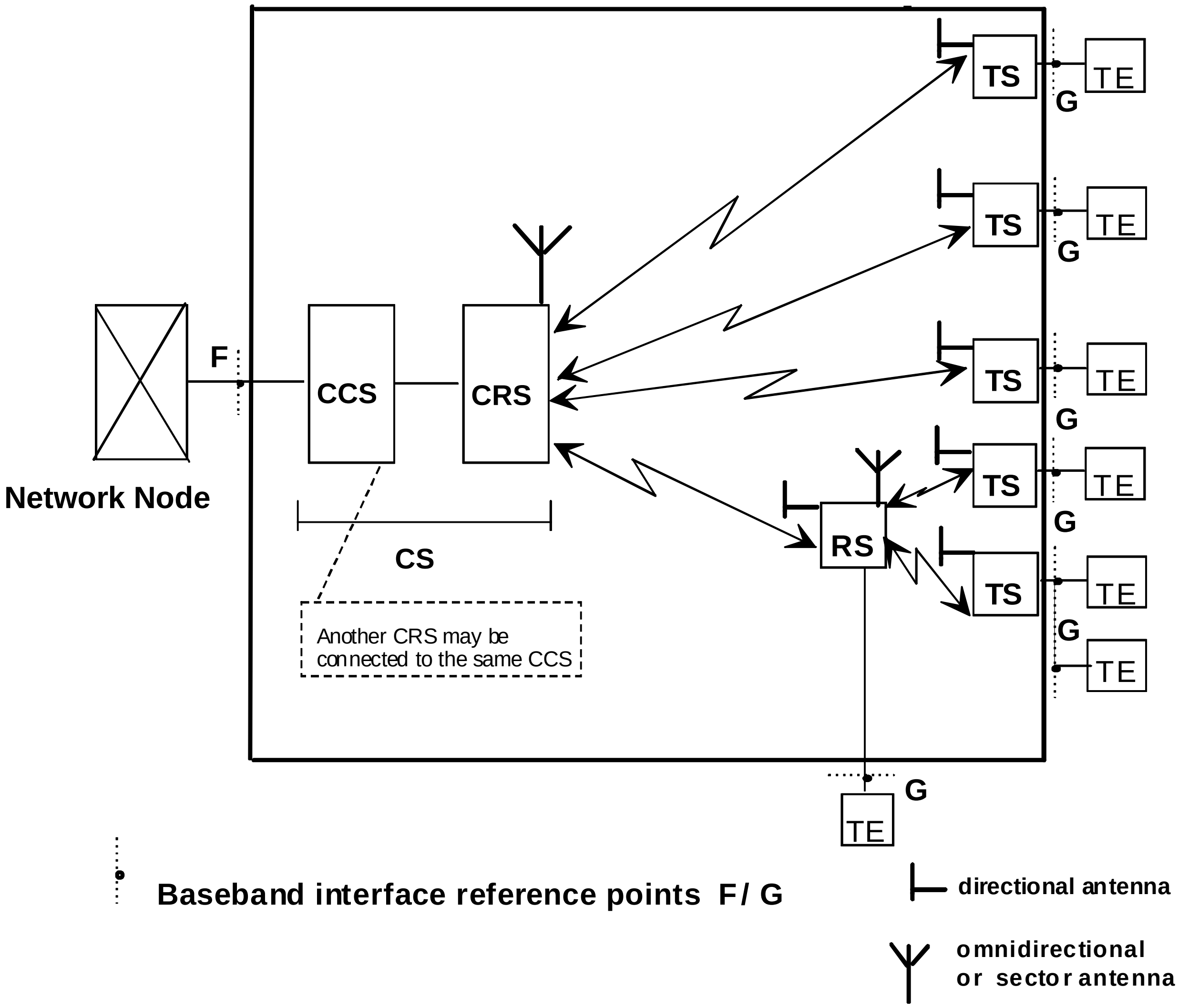

Figure 1: Typical P-MP FWA System Architecture

The main components of these system are:

- **TS**: Terminal stations, which are outstations with subscriber interfaces to serve Terminal Equipment (TE) at interfaces marked G;
- **RS**: Repeater Stations, each of which may serve one or more TS (RSs may also have directly connected TEs);
- **CS**: Central Station, which may be subdivided into two units:
  - the Central Controller Station **(CCS),** also called the exchange unit, which is the interface to the local switch;
  - the Central Radio Station **(CRS),** also called the radio unit, which is the central baseband / radio transceiver equipment. More than one CRS may be controlled by one CCS.

The central station performs the interconnection with the network node carrying out a concentration function by sharing the total number of available channels in the system. The central station is linked by radio paths to each TS either directly or via one or more RS.

4.2 The TDD technique

Time Division Duplex (TDD) is not a new technique but it is one that is often overlooked in fixed service channel plans and by Regulators. It is a technique widely used in two way digital communications systems where the two directions of traffic (up and down) of one channel are carried on the same carrier frequency but in discrete time intervals in a time divided way. These time intervals are often of fixed duration with equal time allocated for up- and down-link directions but annex B indicates that there are several other types of TDD.

Notable examples in European radiocommunications standards employing TDD are DECT and CT2, and one of the UMTS systems (see, for example, reference [4]). Elsewhere, Canada has recently recognized the advantages of allowing TDD systems for FWA P-MP systems (see SRSP 303.4 [1]), and China has dedicated a band exclusively for the use of TDD systems (see MII (1998) No.649 [2]) and the FCC is considering allocating a band for FWA systems without duplex spacing for TDD (see FCC 98-337 [3]). Other references to the use of TDD can be found in UMTS documents such as reference [4] which incidentally, also indicates ways of combining FDD and Time Division Duplex TDD transmissions in adjacent parts of the same bands.

TDD systems use the same frequency for transmission and reception, and the transmitted and received signals are separated in the time-domain. This contrasts with FDD, where each transceiver transmits and receives on two different frequencies, separated by the duplex spacing as defined in various CEPT recommendations.

CEPT recommended channel arrangements for both point-to-point and point-to-multipoint make little explicit reference to duplex method although those arrangements which incorporate paired frequencies clearly are able to accommodate FDD systems but do not necessarily preclude TDD systems. However Regulators often overlook the P-MP possibilities offered by TDD, especially in bands traditionally occupied by FDD systems. TDD was not a practical alternative to FDD for analogue systems, which is one reason why FDD is traditionally used in some bands.

4.3 Attributes of TDD

Some of the positive attributes claimed for TDD, as compared with FDD, are:

1) simplification of some equipment: for example, the diplexor can be replaced by a lower cost solid state transmit/receive switch, and other components required by a second radio channel such as mixer, oscillator, and synthesizer;

2) because both up- and down-links operate at the same radio frequency, and because the instantaneous propagation and fading characteristics in a given environment are determined by radio frequency, and because these characteristics for a fixed system are slow changing compared with the typical transmit burst rate, particularly efficient antenna spatial diversity algorithms and implementations are available as diversity can be implemented at one end of the link only. This opens up possibilities of reducing the complexity of equipment on customer premises by implementing the diversity processes at the shared central stations or allows for totally independent diversity processes to be applied at many Terminal Stations operating with a single Central Station;

3) the similarity of the characteristic of up- and down-links also allows for channel equalization to be allocated on the transmit side thus allowing trade off of TS and CRS complexity. And this also enables the use of adaptive channel equalization combined with transmitter pre-distortion to improve resistance to multi-path propagation;

4) TDD can allow simpler and more effective implementation of adaptive antennas;

5) some suppliers claim that more effective power control can be achieved due to the symmetry of the up- and down-links;

6) TDD, in principle, allows the capacity for up- and down-links to be more flexibly allocated. For FDD systems, the relative capacity of up- and down-links are largely determined by the ratio of spectrum allocated to the two sub-bands. But for TDD, the ratio of time allocated to up- and down-link traffic may be determined dynamically to match instantaneous demands. This is less relevant for telephony with its symmetric characteristic, but with data traffic becomes a significant factor. In particular, TDD provides improved spectral efficiency in packet data applications due to the dynamic character of the transmit/receive traffic ratio;

7) from the Regulators' viewpoint, paired frequency assignments are not required for TDD. However, TDD may operate in non-contiguous frequency assignments or can operate separately in the two paired sub-bands.

However, TDD is a burst transmission system and therefore exhibits some characteristics common to all burst systems:

1) additional latency due to the intrinsic delay cause by the transmission being in discrete bursts;

2) a "guard time" is required between consecutive the transmission intervals of a specific link to allow for the propagation time between the two stations comprising that link. This guard time together with any other unusable time while the transceiver switches between transmit and receive modes may reduce the spectral efficiency slightly. However, using synchronization techniques common in burst transmission systems this time can be used by other users of the system.

The main advantage claimed for FDD systems over TDD systems concerns the interference situation. FDD systems enjoy the benefit of a relatively large "duplex separation" in frequency whereas in TDD systems the radio frequencies for such systems can be much closer. Assuming that two nearby FDD FWA systems have adopted the same convention on allocations of sub-bands to up- and down-links, there will be negligible interference between the CRSs and between TSs, as stations will receive on frequencies which are well separated from nearby like stations transmission. However, FDD provides little benefit over TDD when interference between CRSs of one operator are interfering with TSs of another operator.

In an "all TDD" environment, this CRS-CRS and TS-TS interference modes can be mitigated by synchronization of the two systems CRS and TS transmit bursts so that one CRS is not receiving when another is transmitting. However, such synchronization is not always possible, or may only be possible at the expense of the variable asymmetric property of TDD systems. Furthermore, TDD systems may be operated in the vicinity of FDD systems. The mutual interference between unsynchronized TDD systems and between TDD and FDD systems has been the subject of substantial work within several bodies, and is discussed in clause 6.

5 Deployment issues of P-MP FWA systems

The ability of unlike FWA systems to coexist depends as much on deployment issues as it does on their technological attributes. This clause explores how regulatory and deployment characteristics of FWA systems differ from other wireless communications systems.

5.1 Typical P-MP FWA regulatory regime

It is assumed that the Regulator will wish to delegate the clearance of all stations that comprise a P-MP FWA system to licensed operators. This is because it is supposed that the numbers of stations in a P-MP FWA system is likely to be large and the establishment of stations on customer premises will be carried out at short notice. New Central Stations will often be deployed to relieve pressure on existing stations as the customer base builds. Where an operator has exclusive licence for the frequencies in a particular area he can manage the deployment and utilize the spectrum in such a way as to maximize the efficiency with which the assigned spectrum is used.

It is likely that the Regulator will wish to promote competition for the provision of services via P-MP FWA systems by licensing multiple operators in neighbouring blocks of frequency in any region. The Regulator, in consultation with the licensed operators, must establish the appropriate regime to ensure that operators licensed to use neighbouring allocations of spectrum do not cause mutual interference. There are many ways of doing this including the definition of guard bands between the frequency blocks allocated to operators in the same region. Ideally, these Guard Bands should be calculated on the basis of the transmission spectrum masks of the two systems and the receiver performance of the two systems. The ETSI TM4 standards give limiting values of both transmitter masks and receiver performance for the various types of system.

In the case of two licensed P-MP FWA systems A and B in adjacent or near adjacent frequency allocations, the Regulator needs to consider the potential interference which might occur:

- between the Central Stations of System A those of System B;
- between the Terminal Station of System A and those of System B;
- between the Terminal Stations of System A and the Central Stations of System B and vice versa.

NOTE: The Regulator does not need to consider interference between stations of the same system, as this is assumed to be delegated to the operators. It is not considered necessary to consider separately the potential interference cause by Repeater Stations as all potential interference situations involving such stations are address by the above three considerations.

In addition to controlling mutual interference between P-MP FWA systems the regulator has to consider the mutual interference between P-MP FWA systems and other fixed services, particularly P-P links in the same band. When P-MP FWA systems are deployed in the same area and near adjacent frequencies to P-P systems the Regulator needs to consider the potential interference between both ends of the point P-P link and both Central Stations and Terminal Stations of the P-MP system.

5.2 How FWA differs from P-P and Cellular Mobile systems

Conventional wisdom on the use of traditional FDD techniques to address coexistence issues stems largely from experience of fixed Point-to-Point (P-P) systems and cellular mobile systems. We should be wary of assuming that FDD addresses the coexistence issue of P-MP FWA systems, just because it has been applied in these other arenas. There are the significant differences not only in the regulatory regime but also in the different physical attributes of the of P-MP FWA systems.

The typical regulatory regime described in clause 5.1 differs substantially from the typical regime for P-P systems where every station is subject to a site clearance process, during which the interference potential between a proposed new station and all other existing (licensed) stations in the vicinity is assessed. For cellular mobile, the regulatory regime may also involve site clearance of the fixed base stations on an individual basis.

P-P systems, typically where several independent stations not only share a mast but have very high gain antennas directed at another set of stations also sharing a mast. This is a very different deployment scenario from that considered with P-MP FWA systems.

Cellular mobile systems, cell sites of different operators sharing high points is commonplace and as common technology is used common ranges are expected and so different operators cells will be well aligned. Furthermore, terminal stations will have relatively low power emissions and lower gain (non-directional) antennas.

P-MP deployment appears at first glance to share much in common with deployments cellular mobile systems. However, on further examination such systems can depart significantly from cellular mobile paradigm. Firstly for P-MP systems, the link is more symmetrical with similar power and similar gain antennas at both ends of the link. Secondly the "cell structures" of two operators in the same area will not coincide, leading to the "overlapping cell problem" which is discussed later. But many other differences have been noted which may significantly affect the direct transfer of conclusions from the cellular domain to the FWA P-MP domain. Examples of these differences include:

- FWA performance expectations are set by wire-line performance which, in some respects, are more demanding than cellular in terms of data rates, grade of service, availability, transparency and bandwidth;
- FWA systems are required to provide the required performance for every subscriber in the area and not as an average over the area. A single subscriber cannot move to areas where performance is better to enjoy the average;
- cellular mobile systems are required to support mobility and contiguous coverage;
- propagation conditions for FWA are better, as the installation is typically on rooftop level, with Line of Sight conditions, directional antennas and the fact that antenna location can be optimized;
- traffic load is supported per sector in FWA and not per area as for cellular mobile;
- for a FWA system roll-out can be made gradually according to the demand. Unlike cellular mobile systems where wide coverage system has to be deployed for the first customer can have a useful service;
- the cellular subscriber pays more for mobility. The charges from a FWA subscriber are comparable with the wire-line rates;
- the regulatory regime is different. cellular mobile enjoys dedicated bands, while FWA has to share with other services;
- FWA has to be more flexible in the network, user and air interfaces.

Because of these several differences between FWA and cellular mobile or point-to-point one must be wary of applying experiences and analyses undertaken in the context of either cellular mobile or point-to-point to the relatively less researched FWA application. For example, criteria for analysis for a typical cellular mobile system might be 95 % availability for randomly located users in the nominal coverage area, but for FWA systems require availability figures of 99,99 % or better for the particular customers in known locations. This difference not only affects the parameters used in the analysis but can also affect the whole methodology used.

Not surprisingly, the issue of coexistence of unlike FWA systems (including systems employing different duplex methods) is being studied in many bodies. It is recognized that ensuring mutual coexistence of like or unlike system through the provision of adequate guard bands, or minimum separation distances coupled with other mitigation techniques is a complex issue, which is attracting attention in ITU, IEEE, CEPT and more than one of ETSI's technical bodies. These bodies are considering many factors which affect coexistence only one of which is the duplex method.

Beyond Europe, ITU Joint Rapporteurs' Group 8A/9B are drafting recommendations for TDD systems operating in the bands that are traditionally occupied by FDD systems (see for example Draft Recommendation ITU-T [9B/100] [18], which recognizes that TDD systems could be accommodated in paired frequency bands, provided that coexistence criteria can be met). Also, IEEE 802.16 is in the process of drafting standards for broadband wireless access systems for either TDD or FDD techniques.

However, the present document is focused on current work in Europe.

CEPT project team SE19 has been addressing the implication of the use of TDD in its *New Technologies* sub-group. This has produced an ERC Report offering a set of guidelines for administrations and operators related to the use of TDD in bands which can also accommodate FDD systems [12]. These guidelines are still subject to national consultation Those which are directly applicable to TDD appear in annex D to the present document.

The same CEPT project team SE19 has been working on a another ERC Report addressing the coexistence of FWA systems in the 24 GHz to 29 GHz bands. This has generated a lively debate on fundamental issues such as what the appropriate metric for coexistence is, whether we should be considering probabilistic measures or worst case, and what geometric model should be used. Furthermore, there are a range of views on whether administrations should specify pre-determined fixed co-ordination distance and guard bands between operators licensed in neighbouring geographic areas or with neighbouring frequency assignments. The contrary view is also proposed that such issues can only economically be resolved by the neighbouring operators having full knowledge of their systems' characteristics duplex method is only one such characteristic, and not considered to be the dominant one. Although this work is targeted at the 24 GHz to 29 GHz band, the dilemmas it is exposing are not frequency dependent show the difficulty experienced by any such study.

