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Technical Report

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Feasibility Study considering the viable deployment of UTRA in additional and diverse spectrum arrangements
(Release 6)

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3GPP

Postal address

3GPP support office address

650 Route des Lucioles - Sophia Antipolis
Valbonne - FRANCE
Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Internet

http://www.3gpp.org

Contents

Foreword

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Introduction

This clause is optional. If it exists, it is always the second unnumbered clause.

1 Scope

The present document summarises results from the Study Item “Feasibility Study considering the viable deployment of UTRA in additional and diverse spectrum arrangements”. Both UTRA FDD and UTRA TDD are considered. For UTRA FDD, the spectrum arrangements include the present FDD frequency bands as defined in Release 5 of the relevant 3GPP specifications as well as the additional bands identified for IMT-2000 by ITU-R WRC-2000, in particular the band 2500-2690 MHz. For UTRA TDD, the study focuses on the use of the additional band 2500-2690 MHz.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[<seq>] <doctype> <#>[([up to and including]{yyyy[-mm]|V<a[.b[.c]]>}[onwards])]: "<Title>".

[1] 3GPP TR 41.001: "GSM Release specifications".

[2] 3GPP TR 21 912 (V3.1.0): "Example 2, using fixed text".

[3] ITU-R 8F/623, “REPORT OF THE SEVENTH MEETING OF WORKING PARTY 8F (Queenstown, 27 February – 5 March 2002)”; ATTACHMENT 7.2, “Working document on preferred options for frequency arrangements for IMT-2000 systems in bands identified by WARC-92 and WRC-2000 (Revision to Att. 8.2 of Doc. 8F/489)”

[4] 3GPP TS 25.331 v 3.9.0 (2001-12)“Radio Resource Control (RRC); Protocol Specification (Release 1999)”

[5] R2-011087 Proposed CR 776 on Missing UARFCN uplink info, Nokia.

[6] R2-011511 Approved Report of the 21st TSG-RAN WG2 meeting, Secretary.

[7] 3GPP TS 25.101 v 3.9.0 (2001-12) “UE Radio Transmission and Reception (FDD) (Release 1999)”

[8] 3GPP TS 25.104 v 3.9.0 (2001-12) “UTRA (BS) FDD; Radio transmission and Reception (Release 1999)”

[9] 3GPP TR 25.931 V3.6.0 (2002-03), “3rd Generation Partnership Project; Technical Specification Group RAN; UTRAN Functions, Examples on Signalling Procedures (Release 1999).

[10] UMTS Forum Report #9: “The UMTS Third Generation Market – Structuring the Service Revenues Opportunities”

[11] UMTS Forum Report #13: “The UMTS Third Generation Market – Phase II, Structuring the Service Revenues Opportunities”

[12] SAG 34/4, 12-14 Sept 2001

[13] SAG 35/2, 3-5 Dec 2001

[14] UMTS Forum SAG Doc SAG 36/3, 11-12 April 2002

[15] Holma, Toskala, ”WCDMA for UMTS”, Wiley

[16] Wacker, Laiho, Novosad, “Radio Network Planning and Optimisation for UMTS”, Wiley

3 Definitions, symbols and abbreviations

Delete from the above heading those words which are not applicable.

Subclause numbering depends on applicability and should be renumbered accordingly.

3.1 Definitions

For the purposes of the present document, the [following] terms and definitions [given in ... and the following] apply.

Definition format

<defined term>*: <definition>.*

example: text used to clarify abstract rules by applying them literally.

3.2 Symbols

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

Symbol format

<symbol> <Explanation>

3.3 Abbreviations

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

Abbreviation format

<ACRONYM> <Explanation>

4 Background and Introduction

The present 3GPP specifications cover the IMT-2000 2 GHz band (Band I and II), in accordance with ITU-R Radio Regulations Article S5 Footnote S5.388, in R99 and Rel4 and the work is continuing with the UMTS1900 Band II improvements and UMTS 1800 Band III.

ITU-R WRC-2000 identified additional extension bands for IMT-2000 that requires further studies for the subsequent future deployment of UTRA in the whole or parts of the bands as indicated below:

- 806 - 960 MHz (The whole band 806 - 960 MHz is not identified on a global basis for IMT-2000 due to variation in the primary Mobile Service allocation across the three ITU Regions)
- 1710 - 1885 MHz, where the work is progressing under UMTS1800 WI.
- 2500 - 2690 MHz (In ITU Region 1 the bands 2500 - 2520 MHz and 2670 - 2690 MHz is also allocated on a co-primary basis to the Mobile Satellite Service subject to market demand)

4.1 Scope and Objective of work

4.1.1 General considerations

The viable deployment of both UTRA modes FDD and TDD in additional and diverse spectrum arrangements should be assessed. Due to the difference in their duplex scheme, these modes have unequal intrinsic characteristics. It seems therefore appropriate to treat both UTRA modes separately from each other.

For the purpose of this feasibility study, it is assumed that additional spectrum, and in particular the frequency band 2500-2690 MHz, will be used exclusively by either UTRA FDD or UTRA TDD, respectively. Thus, co-existence between UTRA FDD and UTRA TDD is not considered, and corresponding compatibility studies between these modes are not considered in this report. It is however acknowledged that the combination of FDD and TDD in new bands is a valid option, as already discussed in ITU-R WP 8F.

4.1.2 UTRA FDD

In case of UTRA FDD, the assessment includes

- Duplex spacing arrangements other than for Bands I, II and III.
- Arbitrary selectable or variable duplex spacing methods.
- Use of asymmetric spectrum arrangements considering the need for additional downlink traffic capacity
- Impacts on equipment performance requirements due to new frequency bands and operating bandwidths.
- Terminal capabilities and signalling
- Possible interface impacts

Spectrum bands to study in an initial phase are

Present bands:

- 1920 - 1980 MHz paired with 2110 – 2170 MHz Band I (core band)
- 1850 - 1910 MHz paired with 1930 – 1990 MHz Band II (PCS1900 band)
- 1710 - 1785 MHz paired with 1805 – 1880 MHz Band III (GSM1800 band)

Implementations to study for new bands and combinations of bands:

1) 1710 - 1770 MHz paired with 2110 - 2170 MHz

2a) 1710 - 1800 MHz paired with 2110 - 2200 MHz

2b) 1920 - 2010 MHz paired with 2110 - 2200 MHz

3) 1755 - [1805] MHz paired with 2110 - [2160] MHz

4) 1710 - [1755] MHz paired with 1805 – [1850] MHz

5) 2500 - 2690 MHz:

(Alt A) Entire band as additional DL to other bands used for technologies within scope & objective of 3GPP.

(Alt B) DL and UL in this band.

(Alt C) DL and UL in this band, and additional DL to other bands used for technologies within scope & objective of 3GPP.

The technology study should describe a possible technical implementation of a Variable Duplex technology (VDT)solution to satisfy the addressed new spectrum arrangements but also considering the existing spectrum arrangements. Enabling technologies for operating of UTRA FDD in the new bands are examined in clause 6. Examples for viable implementations of spectrum arrangements for UTRA FDD are described in clause 7.

4.1.3 UTRA TDD

In case of UTRA TDD, the same frequency channel is used sequentially for transmission in the uplink and downlink direction. Therefore, the duplex arrangement is independent of the spectrum arrangement. Other technical issues and assessments to consider are:

- Impacts on equipment performance requirements due to new frequency bands and operating bandwidths.
- Terminal capabilities and signalling.
- Possible interface impacts.

4.1.4 Caveat/Notice

The information in this TR is partly based on text from RAN4 meeting documents that also contained information in areas outside of the RAN4 mandate. Examples are paragraphs containing information on how the split of uplink versus downlink traffic will develop with time, as well as suggestions on how to develop a specification assuming certain decisions are taken in e.g. regulatory bodies on how the new spectrum is to be used. As this information is useful in helping understanding of the technical feasibility assessment and related conclusions in these sections, this information has been kept. RAN4 has refrained from discussing the text parts outside of its mandate for this TR, and thus conclusions should not be drawn from these parts.

The part related to the technical feasibility, and especially the text in the conclusion clause, have been agreed by RAN WG4.

5 Description of the spectrum arrangements

Document 8F/623 [3] lists several options for paired and unpaired frequency arrangements for IMT-2000 systems in bands identified by WARC-92 and WRC-2000.

For UTRA FDD, the options for paired frequency arrangements are applicable. Table 1 provides a selection of these options and additionally proposes some further opportunities based on VDT.

Table 1: FDD Frequency Arrangements

Arrangements	UE Tx (MHz)	Duplex Centre Gap (MHz)	BS Tx (MHz)	Duplex separation (MHz)	Remarks
Band I	1920 - 1980	130	2110 - 2170	190	Option 1 in 6.1.2 and [3]
Band II	1850 – 1910	20	1930 - 1990	80	Option 3 in 6.1.2 and [3]
Band III	1710 - 1785	20	1805 - 1880	95	Option 2 in 6.1.2 and [3]
(*)	1710 – 1755	50	1805 - 1850	95	
(*)	1755 – 1805	305	2110 - 2160	355	Option 4 in 6.1.2 and [3]
(*)	1710 - 1770	240	2110 - 2170	400	Option 5 in 6.1.2 and [3]
(*)	1920 - 1980	520	2500 - 2690	Variable	
(*)	1850 – 1910	590	2500 - 2690	Variable	
(*)	1710 - 1785	715	2500 - 2690	Variable	
(*)	1710 -1770	730	2500 - 2690	Variable	
(**)	2500 (2520) - x	y≥20	z – (2670) 2690	Variable	x, y and z to be defined
(**)	z – (2670) 2690	y≥20	2500 (2520) - x	Variable	x, y and z to be defined. (Reversed duplex direction)

Note 1: Combination of Bands (*) and Bands (**) may be required to be considered in the future work.

