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D6-4.1

IMR Specification Document

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Abstract:

This documents contains the intermediate module repeater (IMR) specification. It will determine all requirements applying to the IMR for the SDMB commercial system.

Keyword list: SDMB IMR repeater specification

EXECUTIVE SUMMARY

This is the 4th of 8 tasks in Work Package 6 – ”Architecture". The WP aims at the identification and definition of the technical requirements for the SDMB-system. It determines the SDMB architecture which is to inter-work with the 3GPP-architecture and all relevant system requirements.

Under this WP functions and interfaces of the SDMB and all sub-systems will be defined, in particular the user equipment, intermediate module repeaters (IMR), space segment, hub and service centre. After the establishment of alternative system concepts a number of cost considerations will be made aiming at impact investigations of SDMB features like 3G handset, BM_SC, manufacturing and installation cost in particular for the IMR and the hub. Finally investigations into the impact of the SDMB on the 3GPP mobile network will be drawn up.

The IMR specification generating task (Task 6.4, matter of this document) will determine all requirements applying to the SDMB intermediate module repeater (IMR) and evaluate the technical and economical implementations of the IMR functions and performance ensuring and taking into account, too, potential co-siting of the IMR with 3G base stations and other equipment.

This task will deliver specifications for the hardware and software architecture of an IMR and its interfaces with respect to necessary modifications of existing equipment and modules. In addition this task will investigate new equipment to cope with synchronisation and uni-directional I_{ub}-issues and/or optional I_{ur} issues.

Under this task the IMR interfaces for both internal and to the outside world will be determined and described including the required functions and performance,

Furthermore, Task 6.4 will specify the IMR software taking into account, if necessary, synchronisation and O&M requirements.

Finally, the final document will evaluate the IMR cost for both recurring and non recurring costs, including deployment.

As outcome this task will produce engineering results allowing to choose between different types of IMR (cost linked to IMR itself but also to satellite/hub supplementary features to implement). It should also provide some prices regarding RF power, that will be used to choose between many low power IMR Vs a few high power ones.

A special attention should also be paid to the possibility of co-existence of different IMR types in the project, and their possible succession in time if relevant.

This paper contains of 7 chapters, where chapters 1 to 3 deal with the introduction, references, terms and definitions. Chapter 4 gives a view on SDMB system features and requirements relevant for the IMR specifications which will be executed in the subsequent chapter 5. Chapter 6 contains a collection of specifically investi-

gated technical items and issues while chapter 7 is intended to list all specification tables.

Figure 3: Deliverable D06-4.1 document tree depicts a graphical view on the document.

This document will be updated during the Maestro project.

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1 INTRODUCTION - DESCRIPTION ON SYSTEM LEVEL

1.1 Background - SDMB System Break-Down

Figure 1 [Mae0] gives a rough view on the operational context where the SDMB core system is embedded in. A brief description may help both to get a view on the whole SDMB system as well as identify finally the later working area environment of this deliverable D6-4.1.

Starting on right hand side a content provider exemplifies a data source whose data content is forwarded to the ground station (BM_SC) and subsequently fed into a satellite (SPACE) via the functional block accommodating the I_{ub}-generation and the transmission equipment (amplifiers, antennas, etc.). Both blocks together form the hub.