Within ETSI, ERM has undertaken some work at the policy level encouraging the use of TDD where appropriate but has relied on other parts of ETSI and CEPT to address the technical matters. EP-BRAN had held discussions on the use of different duplex techniques but is focussing on an FDD approach with an alternative TDD approach. It has asked ETSI TM4 to take care of coexistence issues however.

ETSI TM4 has drafted a technical report, TR 101 853 [13], which investigates the compatibility of different ETSI TM4 Point-to-Multipoint standards in adjacent frequency allocations in the same area and the same frequency bands in adjacent areas, which forms a basis for investigating the coexistence/interference issues of FDD and TDD systems. Although using a different methodology, this work shows a good correlation with some of the SE19 work at 24 GHz to 29 GHz.

Furthermore, several ETSI members have made contributions to this general area and where relevant these too are noted, if not published elsewhere are reflected in the present document. It is not the intention of the present document to replicate or anticipate the work of these other organization, but merely to note that the matter is receiving attention as a spectrum engineering issue. In the next clause we shall consider the interference scenarios discussed above in the context of TDD systems in the vicinity of FDD systems.

6 The interference scenarios

In this clause we report on a number of pieces of independent work investigating the interference scenarios between two Fixed Service systems operating in the same area with adjacent assignments within the same Fixed Service band. In particular, the effects of unlike combination of the chosen duplex methods are being investigated.

6.1 Coexistence issues for FDD and TDD P-MP systems

6.1.1 Introduction

This clause draws upon other work in TM4 on coexistence of different TM4 standards which are now published as TR 101 853 [13]. That TR develops a quantitative analysis of interference scenarios this clause and uses a similar methodology to that developed in that Technical Report. This clause analyses the main coexistence issues related to the deployment of PMP systems based on FDD and TDD duplex techniques. In particular, it points out the similarities and differences of FDD and TDD considering all the possible deployment scenarios and frequency arrangements.

In this clause are presented a series of qualitative considerations regarding the degree of coexistence, the required co-ordination between operator and the residual risk of interference when two PMP systems are deployed on the same area and in the same frequency band (channel adjacency). In particular, the differences between two FDD/FDD, FDD/TDD and TDD/TDD PMP systems are pointed out.

6.1.2 PMP interference classes

When considering the deployment of PMP systems there are four possible classes of interference to be considered. The distinction is based on different pairs of source (interfering system) and destination of interference (victim system) as follows:

- *Class A1*: the interference source is the CRS of the interfering system and the destination of the interference is the TS of the victim system. This class occurs when the interfering system down-link is adjacent to useful system down-link *(down/down adjacency)*;
- *Class A2*: the interference source is the TS of the interfering system and the destination of the interference is the CRS of the victim system. This class occurs when the interfering system up-link is adjacent to useful system up-link *(up/up adjacency)*;
- *Class A3*: the interference source is the CRS of the interfering system and the destination of the interference is the CRS of the victim system. This class occurs when the interfering system down-link is adjacent to useful system up-link *(down/up adjacency)*;
- *Class A4*: the interference source is the TS of the interfering system and the destination of the interference is the TS of the victim system. This class occurs when the interfering system up-link is adjacent to useful system down-link *(up/down adjacency)*.

Given these definitions the four classes are quite different in terms of requests to mitigate interference, impairments on CRS deployment and required co-ordination between operators. These facts can be easily proved considering the interference methodologies described in TR 101 853 [13] or in other studies such as the ones reported as annexes to the present report.

In the following clauses three possible combinations of PMP systems with different duplex techniques are considered in order to exploit the interference constraints under different possible channel arrangements. The analysis is carried out considering the type and the number of interference classes that must be taken into account in different scenarios. The basic scenarios assumption is the subdivision of the frequency band in two sub-bands, as foreseen in ERC recommendations to allow the allocation of FDD systems (duplex spacing).

6.1.3 FDD/FDD scenarios

When considering two FDD systems operating on adjacent (or near, if guard bands are foreseen) channels there are only two possible channel arrangements as depicted in figure 2. In case 1, both systems use the same sub-band for down-link and, consequently, also for up-link while in case 2 they use the opposite sub-band. In both cases only two types of interference classes have to be considered, in particular:

- class A.1 and A.2 for case 1;
- class A.3 and A.4 for case 2.

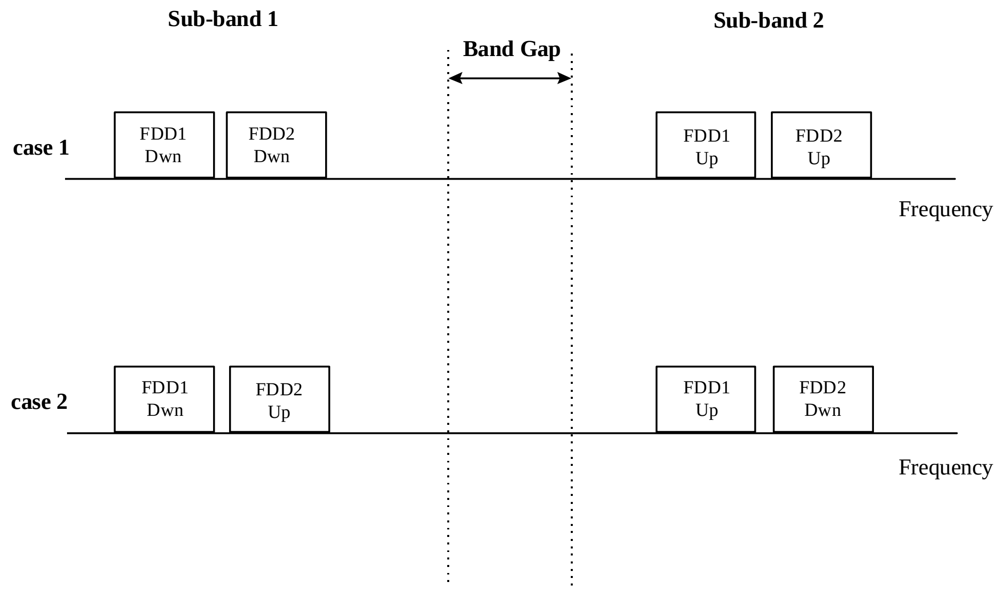

Figure 2: Different channel arrangements for two FDD PMP systems

When considering case 1, the interference is always from a CRS to a TS and vice versa. These kinds of interference lead to the "overlapping cell problem" (that is the near-far effect on interfering and useful link) when the two CRS are in different sites. Thus, the following considerations hold:

1) the site sharing minimizes the interference problem since the overlapping cell problem is not present. In this situation the two systems may coexist on adjacent channel without any guard band. The site sharing could be imposed nationally, or locally in special situations such as in a historical city centre in order to minimize the architectural impact;

2) the near-site placing (CRSs within few hundreds meters) also allows a good degree of coexistence because it is an approximation of the site sharing situation. This condition may not be so unusual since we are considering systems operating in the same frequency range (similar coverage capacity) and in the same area (same coverage impairments due to obstacles or hills);

3) if the two CRSs are placed in different sites the overlapping cell problem must be faced introducing a guard band. In order to avoid wasting of spectrum only limited guard bands (1 channel for example) could be introduced, thus a restricted area around each CRSs still suffer (and produce) interference. Thus, a co-ordination between the operators is necessary in order to:

   - zeroing this area with a co-ordinated frequency planning, the use of sectored antennas and polarization de-coupling (high co-ordination requested);

   - avoid the installation of TS in this restricted area (low co-ordination requested).

When considering case 2, the interference is between CRSs and between TSs. This kind of interference usually requires a minimum distance between two CRSs and any TSs in order to avoid interference. Thus, the following considerations hold:

1) no site sharing is possible;

2) no near-site placing is admitted because A3 requires a minimum distance between CRSs. To reduce this distance as for case 1 (few hundreds meters) a guard band is required. This guard band is usually greater (2 channels) than those necessary in case 1;

3) even with this larger guard band the residual risk of interference between TSs cannot be neglected because of the high number of sources and victims;

4) there is not a well defined residual area with risk of interference (as in case 1) but all the cell area is potentially afflicted by interference between TSs: for example everywhere two TSs of the two operators must be installed above the same rooftop.

6.1.4 FDD/TDD scenarios

When considering an FDD and a TDD system operating on adjacent (or near, if guard bands are foreseen) channels there are three possible channel arrangement as depicted in figure 3. For simplicity the FDD system up/down arrangement is given in that particular sub-bands but it is the same if the arrangement is the opposite.

In case 1 the TDD system is allocated only near the FDD down-link channel while the paired sub-channel is free, or used by a third system. In case 2 the TDD system is allocated only near the FDD up-link channel while the paired sub-channel is free, or used by a third system. Finally, in case 3 the TDD system has two paired channels near the FDD system. All these channel arrangement could be expected since no ERC recommendation is now giving any guideline on how to allocate FDD and TDD PMP systems. In these scenarios the classes of interference that must be taken into account are:

- class A.1, A.3 and A.4 for case 1;
- class A.2, A.3 and A.4 for case 2;
- class A.1, A.2, A.3 and A.4 for case 3.

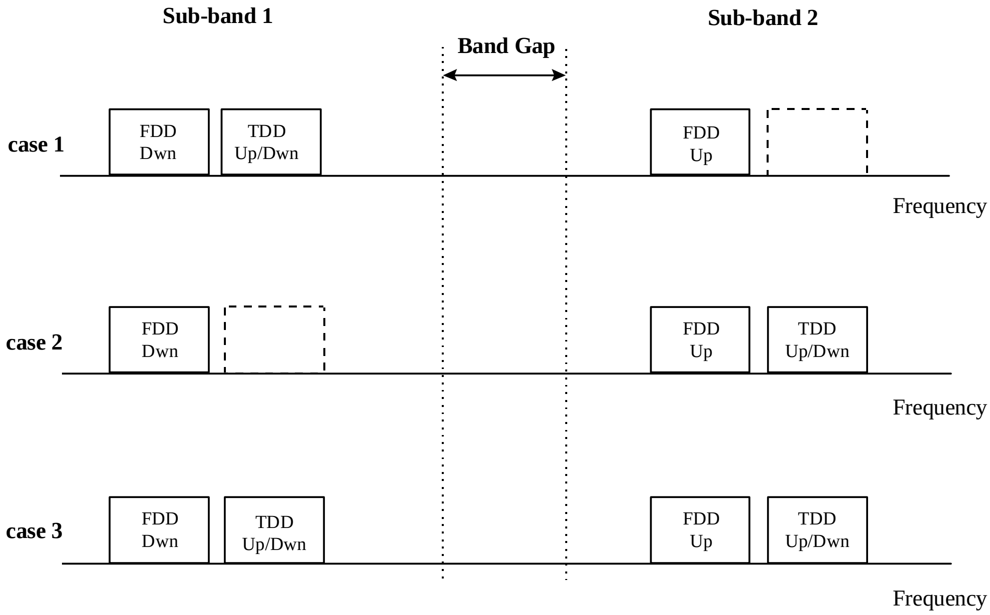

Figure 3: Different channel arrangements for a FDD system and a TDD PMP system

In all three cases depicted in figure 3 there are always classes A.3 and A.4 combined with A.1 or A.2 or both A.1 and A.2. Therefore, all the impairments described for both cases of FDD/FDD adjacency must be taken into account. In particular the following considerations hold.

No site sharing is possible:

1) no near-site placing is admitted because A.3 requires a minimum distance between CRSs. To reduce this distance as for case 1 (few hundreds meters) a (2 channels) guard band is required;

2) even with this larger guard band the residual risk of interference (A.4) between TSs cannot be neglected because of the high number of sources and victims;

3) there is not a well defined residual area with risk of interference (as in case 1 for FDD/FDD) but all the cell area is potentially afflicted by interference between TSs: for example everywhere two TSs of the two operators must be installed above the same rooftop;

4) there is also a restricted area around CRSs with risk of interference (classes A.1 or A.2 or both) is always present and it requires a co-ordination between operators (as in case 1 for FDD/FDD);

5) co-ordination between operators in order to deploy their network respecting minimum distances between CRSs.

6.1.5 TDD/TDD scenario

When considering two TDD systems operating on adjacent (or near, if guard bands are foreseen) channels there is only one possible channel arrangement as depicted in figure 4: the two channels are adjacent or near. The only difference that could be taken into account is whether the systems are synchronous in transmission (CRSs transmit at the same time and TSs transmit at the same time) or not. The interference classes are:

- class A.1 and A.2 for synchronous systems;
- class A.1, A.2, A.3 and A.4 for asynchronous systems.

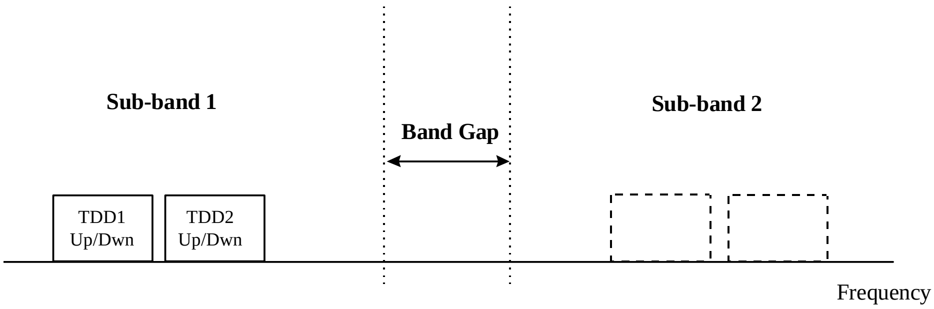

Figure 4: Channel arrangement for two TDD PMP systems

In case of synchronous systems the situation is the same as case 1 of FDD/FDD scenario (site sharing allowed, near site placing possible and overlapping cell problem). But synchronization is not a simple issue to obtain between equipment of different operators.

In case of asynchronous systems the situation is the same as for FDD/TDD scenario (case 3) and the same considerations apply.

6.1.6 Conclusion of this coexistence work of TM4

From the coexistence and co-ordination point of view FDD/FDD channel arrangements presents some advantages with respect FDD/TDD or TDD/TDD channel arrangements. These advantages do not depend depending on actual scenario, although their significance might do.

In particular, if one sub-band is dedicated for CRS transmission (and the other for TS transmission) of all the FDD systems the following advantages can be seen:

- site (or near) site sharing is possible together with a minimum guard band (or even without any guard band in some cases);
- small residual area of interference well defined around the CRS of the other operator;
- little co-ordination between operators.

If no sub-bands is assigned for a particular transmission (CRS/TS) it is possible to have the previous situation or the one described in case 2 for FDD/FDD. Thus, all the interference classes (A.1, A.2, A.3 and A.4) must be considered and the situation is similar to asynchronous TDD/TDD scenario and no advantages can be seen. Due to these considerations it could be useful to define a sub-band dedicated to each transmission (CRS/TS) for FDD systems. CEPT is considering this issue in the ERC Report on Fixed Wireless Access (FWA) spectrum engineering and frequency management guidelines [12].

On the other hand, when deploying a TDD system adjacent to a FDD or another TDD system the following additional impairments, with respect the best FDD/FDD scenario, must be taken into account:

- higher (1 or 2 channel) guard band in order to reduce (few hundred meters or less) the required distance between CRSs in order to minimize co-ordination between operators;
- a residual potential area of interference is spread all over the cell area due to interference between TSs.

6.2 Interference scenarios between P-MP and P-P systems

Where the P-P transmission system shares the same band as the P-MP system, there is the potential for interference between the two. P-P transmission systems are normally configured with high and low transmission frequencies alternating at sites along the transmission path. P-MP systems are defined with the CRS and TS in a network using the fixed configuration of CRS (normally low) and TS (normally high) and are not reversible. With FDD access systems, alternating nodes will be subject to potential interference between the two, whereas for TDD, all nodes are affected.

The interference is reciprocal, although interference into the transmission path must be considered the more damaging for the operation of the network. However, since the transmission network is generally operated at a higher power level to guarantee availability, interference into the P-MP system is more likely.

6.2.1 One view of co-ordination of FDD or TDD systems

The interference scenarios in P-MP and P-P systems when either FDD or TDD are used are based on an hypothesis of geographical deployment corresponding to several networks operated in the frequency band and belonging to different operators. For the most general case, the links are randomly distributed over a given area and their lengths are homogeneous for a given frequency band. A certain number of transmitters will contribute to the interference level into the victim receiver: the main lobe or the side lobes of the antenna aims the receiver antenna, the operating channel coincides partly or fully with the receive one or is adjacent to it.

For FDD operation, contributions to interference at input of any receiver shall be aggregated. For TDD operation, the number of interfering transmitters is greater, as the same operating channel is used for go and return (down-link and up-link) transmission. From a statistical point of view, the number of interferers should be twice that of the FDD case, but with transmission on1y during 50 % of the time for each of them, the overall contribution should be equivalent.

Current deployments of networks are not made randomly: the future users/subscribers are concentrated in certain areas and the networks are implemented to fit their needs. P-MP networks dedicated to Fixed Wireless Access (FWA) are arranged in a mesh of cells. Frequencies used by the Central Radio Station of one cell are co-ordinated with the frequencies of the neighbouring cells. Terminal/User stations are placed within cells, step by step according to the demand, at the nearest site of the customer's premises with adequate radio clearance. When several operators are deploying networks in the same area, they must commit to either observe the engineering rules imposed by the regulator (such as, for example, co-sitting of the CRSs), or to co-ordinate with other networks.