Note 2: ITU-R Resolution 225 from the World Radio Communication Conference 2000 (WRC-2000) states that the bands 2500 - 2520 MHz and 2670 - 2690 MHz (as identified for IMT-2000 in the footnote S5.384A of the RR, and allocated to the mobile-satellite service (MSS)) may be used for the satellite component of IMT-2000. However, depending on market developments it may be possible in the longer term for bands 2500 - 2520 MHz and 2670 - 2690 MHz to be used by the terrestrial component of IMT-2000.

For UTRA TDD, the options for unpaired frequency arrangements are applicable. For the purpose of the present study, however, the only option of consideration is the use of UTRA TDD in the new band 2500-2690 MHz.

Although some of the general trends of traffic and spectrum development may be understood, there is still considerable uncertainty on the detailed market development. Therefore, regulators will decide on the use of additional spectrum for UMTS not until actual market demand will become clearer. CEPT ECC, for example, has stated in its Draft Decision on the designation of frequency band 2500 – 2690 MHz for UMTS/IMT-2000 [ECC/DEC/(02)FF], that the “detailed spectrum arrangements for the band 2500-2690 MHz will be decided by the end of year 2004”. Furthermore, the draft states that “the frequency band 2500 – 2690 MHz should be made available for use by UMTS/IMT-2000 systems by 1 January 2008, subject to market demand and national licensing schemes”.

6 Enabling technologies for operation of UTRA FDD in the new bands

6.1 Solutions for implementing variable duplex separation in one terminal

Enabling terminals to operate with a variable duplex separation will facilitate roaming between different countries or regions. In addition, for operators with multiple band pairings, such terminals will be able to handoff from one band to another.

It is to be noted that, at this stage, the variable duplex separation may be understood as a variable duplex separation on a frequency block basis or a variable duplex separation on a frequency channel basis. Both are already supported by channel numbering and frequency band concept in 3GPP specifications. There are aspects on signalling and control of the UE, and hardware impact, which are shown in the following sub-chapters.

6.1.1 Status in 3GPP specifications for accommodating variable duplex separation in one terminal

Several technical specifications allow the possibility of accommodating variable duplex separation in one terminal. Mainly affected are the specifications in RAN WG2 regarding the signalling and RAN WG4 regarding the Radio Transmission and Reception, but also test specifications in TSG-T1.

6.1.1.1 Signalling and control of the UE (RAN2)

Affected specifications in RAN WG2 are TS 25.306 and TS 25.331. TS 25.306 specify the UE capabilities, which includes supported frequency bands and Tx/Rx frequency separation. TS 25.331 specify the UE signalling and some UE behaviour related to random access and utilisation of the common channels. For the signalling two main cases are seen; signalling related to a UE using common channels and signalling related to a UE using dedicated channels.

6.1.1.1.1 Common channel aspects

In Rel’99, Rel-4 and Rel-5 when a UE sends its first access to a UMTS network, the UE will after it has found a cell on a certain downlink frequency, read the system information sent in that cell. This system information will give the channel parameters for the uplink random access channel in system information block (SIB) number 5 (see TS 25.331 [4] section 8.1.1.6.5). SIB 5 contain all configuration for common channels, both uplink and downlink. It should be noted that uplink frequency or duplex spacing is not included in the random access channel parameters. The UE will then send an access attempt on an uplink frequency that is according to the default duplex of the downlink frequency that the UE have selected and have been using to read system information (see TS 25.331 [4] section 8.5.17). This means that for 2100 MHz the uplink frequency will be 190 MHz below the downlink, for 1900 MHz the uplink will be 80 MHz below the downlink and for 1800 the uplink will be 95 MHz below the downlink.

Since a Rel'99, Rel-4 and Rel-5 UE always assumes that the uplink frequency is according to the default duplex distance, there is a risk that the UE transmits on an uplink frequency that is erroneous according to the assigned band. This could be a problem in option 1, 2a and 3 according to section 4.1 if default duplex is used or in any option (including also the core band) if the network only supports a non default duplex. Solutions to this potential problem were discussed at 3GPP RAN2 meeting #21 related to document R2-011087 [5]. The discussions are captured in the minutes in R2-011511 [6].

The solution that was discussed could in short be described as; that SIB 5 should only be used in networks where the default duplex distance is used and with the 2100, 1900 or 1800 MHz bands . In a network where another duplex distance or a new band allocation is used, a new SIB 5 should be introduced, "SIB 5 bis". This "SIB 5 bis" should be sent instead of the Rel'99, Rel-4 or Rel-5 SIB 5 and may then also contain the uplink frequency or an indication of the non default duplex distance.

According to the current specifications a Rel'99, Rel-4 or Rel-5 UE that enters a network (e.g. cell) that do not send SIB 5 will be barred from access (see TS 25.331 [4] section 8.1.1.5). The UE will not be able to transmit on the uplink neither for normal access nor emergency calls. This is also the desired behaviour since, the UE do not have the correct frequency support .

The result of sending "SIB 5 bis" will be that only UEs that understand this new SIB and have the correct frequency support can access that network. This could be captured in a future Release of the 3GPP specifications when the new frequency bands or duplex distances are introduced for common channels.

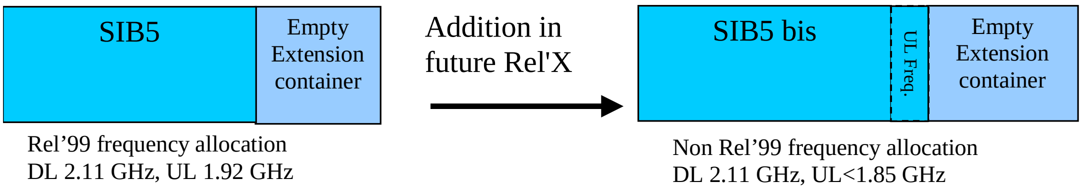


Figure 1. Possible solution in RAN2 specifications for accommodating several band pairings in one terminal.

6.1.1.1.2 Dedicated channel aspects

For dedicated channels UTRAN is in control of what frequencies the UE shall use, both for uplink and downlink. When the UE is moved from one frequency to another, signalling includes the downlink frequency and in case a non default duplex is to be used also the uplink frequency is included (see TS 25.331 [4] section 10.3.6.36). This means that the current Rel’99, Rel-4 and Rel-5 specifications support variable duplex distance or any of the new frequency allocations described in section 4.

However, in order for UTRAN to only signal a frequency allocation that is supported by the UE, capabilities need to be extended with new frequency bands and duplex spacing configurations.

6.1.1.1.3 UE capability aspects

The RF capabilities are specified in TS 25.306. These UE capabilities are sent to UTRAN during the initial RRC signalling. Alternatively if the UE does an access via e.g. GSM the capabilities are sent over the GSM air interface and transferred to UTRAN at the GSM to UMTS handover in a network container.

The RF capabilities are necessary for UTRAN to be able to know in advance which bands and duplex spacing that the UE supports prior to assignment of frequencies on a dedicated channel.

In Rel’99 and Rel-4 signalling specifications the UE is able to indicate support of the core bands 2100 MHz and the additional band 1900 MHz. It is also possible to indicate a duplex distance support that is only the default 190 MHz, 174.8 to 205.2 MHz or 134.8 to 245.2 MHz.

In Rel-5 signalling specifications the UE is able to indicate support of the 2100, 1900 and 1800 MHz bands.

In addition, a UE that is of one release (Rel’99 or Rel-4) can indicate support of additional frequency bands as specified in 25.307 “Requirements on UEs supporting a Release Independent Frequency Band” for that release. So with this addition it is possible for a Rel’99 or Rel-4 UE to also indicate support of the 1800 MHz band (or if extended any new future bands).

6.1.1.1.4 Signalling summary

The following table summarises the status on signalling support in the Rel'99, Rel-4 and Rel-5 specifications for the existing bands.

Table 2: Summary of signalling aspects for existing bands

Signalling aspect	Band I (2100 MHz)	Band II (1900 MHz)	Band III (1800 MHz)
Common channels Rel'99, Rel-4, Rel-5	Duplex distance = 190 MHz	Duplex distance = 80 MHz	Duplex distance = 95 MHz
Common channels with a SIB 5 bis	Duplex distance flexible	Duplex distance flexible	Duplex distance flexible
Dedicated channels Rel'99, Rel-4, Rel-5	Duplex distance flexible	Duplex distance flexible	Duplex distance flexible
UE Capability Rel'99, Rel-4	Signalling supported	Signalling supported (Note 1)	Signalling supported only with additions according to TS 25.307 (Note 1)
UE Capability Rel-5	Signalling supported	Signalling supported (Note 1)	Signalling supported (Note 1)

Note 1. Signalling is currently not complete when it comes to signalling of degree of UE support of variable Tx/Rx frequency separation for 1800 and 1900.

6.1.1.2 Frequency bands and hardware issues (RAN4)

6.1.1.2.1 Frequency bands

In TS 25.101 [7] (see section 5.3) the TX-RX frequency separation is specified for fixed separation of 190 MHz and 80 MHz depending on the frequency band. Further it states that UTRA/FDD can support both fixed and variable transmit to receive frequency separation. And it also states that the use of other transmit to receive frequency separations in existing or other frequency bands shall not be precluded. Similar text can be found in TS 25.104 [8] regarding the Base Station.

When other frequency arrangements are introduced in 3GPP this section would be updated to list the TX-RX frequency separation for those frequency arrangements. Depending on the frequency arrangements there would also be other additions to RAN WG4 specifications, including that section 5.2 in 3GPP TS 25.101 [7] would be expanded by the relevant frequency bands.

The number of bands implemented in the UE is left to the manufacturers in agreement with operator partners.

6.1.1.2.2 RF performance

The impact to RF performance, firstly sensitivity, transmitter power and current drain, and secondly additional interference requirements, may require a change in the specifications. The variety of band combinations and the need for non-compressed as well as compressed mode terminals leads to a high number of possibilities that must be taken into account. It must be considered that RF performance specifications may be negatively affected, especially as the complexity in modes/bands increases.