To examine how such a co-ordination could be carried out in an analytical way, two simplified P-MP networks could be considered, each composed of one Central Radio Station (CRS) and of one Terminal Station (TS) The two CRS-TS links having similar lengths (same frequency band), the two main parameters to consider are the distance $\boldsymbol{d}$ between the two Central Radio Stations and the angle $\boldsymbol{\theta}$ between the two links. The calculation of the contribution of interference of one system into the other can be easily extrapolating to more complex networks.

6.2.2 Another view of the possible interference modes

Annex A, which is based on an unpublished paper submitted to SE19, considers the various interference situations between two independently deployed P-MP FWA systems operating in adjacent (or near adjacent) parts of the same fixed service band. It is assumed that the band plan has paired frequencies and so can accommodate either FDD or TDD systems or both.

Eight different station types are considered and the interference between all 64 interferer/victim combinations considered The eight station types considered are:

Table 1: Types of stations considered

P-P	FDD	Station transmitting in Upper sub-band
		Station transmitting in Lower sub-band
P-MP	FDD (see note)	Station (CRS or TS) transmitting in Upper sub band
		Station (CRS or TS) transmitting in Lower sub-band
	TDD	CRS Transmitting/Receiving in Upper sub band
		TS Transmitting/Receiving in Upper sub band
		CRS Transmitting/Receiving in Lower sub band
		TS Transmitting/Receiving in Lower sub band

NOTE: In the case of FDD P-MP FWA system, for completeness the annex considers both central and terminal stations transmitting in both upper and lower sub-bands. In practice it is certain that the Regulator will require all operators the same designated sub-band for CRS transmit and the other sub-band for TS transmit. In this case, for FDD systems, we can ignore the interference scenarios between say a System A's CRS transmitting in the upper sub-band and System B's TS also transmitting in the upper sub-band.

The conclusions of this annex are:

- none of the 64 situations considered is completely free from interference except for two TDD systems implemented in different sub-bands or two TDD systems in the same sub-band but which are synchronized;
- not all interference situations are equally severe and some present better prospects of mitigation;
- FDD P-MP systems present no clear advantage over TDD P-MP systems when considering the coexistence with P-P links, as half of the P-P sites will transmit in the same band as the Central Radio Station of the P-MP system receives preventing sharing;
- whereas FDD equipment avoids mutual interference between close CRS stations of the different systems or between close TS stations of different systems, they are exposed to interference between a TS of one system and the CRS of another system. This situation is likely to occur with P-MP systems, for example, when two operators deploy systems in a urban environment choosing sites for their CRS stations independently. In this way it is probable that some TSs from one system will be close to CRSs of the other. This scenario has been called elsewhere the "overlapping cell problem" and has been addressed in TR 101 370 [15], a substantial part of which is reproduced in clause 6.3.

6.3 The interference problem in adjacent frequency bands

This clause, and the associated annex F, was drafted by an expert group and was based on material derived from PCS Interference Experts Group on incompatibility issues between FWA and PCS systems.

When two systems are allocated in adjacent frequency bands it is probable that devices using the closer carriers to the common band edge might produce and/or receive higher interference than others.

The traditional way to avoid this potential problem has been to provide a sufficient guard-band between these two systems, increasing the frequency gap between them. It reduces the interfering energy received in the victim receiver by both, decreasing the out-of-band emission of the potential interfering transmitter, and increasing the positive effect of the interference rejection filters at the victim receiver.

Since these guard-bands are not desired (because they reduce the effective available frequency band, and hence, system capacity), modern radio technologies try to improve both the out-of-band emission limits and the interfering rejection filter quality, regardless of other additional interference-avoiding mechanisms.

Note that, as described above, the interference problem does not depend intrinsically on the duplex division technique, but rather on the radio performances of both interfering transmitter and victim receiver. Why should a system using TDD be more problematic than one using FDD? This question is investigated in annex F.

The conclusions drawn in that annex are:

- TDD/FDD mixed scenarios do not present worse interference behaviour than FDD/FDD mixed scenarios, neither in the number of interference paths nor qualitatively talking (potential damage to victim system);
- both scenarios present the same possible interference paths;
- in FDD/TDD scenarios there is always some FDD device that is completely free of interference from TDD systems. In FDD/FDD scenarios all devices may suffer interference;
- in FDD/TDD scenarios there is always some FDD device that does not generate any kind of interference to TDD system. In FDD/FDD scenarios all devices may produce interference;
- the possible interference paths (base-to-terminal, terminal-to-terminal, terminal-to-base and base-to-base) do not present intrinsically any worse case compared to each other.

As a consequence, the influence of the choice of duplex division technique on the possible interference damage between two adjacent radio systems is negligible, and it seems that FDD/TDD scenarios present some better interference behaviour than FDD/FDD scenarios.

6.4 The overlapping cell problem

This clause addresses a specific interference scenario originally developed by EP-DECT in TR 101 370 [15] and has been further developed and adapted to be applied FWA systems in general. The analysis is reported in annex E. This concerns the so-called "overlapping cell problem". annex E considers the potential interference to two CRS receivers of two different operators P-MP systems operating in different parts of the same band. It is assumed that the radii and locations of the CRS stations of different operators differ and so their coverage cells overlap.

Subject to a number of deployment assumptions explained in annex E. Four observations are made:

- the distance between the closest CRSs is fixed, but the distance to the nearest interfering TSs, having the same EIRP as the CRS, is normally much closer. Thus the highest interference to one operator's CRS levels will come from TSs (FDD or TDD) of the other operator and not from the CRS of the other base even if that is operating on TDD;
- when one system is FDD and the other is TDD, the interference to one operator's FDD CRS from the other (TDD) connection comes half the time from the TDD TS and half the time from the TDD CRS. This compares with the where both systems are FDD where the interference to one operators CRS comes all the time from the other operators TSs;
- thus, on average, (depending on how close the actual TSs of one operator are to the CRS of the other), the interference potential, or the probability of interference, will be about the same between two FDD systems as between an FDD and a TDD system, supposing similar attenuation of the modulation spectrum mask in the adjacent sub-bands;
- it is concluded that, it is not critical if TDD or FDD is used, but it is important to have as good as possible attenuation of the modulation spectrum mask in the adjacent sub-bands. Thus there is no reason to discourage the use of TDD systems in neighbouring parts of the bands occupied by FDD.

6.5 A view of FDD/FDD versus FDD/TDD scenarios

This clause is a further *ab initio* view of the differences and similarities of FDD - FDD and FDD - TDD interference scenarios submitted by an expert group.

It is often asserted that the interference scenarios of two FDD systems operating in the same area is significantly less severe and complex to manage than two TDD or mixed TDD/FDD systems operating in the same area. This is not necessarily the case as discussed below.

It is considered very unlikely that different Fixed Wireless Access operators will choose to have all of their CRS located on the same shared sites nor is it a realistic constraint to place upon them to do so. Therefore, we must consider the general scenario where two operators, assigned (near) adjacent frequencies choose to position their respective CRSs at nearby but separate locations.

Consider firstly two FDD systems. Whereas the mutual interference between the nearby CRSs and between nearby TSs of the different operators would be mitigated by the frequency separation of the duplex spacing, there are other important interference considerations. We consider specifically the mutual interference CRSs of one operator and the TSs of the other. Typically, for the deployment of such adjacent band FDD systems, it will be necessary to define a maximum distance ***d*** (perhaps a few tens of metres) from the CRS of one operator within which it is acceptable not to be able to locate a potential subscriber (TS) of the other operator.

Based on the agreed value of ***d*** and the actual out of band emissions of one transceiver and the actual out-of band filter performance of the other transceiver, we can determine the appropriate minimum frequency separation of the carriers assigned to the two operators, using techniques such as those being developed by CEPT SE19 (and other bodies).

Consider now the case where one of the two operators had opted to use a TDD based system, with the same actual transceiver out-of-band emissions and filter performance as for the FDD system above. If an additional deployment constraint that no CRS shall be deployed within the same distance ***d*** of a CRS of the other operator in an adjacent bands (this is based on the fact that CRS typically has similar or less EIRP transmit power than a TS).

For simplicity at this stage we assumes that isolation between stations is achieved only by distance although, in practice, isolation may be achieved in other ways, especially in the case where a common CRS site is chosen by the two operators.

Therefore, the same minimum frequency separation as required between carriers of two FDD adjacent band systems is typically required also if one or both of the systems are TDD systems with similar specifications (this conclusion is tied to the characteristics of P-MP systems, terminal EIRP similar or higher than for the base station in combination with LOS deployment, and does not apply for mobile systems).

It is argued, therefore that, the requirements of TM4 equipment standards to cover both FDD and TDD implementations do not require different parameters for FDD and TDD from a coexistence aspect. Only two parameters related to intrinsic properties of TDD seem to need to be considered. One is to state that any reference to the transmit/receive frequency separation shall be disregarded for TDD equipment. The other is that the receiver sensitivity shall be related to gross bit rate.

6.6 Interference scenarios and results

Using TDD systems alongside FDD systems introduces two additional coupling mechanisms: CRS-CRS and TS-TS. Each coupling has a different significance depending on whether the systems operate in adjacent channels or co-channel. ERC Report 99 [14] contains some analysis of the level of interference for both couplings in both cases. Whilst these results are computed for the 24 GHz to 29 GHz bands, the methodology can be generalized to other bands, with appropriate adjustment to parameter values including those relevant to propagation. The analysis is based on the following general assumptions:

- it is assumed that the TDD systems are unsynchronized;
- the systems follow ETSI standards in the EN 301 213-1 [8] series for P-MP equipment;
- the use of up-link proportional Automatic Transmit Power Control (ATPC) is assumed;
- for adjacent channel operation, interference is avoided by allowing a guard band between closest carriers of different operators, possibly combined with a minimum spacing between systems;
- for co-channel operation, interference is avoided by imposing a minimum system spacing or co-ordination distance between systems for co-channel operation;
- the guard band and co-ordination distances are chosen so that either the absolute level of interference is at least 21 dB below the victim system's threshold; or the probability of the interference exceeding that level is typically less than 1 %. Which criterion is employed depends on whether or not the interference is a stochastic function of system deployment (e.g. depends on random TS placing in unfavourable areas).

The critical issue is whether the level of interference generated by these TDD-specific coupling mechanisms dominates the other coupling mechanisms that are common with FDD, and therefore impose tighter requirements.

6.6.1 CRS-CRS interference

6.6.1.1 Adjacent channel

Table 2 gives the minimum spacing between facing co-polar CRSs for quaternary modulation systems conforming to EN 301 213-1 [8] to achieve a 21 dB threshold/interference ratio assuming a 28 MHz guard band between the systems, typical for systems in the 24,5 GHz to 29,5 GHz band, assuming operation in rain zone K.

Table 2: Minimum distance between CRSs for various system bandwidths

Victim channel bandwidth MHz	Interferer channel bandwidth MHz	Minimum distance km
3,5	3,5	0,016
	7	0,018
	14	0,018
	28	0,412
7	7	0,016
	14	0,032
	28	0,260
14	14	0,041
	28	0,206
28	28	0,184

The above guard band would also be applicable to any system combination achieving a net filter discrimination (NFD) of at least 54 dB. Clearly quite small CRS spacings are achievable. At lower frequencies, the required spacing will increase according to the inverse of the square root of frequency. Given that the above minimum spacings are observed then the guard band requirement for TDD is no greater than for FDD.

If the guard band is increased to 56 MHz (or the equivalent for narrower channels, to obtain an NFD around 73 dB) then completely uncoordinated deployment will be possible.

6.6.1.2 Co-channel

In the co-channel FDD case the co-ordination distance is limited by uplink interference (i.e. a co-channel TS in a distant cell interfering with the victim CRS). The interference situation with a distant co-channel CRS is very similar, except for three distinct differences:

- the interfering CRS power will be higher than the TS power because downlink ATPC cannot be assumed;
- the interfering CRS antenna gain will be lower than the TS antenna gain;
- the interfering CRS will be closer to the victim CRS by up to one cell diameter.

In practice, the first and second factors generally annul each-other as the uplink ATPC setting margin will tend to be set to approximately the difference between the antenna gains. Thus the co-channel CRS-CRS co-ordination distance will in principle need to be slightly higher than the TS-CRS co-ordination distance. However, it is quite likely that other mitigation factors, such as terrain and clutter screening, will anyway reduce the required co-ordination distance.

6.6.2 TS - TS interference

ERC Report 99 [14] contains results of Monte-Carlo analyses of TS-TS interference. In general, the following conclusions may be drawn.

6.6.2.1 Same area, adjacent frequency

For small values of cell overlap, where any pair of interfering TSs must be very close and the interfering TS must be transmitting at maximum power, low values of C/I can arise; made worse by rain fading. However the probability of any interference conflict arising is extremely low (of the order of 0,02 % for the scenario investigated). At the most one channel guard band will be needed; and even adjacent channel operation may be possible depending on the operators' judgement of the acceptability of the probability level.

The maximum probability of interference arises when the TSs are served by co-sited CRSs. In this case however the C/I ratio distribution is such that virtually no terminals will experience a C/I below threshold even with adjacent channel operation. Rain fading will either improve the C/I or leave it unaffected.

6.6.2.2 Same frequency, adjacent area

Over the range of cell spacings of interest from the viewpoint of other interference mechanisms (principally uplink co-channel), the C/I ratio will be in excess of 50 dB for a cell boundary separation of 21 km, and the probability of interference will be ≈ 0,5 %.

Rain fading will either improve the C/I or leave it unaffected.

From these studies it can be concluded that TS-TS interference does not impose more severe deployment constraints than other interference mechanisms.

6.7 Mitigation of interference

The use of FDD-only systems, (like synchronized TDD or TDD systems one in upper and one in lower sub-band in paired spectrum) provides a useful strategy for managing CRS to CRS interference, whereas FDD does little to address the "overlapping cell issue". In this clause we shall show that there are practical ways to mitigate against the CRS to CRS interference even if it is present due to TDD - FDD system operating in adjacent parts of the same band. However, such mitigation techniques do not lend themselves so well to TS-CRS interference.

There are many standard mitigation techniques which are relevant whichever combination of systems' duplex methods are considered, such as use of sectorized antenna at the CRS, power control at the TS, forward error correction and (selective) retransmission of lost information. Annex C addresses some spectrum engineering and site engineering procedures which can alleviate the interference situation whatever combination of duplex methods are used. Some of these techniques are more appropriate when considering CRS to CRS which are more manageable being more deterministic than situations involving TSs which are installed at short notice in response to customer needs.

CEPT SE19 has recently drafted a set of FWA spectrum engineering and frequency management guidelines published as ERC Report 097 [12] and an extract of those related to the use of TDD appears as annex D.

6.8 The differing views on interference scenarios

The arguments presented in clauses 6.1 to 6.6 above are drawn from several sources and they apparently show somewhat different conclusions, sometimes apparently contradictory. Whereas there is no disagreement about the existence of additional modes of interference when TDD systems coexist with FDD systems, there is little agreement about the significance of these additional modes. The reason for this is that different implicit assumptions about deployment and the nature of two systems deployed in the same area in near adjacent frequencies.

The standards defined for P-MP equipment restrict deployment decisions of that equipment very little. Different assumption and different equipments compliant with the same or different P-MP standards will result in different conclusions being drawn. It is clear that it is possible to aggravate the interference scenarios by allowing incompatible systems to be operated in the same area but it is far from clear from the above arguments that any FDD-FDD configurations are always less interference prone than any FDD-TDD configuration. Indeed several of the arguments summarized above and set out more fully in the annexes suggest that either there is little difference or in some cases the TDD situation is less interference prone and is more amenable to mitigation.

Considering the amount of work undertaken on this issue, and that still on-going in other bodies, it is clear there can be no general conclusion that that TDD create more significant frequency management or deployment problems than FDD only scenarios.

7 Parameters for TDD systems

One objective of the present document was to identify and describe the selection of any additional parameters, or the modification of existing parameters, required for specifying the TDD characteristics of TM4 P-MP standards. This matter is addressed in the clause.

7.1 Classification of TDD types and synchronization issues

The main characteristics that describe the nature of TDD applied in any system are:

a) the type of TDD as defined in annex B (Slotted TDD, Non slotted TDD, Random slotted TDD) according to whether the duplex time intervals are Fixed, Adaptive, Dynamic or Random allocation);

b) for Slotted TDD systems only, where fixed , the duration of the TDD time interval, and its tolerance;

c) for Slotted TDD systems only, the means if any of synchronizing duplex time intervals with similar compatible systems.

NOTE: References to "Synchronization" in this clause refer to inter-system synchronization of transmit intervals either on a area-wide basis or at a single central station site. Any synchronization of duplex transmission intervals within any one system is part of that system's design, and is not part of the definition of the standard.

It is recognized by SE19 (see ERC Guidelines, [12], and annex D) and others, that in some circumstances, the performance of two or more TDD systems operated at close frequencies might be improved by synchronizing the systems. However, this is only possible for slotted TDD systems with the same timing characteristics and compatible synchronization mechanisms. It is argued elsewhere, clause 6.6 for example, that such synchronization is unnecessary.

Systems are being introduced specifically to address the data communication application. Such systems typically do not operate within slots allocated on a regular cyclical basis with equal allocations to up- and down-links, but divide the time between up- and down-stream directions based on the demand for data packets. Given this trend, and given the current regime of coexistence standards, it is believed it is not practical to standardize on a specific fixed transmit interval which would be a necessary condition for synchronization of different systems. For this reason, no case could be sustained for specifying, or limiting the variety of, TDD types by limiting the duration of the duplex time intervals, nor for mandating a specific means of synchronization technique between unlike systems, even if this were possible.

7.2 Suppliers' Declarations related to TDD

Some aspects of conformance testing are conducted differently for TDD and FDD systems. It is therefore necessary for the supplier to declare which duplex method is used and so the supplier is invited to declare for conformance testing the characteristics of the duplex system:

a) whether TDD is used in the system;

b) if so, the type of TDD see annex B;

c) where relevant and fixed, (in the case of slotted TDD) the duration of the TDD transmit interval and any tolerances;

d) any means of synchronizing with unlike systems with a compatible transmit interval and its locking range.

Only (a) should be a mandatory declaration, (b), (c) and (d) may be declared by the supplier when appropriate. These declarations will allow the regulator and the operators to decide if synchronization of unlike systems is practical, and will allow frequency management to be undertaken accordingly.

CEPT SE-19 had suggested (see liaison statement of 8-10 March 1999): that *"…the duration and associated tolerances of the transmit and receive times (including the degree of asymmetry, together with the synchronization locking range and stability…"* might be relevant parameters to be specified to allow synchronization of unlike systems. However, only for slotted TDD systems (as defined in annex B) will such parameters be fixed. Even for slotted TDD systems where they are fixed, with the wide variety of applications and deployment models it is unlikely that they will be similar for different suppliers. For these reasons, it is not felt practical to standardize such parameters.

7.3 Out of band aspects

It has been questioned whether different out-of-band emission characteristics (including spurious emissions) or received filter rejection characteristics should be specified for TDD systems as compared with FDD systems.

One arguments advanced in clause 6 is that the carrier frequency separation to achieve the isolation between stations of different operators, equivalent to a spatial separation of ***d***, is determined *only* by the level of out-of-band emissions and the receive filter characteristics of the two operators' systems. These specified parameters are the same whether both systems are FDD or whether one is TDD.

Hence, no argument can be sustained for setting different levels of such characteristics for FDD and TDD systems from a coexistence viewpoint.

7.4 System Capacity

Most existing TM4 P-MP standards specify minimum traffic capabilities by stating a minimum bit rate which can be supported by a given channel bandwidth or channel separation. This is stated in different ways in different standards. With some of the older standards this led to a potential source of confusion or ambiguity when the system was applied to TDD systems when originally drafted with only FDD in mind.

Because FDD systems are always defined in terms of paired frequencies reference to a channel separation of ***f*** MHz implied a total frequency assignment per channel of ***2f*** MHz **-** and this is required to support at least ***n*** bits per second (duplex) traffic. Reference to a channel separation of ***f*** MHz in the context of a TDD system implies only a frequency assignment of ***f*** MHz and so the same minimum *duplex* bit rate might be assumed to impose a factor of 2 increase traffic efficiency in bits per Hz for TDD systems.

However, the currently accepted "generic wording" which has been incorporated in newer standards, and should be used in future standards, reacts to the difficulty of specifying capacity in systems which transmit intermittently, by defining the capacity in terms of "gross bit rate". The following definition appears in recently agreed standards (see for example EN 301 021 [11]):

"The gross bit rate is defined as the transmission bit rate over the air. In case of a transmitter working in burst mode the gross bit rate is the instantaneous maximum transmission bit rate during the burst".

As an illustration of this definition, suppose a standard requires a P-MP system to have a gross bit rate of N bits/s with a channel separation S MHz. A symmetrical TDD system must handle at least N bits/s during period of transmission which is approximately 50 % of the total time so its mean traffic rate would be required to be at least N/2 bit/s. However, a continuously transmitting FDD system, with the same channel separation, S, would be required to sustain a traffic rate of N bit/s. This reflects the fact that a channel separation S corresponds to a total channel bandwidth of the order of 2S for a paired spectrum FDD system. Hence, the bit/s/MHz requirements will be similar for the two systems.

So, provided system capacity requirements are specified in terms of Gross Bit Rate, no amendments are needed to System Capacity for TDD systems.

7.5 Duplex spacing

Several CEPT (and other bodies') Fixed Service channel arrangements allow for paired frequencies and often specify the separation between corresponding paired channels. Several TM4 equipment standards make explicit reference to the Tx/Rx spacing of FDD systems. Clearly, such a parameter as duplex spacing is not required for TDD systems and two ways of addressing this have been used in existing standards:

- to include a statement that for TDD systems, all references to Tx/Rx spacing or duplex spacing should be disregarded;

- to include explicitly a Tx/Rx spacing of 0 MHz.

Generally the former would be preferred as being a clearer specification but some older standards, not written with TDD in mind, might be more easily amended by the latter method perhaps with an explanatory note.

7.6 Summary

Regarding the "selection, modification or addition of technical parameters relevant to the usage of TDD arrangements in FWA applications" we conclude only that only the following changes are needed to the parameters in the standards:

1) where system capacity is specified in terms other than *gross bit rate* then this should be amended to reflect the current generic wording;

2) where references to Tx/Rx separation or duplex spacing are made in a P-MP EN intended for either TDD or FDD systems, then *either* a statement should be included saying this should be disregarded when TDD is used *or* an explicit reference to a 0 MHz spacing should be included.

No specific requirements for specification of transmission interval, duration, tolerance, or synchronization means should be included in the ENs to facilitate TDD use. However, the supplier should be required to declare whether TDD is used, and may optionally further declare the characteristics of the TDD and the means of synchronization with systems from other manufacturers.

It should be remembered that the ETSI standards should only specify equipment standards and should not make any implication on the way the spectrum should be managed.

8 Conclusions and proposed way ahead

8.1 General conclusions

TDD has many positive attributes when applied to FWA P-MP systems (see clause 4). However, there is an understandably cautious reluctance on the part of some regulators to assign TDD systems frequencies within bands where channel arrangements permit paired radio spectrum and which have historically been used for FDD systems only.

The traditional practice of point-to-point and mobile systems utilizing FDD for its ease of managing mutual interference of two systems operating in the same area is far less applicable in the context of FWA P-MP systems using digital technology. This is partly because of the significant differences between point-to-point, cellular mobile on the one hand and the subject of the present document, FWA systems on the other. Furthermore, FWA systems have been perceived as digital systems from the outset whereas other systems have evolved from an analogue background where TDD could not readily be used. However, the use of common bands and channel arrangements for P-P and P-MP systems and the continuing presence of legacy FDD systems in Fixed Service bands defined to be consistent with paired frequency assignments, means that new TDD systems will, in general, need to coexist with FDD systems.

In general, there are non-trivial interference issues to address whenever any two FWA systems are operated in neighbouring bands whether the two systems are both FDD, both TDD or one TDD and one FDD. There is no complete consensus as to the major area of concern and which system, and which stations, are main potential victims from such interference. Arguments have been presented suggesting variously:

a) that there are additional interference modes in mixed TDD/FDD scenarios and in unsynchronized TDD/TDD scenarios when compared with FDD/FDD scenarios but the significance of these has to be evaluated in particular cases (clause 6.1);

b) that the main concern is the mutual interference of terminal stations of different operators, but it is not significant whether the systems are of like or unlike duplex methods. That the interference situation between TDD/FDD is not necessarily intrinsically worse than that between FDD/FDD as factors other than duplex method can dominate, particularly the spectral mask (clauses 6.3 and 6.4);

c) that the main concern is mutual interference between central stations of the two systems. Here, the potential for interference is equally possible with FDD-FDD and FDD-TDD situation but in the case of a TDD - TDD situation the situation in no worse, and if the two systems can be synchronized so that both systems CRSs transmit simultaneously and receive simultaneously there is no prospect of mutual interference (see clause 6.5);

d) in certain scenarios in practice the CRS-CRS co-ordination distance is less than the CRS-TS distance, which choice of duplex method does not affect. Further, TS-TS interference does not impose a severe deployment limitation in comparison with other interference mechanisms (see clause 6.6).

One reason for the different perceptions of the key problem stems from differing presumptions about how FWA systems are deployed and what their actual performance parameters are. There is unlikely to be a common consensus on the issues as long as the wide variety of systems are permitted within ETSI TM4 coexistence standards and diverse system deployment concepts exist. Provided this situation is recognized, the absolute levels of interference and the strategies of spectrum management and system planning are not significantly different in complexity when considering FDD-FDD systems or FDD-TDD systems although the additional mechanism when TDD systems are involved must be considered.

Whatever the combination of duplex methods used by the two systems, the effects of interference between them can be mitigated by a number of techniques exemplified in clause 6.7. However, none of these is particularly related to the choice of duplex method and so mitigation techniques are not explored in depth in the present document.

CEPT SE19 has been addressing this issue of TDD techniques for FWA systems (amongst other new technology issues) for over two years and has devised a draft set of guidelines for spectrum engineering and frequency management of FWA systems in general. Several of these guidelines relate to how to manage FDD and TDD in the same band, and how to manage multiple TDD systems in the same band. Spectrum engineering and Frequency Management for FWA systems is non-trivial whatever the duplex methods. TDD brings additional capabilities but may add additional considerations. CEPT has indicated no regulatory reason to restrict FWA systems from using TDD methods from being allocated to unpaired bands. If additional guard bands are necessary between FDD and TDD systems, this can be offset by some efficiency or performance advantages available in TDD systems. In CEPT, like ITU, the question is no longer *whether* TDD systems should be allowed to coexist with FDD system but *what are the rules* for such coexistence. It is beyond the scope of the present document, and outside ETSI's role, to specify such frequency management rules, any more than ETSI specifies the rules for frequency management of other like or unlike FWA systems.

8.2 Way ahead for TDD in TM4 P-MP standards

TM4 standards are concerned only with equipment specifications and do not define aspects of deployment, spectrum engineering and frequency management issues, which are beyond the terms of reference of ETSI, and under the purview of national regulators and international bodies such as CEPT and ITU. No exception to this division of responsibility in the area of duplex method seems justifiable even though several issues are raise by TDD and FDD systems operating in the same band and territory. Guidelines for the deployment of TDD systems in isolation or neighbouring other systems, including FDD systems, in nearby frequencies are being developed by CEPT and other bodies, and should be respected.

Recommendation 1: no change to current practice of ETSI TM4 P-MP standards should be made to address deployment, spectrum engineering or frequency management issues specifically in respect of duplex methods.

Well over a dozen different TM4 P-MP standards currently address four frequency bands and four access methods. Noting the drive to *reduce* the number of standards, it is strongly recommended that TM4 avoids embarking on a path that could lead to a potential doubling of the number of standards to reflect two different duplex modes. Where an equipment standard potentially allows either TDD or FDD, then that single EN should permit either rather than separate versions of standards being developed for separate duplex schemes.

Recommendation 2: as far as possible, development of *separate* versions of TM4 P-MP ENs just to allow different duplex methods should be avoided.

It is further suggested that as far as possible all extant ETSI TM4 P-MP standards should remain silent or agnostic on duplex method, unless there are specific considerations relating to duplex arrangements in a particular standard. Even when some reference to duplex method is necessary, the vast majority of the content of such standards will remain independent of the chosen duplex method.

Some current and draft FWA standards have seen no need to make reference to duplex method, but nevertheless some make specific reference to "*Tx/Rx Spacing*". When such standards are next updated it is suggested that a note be added saying: "*When applied to TDD equipment, references in the present document to Tx/Rx separation should be disregarded".*

Recommendation 3: where possible, existing standards TM4 P-MP standards should remain silent on duplex method. However, if a reference to *Tx/Rx spacing* appears, a clarifying statement is necessary to cover the situation when TDD is employed.

One particular standard, EN 301 021 [11], makes reference to duplexing bands in the title, the published version of which reads: *"Transmission and Multiplexing; Time Division Multiple Access (TDMA); Point-to-Multipoint radio systems in Frequency Division Duplex (FDD) bands in the range 3 GHz to 11 GHz."*. There is also some suggestion that a separate standard might be produced for TDD equipment. This title has caused confusion and could be interpreted as implying that the equipment shall employ FDD rather than TDD processes. A statement, agreed by TM4 for inclusion in the introduction in the latest draft says:

"… the present document might be applied to Time Division Duplex (TDD) equipment, subject, as always, to the specific frequency allocation arrangements being approved by the administrations. When applied to TDD equipment, references in the present document to Tx/Rx separation should be disregarded".

Currently another TM4 work item is addressing a revision to the present document.

Recommendation 4: specifically for EN 301 021 [11], the Work Item TM4085 should consider incorporating the following changes when that standard is next amended:

a) Clarify the situation by removing the phrase "*…in Frequency Division Duplex Bands (FDD)…"* from the title.

b) Clarify in the introduction that no separate standard is proposed for TDD systems using the same accept method and in the same bands

c) In view of the confusion that has been caused by references to duplex method, confirm the agreed explicit statement in "Scope" and/or "Introduction" that "*Either FDD or TDD may be used, subject to specific frequency arrangements being approved by the regulators. Where TDD is used, references to Tx/Rx spacing should be disregarded*".

Two other recent standards which make specific reference to the duplex method namely EN 301 179 [6] and EN 301 253 [10] have been approved by ETSI and are in the National Vote phase, and these incorporate a clarifying statement as follows:

"The present document may cover equipment which uses either FDD or TDD".

NOTE: As with other point-to-multipoint standards, attention must be given to assigning spectrum so as to allow different systems to operate in adjacent assigned frequencies without unacceptable mutual interference. This is the responsibility of the regulatory authorities who are advised to note any guidelines produced by CEPT, particularly those with reference to spectrum where unlike duplex methods are to be used".

Recommendation 5: Where it is felt insufficient for the standard to be silent on duplex method and it is necessary to emphasize that *either* TDD *or* FDD implementations of a standard are permitted then such wording is should be used.

Finally, to reflect the conclusions of clause 7.6, the following recommendations are also made:

Recommendation 6: Requirements of system capacity within TM4 P-MP standards should be expressed in terms of gross bit rate to avoid any ambiguity with TDD implementations.

Recommendation 7: No addition parameters for TDD implementations of TM4 P-MP systems need to be specified. However, the Supplier will be required to declare the duplex method used when the equipment is offered for conformance testing, and if the supplier claims any capability of synchronization with compatible equipments from other suppliers, the characteristics of such synchronization should also be declared.

Annex A (normative): Spectrum Planning for mixed P-MP & P-P, and FDD & TDD systems

A.1 Introduction

Spectrum management for Point-to-Multipoint (P-MP) systems introduces issues which are not present with Point-to-Point (P-P) fixed links. In some ways, P-MP planning resembles planning for mobile systems: although the terminal stations do not move, their position is unknown at the time the frequency planning is undertaken.

With fixed P-P links exact locations of the stations and directions of the links are known at installation. It is possible to determine the interference scenario at each station from all others in the vicinity and allocate channels accordingly. Several different fixed links often share masts and Frequency Division Duplex (FDD) is often employed to reduce interference between transmissions and receptions at the same location.

P-MP systems comprise Central Radio Stations (CRSs) which typically serve customers in their vicinity directly communicating with Terminal Stations at customers' premises or via repeater stations which emulate a TS to a CRS and a CRS to a TS. Because P-MP systems are often deployed in urban environments it is not uncommon for one (or several) TSs to be located close to a CRS. For example, a high rise building might be a natural choice for a CRS location and the residents or businesses in that building might be potential customers for the service. The customers in the building might be served either by the same CRS, or by a different one, from that installed on the same building.

In this scenario, Frequency Division Duplexing (FDD) fails to offer a complete solution to interference issues. Where a service has exclusive access to a band, with suitable guard bands between it and unlike services, planning for P-MP systems resembles that of mobile systems, usually along cellular lines. However, where a P-MP systems have to coexist in the neighbouring band to P-P systems there is scope for mutual interference. This paper explores these issues of mutual interference between:

- independent P-MP systems operating in neighbouring bands; and
- P-P and P-MP system operating in neighbouring bands.

We consider the additional dimension to this question applicable to:

- Frequency Duplexing (FDD) system;
- Time Division Duplexing (TDD) systems;
- between systems which use unlike duplexing techniques.

A.2 Interference issues of FDD and TDD, mixed P-MP and P-P systems

A.2.1 Introduction

Deploying a TDD P-MP system in the vicinity of a FDD P-MP system raises some technical issues, which are elaborated below in order to give a deeper understanding of the real problems involved. However, to place these in context, we also consider the interference problems which exist anyway with deploying a new FDD P-MP system in the vicinity of an existing FDD P-MP or P-P system.