It is therefore recommended to further study Rx and Tx RF performance before specifications can be finalised for UEs supporting multiple duplex spacings.

6.1.2 Examples of Implementation of variable duplex separation in one terminal

The Table 1 in chapter 5 lists several band paring options in 1710 – 2200 MHz.

The UMTS core band is according to option 1 with 190 MHz fixed duplex separation as specified in 3GPP. Since not all options will be available in every region there will be a need to support more than one option in one terminal if global roaming is envisaged. Based on the assumption that the UMTS core band will be used in several regions and will be available first on the market, one scenario is to combine option 1 with one or several other options. The following scenarios have been chosen for further evaluation:

- Options 1 + 5 (+4)
- Options 1 + 2

The combination Options 1 + 3 has similar design impacts as Options 1 + 2.

Any of the proposed additional bands to the existing UMTS core band (Option 1) will require variable duplex separation. The simplest configuration to consider is Option 1 + Option 5 configured in a compressed mode with DCS1800 or PCS1900.

- Options 1+5 (+4):

Adding Option 5 leaves the core RX band (Option 1) untouched, so the complete receiver can be reused. The added TX band is at a larger duplex gap making it potentially relatively straightforward to implement. An example of a compressed mode implementation is shown in Figure 2. The duplex filter in Figure 2 is a new component, but it is assumed it can be based on existing technology.

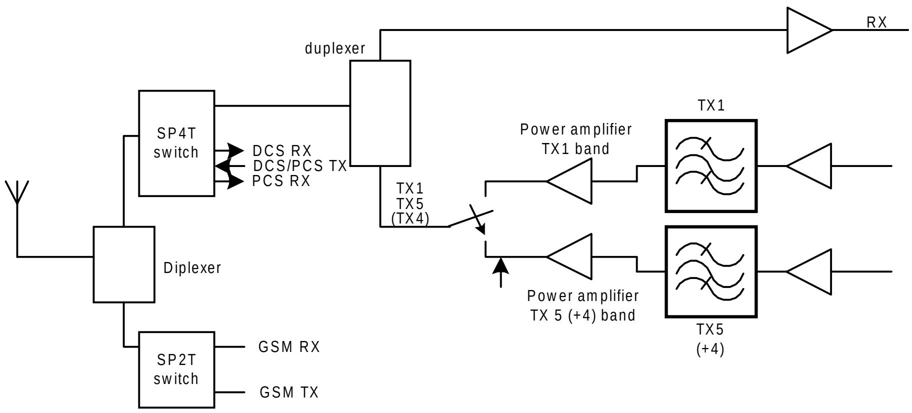


Figure 2. Example of compressed mode implementation for Option 1+5.

In Figure 3, another example of a compressed mode implementation is shown, which is more readily realizable, as multiple RF filters are used instead of one single duplexer.

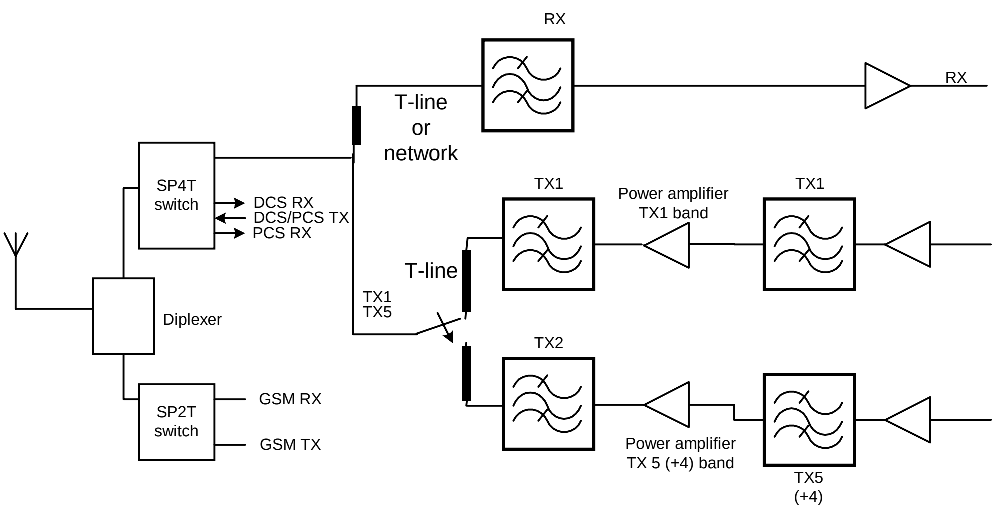


Figure 3. Example of compressed mode implementation for Option 1+5.

Having an additional duplex mode results in additional losses to both the Tx and Rx sides of the WCDMA system. As the number of bands increases, the losses can be expected to increase even more. Furthermore if a non-compressed mode implementation is chosen for associating DCS1800 or PCS1900 to WCDMA, then the losses are likely to be even more important. In any case, these losses are likely to be bounded by [2] dB on either Tx or Rx side. Further studies are needed so as to clearly evaluate the additional losses induced before specifications can be finalised.

- Options 1+2:

As diplexers and duplexers are carefully designed for specific frequencies, a classical implementation is to have one duplexer for each band pairing supported by the terminal. This combination will thus require 2 duplexers with very different requirements. Two complete receivers are needed for this combination. The general transceiver requirements from GSM 1800 are different, so reuse of GSM 1800 RF components for UMTS on 1800 is not possible. Further studies are needed before specifications can be finalised.

Note: The coexistence of Option 2 with the PCS1900 band is an open issue. The closeness of the bands will further complicate the RF filter requirements and/or require large guard bands.

6.1.3 VDT Conclusion

Having terminals able to operate over several band pairings will facilitate roaming and will also enable operators to provide service in multiple bands. Any vendor-specific implementation is suitable as long as RF performance are carefully studied and specified. A choice is to be made between having the terminals implementing variable duplex separation on a frequency block basis or on a frequency channel basis. It is however recommended not to have this variable duplex spacing capability mandatory in terminals.

6.2 Solutions for having a terminal accommodating frequency band asymmetry

7 Examples for viable implementations of spectrum arrangements for UTRA FDD

Table 1 in chapter 5 list several band pairing options in the 1710 – 2200 MHz range. The implementation aspects of these were treated in chapter 6. The usage and implementation of the band 2500 – 2690 MHz will be discussed further in this chapter 7. And additional use of VDT for deployment for public indoor systems is shown in chapter 7.2.

7.1 DL usage of the new band 2500 – 2690 MHz in conjunction with the Band I for UTRA FDD

This clause discusses the usage of the 2500 - 2690 MHz spectrum on the assumption that it is used for for UTRA FDD DL in conjunction with an assumed operation of UTRA FDD within the 1920 - 1980 / 2110 – 2170 Band I (UTRA FDD core band). The following aspects shall be covered:

- Relevant radio network propagation and performance aspects for UL/DL operation within the 2.5 GHz band
- UTRA system requirements for efficiently supporting the 2500 – 2690 MHz band for asymmetric DL operation
- Required changes of current UTRA specifications in order to support efficient operation within the 2.5 GHz band

7.1.1 Radio Network Performance Aspects regarding utilization of the 2500 – 2690 MHz Band

In this clause we consider propagation and radio performance aspects related to the UTRA operating efficiency in the 2.1, respective, 2.5 GHz bands.

7.1.1.1 Relevant Propagation Aspects for 2.5 GHz Band

There are no significant differences in the basic physical mechanisms of radio propagation in 2.5 GHz compared with 2 GHz. All effects (PL, diffraction losses, building/wall penetration losses, etc) are understood to scale as a continous function of frequency and thus the basic modeling assumptions concerning radio propagation developed for the 2 GHz band can be re-used without much loss of accuracy.

However, and this is significant for the following discussion, there will be a larger path loss (PL) for the 2.5 GHz bands compared to the 2 GHz . Assuming that the Okumura-Hata (OH) model (see e.g. [5]) is still valid around 2.5 GHz, we can estimate the additional PL from the frequency dependent term in the OH model, *B*log10(f)*, where B = 33.9 [1]:

$$\Delta PL = B * \log 10(2.5/2.1) = 2.57 dB$$

Compared to operation in the 2 GHz bands, also additional cable losses for the 2.5 GHz signal relative to the one around 2 GHz will occur at Node B sites - these are typically in the order of 1 … 3 dB/100 m, depending on the cable type and size. Thus, for cable length of up to 20 m (typical for rooftop installations) the additional cable losses in 2.5 GHz will be in the order of 0.3 … 0.6 dB – these are the values used in the following calculations.

7.1.1.2 Impact of increased PL in the 2.5 GHz band on UTRA UL/DL Cell Coverage

Currently deployed urban UMTS cells are frequently co-sited with existing GSM cells and are typically designed for a coverage target on UL of about 64 – 144 kbps data and for DL of up to 384 kbps data, thus matching the GSM cell footprint with typical PLs of some 150 – 155 dB. Typically an UL load factor of 0.3 … 0.6 is assumed resulting in an equivalent noise rise of some 1.5 … 4 dB. For DL larger load factors of up to 0.8 are frequently assumed. Under these (typical) conditions *the UTRA UL becomes coverage and the DL capacity (or interference) limited*, for a more detailed discussion see e.g. references [15,16].

It is important to note now that the increased PL in the 2.5 GHz band of approximately 3 dB effects the UTRA UL/DL cell coverage limitations. In fact, an additional PL will not affect *an interference limited link* such as the UTRA DL typically is. However, the UTRA coverage limited UL (data coverage being essentially limited by the limited UE Tx power) would be adversively affected by the increased PL if deployed within the new 2.5 GHz band. In order to retain the same cell coverage as in the 2 GHz Band I, additional and costly means to recover this 3 dB PL loss would need to be deployed (e.g. UE with higher power class, smart antenna solutions in Node B, etc).