Some channel plans allow for both P-MP and P-P systems in the same or immediately adjacent bands. Thus the mutual interference of both types of systems, and both means of duplexing, should be analysed. A P-MP system might be either a TDD system which uses only one sub-band for both reception and transmission or a FDD system which uses both sub-bands. Existing systems use one sub-band for Central Radio Station (CRS) transmission, and the other sub-band for Terminal System (TS) transmission.

We examine the various cases and study the possibility of interference between CRSs and TSs for different kind of systems. None of the cases studies, including the case of two FDD systems, provides a clear-cut interference free solution. While FDD is an effective solution at present to some sharing problems TDD can, in some circumstances, offer a more complete solution for interference problems in the future.

As always, the solution to a specific sharing problem depends highly on the situation in the area where the system is to be deployed and the policy of the regulatory authority. Issues include:

- how many operators are expected to be licensed in a given region? What is the bandwidth allocated to each of them?
- are there any P-P links in the area, in the relevant band? Is there any intention to move them out of that band and when?
- what are the parameters of the system operating in the band in the deployment area?
- what is the policy of the regulating authority regarding frequency sharing and duplex methods?

A.2.2 Scenarios considered: Operation of TDD and FDD in neighbouring bands

We presume that paired spectrum is available otherwise FDD is not feasible. We assume that a FDD system is already deployed in the vicinity and we look at interference implications of introducing a new system: TDD or FDD. We consider separately the cases where the pre-existing system is P-MP and when it is P-P and we consider three scenarios according to the nature of the new system introduced:

Scenario 1: a TDD system is allowed to operate over both sub-bands. In this case the system will operate in TDD mode, over both sub-bands, and provide a maximum capacity.

Scenario 2: a TDD system is restricted to one sub-band. In this situation the system will use half of the allocated bandwidth and provide half the capacity of the previous case but it will free the other sub-band to other uses such as another, totally independent, TDD system.

Scenario 3: the new system is FDD.

A.2.3 Discussion

Table A.1 summarizes all the cases where mutual interference may occur. Four types of systems are listed in the table both as potential interferer (in rows) and potential victim (in columns):

- P-MP, FDD system, where the CRSs transmit in sub-band 1 (sb1) and the TSs in sub-band 2;
- P-MP, TDD system operating in sub-band 1;
- P-MP, TDD system operating in sub-band 2;
- P-P, FDD system with sites transmitting at sub-band 1 and sub-band 2.

A zero in the table indicates a non-interference situation, while any other reference refers to the "Cases" below and indicates potential interference between the interferer (row) and the victim (column). For the purpose of the discussion we assume that a transmission at one sub-band may cause interference to receivers in the same band, but the duplex spacing is large enough to reject interference from the other sub-band transmissions.

Table A.1: Interference between two operators' P-MP FWA system operating in near adjacent bands in the same vicinity

	Victim	P-MP	FDD	P-MP	TDD	P-MP	TDD	P-P	FDD
Interferer		CRS sb1	TS sb2	CRS sb1	TS sb1	CRS sb2	TS sb2	sb1 sites	sb2 sites
P-MP	CRS - sb1	0	A1	A2	A2	0	0	0	B2?
FDD	TS - sb2	A1	0	0	0	A2	A2	B1a	0
P-MP	CRS - sb1	0	A2	A3	A3	0	0	0	B2a
TDD	TS - sb1	0	A2	A3	A3	0	0	0	B1a
P-MP	CRS - sb2	A2	0	0	0	A3	A3	B2a	0
TDD	TS - sb2	A2	0	0	0	A3	A3	B1a	0
P-P	sb1 site	0	B2b	B2b	B2b	0	0	0	0
FDD	sb2 site	B1b	0	0	0	B1b	B1b	0	0

NOTE: Non zero entries in the table are references to specific case discussed below.

A.2.3.1 Interference between two P-MP systems (Cases A1-A3)

A.2.3.1.1 Case A1: FDD with FDD systems

FDD offers a simple sharing mechanism, which eliminates interference between CRSs and between TSs. However, with P-MP systems, particularly in urban environments, there is potential scope for interference between a CRS of one system with the TS of another system which could well be in close proximity.

A possible solution is to constrain the base stations to the same set of sites and to make sure that the power of the TS does not exceed a given level. This solution may lead to adverse economic results, as both systems would not be deployed optimally, and both would have to be very similar in nature, thus reducing diversity and limiting competition.

The situation becomes more complex, however, when combined TS and repeaters stations are used at customers premises.

A.2.3.1.2 Case A2: TDD with FDD systems

A TDD system operating in sub-band 1 will not interfere with the FDD CRSs, however the TSs may interfere with neighbouring TSs of the P-MP system. There might be interference to the TDD system's base stations by the FDD system's base stations. A TDD system operating in sub-band 2 may interfere with the FDD system base stations, but it will not interfere with the terminal stations.

For operation in that band, it is recommended to restrict the TDD system only to sub-band 1 (FDD system BS transmission), with local solution for the case of TS interference. It is up to the TDD system manufacturer to provide adequate shielding from the FDD system interference.

A.2.3.1.3 Case A3: TDD with TDD systems

Two TDD systems can be deployed when each uses another sub-band. This would lead to an interference free deployment of both systems.

In order to enable more than two systems one may use the synchronized nature of the transmission and impose inter-system synchronization. It is true that nowadays there is no developed standard mechanism of sharing in the time domain, as can be found in the frequency domain, however it offers a very big improvement as "time filters" (namely switches) can achieve a much better selectivity than conventional frequency filters. The infrastructure of accurate time references, as common clock frequencies and GPS satellite network is in place today and provides the required basis for such time sharing standard development to take place in the future.

A.2.3.2 Interference between P-P and P-MP systems (Cases B1- B2)

Let us consider a scenario where a P-P radio link network, composed of several links, operates in a given area. We assume that the P-P system is designed such that each site transmits in either sub-band 1 and receives in sub-band 2 or vice versa (FDD arrangements). A P-MP system is to be deployed to cover the same area, and it is supposed to share the same frequency band. We denote the operating band of a P-MP TDD system as sub-band 1, without loss of generality, as the problem is now symmetric for both sub-bands.

We shall analyse the constraints imposed on either a FDD or a TDD P-MP system, to avoid interference with the links.

A.2.3.2.1 P-MP Terminal Station (TS) considerations (Cases B1a and B1b)

It is assumed that P-MP Terminal Stations (TS) at customers' premises can be located anywhere within the service area. We consider separately the cases where the P-P system is the victim (Case B1a) and the case where the P-MP system is the victim (Case B1b).

A.2.3.2.1.1 Case B1a: P-MP terminal station causing interference to a P-P station

For P-P sites which use the same sub-band for transmission as the TSs there is no interference from the P-MP system. For P-P sites which transmit on the other sub-band, there might be some areas where TS installation is limited in direction or forbidden all together. The size and shape of the area depend on the TS transmission power, antenna radiation patterns, channel separation and the P-P receiver selectivity and sensitivity.

For a FDD P-MP system, such limitation might be necessary around P-P sites transmitting in sub-band 1. While for a TDD system such limitation may exist around P-P sites transmitting in sub-band 2 (and receiving in sub-band 1).

A.2.3.2.1.2 Case B1b: P-P stations causing interference to a P-MP TS

Around P-P sites which transmit on the receive sub-band of the TS there might be some limitations on the TSs deployment. The size and shape of the limited area depend on the P-P transmission power, antenna radiation patterns, channel separation and the TS receiver selectivity and sensitivity.

For both FDD and TDD systems, such limitations might exist around those P-P stations transmitting in sub-band 1.

A.2.3.2.2 P-MP Central Radio Station (CRS) considerations (Cases B2a and B2b)

A.2.3.2.2.1 Case B2a: P-MP CRSs interfering with P-P stations

Base stations of the P-MP system may interfere with P-P sites located in their vicinity and receive in the same sub-band. Namely, an FDD system will interfere with P-P sites operating in sub-band 2, and the TDD system will interfere with systems operating in sub-band 1.

A.2.3.2.2.2 Case B2b: P-P stations interfering with P-MP CRSs

P-P sites transmitting in sub-band 1 will interfere with TDD systems (which operate in that band), while P-P systems transmitting in sub-band 2 will interfere with FDD systems.

A.3 Summary

None of the situations described is completely interference free (except for TDD systems in two sub-bands, or synchronized TDD systems in the same sub-band).

However, not all the interference scenarios described in the table are equally severe. Indeed, a FDD P-MP system may share the band with another FDD P-MP system with minor interference, but still it is possible to install a TDD P-MP system operating in the CRS transmission band (sb1) of a FDD system sharing the same band, provided the manufacturer ensures the system can tolerate the expected interference.

FDD P-MP systems present no clear advantage over TDD P-MP systems when considering their sharing with P-P links, as half of the P-P sites transmit in sub-band 2 and cannot be shared with the P-MP Central Radio Stations.

Although seldom specifically mentioned, TDD systems are not specifically disallowed by many channel plans intended for P-MP applications. Pending suitable standardization, TDD can provide much better sharing situations in the future assuming SE19 can provides guidance notes for regulators.

Annex B (normative): Various types of Time Division Duplexing

Time Division Duplexing often employs regular, constant duration transmission intervals, equal duration for both traffic transmission directions. This supports symmetric traffic such as occurs in classical telephony applications. However, there are many other ways in which the transmission slots might be allocated. Here is some terminology which is used to classify the TDD systems.

There are several different types of TDD system. These may be classified according to the way that the timeslots are allocated, such as:

- **Fixed allocation**, in which every transmitter is allocated a fixed time within a cycle for transmission. This is typical for voice and "circuit switched" communication. Within this category one can distinguish between symmetric and asymmetric allocations in which there is either a uniform or a non-uniform allocation of transmission time to each transmitter.

- **Adaptive allocation**, in which the transmitted duration adapts to the load, it has to carry **Random allocation,** in which the transmitters transmit at random times. Transmission can occur randomly at any time or within a predetermined time-slot (usually much more finely defined than in a fixed allocation systems). This is the most common for data transmission.

- **Dynamic allocation**, where the medium is sensed and a timeslot is taken only if free.

These different slot allocation algorithms lead to the following different TDD types:

- **Slotted TDD**: a TDD system where transmission occurs within a predetermined time-slot.

- **Non slotted TDD**: A TDD system where each transmitter may transmit at any time.

- **Random slotted TDD**: A slotted TDD system where each transmitter may or may not transmit within the predetermined slots.

Annex C (normative): Some spectrum engineering and site engineering considerations

C.1 Means of mitigating effects of interference between systems operating in same band

There are many means to avoid interference between systems, which include:

- physical separation;
- frequency separation;
- use of directional antennas;
- polarization;
- barriers between interfering antennas;
- synchronization;
- active nulling in the antenna pattern;
- interfering signal cancellation.

For fixed systems the regulating authorities use mainly physical and frequency separations. The existing standards refer to the basic parameters needed for co-ordination of systems based on frequency and physical separation.

Directional antenna and to some extent polarization are used for co-ordination of P-P systems. The use of directional antennas can be used mainly for the TS for P-MP systems. The gain, RPE and X-POL are specified in the existing antenna standards.

Physical barriers between close antennas might be used in some cases, however, it is highly dependent on the actual deployment and cannot be used as a regulatory tool. As such no need to refer to those in the standards.

Synchronization is mentioned in the standards, but it seems it refers to clocks synchronization (in the network interface side) rather than transmission synchronization. This can be a very powerful tool in sharing if a scheme could be devised to ensure that all transceivers which are prone to interference are transmitting together, or at least do not receive any important information during transmission time. Inter-system synchronization requires an absolute time reference for which atomic clocks, GPS clocks, or the exchange clocks can be used. A more difficult thing to standardize is the way the two system use the time-domain, namely the transmit/receive cycle length and transmit/receive ratio. It is even more difficult in random TDD systems.

One can think of slotting schemes parallel to the channelization schemes which exist now in the frequency domain, blanking signals between co-located systems and a lot of other means.

Active nulling in the antenna pattern, is certainly a very important means, never referred to in any TM4 standard. It can be used only with smart antennas. At this stage a supplier declaration of this ability and its parameter (such as null depth, number of nulls, possible null location etc.) would be adequate. It should be noted that TDD is very beneficial to smart antennas and we are expecting that smart antennas are more commonly used by TDD systems.

Interfering signal cancellation is a feature that can be used between two collaborating systems. A sample of the transmitted signal from the interferer is provided to the victim (either by a cable if the systems are co-located or by dedicated antennas) which subtracts it, with the proper gain and phase from the input signal either at RF, IF or baseband levels. This might be a useful solution for interference between base stations (a major problem for TDD systems, none for FDD), and much more problematic for interference scenarios where TSs are involved (various FDD scenarios). A supplier declaration on this feature might suffice at this stage.

C.2 Some issues for consideration by frequency planners

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To realize these TDD advantages the spectrum planners could (and indeed do in many parts of the spectrum) designate parts of the spectrum to TDD, relieved of the need to provide paired spectrum. However, there is no overriding reason why paired spectrum should not be assigned to TDD systems. This is particularly true for frequency hopping systems able to hop between both components of the allocated spectrum but even for less agile systems, it is feasible that the paired spectrum could be allocated to two different sub-systems (or perhaps systems of two different operators) each using TDD techniques.

A separate input paper addresses the interference issue between TDD and FDD P-MP systems and between P-MP and P-P system whatever duplexing methods are used and concludes that most combinations of unlike systems pose some potential interference questions. However, in general these need be no more severe than mixed P-MP and P-P systems operating in neighbouring bands, even if they use like duplexing methods.

Frequency planners often mistakenly overlook the P-MP possibilities offered by TDD, especially in bands traditionally occupied by FDD systems. It is suggested that CEPT, through SE19, draws the attention of frequency managers to the merits of TDD particularly in the context of point-to-multipoint systems. Further it is suggested that it be clarified that the existence of paired frequency channel plans does not, of itself, prevent the channels being used for TDD systems.

C.3 CEPT SE19 Guidelines

CEPT/ERC SE19 has been studying the issue of New Technologies including issues specifically concerning the use Time Division Duplex techniques by FWA systems for nearly two years. A draft report is in preparation and a recent draft is reproduced in annex D. As can be seen, several guidelines have been drafted which address the TDD question.

Annex D (normative): Extracts from "Draft ERC Report on Fixed Wireless Access (FWA) spectrum engineering and frequency management guidelines (qualitative)"

D.1 Introduction

CEPT SE19 has drafted a document proposing qualitative guidelines Spectrum Engineering and Frequency Management for FWA systems. Those parts of the ERC Report 097 [12], specifically concerned with TDD issues are reproduced below.

D.2 Frequency allocation guidance

For co-deployment of FWA systems in the same geographical area, it is necessary to:

- specify for FDD systems, a consistent plan for the forward (CRS to TS) and reverse (TS to CRS) sub-band frequencies;
- take account that for TDD systems the designation of forward and reverse link directions is no longer possible, and in this case additional interference scenarios need to be considered.

D.3 Frequency planning

For geographically co-deployed FWA systems, it is necessary to:

- take note that to date FS frequency plans have generally been prepared for P-P telecommunications systems featuring use of FDD, with symmetric channel/sub-band widths which may not be appropriate for all FWA systems;
- take account that services with variable asymmetry are often needed, especially for broader band applications;
    - take account that asymmetry may be achieved by:
        - pairing narrower channels in one direction with wider channels in the other;
        - using different orders of modulation in one direction from that used in the other;
        - using asymmetrical TDD within the paired spectrum;
- take account that TDD with variable time allocated to up- and down-link directions can provide a manner of achieving applications having variable, asymmetrical traffic.

D.4 TDD assignments in bands with paired spectrum

In the case of TDD systems in bands with conventional channel arrangements for P-P systems, it is necessary to:

- note that where part of the lower band is assigned to a TDD system then the corresponding part of the upper band should also be assigned to TDD systems, and *vice versa*;
- ensure that the TDD assignment fully respects the homogeneous pattern of frequency slots as stipulated for the FDD channel raster;
- note that for *fixed asymmetrical* applications based on FDD and operated with channel arrangements previously designed to be suitable for symmetrical FDD use (having equal channel widths in both upper and lower bands), it is possible for n channels of the lower sub-band to be paired with m channels of the upper sub-band. The "surplus" unpaired |m-n| channels could be usefully assigned to TDD services (including any necessary guard band allowance);
- take account that, notwithstanding the availability of the m + n channels for fixed asymmetric FDD services, it is possible that these channels could be assigned to one or more TDD channels;
- take into account the possibility of using the centre gap for TDD.

In the case of TDD systems in bands with a conventional channel arrangement for P-P systems, it is necessary to:

- note that there may be particular spectrum engineering issues (such as constraints on transmitter masks and the need for guard bands) associated with operating TDD systems in a band already accommodating FDD systems;
- note that additional parameters may be needed for the coexistence planning of TDD systems;
- note that it has been asserted that the issue of verifying TDD compatibility with existing FDD systems is a larger task than checking compatibility of a FDD system with existing FDD system (with the same duplex spacing).

Annex E (normative): The overlapping cell problem

E.1 Description of the problem

Figure E1 shows the potential interference to CRS receivers of two FWA PMP systems A and B. Both systems are assumed to consist of several cells. They are operating in adjacent parts of the same band, but are covering the same geographical area. If for instance system B uses TDD, it is supposed that TDD is used in each of the two sub-bands for system B. The systems are owned by different operators and may use different technologies and may have different business cases. Therefore it is very realistic to assume that cell sizes are not co-ordinated between the operators and that no co-ordination is made on having common base station sites. Therefore the scenario in the figure is very realistic, where, supposing a certain minimum subscriber density, there will always be subscriber stations from one system very close (100 m) to each base station of the other system.

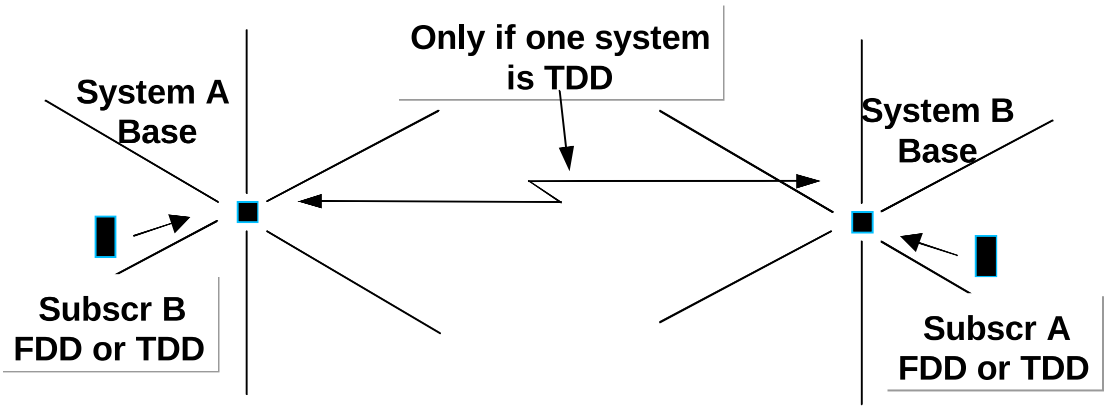

Figure E.1: Typical example where FDD subscriber to base may cause higher interference than TDD base to FDD base interference

NOTE: The interference from subscriber stations from one system to base stations from the other system always occur between FDD systems as well as between a TDD and an FDD system. If one of the systems is a TDD system, then a potential for interference between bases will also exist.

It should be recalled that for FWA or PMP systems, typically line of sight, LOS; installations are used, and that the transmit power and antenna gain are typically very similar for the subscriber units and the base stations. Therefore the EIRP from bases and subscriber stations will be very similar, and we can assume that interference both from relevant subscriber stations and from TDD bases of one system to the base stations of the other system is typically line of sight.

Four observations are made:

- the distance between the closest bases is fixed, but the distance to the closest interfering subscriber station, having the same EIRP as a base, is normally much closer (100 m). Thus the highest interference levels will come from subscriber stations (FDD or TDD) and not from the TDD base (base station separation within an FWA or PMP network is typically 1 to 10 km);
- in the case where system B is a TDD system, the interference to the FDD base (A) from a TDD connection to the subscriber station (B) comes half the time from the subscriber station (B) and half the time from the base (B). In the case the System B is an FDD system, the interference to the FDD base (A) from an FDD connection to the subscriber station (B) comes all the time from the subscriber station (B);
- thus, on average, depending on how close the actual subscriber station (B) is to the base (A), the interference potential, or the probability of interference, will be about the same between two FDD systems as between an FDD and a TDD system, supposing similar attenuation of the modulation spectrum mask in the adjacent sub-bands;

- as seen from the information above, it is not critical if TDD or FDD is used, but it is important to have as good as possible attenuation of the modulation spectrum mask in the adjacent sub-bands. Thus there is no reason to discourage the use of TDD systems in neighbouring parts of the bands occupied by FDD.

Since interference to some degree always occur between overlapping systems on adjacent bands (no matter if FDD or TDD), this means that site engineering/site co-ordination, which for mobile systems only are required for base stations, for FWA station also will be required for some number of the TS. Unlike mobile systems, the FWA subscribers are fixed, and therefore each subscriber requires proper transmission performance. Thus in the scenario in the figure E1 above, site co-ordination/engineering (change antenna position, height, direction or directivity etc.) may not only be required sometimes between bases A and B, but also for the TSs, e.g. between Subscriber B and Base A.

Thus site engineering for TSs will be required in FWA FDD/FDD scenarios. For FDD/TDD TS to TS interference also occurs. It is therefore important to estimate how much the potential TS to TS interference contributes the probability to need to perform TS site engineering, in relation to the site engineering efforts anyhow required for the CRS to TS mutual interference. Site engineering between two TS is simpler, since both ends have directivity in the horizontal plane.

To estimate this, we define two overlapping multi-cell FWA systems A and B (operating on adjacent bands) which have:

- the same cell radius R;
- the same number of TS, N_R, in each cell;
- the TSs are evenly distributed over the cell areas;
- a fraction β of the calls within a cell will be set up on those carriers that are so close the adjacent band the interference will occur within r (< R) meters;
- the same output power;
- the same antenna gains;
- the same antenna opening angle, α;
- the same sensitivity;
- the same out of band emissions;
- the same bandwidth;
- the same adjacent channel selectivity;
- CRS and TS have the same opening angle, α;
- CRS and TS have the same power and antenna gain;
- the circular cell consists of $360/\alpha$ sectors with on CRS in each sector;
- whereby each sector serves $N_R \times \alpha/360$ TSs.

E.2 TS to TS interference

For simplicity we suppose that interference occurs when two TS from the different systems are within r meters from each other and they are within the opening angles of both TSs. We also suppose that due to set up on different carriers, in average, only a fraction β of the calls within a cell will be set up on those carriers that are so close the adjacent band the interference will occur within r meters.

Thus the probability that a TS(A) is within r meters from a **specific** TS(B) is $(r/R)^2 \times N_R$.

The probability that a TS(A) is within r meters from a **specific** TS(B)s and that the antennas of **both** these TSs are facing each other becomes: $(r/R)^2 \times N_R \times (\alpha/360)^2$.

The probability that a TS(A) is within r meters from **any** of the TS(B)s in a cell and that the antennas of **both** these TSs are facing each other becomes: $(r/R)^2 \times N_R \times N_R \times (\alpha/360)^2$.

Thus the probability for interference between TSs to occur within a cell area (πR^2) is:

$$(r/R)^2 \times (\beta \times N_R \times \alpha/360)^2$$

For example, if α = 60 degrees, β = 0,2, r/R = 0,1 and N_R = 150, the probability for interference between TSs to occur within a cell area (πR^2) becomes 0,25 which is 0,25 % of the TSs (or about one TS per every 4 cells requires site engineering).

This probability is an upper bound, supposing that only one TS(A) is within the radius r when interference occur, i.e. $(r/R)^2 \times \beta \times N_R < 0,3$. This is fulfilled with the above example parameters (for larger values, the probability will normally be lower than indicated by the formula).

E.3 TS to CRS interference

The probability that a TS(A) is within r meters from a base station with CRS(B)s (or vice versa) is $(r/R)^2 \times N_R$ (there is in average only one Base B within a cell of radius R). This TS(A) will interfere with one of the CRS(B) sectors in Base B. This sector serves $N_R \times \alpha/360$ TS(B)s, of which $\beta \times N_R \times \alpha/360$ TS(B)s then will be interfered.

Thus the probability that a TS(A) is within r meters from one of the CRS(B)s in a system and that the antenna of this TS(A) is facing the CRS(B) becomes: $(r/R)^2 \times N_R \times \alpha/360$. But a fraction β of these TS(A)s will interfere with the up-links of all $\beta \times N_R \times \alpha/360$ TS(B)s.

Thus the probability for TS(A) to CRS(B) interference to cause interference to a system B subscriber TS(B) becomes:

$$\beta \times (r/R)^2 \times N_R \times \alpha/360 \times \beta \times N_R \times \alpha/360 = (r/R)^2 \times (\beta \times N_R \times \alpha/360)^2$$

This is exactly the same figure as direct TS(A) to TS(B) interference.

E.4 Conclusion on TS to TS interference when one system is a TDD system

As shown with the above simplified analysis, the probability for the connections to become interfered due to the TS to TS interference that occurs when one system is TDD and the other is FDD, is the same as the probability due to TS to CRS interference that occurs between FDD systems on adjacent band allocations.

This supports the conclusion that the actual level of out of band emissions (and the actual receiver blocking performance) is generally more important to minimize mutual interference than to prescribe a specific duplex method. Similarities between systems could however simplify coexistence, e.g. ability to detect interference from the other system and make hand-over to a carrier more distant from the band edge, to have the same procedure for dynamic channel allocation, to have the same frame cycle time for TDD and TDMA systems etc.

Actual systems, will normally not fit to the model used in the simplified analysis. Therefore, recommended minimum carrier spacing, minimum separation distance and proper local site engineering means, will depend on the actual system and equipment parameters.

Annex F (normative): The interference problem in adjacent frequency bands: a quantitative analysis

F.1 Methodology

The methodology described here is based on the one used by the Experts Group created in the CITEL organization, Permanent Consultative Committee III - Radiocommunications, to analyse the interference problems among several FDD and TDD systems in adjacent bands at 1,9 GHz.

Experts from several telecom suppliers companies formed this group (Alcatel, Ericsson, Lucent, Motorola, NEC, Nortel, Qualcomm and Siemens among them) which worked during two years on this matter, providing two extensive final reports of PCC III Interference Expert Groups([16], [17]). Though that work was performed for the 1,9 GHz band, the methodology can be extended to 3,5 GHz by changing the required parameters, as explained below.

The methodology is based on the following assumptions:

- the basic threshold parameter to analyse the interference is the Rise In The Noise Floor, which occurs when external interference appears;
- this methodology calculates:
  - the required minimum signal attenuation in the air interface;
  - and by applying the chosen propagation model, the corresponding minimum distance.

For each scenario between a single interfering TX and victim RX device:

- the methodology assumes that both victim and interferer are operating at the closest possible adjacent channels;
- this methodology only uses emissions due to the modulation mask and does not consider other emissions such as spurious emissions, switching transients, etc. The emissions due to modulation have been chosen as highest priority, since they are the most relevant interference source;
- this methodology does not take into account the probability of interference;
- the methodology uses the following steps:
  1) calculate the maximum level of the interfering TX at the antenna output. To do that, it is assumed that TX is working at the adjacent carrier to the victim system, at maximum power and assuming the corresponding TX mask and the out-of-band filtering of the TX system. Possible misalignment of the TX antenna relative to the victim RX position is also considered;
  2) calculate the maximum level of the interfering signal that can be tolerated at the victim RX antenna. The interference is calculated when the RX is working at the minimum operating threshold level (sensitivity threshold), and assuming a specific Rise in the Noise Floor. A typical fading margin of the interference signal as well possible misalignment of the RX antenna relative to the interfering TX position are also considered;
  3) the Path Loss difference between above two values gives the required isolation in the air interface. Then, a propagation model is applied to obtain the required minimum separation distance between interfering TX and victim RX devices;
- the above calculations assume only one single interfering signal, but the worst case, in such a way that the effect of any other interfering signal is negligible compared to the considered one.

F.2 Formulae and Variable Description

The following variables are defined and used in the calculations.

By convention, terms are presented in two ways: with prime symbol' it represents analogue value (e.g. watts or power ratios) and without any prime symbol' it represents the logarithmic equivalence (e.g. dB, or dBm).

F.2.1 Transmitter Path

Table F.1

Parameter		Description
Analogue form	**Logarithm form**	
P'_L (mW)	P_L (dBm)	Launch power of the interfering device at TX antenna output. Its value is obtained by calculation (see formulae).
P'_{tx} (mW)	P_{tx} (dBm)	Peak power of the interfering transmitter during active burst (value given in systems specifications).
	G_{tx} (dB)	Gain due to TX antenna system, including feeder effects. Its value is obtained by calculation (see formulae).
	L_{mask} (dB)	Losses due to the TX emission mask. This value is obtained as the relative difference between P_{tx} and the power level (in dBm) of the TX emission mask due to modulation (as specified in the standards), at a given frequency offset and adjusting the measurement bandwidth of the mask to the victim RX bandwidth.
	L_{ext-tx} (dB)	Losses due to out-of-band filtering of the TX system (Filter rejection)
	G_{iso-tx} (dBi)	Isotropic gain of the TX antenna.
	$L_{beam-tx}$ (dB)	Losses due to the directivity of TX antenna. Both horizontal and vertical radiation patterns effects have been taken into account.
	$L_{teed-tx}$ (dB)	Losses due to the TX antenna feeder.

F.2.2 Receiver path

Table F.2

Parameter		Description
Analogue form	**Logarithm form**	
P'_R (mW)	P_R (dBm)	Maximum allowed interfering signal at the RX antenna.
D' (ratio)	D (dB)	Rise in the Noise Floor (also called "desensitization"). It is the basic interference threshold assumed in calculations (see formulae).
RX'_{sens} (mW)	RX_{sens} (dBm)	RX sensitivity level to assure a BER < 10^{-3} performance. Its value is defined in the corresponding systems specifications.
(C/I)'	(C/I) (dB)	Specific C/I ratio defined in system specifications for a system alone (i.e. without external interference). It is assumed that this ratio is constant for the whole range of received useful signal.
	F_{margin} (dB)	Fading Margin used in power budget calculations in normal system deployments.
	G_{rx} (dB)	Gain due to RX antenna system, including feeder effects. Its value is obtained by calculation (see formulae).
	G_{iso-rx} (dBi)	Isotropic gain of RX antenna.
	$L_{beam-rx}$ (dB)	Losses due to the directivity of RX antenna. Both horizontal and Vertical radiation patterns have been taken into account.
	$L_{feed-rx}$ (dB)	Losses due to the RX antenna feeder.

F.2.3 Propagation Model

The used propagation model for the interfering signal is the worst case of L.O.S. propagation extended to 3,5 GHz band, which can be expressed as:

$$L(dB) = 43{,}3 + 20 \log (d) \text{ with d in meters} \qquad (1)$$

Formulae

For the transmitter path two simple equations have to be taken into account:

$$P_L\ (dBm) = P_{tx}\ (dBm) + G_{tx}\ (dB) - L_{mask}\ (dB) - L_{ext\text{-}tx}\ (dB) \qquad (2)$$

Where:

$$G_{tx}\ (dB) = G_{iso\text{-}tx}\ (dBi) - L_{feed\text{-}tx}\ (dB) - L_{beam.tx}\ (dB) \qquad (3)$$

Calculation of L_{mask} and $L_{ext\text{-}tx}$ are detailed some lines below.

For the receiver path some more complex calculation should be made.

The fundamental philosophy that has been adopted is that the effect of interference can be modelled as an increase in received interference power. The primary used interference metric is the Rise in the Noise Floor, D, i.e. the increase in noise + interference power compared to the original noise + interference power:

$$D' = (N' + I'_{act} + I'_{ext}) / (N' + I'_{int}) \qquad (4a)$$

Or, in dB:

$$D = 10 \log(N' + I'_{act} + I'_{ext}) - 10 \log(N' + I'_{int}) \qquad (4b)$$

Where:

N = an equivalent noise power in the receiver and includes allowance for receiver implementation and, sometimes, fading threshold as well as pure thermal noise;

I_{int} = the internal (expected) interference power from the victim system itself - both same cell/sector and adjacent cell/sector, before any external interference is applied;

I_{act}= the internal (expected) interference power from the victim system itself - both same cell/sector and adjacent cell/sector, after any external interference is applied. Note that in same cases $I_{act} = I_{int;}$

I_{ext}= the incremental external interference power received from the interfering system.

If we assume that interference is a single event, that is assuming only a worst case of single interference, it can be assumed that $I_{act} = I_{int}$. Then re-writing (4a):

$$D' = 1 + I'_{ext} / (N' + I'_{int}) \qquad (5)$$

On the other hand, a fundamental relationship between C and I and N can be modelled as:

$$M' = C' / (N' + I') \qquad (6)$$

Where:

C = the received carrier power level on the channel;

N = an equivalent noise power in the receiver (as defined before);

I = the same-channel received interference power;

M = the specified minimum carrier-to-noise + interference ratio needed to guarantee the specified performance. M is colloquially referred to as the C-to-I (C/I) ratio.