A more detailed case study analysis has been conducted to illustrate this dynamics and the results are presented in Appendix A. When introducing additional carriers in the 2.5 GHz band to share the DL traffic with the Band I carriers the following observations can be made (see also to Fig.1 in the Appendix A):

- at each DL throughput point, the fractional DL load value is equal for 2.1 / 2.5 GHz carriers, in particular for the pole capacity (DL load = 1). No DL capacity is lost due to the extra PL. This is a consequence from the fact that the DL load equation (see [15], p. 159) does *not* depend on the path loss.
- The introduction of each additional DL 2.5 GHz carrier adds the same DL capacity as a corresponding Band I carrier would do
- The introduction of each additional DL 2.5 GHz carriers increases the achievable DL / UL throughput asymmetry of the system
- There appears to be no need for power compensating the additional 3 dB PL on the 2.5 GHz carrier for *coverage reasons* as there is ample margin for DL coverage available
- As long as the DL / UL throughput asymmetry is high enough, the UL can carry the additional traffic to support the 2.5 GHz carrier with no adverse effect on the cell size / coverage

[1] This value for B is expected to be larger for 2.5 GHz, thus in here we may underestimate the increase of the PL compared to 2.1 GHz

- Significant DL capacity gains (and thus the DL / UL throughput asymmetry ratios) could be effectively gained by introducing additional carriers in 2.5 GHz. The maximum achievable capacity asymmetry ratio is essentially limited by the amount of spectrum available for DL operation. E.g. the case of deploying the full 2500 – 2690 MHz band for DL operation a ratio of up to 4:1 for DL / UL throughput could be obtained for UTRA (now considering operation in 3G spectrum allocations only).

Considering the desire to operate also future UTRANs supporting operation within the 2500 – 2690 MHz band from today's site grid and to minimize construction of additional sites to compensate for the extra 3 dB PL of a hypothetical UL operation, it appears advantageous to utilize carriers in these new 2.5 GHz bands for DL operation. Operation of DL carriers within the 2500 – 2690 MHz band will not suffer from any propagation related impairments under realistic operating conditions when compared to Band I operation and thus deliver very similar capacity / performance as in the Band I. This effective use of the spectrum can then conveniently be used to increase the available DL / UL throughput ratio of UTRA to meet the expected needs of future 3G services.

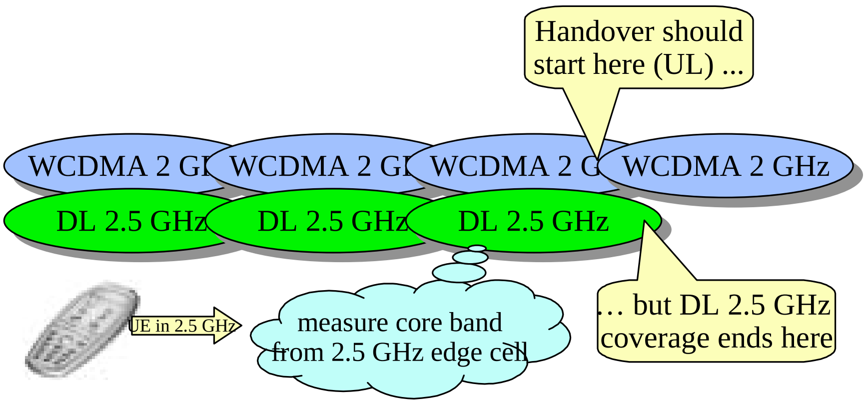
7.1.2 Radio Resource Management (RRM) aspects with extension DL carriers in 2500 – 2690 MHz

7.1.2.1 UL interference scenario

The DL extension carriers in the 2.5 GHz band can be used on a cell-by-cell basis. DL capacity can be enhanced either for the whole layer mirroring the coverage of the associated core band carrier or for some hot spot areas. RRM procedures are applied the same way as in the core band baring in mind that one UL carrier is associated with multiple DL carriers, i.e. one DL carrier in the core band and one or more in the extension band. Balancing of DL load as an example can therefore be achieved by an inter-band handover (UL, DL1 => UL, DL2) while balancing of UL load requires an inter-frequency (UL1, DL1 => UL2, DL2) or inter-system handover.

Intra-frequency measurements within the 2.5 GHz band e.g. for soft handover purposes are performed the same way as in the core band. At the coverage edge, however, a pre-emptive coverage reason handover is needed in order to avoid the risk of extensive UL interference to the intra-frequency neighbour(s) of the associated core cell. Since the coverage edge of the 2.5 GHz cell does not necessarily coincides with the border to the neighbour of the associated core cell as illustrated in the figure below, the pre-emptive coverage reason handover is likely to be required a bit earlier than it would occur by typical coverage triggers e.g. UL/DL power limitation. The area where UL interference can happen is somewhat the core band soft handover (SHO) area that is not mirrored in the 2.5 GHz band (i.e. some of the cells on the core band do not exist on the 2.5 GHz band).

In the following the term "SHO area" will be used to describe this geographical area of potential UL interference although the UE itself is not in SHO. Also, significant interference does not occur yet when the UE is just entering the core band SHO area but only when the core band neighbour becomes the strongest cell in the core band. For simplicity, we still use the term "SHO area" because the area of UL interference geographically strongly correlates with the SHO area in the core band that is un-mirrored in 2.5 GHz.



7.1.2.2 Interference detection and avoidance

With the current 3GPP measurements, the UE in the 2.5 GHz band cannot recognize when it is entering an UL interference area.

One way to solve this issue is to apply **tight coverage reason triggers** that enable the escape handover before the UE reaches the interference area. This is a valuable option for cells where the un-mirrored core band SHO area is far from the Node B location and thus tighter handover triggers will not extensively reduce the coverage of that cell.

In case the un-mirrored core band SHO area is relatively close to the Node B location - close in terms of pathloss - that cell would however have significant part of the coverage unused. Also, if it is as close as or even closer than other mirrored SHO areas (left hand side of the 2.5 GHz edge cell in the figure above), the SHO to other 2.5 GHz neighbours would not be possible. Instead an inter-band handover would take place even though not necessary. For those cells, an alternative method is provided by **additional core band measurements** to detect un-mirrored SHO areas in the associated core band. As UL interference arises only in 2.5 GHz border cells also measurements can be limited to these cells.

In the following measurements in different RRC service states are considered. Although in principle UL interference does not occur in every RRC state, measurements are still recommended in all states to allow a fast transition between the states. This means that also measurements in idle mode are considered to avoid extensive delay during call initiation.

CELL_DCH

To minimize UE inter-band measurements in CELL_DCH state, core band measurements for interference area detection can be split into 2 steps

(a) periodic RSSI measurements of the associated core carrier

(b) event (i.e. need) based inter-band neighbour measurements of the core band neighbours using e.g. compressed mode

While (a) gives an indication of increased other cell interference when comparing it with the 2.5 GHz RSSI value, (b) verifies that the increased RSSI value is due to an un-mirrored core band neighbour. The first light measurement (a) should be on for all UEs all the time in that cell as in principle, SHO areas can be at any distance from the Node B location while the more extensive inter-band measurements (b) are triggered only for UEs close to the interference area. The split of core band measurements into 2 steps reduces UE measurement time, which furthermore reduces necessary compressed mode time.

Idle mode, CELL_PCH, URA_PCH

To allow camping in all 2.5 GHz cells without the risk of UL interference at RACH transmission, potential interference areas must be detected by inter-band measurements. In order to maintain reasonable activity in paging modes the measurements can be controlled by measurement rules and criteria, which are based on e.g. CPICH Ec/Io level. By comparing the 1:1 co-siting in both bands, the UE notices an un-mirrored SHO area in the core band and autonomously initiates a cell re-selection to the core band.

In cells with distant SHO areas, again tighter cell re-selection triggers are an alternative to the additional UE measurements. Then, cell re-selection will be initiated before the UE can enter the potential interference area.

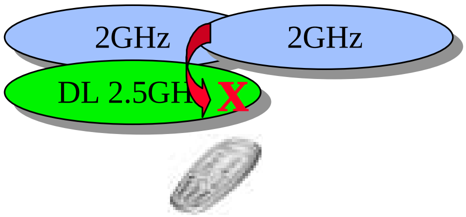
CELL_FACH

In CELL_FACH state the UE can use the measurement occasions to perform interference area detection in the core band.

Interference avoidance

Interference is effectively avoided by an escape inter-band handover to the core band (pre-emptive coverage handover). In idle mode, CELL_FACH, CELL_PCH, and URA_PCH state, when entering an interference area the UE initiates cell re-selection to the core band to prevent UL interference at RACH transmission.

When camping in the core band, a directed RRC connection setup to the 2.5 GHz band must be avoided from an un-mirrored SHO area.



Compressed mode (CM) usage

Identifying the core band neighbours during CELL_DCH state requires compressed mode (CM) measurements or a dual-receiver in the terminal. The additional CM UE measurements replace CM measurements performed for the preparation of coverage reason handover. Considering the effect of CM usage on network capacity, which relates directly to the number of mobiles simultaneously in CM, it can be expected that in total the effect is not likely to increase and it can even decrease due to the following facts.

- The interference escaping handover is pre-empting the coverage reason handover. So, additional UE measurements are replacing measurements to prepare coverage reason handovers. In addition, as co-sited DL carriers in the core and extension band are synchronized, CM measurements for inter-band handovers can be made more efficiently i.e. in shorter time by utilizing the synchronization information.

- The main load balancing in this concept can be achieved already at call setup by directing the RRC connection to another carrier. This does not require CM measurements at all. It almost completely substitutes load reason handovers and thus also CM measurements as preparation for load reason handovers.

- Inter-band handovers for any reason (service, load etc.) can utilise the synchronisation of the co-sited DLs. CM usage is required less if necessary at all for inter-band handovers.

7.1.3 Towards an UTRA Standard for supporting DL optimised utilisation of the 2500 – 2690 MHz band

Having noted the motivations of the previous clauses we shall explore in this clause the main avenues a 3GPP standards development UTRA may take in order to support DL optimised utilisation of the 2500 – 2690 MHz band.

In particular, a number of conceptional UTRA system design decisions will need to be made, in order to establish detailed requirements for enhancing the (evolving) 3GPP standards to support DL optimised utilisation of the 2.5 GHz band. On a high level a number of system design issues have been identified, including but not limited to:

- How will the operation of DL physical channels / TrCHs on 2.5 GHz carriers be linked to those residing on UL Band I carriers ?

- What are the supported DL physical channels / TrCHs on 2.5 GHz carriers, in particular CCCHs ?

- What are the supported cell topologies / hierarchy (ie macro/micro/pico cells) when using 2.5 GHz DL carriers in addition to those within the Band I?

- Should a UE be prepared to use *simultaneously* or *alternatively* use a 2.5 GHz DL carrier with/to a DL carrier active in the Band I?

- Should a UE support the same RRC states and state transitions as in the current Band I standard as well in the 2.5 GHz band?

- What additional RRM measurements and RRC procedures are needed for extending existing IFHO mechanisms to include inter-band handovers (IBHO) between the core and 2.5 GHz bands?

In order to find meaningful answers to these questions we suggest consideration and discussion on the overall objectives for UTRA 3GPP standards development in order to support DL optimised utilisation of the 2500 – 2690 MHz band.

7.1.3.1 Overall Objectives for UTRA 3GPP standards development to support DL optimised utilisation of the 2500 – 2690 MHz band

We propose that the following overall objectives shall be taken into account when developing the 3GPP UTRA specifications for supporting DL optimised utilisation of the 2500 – 2690 MHz band:

- No or minimum restrictions in the utilization of services and features available from the (evolving) 3GPP UTRA Band I specifications, including those currently under development (such as e.g. HSDPA). There shall be full flexibility in locating services and features between the core and 2.5 GHz bands primarily limited by the basic capability of UE and Node B to operate in the 2500 – 2690 MHz band (in addition to the Band I).

- Reuse of all standard UTRA TrCH and physical channels in 2.5 GHz DL carriers, including those currently under development (such as e.g. HSDPA). The goal shall be that the required capabilities and mechanisms for UTRA to operate in the 2500 – 2690 MHz band are *orthogonal* to the features developed for the UTRA Band I specifications, in order to simplify UTRA standards development and minimise adverse affects from feature interactions.

- Possibility to implement the 2.5 GHz DL capability into UE and UTRAN Band I product families at low cost and with comparably small development effort. In particular, it shall be possible for the UE to retain low cost single-receiver architectures (as supported by today's Band I UTRA standard) also for the 2.5 GHz DL enhancement. This is seen as important to migrate mass-market data traffic into the 2.5 GHz band.

- Support for flexible range of achievable DL-UL traffic asymmetry, limited by the available spectrum (up to 1:4 ratio) only

- Spectrally efficient utilization of carriers residing within the additional 2.5 GHz spectrum in order to support increased DL throughput

- No or minimal negative impact (other than the required traffic handling capacity) on the operation and performance of the utilized UL carriers in the Band I

- Smooth evolution of operational Band I UTRANs and operational and network planning practices when utilizing additional 2.5 GHz DL carriers. A 2.5 GHz enabled UTRAN shall not be a "new mode", but an additional capacity enhancing capability which does not require to enter a new significant learning curve. Adding a 2.5 GHz DL carriers to a deployed UTRAN should be an effort comparable to adding an additional carrier in the Band I.

7.1.3.2 Towards a technical framework for extending UTRA to support DL optimised utilisation of the 2500 – 2690 MHz band

We feel that the above overall objectives for development of the 3GPP UTRA standard for supporting DL optimised utilisation of the 2500 – 2690 MHz band can be effectively met when making the following *technical working assumptions* the starting point for further concept development:

1) Each additional 2.5 GHz DL carrier should be seen simply as an additional "other-frequency layer" for DL capacity addition, *matched* to one of the corresponding layers already existing within the Band I. The additional layer(s) within the 2.5 GHz band could thus "mirror" either a macro, micro, or indoor/pico layer implemented in the Band I in a certain geographical area. This concept does *not* support eg a 2.5 GHz DL micro cell matched with a Band I macro cell UL[2], however, there could be a 2.5 GHz micro cell layer coverage-matched to a Band I micro cell layer. Mirroring an existing Band I UL/DL cell footprint/layer in 2.5 GHz, is the key for the simplicity in the areas of

    - Re-using to maximum extent existing UTRA procedures and mechanisms (cell reselection, IFHO, RRM measurements and control); minimal impact on the UTRA standard

    - Ease of radio network evolution; utilization of the additional 2.5 GHz cells is then building on known cell designs / concepts / cell coverage plans and operational practices already available within the Band I UTRAN

    - Full leverage of existing (mostly proprietary) RRM features for traffic management between cell layers

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[2] this is for following reason: for soft HO detection UL and DL cell coverage should be similar, in particular we should be able to derive the need for soft HO from the UL perspective (for interference avoidance) from measurements of CPICH Ec/Io measurements obtained from 2.5 GHz carriers

2) VDT is utilized to flexibly pair a carrier within the 2.5 GHz band with a Band I UL carrier; this pairing can be determined by UTRAN based on e.g. UE capabilities, UL/DL load reasons, etc. The UE should not be required to receive at the same time the associated Band I DL carrier other than occasionally monitor eg the CPICH Ec/Io for inter-band HO (IBHO) purposes when instructed so by the UTRAN, in a similar fashion as UTRA currently manages IFHO procedures.

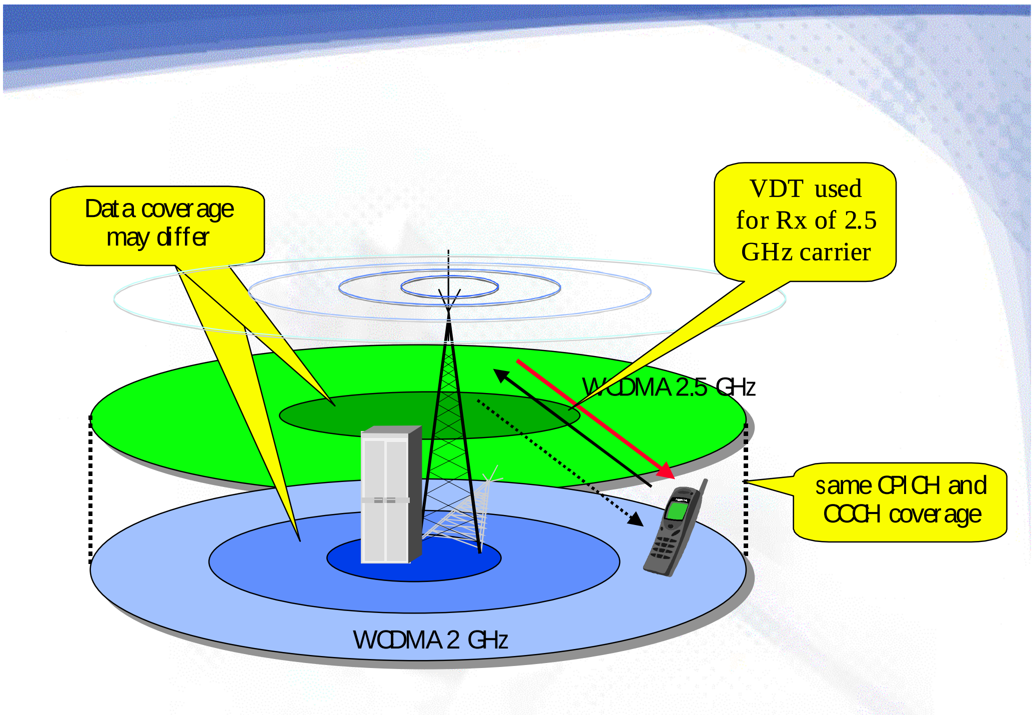

Figure 4

3) The DL 2.5 GHz DL coverage[3] (for the various service bit rates) shall be the same as the coverage of the associated Band I DL. Thus also the Band I coverage of the used UL carrier will be matched and we are able to rely on all the standard UE RRM measurements (CPICH Ec/Io, RSCP, etc) for cell reselection and soft handover purposes.

4) It is assumed that all standard UTRA DL physical and TrCHs (CPICH, SCH, AICH, …; BCH, PCH, FACH, DCH, DSCH, HS-DSCH, etc) can be made available within the 2.5 GHz carriers. Consequently, one is able able to offer

   - The same services and bit rates, whether RT or NRT

   - The same performance enhancing features (eg TxDiv, BF)

   as in the Band I. Also load sharing and trunking gains across the DL bands can be achieved according to the network operators needs.

5) UEs currently camped or active on 2.5 GHz carriers should be able to perform all RRC state transitions (e.g. Cell_FACH <-> cell_DCH) as would be the case on a Band I carrier. This again minimizes the need for additional procedures to distribute traffic between the bands and allows flexible UTRAN controlled distribution of the UE population during RRC connection setup.

The additional 2.5 GHz DL carriers shall be co-located with the associated matching UL / DL carriers within one node B. Thus, we can use all the standard UTRA fast L1 related processing (fast closed PC, any form of L1 related feedback

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[3] here and in the following with *DL coverage* we mainly refer to the *CPICH Ec/Io* coverage, ie we don't assume the necessarily that the *user bit rate* coverage is the same between the bands. Thus it shall be feasible to offer in either DL band better data coverage than in the other (eg by deploying more efficient schemes such as HS-DSCH).

signaling typically carried on DPCCHs) between UL-DL[4]. The philosophy is to treat the additional 2.5 GHz DL carrier just as any other additional Band I carrier, except for the obvious items related to the different carrier frequency. Certainly this list of technical assumptions is neither complete, nor "canonical", however, we believe these are an indication of the kind of items 3GPP would be required to study further when developing an efficient UTRA support for the new 2.5 GHz bands.