Then, this basic relationship can be applied to our analysis, assuming a C value equal to RX_{sens} (minimum operative RX level) and I value equal to I_{int}, as follows:

$$M = (C/I)' = RX'_{sens} / (N' + I'_{int}) \qquad (7a)$$

Or:

$$N' + I'_{int} = RX_{sens} / M = RX_{sens} / (C/I) \qquad (7b)$$

Then substituting ($N + I_{int}$) in (5):

$$D' = 1 + I'_{ext} / (RX'_{sens} / (C/I)') \qquad (8)$$

And from this equation, the maximum external interference level allowed by the receiver can be deduced:

$$I'_{ext\text{-}max} = RX'_{s'ens} \text{ x } (D' - 1) / (C/I) \qquad (9a)$$

$$I_{ext\text{-}max} = RX_{sens} - (C/I) + 10 \log(10^{0,1\,D} - 1) \qquad (9b)$$

Therefore the equations obtained for the receiver path is (note that RX antenna effects and Fading margin have been already included):

$$P_R \text{ (dBm)} = I_{ext\text{-}max} - G_{rx} - F_{margin} \qquad (10)$$

Where:

$$G_{rx} \text{ (dB)} = G_{iso\text{-}rx} \text{ (dBi)} - L_{feed\text{-}rx} \text{ (dB)} - L_{beam\text{-}rx} \text{ (dB)} \qquad (11)$$

F.2.4 Final formulae

According to above formulae (2) and (10), the final power calculation should comply with the following rule:

$$L \text{ (dB)} \geq P_L \text{ (dBm)} - P_R \text{ (dBm)} \qquad (12)$$

And then, the minimum required distance, d, can be calculated by (1):

$$d = 10^{((L-43,3)/20)} \qquad (13)$$

F.3 Calculation of Losses due to modulation masks and out-of-band filtering

Relative losses due to TX modulation masks need to be integrated over the whole RX victim operational bandwidth. To do that, we have to consider three different cases:

- the mask is a constant value within the RX victim bandwidth, BW_{rx}, allocated at the defined frequency offset (F_{offset}):

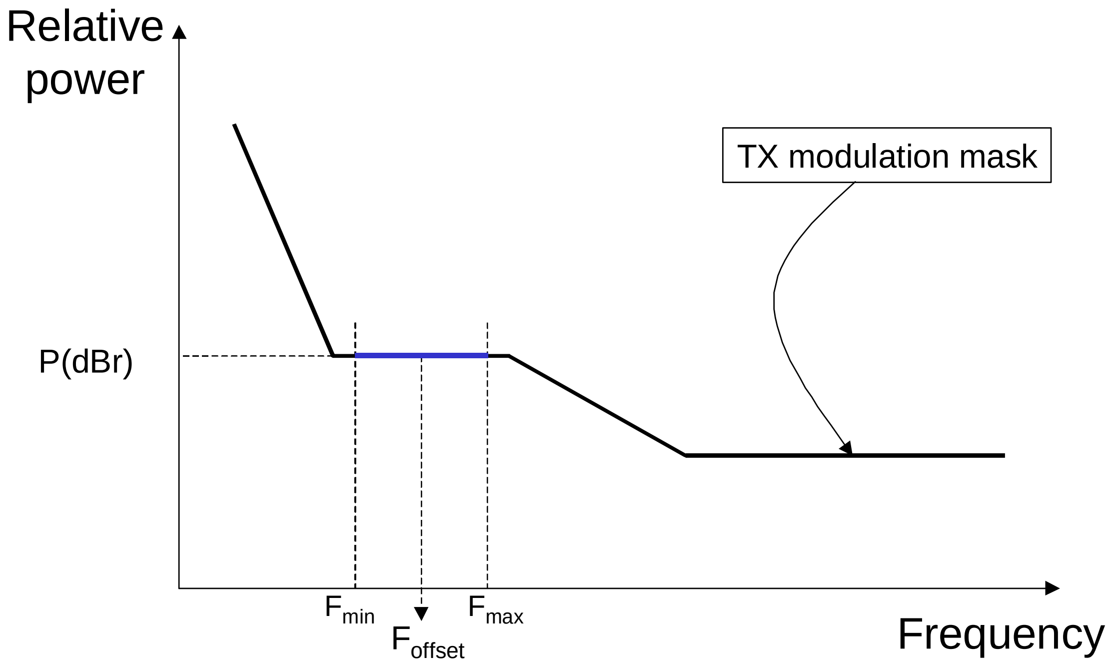

Figure F.1

In this case, calculation is simple, since the total relative noise floor power ($TX_{noise\text{-}floor}$) over the whole RX bandwidth, $BW_{rx} = F_{max}\text{-}F_{min}$, is:

$$TX'_{noise\text{-}floor} = 10^{(0,1P)} \text{ x } BW_{rx} / BW_{measure} \quad (14a)$$

Where:

$BW_{measure}$ = is the measurement bandwidth applied to modulation mask;

- the mask is falling linearly with frequency over the whole RX bandwidth.

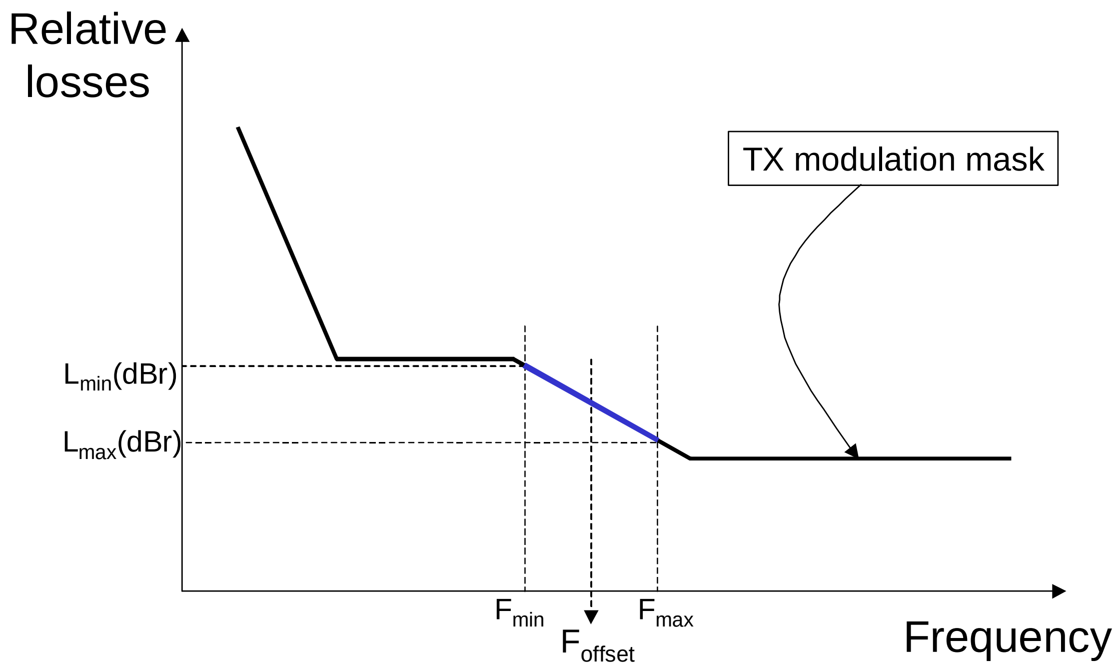

Figure F.2

In this case power integration is needed. In that case, after a simple mathematical integration we obtain:

$$TX'_{noise\text{-}floor} = (EXP(0,1 \times \ln10 \times P_{max}) - EXP(0,1 \times \ln10 \times P_{min}) / (BW_{measure} \times 0,1 \times \ln10 \times a) \quad (14b)$$

Where:

a = the slope of the mask line = $(P_{max} - P_{min}) / (F_{max} - F_{min})$

Obviously, the mixed case (constant and falling linearly) within the RX bandwidth is also possible (see figure F3). In that case a mixed formulae should be used.

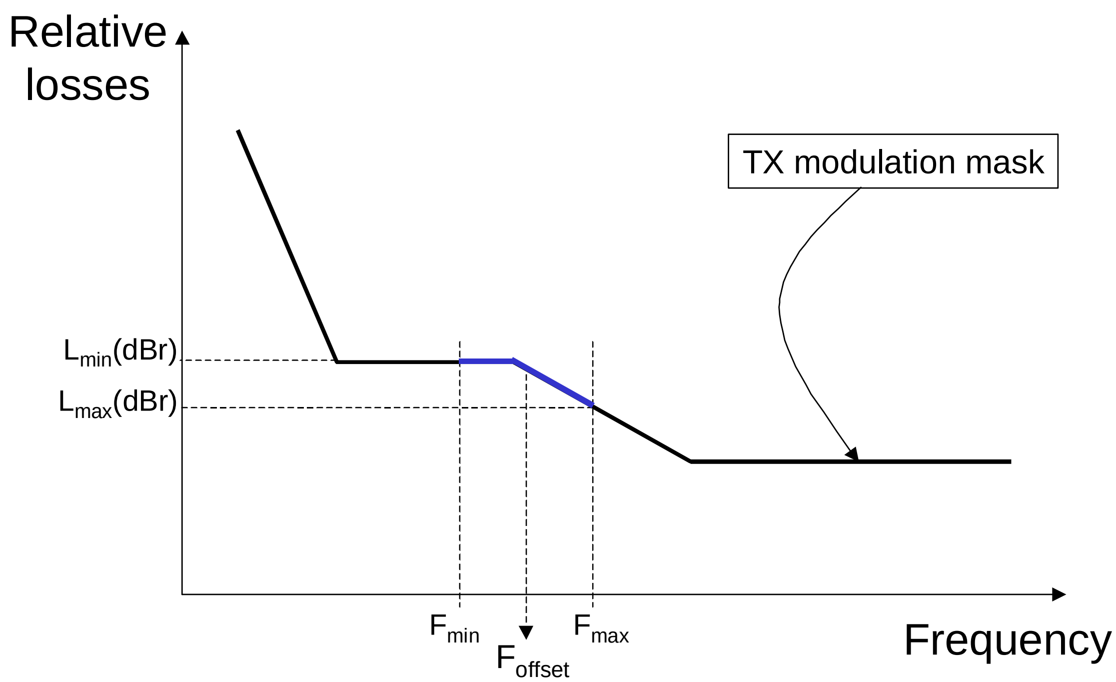

Figure F.3

Additionally, in order to provide the applicable losses due to modulation a correction factor of the TX bandwidth shall be applied. Since the resolution bandwidth for modulation mask, BW_{res}, is usually different than the real TX bandwidth, BW_{tx}, this correction factor is needed. Losses due to TX mask modulation mask, as used in the described methodology is given by:

$$L_{mask} = - TX_{noise\text{-}floor} + F_{BW} \qquad (15)$$

Where:

F_{BW} = TX bandwidth correction factor = 10 x log (BW_{tx} / BW_{res})

Finally, it should be considered that interfering system equipment often includes an in-band filter which to avoid emissions out-of-band. Since the effects of the interference is calculated in adjacent bands, it can be assumed that there is an extra attenuation in the interfering signal due to this "out-of-band" filter.

Since this filtering is usually out of specifications, here it is assumed a very simple bi-pole filter (to be consequent with the worst case analysis). In this case, and in order to simplify calculations the attenuation is not integrated over the whole RX bandwidth but only considered as an extra attenuation, calculated by simple interpolation of the filter mask, to be taken into account for the actual launched power as indicated in formula (2).

The used filter for calculation is shown in figure F.4 below, where it has been assumed a 25 MHz frequency block. The figures here used are pessimistic, being actual filters much better than below expressed.

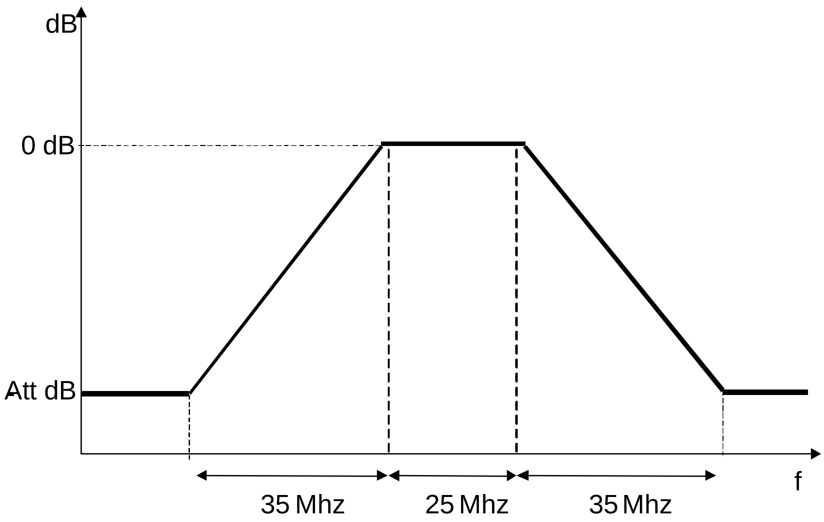

Figure F.4

F.4 Other Considerations

The systems taken into account in this analysis are those TDMA point-to-multipoint systems as defined in EN 301 021 [11] (both FDD and TDD based). In addition it is also analysed the interactions between these systems and the DECT standard within the 3,5 GHz band;

Obviously, all the systems considered in the analysis could include a set of mechanisms to avoid interference. These mechanisms have not been considered in the quantitative calculation performed. These mechanisms are Power Control, Frequency Hopping, Intracell and Intercell handover, Dynamic Channel Allocation, etc;

It should be remarked than there are not any interference probability analysis, which obviously should affect to the global conclusions;

As a main reference point for the analysis, it should be noted that the obtained quantitative values might be unrepresentative as an absolute value, especially because they are obtained in a worst case analysis with an extremely very low of probability of occurrence. However, relative comparison between scenarios could provide a very reliable information and sensibility about how different scenarios could work.

F.5 System Parameters and Analysed scenarios

It is not the aim of the present document to describe each analysed technology but only give the values of the parameters that have been used for calculation.

The main parameters are based on the EN 301 021 [11] standard. However there are a set of others than have been chosen based on typical deployments, that have been considered as "reference" values and which can provide a reliable results for comparison purposes.

The analysis will initially assume these "reference" values and any further sensitivity analysis would encompass other values within the range as appropriate for each specific scenario.

For example, the interference threshold "reference" value of 1 dB is chosen, however it could be within a range between 0,5 dB to 3 dB.

These are the chosen parameters for analysis:

Table F.3

	Parameter	Value for ETSI EN 301 021 system
P_{tx}	Maximum transmitter power	35 dBm
G_{tx} G_{rx}	Antenna isotropic gain	17 dBi (BS & TS)
$L_{feed-tx/rx}$ BS	Feeder losses for Base stations (BS)	1 dB
$L_{feed-tx/rx}$ TS	Feeder losses for Terminals (TS)	0 dB
$L_{beam-tx/rx}$ BS	Beam misalignment losses for BS	1 dB
$L_{beam-tx/rx}$ TS	Beam misalignment losses for TS	1,5 dB
	Modulation masks	ETSI EN 301 021 [11]
BW_{res}	Resolution bandwidth for TX mask	0,1 KHz
$BW_{measure}$	Measurement bandwidth for TX mask	30 KHz
(C/I)	Carrier to Interference ratio	13 dB
RX_{sens}	RX sensitivity	-90
F_{margin}	Fading Margin	10 dB
D	Rise in the Noise Floor	1 dB
$BW_{tx/rx}$	TX and RX carrier Bandwidth	1,75 MHz
	Frequency blocks width assumed	25 MHz (TDD) 25 MHz + 25 MHz (FDD)
	Duplex separation distance (for FDD systems)	100 MHz (FDD)

The following scenarios have been analysed:

1) FDD system based on EN 301 021 [11] with an adjacent FDD system based on EN 301 021 [11] (see figure F.5);

2) FDD system based on EN 301 021 [11] with an adjacent TDD system based on EN 301 021 [11]:

   a) when TDD is adjacent to the lower sub-band of the FDD system (see figure F.6);

   b) when TDD is adjacent to the upper sub-band of the FDD system (see figure F.7).

F.6 Calculation Assumptions

- frequency blocks of 25 MHz (TDD) or 25 MHz + 25 MHz (FDD) are assumed. When FDD it is assumed 100 MHz of Duplex separation;
- minimum distance between 1st (last) FDD carrier and low (high) band-edge for arbitrary sub-band within 3,5 GHz = (carrier BW) / 2 MHz;
- modulation masks are from EN 301 021 [11] standard;
- interference energy (from modulation mask) is integrated over the whole victim RX carrier bandwidth;
- C/I value for System based on EN 301 021 [11] is assumed equal to 13 dB;
- antenna gain, feeder losses and losses due to antenna beam un-alignment between TX and RX are assumed as indicated in table;
- maximum TX power as specified in EN 301 021 [11];
- worst case of LOS propagation for interfering signal is always assumed (slope of 20 dB/decade);
- a Fading Margin of 10 dB is always assumed;
- a rise in the noise floor of 1 dB is allowed (maximum could be up to 3 dB);
- a Filter Rejection has been assumed: 30 dB @ 35 MHz for the base, 10 dB @ 35 MHz for the terminal;
- 0 MHz of extra Guard Band has been considered for this scenario;
- receiver operates at sensitivity level.