7.1.4 Needed Additions to the UTRA Standard for supporting DL optimised utilisation of the 2500 – 2690 MHz band

It is perhaps premature to list the precise impact on the 3GPP UTRA specifications, before the overall system concept has been agreed and stabilized.

However, assuming the UTRAN support for DL optimised utilisation of the 2500 – 2690 MHz band would be build within the framework of Sect. 3.3, the most significant revisions are believed to be required for the following TSs:

TS 25.101 UE Radio Transmission and Reception (FDD)

UE RF requirements for 2.5 GHz band

TS 25.133 Requirements for Support of Radio Resource Management (FDD),

Additional RRM measurements for IBHO

TS 25.104 UTRA (BS) FDD; Base station Radio Transmission and Reception,

Node B RF requirements for 2.5 GHz band

TS 25.304 UE Procedures in Idle Mode,

Extending the cell selection/reselection procedures for to support the 2.5 GHz band

TS 25.331 Radio Resource Control (RRC) Protocol Specification,

"cleaning up" some of the missing parameters in RRC signalling required to fully utilize VDT, e.g. currently only fixed distance duplexing for UL/DL CCCHs is supported

As can be seen from the list, this SI will also impact other WG's than TSG RAN WG4 alone.

7.1.5 Summary of section 7.1 for usage of the new band in 2500 – 2690 MHz in conjunction with the Band I for UTRA

The section 7.1 has presented key system considerations and requirements for 3GPP UTRA standard development towards supporting DL optimised utilisation of the 2500 – 2690 MHz band with the goal to obtain a capacity enhancing complement for UTRA operating in the Band I.

The main findings presented in this section were:

- There appears to be evidence that the nature of future mobile traffic points towards an increased asymmetry of DL/UL traffic volume and that the use of the 2.5 GHz bands to increase DL capacity may be required to sustain these future traffic needs at reasonable a cost
- There appears to be evidence that the use of the 2500 – 2690 MHz band for DL transmission is preferred from the perspective of UTRA radio system performance and propagation related reasons
- It appears entirely feasible to augment the existing UTRA Band I standard in order to support DL optimised utilisation of the 2500 – 2690 MHz band with reasonable work effort effecting the specifications only in a few localized areas (RRM measurements, RRC procedures)
- Use of VDT is an essential technological element in providing this solution

[4] Otherwise there is either a large impact on 3GPP standard or one would need some RF-over-fiber type of concept for remote RF heads, however, then still all the DL BB processing would to be in same Node B as the UL BB.

- Such an enhanced the UTRA standard would be able to offer a large degree of DL / UL traffic handling asymmetry at reasonable complexity and cost

7.2 Use of VDT for deployment of public indoor systems

7.2.1 Introduction to the scenario

Figure 5 below shows an example where an indoor system with general public access is deployed in a building within the coverage area of a macro site. When entering the building, handover is provided from the macro cell to the indoor system.

Indoor systems may be required also in the early deployment of WCDMA to improve indoor coverage and/or off-load the macro cells at local hot spots.

Spectrum is a scarce resource. Available spectrum is often needed to serve the wanted wide area traffic. Therefore the indoor cells will normally reuse all spectrum or parts of the spectrum used by the macro site.

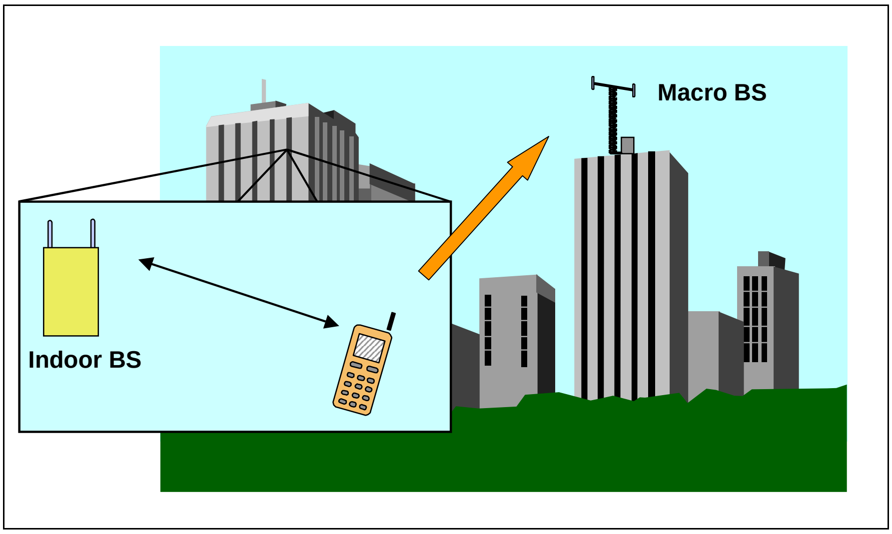

Figure 5: Indoor system for public access within the coverage area of a macro site.

7.2.2 Assumptions for the scenario

The example used in this report is operators with at least a 2x10 MHz license block, enabling 2 UTRA FDD carrier pairs.

For the indoor BSs, each operator will use at least one of the WCDMA carrier pairs that are used by the outdoor macro system, thus providing soft handover between the macro and indoor cells on this carrier. Indoor systems are expected to be mainly deployed in urban areas, but could be introduced also in hot spots surrounded by medium and low traffic areas (e.g. airports and shopping centres located outside of city centres). In an initial phase the deployment of WCDMA is expected to take place as macro sites for coverage, complemented by some limited indoor systems. When traffic increases within the area covered by the macro site, further deployment of indoor systems may be expected to further off-load the macro sites. Once indoor systems are installed, they will not only be able to off-load present indoor users from the macro site, but may manifold multiply the total traffic supported within the area covered by the macro site. Each indoor cell (each building or each floor of a building) is well isolated compared to outdoor macro cells. Therefore the capacity per carrier pair of each indoor cell will be equal to the macro site capacity per carrier pair, if the capacity is code limited, else it may be e.g. twice as high as for the macro site.

This above application of indoor cells is straightforward in non line-of-sight cases, but off-loading will be limited in indoor areas (floors) in line-of-sight from the macro site, since the macro site field strength is dominating there. Designing the indoor system for full off-loading in line-of-sight areas and additionally using the full indoor system capacity in line-of-sight areas may cause increased up-link interference for the macro site. This interference can be eliminated by the use of Variable Duplex Technology.

A scenario without VDT is described in Table 2. The table indicates columns for areas with different average traffic densities from high to low. In each type of area there could be hot spots where an indoor system is beneficial. Dx and Uy are notations for downlink and up-link carriers. Dx-Ux indicates a coupled pair with the standard duplex separation (190 MHz for band I). The terminology Initial Phase means that providing coverage is most important. Carrier pairs within parenthesis indicate possible application, but the traffic requirements do not require any special measures to protect the macro cell from up-link interference. In the Second Phase traffic requirements increases also for indoor systems. This may lead to increased up-link interference to the macro site. See next section.

Table 2:Scenario without VDT. Dx-Ux are coupled Downlink/Uplink carrier pairs. Pairs in brackets are with limited or no traffic.

Phase	High traffic areas		Medium traffic areas		Low traffic areas		Comment
	Indoor Systems	Macro	Indoor Systems	Macro	Indoor Systems	Macro	
Initial	(D1-U1)	D1-U1 (D2-U2)	(D1-U1)	D1-U1	(D1-U1)	D1-U1	Coverage only. Mainly D1/U1.
Second	D1-U1	D1-U1 D2-U2	(D1-U1)	D1-U1	(D1-U1)	D1-U1	Traffic increases. Indoor Systems are introduced. D2/U2 is added.

7.2.3 UL interference from increased traffic in indoor system

When assessing the impact of additional up-link, UL, interference, it is important to note that the WCDMA macro site capacity normally is downlink, DL, limited for symmetric (speech) traffic. We could furthermore assume that there could substantial asymmetric (internet) traffic as well. This would make the WCDMA capacity even more DL limited when using a symmetric DL/UL spectrum allocation. Thus we could assume that the macro site could stand additional interference on the UL before the macro site capacity is affected.

In the example of Figure 6 below we assume that the macro base station UL could be degraded to about 2/3 of its available capacity before the macro cell capacity is degraded. The figure indicates how the macro site will have full U1 capacity, but when the indoor traffic increases, the U1 capacity in the same macro site may be reduced due to interference. The U1 capacity may for this example be reduced to 1/3 before the macro cell capacity is affected.

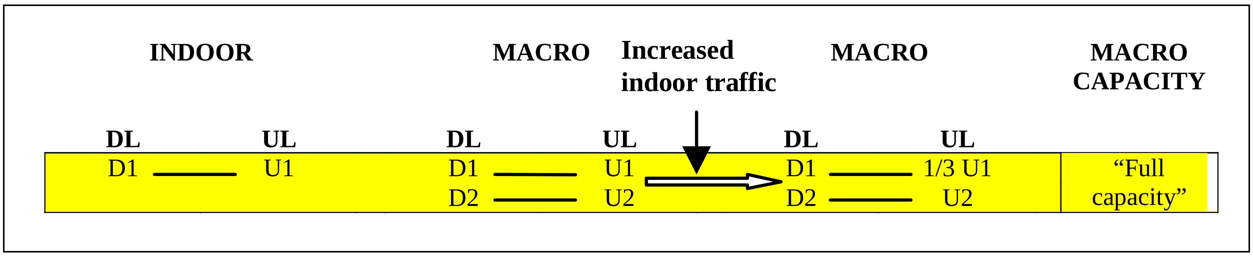

Figure 6: Indoor system for public access within the coverage area of a macro site.

When continuously increased Indoor Systems, traffic degrades the macro cell UL capacity below e.g. 1/3 UL capacity, the remaining U1 capacity may be very small. This is indicated in Figure 7below. The D1-U1 carrier pair cannot carry much traffic any longer, and the resulting total macro cell capacity may approach ½ of its original capacity (in case of two carrier pairs).

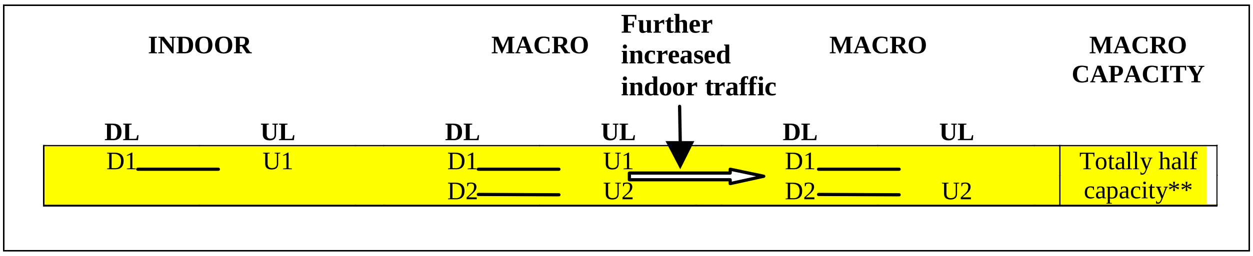

Figure 7: Indoor system for public access within the coverage area of a macro site.

7.2.4 Controlling the UL interference with the use of VDT

A suggested migration path to full utilization of both Indoor Systems and macro cell traffic capabilities is to de-coupling of the macro base station DL/UL frequency associations using VDT as indicated in Figure 4. The D1 carrier is allowed to be associated with U1 and U2.

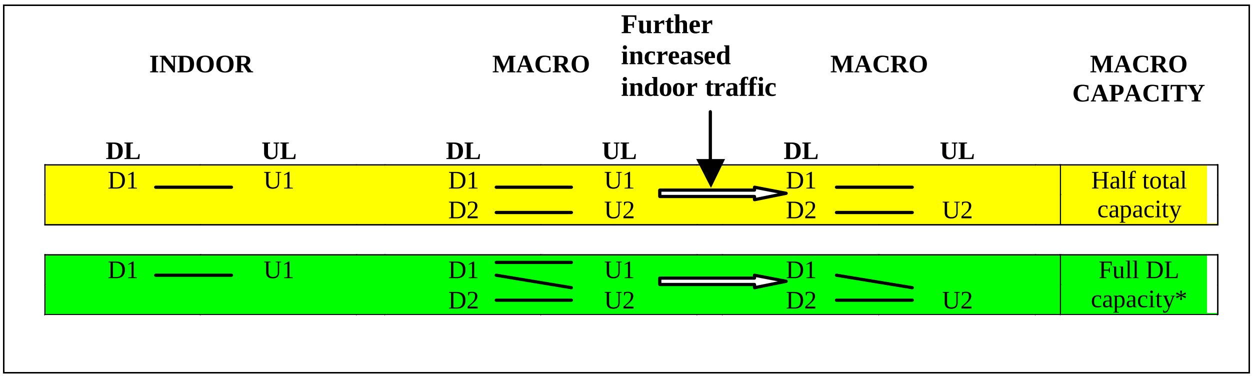

Figure 8: Indoor system for public access within the coverage area of a macro site.

Further increased aggregated indoor traffic may almost block U1. In this case carrier pairs D1-U2 and D2-U2 will carry the macro site traffic. Full macro site capacity equals full total capacity if DL traffic > 2 times the UL traffic, which may be a typical case.

This migration path requires mobiles that can perform handover between cells with different duplex distances. Such functionality is supported by the WCDMA standard.

The concept provides for a mix of handsets with and without VDT during a transition period. Handsets without VDT will in the macro site mainly use D2-U2. (VDT could additionally if wanted also be applied for the indoor system by adding D2-U1).

This solution provides full Indoor Systems and macro cell capacity. The capacity of the indoor systems can be increased as much as wanted by adding equipment (e.g. cell splitting) without damaging the planned macro site coverage.

Table 3 below is an extension of Table 2. The Third Phase with de-coupling of the macro base station DL/UL frequency associations, where macro base stations using carriers D1-U1 and D2-U2 to also support D1-U2, has been added. This phase is relevant when the indoor system traffic (aggregated traffic over the coverage area of a macro site) has further increased, so that the U1 carrier at the macro site is substantially interfered.

Table 3. Scenario with VDT. Dx-Ux are coupled Downlink/Uplink carrier pairs. Pairs in brackets are with limited or no traffic.

Phase	High traffic areas		Medium traffic areas		Low traffic areas		Comment
	Indoor Systems	Macro	Indoor Systems	Macro	Indoor Systems	Macro	
Initial	(D1-U1)	D1-U1 (D2-U2)	(D1-U1)	D1-U1	(D1-U1)	D1-U1	Coverage only. D1/U1 only. Full macro capacity/coverage.
Second	D1-U1	D1-U1 D2-U2	(D1-U1)	D1-U1	(D1-U1)	D1-U1	Traffic increases, need for Indoor Systems. D2/U2 added. Full macro capacity/coverage.
Third	D1-U1	D1-U1 \ D2-U2	D1-U1	D1-U1 D2-U2	D1-U1	D1-U1	Aggregated indoor traffic increases further, add D1-U2 association.Full macro capacity/coverage.

Figure 9 below gives an example of a graphic representation of the three phases of evolution for the macro site traffic on carrier pair D1-U1 shown in Table 3 and Figure 8.

N is the maximum traffic on D1-U1 in the macro site, supposing no limiting interference on U1.

An indoor cell (a building or e.g each floor of a building) is well isolated compared to outdoor macro cells.

Therefore the maximum capacity on D1-U1 is supposed to be between N and 2N at each indoor cell, depending on whether the capacity is code limited or not. In the example of Figure 9 the total aggregated indoor traffic reaches about 6N before the macro site capacity becomes UL limited. At further increase of indoor traffic the D1-U1 macro site traffic would approach zero, unless the D1 is de-coupled to allow D1-U2 pairing as shown in figure 8 and table 3.

The 6N break point is arbitrary. It could be much higher when all indoor systems are designed without trying to "force" off-loading the LOS parts of the building. NLOS areas could carry e.g. 20 N or higher aggregated traffic from several systems, without affecting the macro site. However, a single indoor system close to the macro site, where users on LOS floors are “forced” to connect to the indoor system, and the full indoor system capacity is utilized, could severely affect the macro site UL.

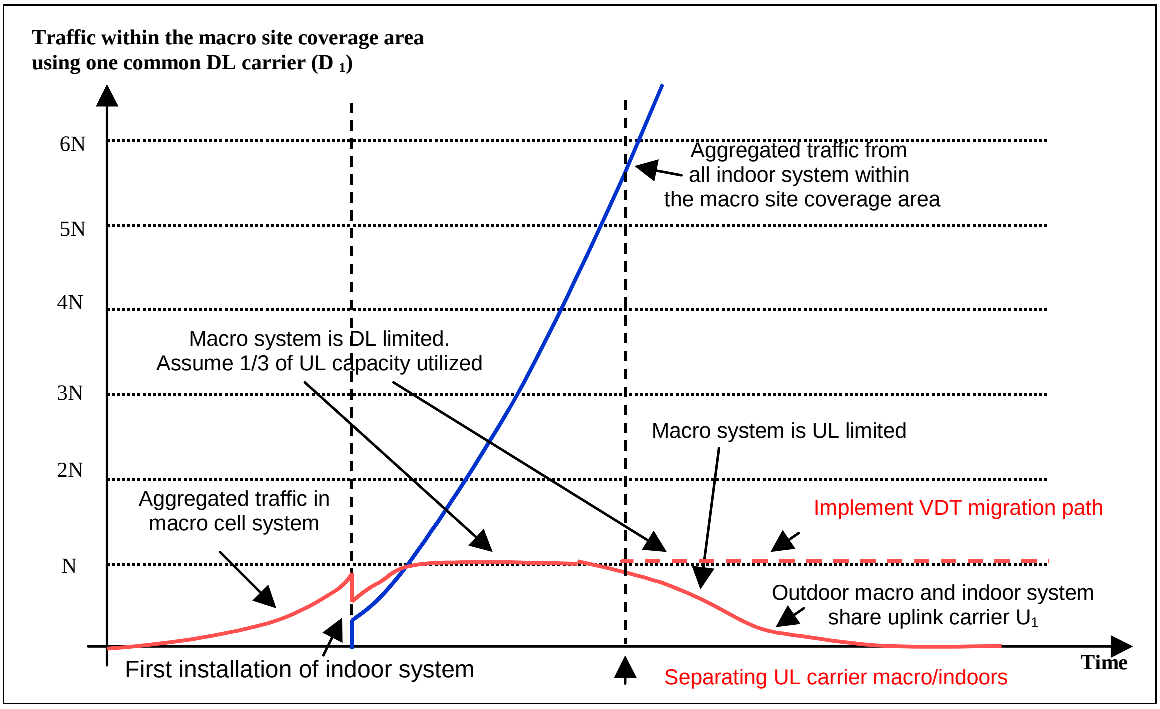

Figure 9. Example of traffic evolution for the macro site and the indoor systems within the coverage area of a macro site.

7.2.5 Summary of the use of VDT for deployment for public indoor systems

This section 7.2 describes one opportunity for using VDT in a scenario with macro and indoor cells using a common set of carrier frequencies. A prerequisite for the method to be implemented is that the Variable Duplex Technology has been developed and ready to be used in commercially available terminals.

The method suggests a de-coupling of the nominal up-link and down-link carrier associations, to provide full off-loading of macro cells and utilising the full additional capacity provided by indoor cells. VDT is implemented allowing for two downlink carriers to be coupled to one up-link. As a result, a serving macro base station can be capable of manifold multiplying the total traffic within a WCDMA macro cell area.