Calculation Results Sheet

			Interfering System:	FDD type B; BW= 1,75 MHz				FDD type B; BW= 1,75 MHz			
			Interfered System:	FDD type B; BW= 1,75 MHz				FDD type B; BW= 1,75 MHz			
			Interfering device:	BS		TS		BS		TS	
			Interfered device:	BS	TS	BS	TS	BS	TS	BS	TS
Parameter		**Unit**	**Applied formula**								
Maximum Transmitted power	P_{tx}	dBm		35	35	35	35	35	35	35	35
TX Antenna Gain	G_{tx}	dB	$G_{tx}= G_{iso\text{-}tx}-L_{feed\text{-}tx}-L_{beam\text{-}tx}$	15	15	15,5	15,5	15	15	15,5	15,5
TX Isotropic antenna gain	$G_{iso\text{-}tx}$	dBi		17	17	17	17	17	17	17	17
TX Feeder losses	$L_{feed\text{-}tx}$	dB		1	1	0	0	1	1	0	0
TX Antennae beam un-alignment	$L_{beam\text{-}tx}$	dB		1	1	1,5	1,5	1	1	1,5	1,5
TX Total Modulation Mask Losses	L_{mask}	dB	$L_{mask}= F_{BW}-TX_{noise\text{-}floor}$	69,7	45,9	45,9	69,7	69,7	45,9	45,9	69,7
TX noise-floor over whole receiver bandwidth	$TX_{noise\text{-}floor}$	dBr		-27,3	-3,5	-3,5	-27,3	-27,3	-3,5	-3,5	-27,3
at centre frequency offset	F_{offset}	MHz		51,75	1,75	1,75	51,75	51,75	1,75	1,75	51,75
TX Bandwidth correction factor	F_{BW}	dB	$F_{BW}= 10\log(BW_{tx}/BW_{res})$	42,4	42,4	42,4	42,4	42,4	42,4	42,4	42,4
TX bandwidth	BW_{tx}	KHz		1750	1750	1750	1750	1750	1750	1750	1750
Resolution BW for mask	Bw_{res}	KHz		0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
C/I co-channel ratio	(C/I)	dB		13	13	13	13	13	13	13	13
Rise in the Noise Floor (Desentization)	D	dB		1	1	1	1	1	1	1	1
RX bandwidth	BW_{rx}	MHz		1,75	1,75	1,75	1,75	1,75	1,75	1,75	1,75
RX sensitivity (for BER= 10^{-3})	RX_{sens}	dBm		-90	-90	-90	-90	-90	-90	-90	-90
RX Antenna Gain	G_{rx}	dB	$G_{rx}= G_{iso\text{-}rx}-L_{feed\text{-}rx}-L_{beam\text{-}rx}$	15	15,5	15	15,5	15	15,5	15	15,5
RX Isotropic antenna gain	$G_{iso\text{-}rx}$	dBi		17	17	17	17	17	17	17	17
RX Feeder losses	$L_{feed\text{-}rx}$	dB		1	0	1	0	1	0	1	0
RX Antennae beam un-alignment	$L_{beam\text{-}rx}$	dB		1	1,5	1	1,5	1	1,5	1	1,5
Fading Margin	F_{margin}	dB		10	10	10	10	10	10	10	10
Maximum allowed External Interference	$I_{ext\text{-}max}$	dBm	$I_{ext\text{-}max}= RX_{sens}-(C/I)+ 10\log(10^{(D/10)}-1)$	-108,9	-108,9	-108,9	-108,9	-108,9	-108,9	-108,9	-108,9
Maximum transmitted interference	P_L	dBm	$P_L= P_{tx}+ G_{tx}-L_{mask}-L_{ext\text{-}tx}$	-49,7	3,3	4,3	-29,2	-49,7	3,3	4,3	-29,2
Extra attenuation for TX out-of-band filtering	$L_{ext\text{-}tx}$	dB		30	0,8	0,3	10	30	0,8	0,3	10
Maximum allowed interference at RX	P_R	dBm	$P_R= I_{ext\text{-}max}-G_{rx}+ F_{margin}$	-113,9	-114,4	-113,9	-114,4	-113,9	-114,4	-113,9	-114,4
Required air propagation Losses (LOS)	L	dB	$L= P_L-P_R= 43,3+ 20\log(d)$	64,2	117,7	118,2	85,2	64,2	117,7	118,2	85,2
Minimum separation distance	**d**	**m**	$d= 10^{((L-43,3)/20)}$	**11**	**5248**	**5559**	**124**	**11**	**5248**	**5559**	**124**

Calculation Assumptions

Frequency blocks of 25MHz (TDD) or 25+ 25MHz(FDD) are assumed. When FDD it is assumed 100 MHz of Duplex separation

Minimum distance between 1st (last) FDD carrier and low (high) band-edge for arbitrary subband within 3,5 GHz = (carrier BW)/2 MHz

Modulation masks are from EN 301 021standards

Interfence energy (from modulation mask) is integrated over the whole vctim RX carrier bandwidth

C/I value for System based on EN 301 021 is assumed equal to 13 dB

Antenna gain, feeder losses and losses due to antenna beam un-alignment bettween TX and RX are assumed as indicated in table

Maximum TX power as specified in EN 310 021 standard

Worst case of LOS propagation for interfering signal is always assumed (slope of 20 dB/decade)

A Fading Margin of 10 dB is always assumed

A rise in the noise floor of 1 dB is allowed (maximum could be up to 3 dB)

A Filter Rejection has been assumed (See extra attenuation due to Out-of-band filtering at TX)

0 MHz of extra Guard Band has been considered for this scenario

Figure F.5: FDD system is adjacent to FDD band

Calculation Results Sheet

TDD SYSTEM IS ADJACENT TO LOWER FDD SUB-BAND

Parameter		Unit	Applied formula								
			Interfering System:	FDD type B; BW= 1,75 MHz				TDD type B; BW= 1,75 MHz			
			Interfered System:	TDD type B; BW= 1,75 MHz				FDD type B; BW= 1,75 MHz			
			Interfering device:	BS		TS		BS		TS	
			Interfered device:	BS	TS	BS	TS	BS	TS	BS	TS
Maximum Transmitted power	P_{tx}	dBm		35	35	35	35	35	35	35	35
TX Antenna Gain	G_{tx}	dB	$G_{tx}= G_{iso-tx}-L_{feed-tx}-L_{beam-tx}$	15	15	15,5	15,5	15	15	15,5	15,5
TX Isotropic antenna gain	G_{iso-tx}	dBi		17	17	17	17	17	17	17	17
TX Feeder losses	$L_{feed-tx}$	dB		1	1	0	0	1	1	0	0
TX Antennae beam un-alignment	$L_{beam-tx}$	dB		1	1	1,5	1,5	1	1	1,5	1,5
TX Total Modulation Mask Losses	L_{mask}	dB	$L_{mask}= F_{BW}-TX_{noise-floor}$	69,7	69,7	45,9	45,9	45,9	69,7	45,9	69,7
TX noise-floor over whole receiver bandwidth	$TX_{noise-floor}$	dBr		-27,3	-27,3	-3,5	-3,5	-3,5	-27,3	-3,5	-27,3
at centre frequency offset	F_{offset}	MHz		51,75	51,75	1,75	1,75	1,75	51,75	1,75	51,75
TX Bandwidth correction factor	F_{BW}	dB	$F_{BW}= 10\log(BW_{tx}/BW_{res})$	42,4	42,4	42,4	42,4	42,4	42,4	42,4	42,4
TX bandwidth	BW_{tx}	KHz		1750	1750	1750	1750	1750	1750	1750	1750
Resolution BW for mask	Bw_{res}	KHz		0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
C/I co-channel ratio	(C/I)	dB		13	13	13	13	13	13	13	13
Rise in the Noise Floor (Desentization)	D	dB		1	1	1	1	1	1	1	1
RX bandwidth	BW_{rx}	MHz		1,75	1,75	1,75	1,75	1,75	1,75	1,75	1,75
RX sensitivity (for BER= 10^{-3})	RX_{sens}	dBm		-90	-90	-90	-90	-90	-90	-90	-90
RX Antenna Gain	G_{rx}	dB	$G_{rx}= G_{iso-rx}-L_{feed-rx}-L_{beam-rx}$	15	15,5	15	15,5	15	15,5	15	15,5
RX Isotropic antenna gain	G_{iso-rx}	dBi		17	17	17	17	17	17	17	17
RX Feeder losses	$L_{feed-rx}$	dB		1	0	1	0	1	0	1	0
RX Antennae beam un-alignment	$L_{beam-rx}$	dB		1	1,5	1	1,5	1	1,5	1	1,5
Fading Margin	F_{margin}	dB		10	10	10	10	10	10	10	10
Maximum allowed External Interference	$I_{ext-max}$	dBm	$I_{ext-max}= RX_{sens}-(C/I)+ 10\log(10^{(D/10)}-1)$	-108,9	-108,9	-108,9	-108,9	-108,9	-108,9	-108,9	-108,9
Maximum transmitted interference	P_L	dBm	$P_L= P_{tx}+ G_{tx}-L_{mask}-L_{ext-tx}$	-49,7	-49,7	4,3	4,3	3,3	-49,7	4,3	-29,2
Extra attenuation for TX out-of-band filtering	L_{ext-tx}	dB		30	30	0,3	0,3	0,8	30	0,3	10
Maximum allowed interference at RX	P_R	dBm	$P_R= I_{ext-max}-G_{rx}+ F_{margin}$	-113,9	-114,4	-113,9	-114,4	-113,9	-114,4	-113,9	-114,4
Required air propagation Losses (LOS)	L	dB	$L= P_L-P_R= 43,3+ 20\log(d)$	64,2	64,7	118,2	118,7	117,2	64,7	118,2	85,2
Minimum separation distance	**d**	**m**	$d= 10^{((L-43,3)/20)}$	**11**	**12**	**5559**	**5888**	**4955**	**12**	**5559**	**124**

Calculation Assumptions

Frequency blocks of 25MHz (TDD) or 25+ 25MHz(FDD) are assumed. When FDD it is assumed 100 MHz of Duplex separation

Minimum distance between 1st (last) FDD carrier and low (high) band-edge for arbitrary subband within 3,5 GHz = (carrier BW)/2 MHz

Modulation masks are from EN 301 021standards

Interfence energy (from modulation mask) is integrated over the whole vctim RX carrier bandwidth

C/I value for System based on EN 301 021 is assumed equal to 13 dB

Antenna gain, feeder losses and losses due to antenna beam un-alignment bettween TX and RX are assumed as indicated in table

Maximum TX power as specified in EN 310 021 standard

Worst case of LOS propagation for interfering signal is always assumed (slope of 20 dB/decade)

A Fading Margin of 10 dB is always assumed

A rise in the noise floor of 1 dB is allowed (maximum could be up to 3 dB)

A Filter Rejection has been assumed (See extra attenuation due to Out-of-band filtering at TX)

0 MHz of extra Guard Band has been considered for this scenario

Figure F.6: TDD system is adjacent to lower FDD sub-band

Calculation Results Sheet

TDD SYSTEM IS ADJACENT TO UPPER FDD SUB-BAND

Parameter		Unit	Applied formula								
			Interfering System:	FDD type B; BW= 1,75 MHz				TDD type B; BW= 1,75 MHz			
			Interfered System:	TDD type B; BW= 1,75 MHz				FDD type B; BW= 1,75 MHz			
			Interfering device:	BS		TS		BS		TS	
			Interfered device:	BS	TS	BS	TS	BS	TS	BS	TS
Maximum Transmitted power	P_{tx}	dBm		35	35	35	35	35	35	35	35
TX Antenna Gain	G_{tx}	dB	$G_{tx}= G_{iso\text{-}tx}\text{-}L_{feed\text{-}tx}\text{-}L_{beam\text{-}tx}$	15	15	15,5	15,5	15	15	15,5	15,5
TX Isotropic antenna gain	$G_{iso\text{-}tx}$	dBi		17	17	17	17	17	17	17	17
TX Feeder losses	$L_{feed\text{-}tx}$	dB		1	1	0	0	1	1	0	0
TX Antennae beam un-alignment	$L_{beam\text{-}tx}$	dB		1	1	1,5	1,5	1	1	1,5	1,5
TX Total Modulation Mask Losses	L_{mask}	dB	$L_{mask}= F_{BW}\text{-}TX_{noise\text{-}floor}$	45,9	45,9	69,7	69,7	69,7	45,9	69,7	45,9
TX noise-floor over whole receiver bandwidth	$TX_{noise\text{-}floor}$	dBr		-3,5	-3,5	-27,3	-27,3	-27,3	-3,5	-27,3	-3,5
at centre frequency offset	F_{offset}	MHz		1,75	1,75	51,75	51,75	51,75	1,75	51,75	1,75
TX Bandwidth correction factor	F_{BW}	dB	$F_{BW}= 10\log(BW_{tx}/BW_{res})$	42,4	42,4	42,4	42,4	42,4	42,4	42,4	42,4
TX bandwidth	BW_{tx}	KHz		1750	1750	1750	1750	1750	1750	1750	1750
Resolution BW for mask	Bw_{res}	KHz		0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
C/I co-channel ratio	(C/I)	dB		13	13	13	13	13	13	13	13
Rise in the Noise Floor (Desentization)	D	dB		1	1	1	1	1	1	1	1
RX bandwidth	BW_{rx}	MHz		1,75	1,75	1,75	1,75	1,75	1,75	1,75	1,75
RX sensitivity (for BER= 10^{-3})	RX_{sens}	dBm		-90	-90	-90	-90	-90	-90	-90	-90
RX Antenna Gain	G_{rx}	dB	$G_{rx}= G_{iso\text{-}rx}\text{-}L_{feed\text{-}rx}\text{-}L_{beam\text{-}rx}$	15	15,5	15	15,5	15	15,5	15	15,5
RX Isotropic antenna gain	$G_{iso\text{-}rx}$	dBi		17	17	17	17	17	17	17	17
RX Feeder losses	$L_{feed\text{-}rx}$	dB		1	0	1	0	1	0	1	0
RX Antennae beam un-alignment	$L_{beam\text{-}rx}$	dB		1	1,5	1	1,5	1	1,5	1	1,5
Fading Margin	F_{margin}	dB		10	10	10	10	10	10	10	10
Maximum allowed External Interference	$I_{ext\text{-}max}$	dBm	$I_{ext\text{-}max}= RX_{sens}\text{-}(C/I)+ 10\log(10^{(D/10)}\text{-}1)$	-108,9	-108,9	-108,9	-108,9	-108,9	-108,9	-108,9	-108,9
Maximum transmitted interference	P_L	dBm	$P_L= P_{tx}+ G_{tx}\text{-}L_{mask}\text{-}L_{ext\text{-}tx}$	3,3	3,3	-29,2	-29,2	-49,7	3,3	-29,2	4,3
Extra attenuation for TX out-of-band filtering	$L_{ext\text{-}tx}$	dB		0,8	0,8	10	10	30	0,8	10	0,3
Maximum allowed interference at RX	P_R	dBm	$P_R= I_{ext\text{-}max}\text{-}G_{rx}+ F_{margin}$	-113,9	-114,4	-113,9	-114,4	-113,9	-114,4	-113,9	-114,4
Required air propagation Losses (LOS)	L	dB	$L= P_L\text{-}P_R= 43,3+ 20\log(d)$	117,2	117,7	84,7	85,2	64,2	117,7	84,7	118,7
Minimum separation distance	**d**	**m**	$d= 10^{((L-43,3)/20)}$	**4955**	**5248**	**117**	**124**	**11**	**5248**	**117**	**5888**

Calculation Assumptions

Frequency blocks of 25MHz (TDD) or 25+ 25MHz(FDD) are assumed. When FDD it is assumed 100 MHz of Duplex separation
Minimum distance between 1st (last) FDD carrier and low (high) band-edge for arbitrary subband within 3,5 GHz = (carrier BW)/2 MHz
Modulation masks are from EN 301 021standards
Interfence energy (from modulation mask) is integrated over the whole vctim RX carrier bandwidth
C/I value for System based on EN 301 021 is assumed equal to 13 dB
Antenna gain, feeder losses and losses due to antenna beam un-alignment bettween TX and RX are assumed as indicated in table
Maximum TX power as specified in EN 310 021 standard
Worst case of LOS propagation for interfering signal is always assumed (slope of 20 dB/decade)
A Fading Margin of 10 dB is always assumed
A rise in the noise floor of 1 dB is allowed (maximum could be up to 3 dB)
A Filter Rejection has been assumed (See extra attenuation due to Out-of-band filtering at TX)
0 MHz of extra Guard Band has been considered for this scenario

Figure F.7: TDD system is adjacent to upper FDD sub-band

F.7 Quantitative conclusions

For the FDD/FDD case, all devices from both FDD systems are affected by interference, and generate it.

For the lower band FDD/TDD scenario, the FDD terminals interfere with both terminals and base stations of the TDD system, but the FDD base stations do not produce significant interference. The TDD system interferes significantly only the FDD base stations.

For the upper band FDD/TDD scenario, the FDD base stations interfere with both terminals and base stations of the TDD system, but the FDD terminals do not produce significant interference. The TDD system interferes significantly only the FDD terminals.

It seems, then, that the FDD/TDD scenario may be better in terms of interference than the FDD/FDD one.

This clearly shows that TDD/FDD mixed scenarios do not present worse interference behaviour than FDD/FDD mixed scenarios.

History

Document history		
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