As a summary, the main objectives of the proposed method using VDT is to:

- give improved spectrum utilisation
- provide capacity of the indoor systems, that can be increased as much as wanted by adding equipment (e.g. cell splitting) without damaging the planned macro site coverage
- admit for a smooth transition of cellular network when traffic increases

7.2.6 Handover between cells with different duplex spacing

In the proposed scheme for use of VDT in public indoor systems, we have macro cells where two downlink carriers are coupled to one uplink carrier. Depending on the downlink carrier used, the duplex distance will be different. We will thus get handover situations where the target cell for handover will have the same downlink frequency available, but not the same uplink frequency. A normal soft handover procedure cannot be used in this case.

In the WCDMA handover procedures there exists a procedure called "Physical channel reconfiguration". This procedure indicates both the UL and DL frequencies to which the handover shall be made. Just taking the WCDMA standard as it is means that handover between cells with different duplex distances will be executed as hard handover using the "Physical channel reconfiguration" procedure as described in [9]. The situation can thus be handled with existing procedures.

It is possible (but not necessary) to define an improved handover procedure for this case and add it to the specifications. This would be a new "quasi-soft" handover, which implies that the handset is staying in soft-handover mode for the DL but changes frequency for the UL. In this way full resynchronisation is not required for the mobile.

7.3 UL/DL usage of the new band in 2500 – 2690 MHz in conjunction with the Band I for UTRA FDD

7.4 UL/DL plus additional DL usage of the new band in 2500 – 2690 MHz in conjunction with the Band I for UTRA FDD

8 The use of UTRA TDD in the 2500-2690MHz band

9 Recommendations

Within the present study, the viable deployment of UTRA in additional and diverse spectrum arrangements was investigated taking into account both the present UTRA frequency bands and the additional frequency bands identified by WRC-2000, in particular the band 2500-2690 MHz. Both UTRA modes FDD and TDD were considered. The study focussed on the feasibility of such deployments; therefore, no attempt was made to compare different frequency arrangements to each other. Accordingly, no specific frequency arrangement is recommended here. Nevertheless, some general recommendations are provided for each UTRA mode, partly covering required further work.

In case of UTRA FDD, the following recommendations are made:

1) Do not require terminals to accommodate several band pairings. This is left to the discretion of the UE manufacturers in consort with the operators.

2) Because of the additional losses in the Rx and Tx parts, further study for Rx and Tx RF performance is required before specifications can be finalised for UEs accommodating several band pairings.

3) Choose between having the terminals implementing variable duplex separation on a frequency block basis or on a frequency channel basis.

4) Further studies are required on possible solutions for signalling to terminals the system duplex configuration.

5) Develop protocol to allow a UE to declare if it can operate in more than one band and what are the bands in which it can operate.

In case of UTRA TDD, the following recommendations are made:

10 Open issues

- How can the requirements for the 2.5 GHz band be addressed?
- How can the requirements for the frequency band asymmetry be addressed?
- Feasibility of UL next to DL allocations with flexible positions?

11 Conclusion

Annex <A>: Impact of increased PL in the 2.5 GHz band on UTRA FDD UL/DL Cell Coverage

Under typical operating conditions of currently fielded UMTS networks, the UL becomes *coverage* and the DL *capacity* (or interference) limited, for a more detailed analysis please refer to e.g. references [15,16].

This fundamental dynamics can be read off from Fig. A.1 when comparing the load curves marked “Uplink path loss” respectively “Downlink path loss_all_traffic_in_2.1GHz” for a single carrier reference case operating in the Band I. The cell is UL coverage limited at 153 dB PL achieving an UL throughput of 1000 kbps corresponding to a load factor of 0.6. However, the DL capacity limit (here as example: load factor of 0.78, giving 700 kbps throughput) is reached *before* the UL reaches it’s load limit of 0.6. On the other hand, there is ample margin for DL *coverage* compared to the UL, here approximately 8 dB. Also we note from Fig. A.1, that the *asymmetry ratio* DL / UL throughput is only 0.7, i.e. the DL has only 70% of the UL capacity.

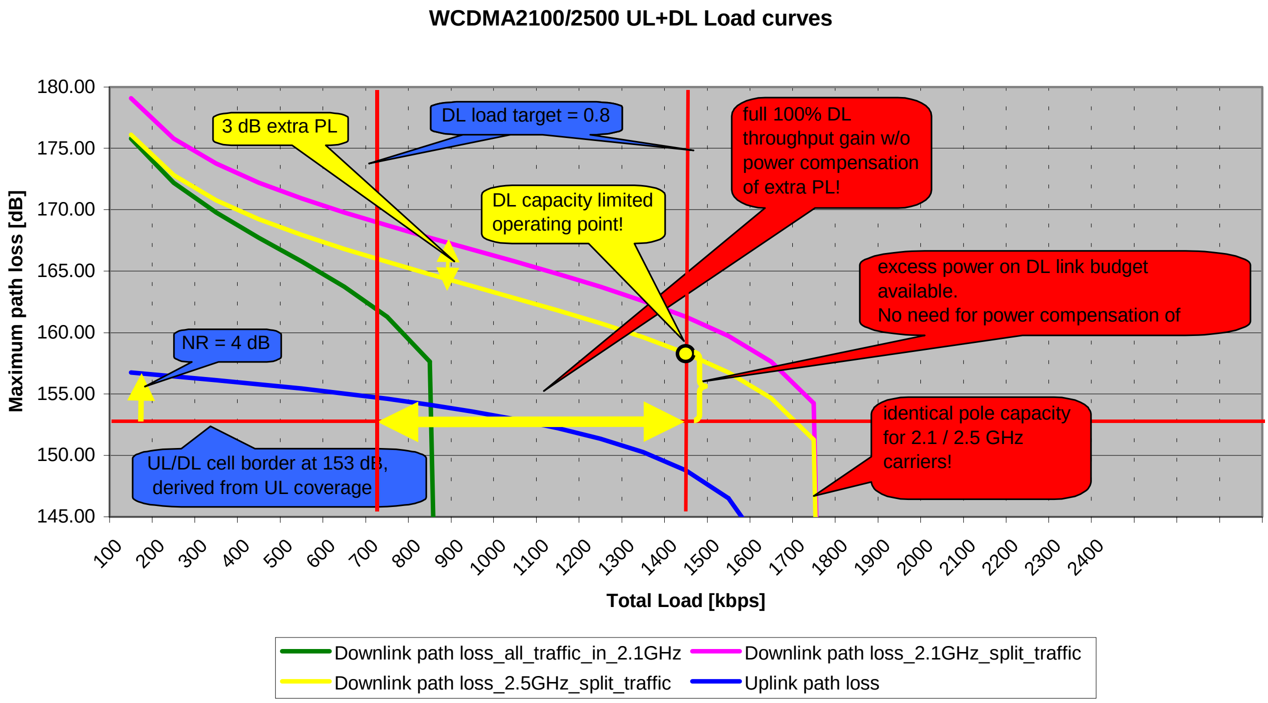

Figure A.1: UL/DL Load Curves for UTRA Operation in 2.1/2.5 GHz band

Figure A.1 also shows how the increased PL in the 2.5 GHz band of approximately 3 dB effects to the UL/DL cell coverage limitations by introducing an additional carrier in the 2.5 GHz band and splitting the DL load equally between these 2 DL carriers. The following observations can be made:

- at each throughput point, the fractional DL load value is equal for 2.1 / 2.5 GHz, in particular for the pole capacity (DL load = 1). No DL capacity is lost due to the extra PL. This is a consequence from the fact that the DL load equation (see [15], p. 159) does *not* depend on the path loss.
- The introduction of the additional DL 2.5 GHz carrier doubles the DL capacity
- The introduction of the additional DL 2.5 GHz carrier doubles the DL / UL throughput asymmetry
- There appears no need for power compensating the additional PL on the 2.5 GHz carrier for coverage reasons as there is ample margin for DL coverage available (5 dB)
- As long as the DL / UL throughput asymmetry is > 1.4 (for this example), the UL can carry the additional traffic to support the 2.5 GHz carrier with no adverse effect on the cell size

The following parameters were assumed in preparing Figure A.1:

Table A.1: Uplink parameters

UL_EbN0_dB	1.5
UL_Cable_loss_dB	2
UL_Other_cell_interference	0.65
UL_load_factor	0.6

Table A.2: Downlink parameters

MS_noise_figure_dB	9
MS_antenna_gain_dBi	0
Peak_to_average_path_loss_dB	6
EbN0_dB	5.0
DL_load_factor	0.78
Orthogonality	0.5
Other_cell_interference	0.65
Antenna_gain_dBi	18
Common_channel_OH	15%
Common_channel_OH_2.5GHz	15%
Cable_loss_dB	2
Body_loss_dB	0

Table A.3: Parameters for 2.5 GHz

additional_Cable_loss_dB	0.4
additional_Path_loss_dB	2.57
additional_Comb_loss_dB	0

Annex <X>: Change history

TSG RAN WG4 #23: Version 1.0.0 approved to be presented to TSG RAN #16
TSG RAN#17: Version 1.1.0 was presented to TSG RAN#17

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
2002-08	24	R4-021153			Handover between cells with different duplex distances	1.0.0	1.1.0
2002-08	24	R4-021091			Signalling and control of the UE (RAN2) for Variable Duplex Spacing	1.0.0	1.1.0
2002-08	24	R4-021159			Considerations of RRM aspects in TR 25.889 V1.0.0 "Viable deployment of UTRA in additional and diverse spectrum arrangements"	1.0.0	1.1.0
2002-11	25	R4-021440			TR 25.889 v1.1.1	1.1.0	1.2.1
2002-11	25	R4-021509			Proposed amendments to the current draft TR 25.889 v1.1.0 ”Feasibility Study considering the viable deployment of UTRA in additional and diverse spectrum arrangements”	1.1.0	1.2.1