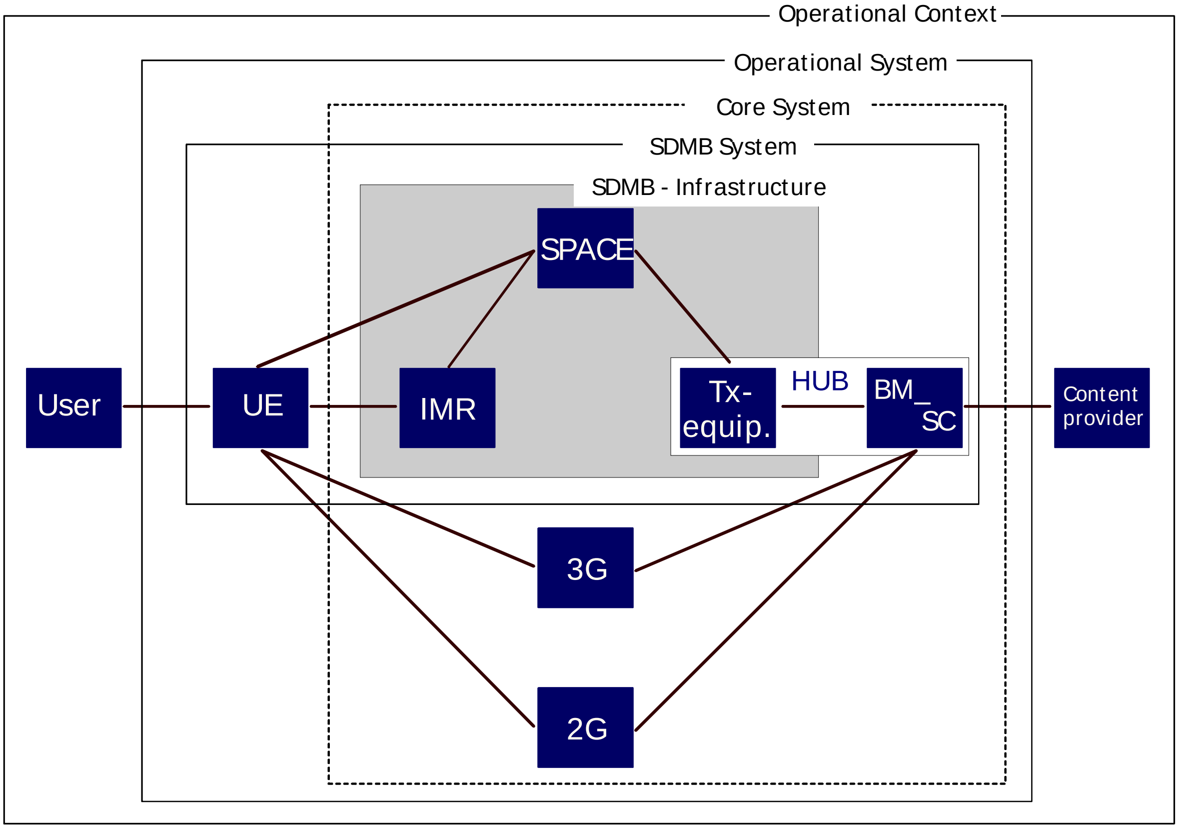


Figure 1: SDMB Architecture

The SPACE satellite beats down the received data, whereas the whole operational system to be covered by the satellite can be regarded (as an example reflecting the approximate dimensions) as at least nation wide. Transmission from satellite to the user equipment (UE) may occur principally across two different branches:

- direct broadcast from satellite to the UE;

- broadcast via IMR (Intermediate Repeater).

The former will be applied to links ranging from direct line of sight (LoS) connections (1Mb/s) to restricted coverage and thus throughput limitations (e.g., indoor 144kb/s) , while the latter may be required in order to achieve full access even in those areas that are located in the satellite´s beam shadow.

Such gaps, explicitly more bad than the lowest level of LoS-type from above, are intended to be bridged by a number of terrestrial repeaters with differing architecture that may operate in different ways and some of them making use of and re-using the national communication infrastructure (e.g., existing private NodeBs, GSM/GPRS/UMTS infrastructure, etc.).

The fall-back on such networks is forced in particular by economical reasons. In particular Terrestrial Repeaters:

- may be deployed to increase service availability in areas subject to high blockage;
- are designed for smooth co-siting with existing 2G and 3G base stations;
- transmit the same signal as the one broadcast by the satellite;
- the NodeB and/or the RNS/RNC architecture shall not be modified significantly for the terrestrial repeater installation.

As the application of the IMR branch requires a relatively high effort for a relative small user group, by this economical behaviour is forced to keep the average cost per user as low as possible.

The basic problem for solutions making use of a NodeB infrastructure is the synchronisation and delay balance of numerous signal streams; for this type of repeaters signals directly arriving from the satellite must comply with signals transported via one or more IMR configurations.

Such arriving various signal streams are regarded by the UE as being generated in a multiple propagation path environment. They must arrive within an extremely narrow time frame. Assuming similar conditions to standard UMTS their time delay difference may differ only approximately 20us which fits into the processing capability of a terminal RAKE receiver. Within this time segment the system has to cope also with all user movements, Doppler effect multiple path propagation, fading, variations in temperature etc.,

Additionally, all user terminals (UE) must be able to communicate within their national telecommunication environment; in particular they have to have communication links to their SDMB ground station (BM_SC) and thus to their Content Providers. In Figure 1 such links are denoted by the 3G and 2G – boxes indicating 2nd and 3rd generation equipment.

1.2 Fields Of Application

Based on Figure 1 the subsequent block diagram Figure 2 is to depict the working area for the IMR specification. The IMR is embedded between two interfaces (Space I/F and UE – I/F). For some IMR variants a number of specific measures have to be carried out. In particular additional effort has to be spent on synchronisation via GPS (bit, symbol, frame) and frame trip delay balance.

The maximum of processed channels depends on the Receiving Path-Searcher and thus on the number of Rake fingers.. It has to be pointed out again that the time frame for correct reception is extremely narrow [20us].

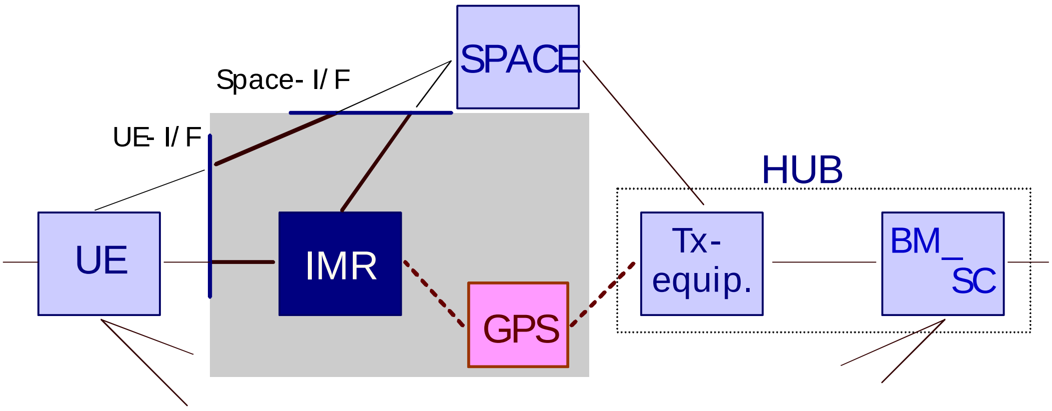


Figure 2: Underlying architecture for IMR-specification

1.3 Document Structure

The document structure follows the documentation tree depicted in Figure 3 and will be kept applicable for later versions, too.

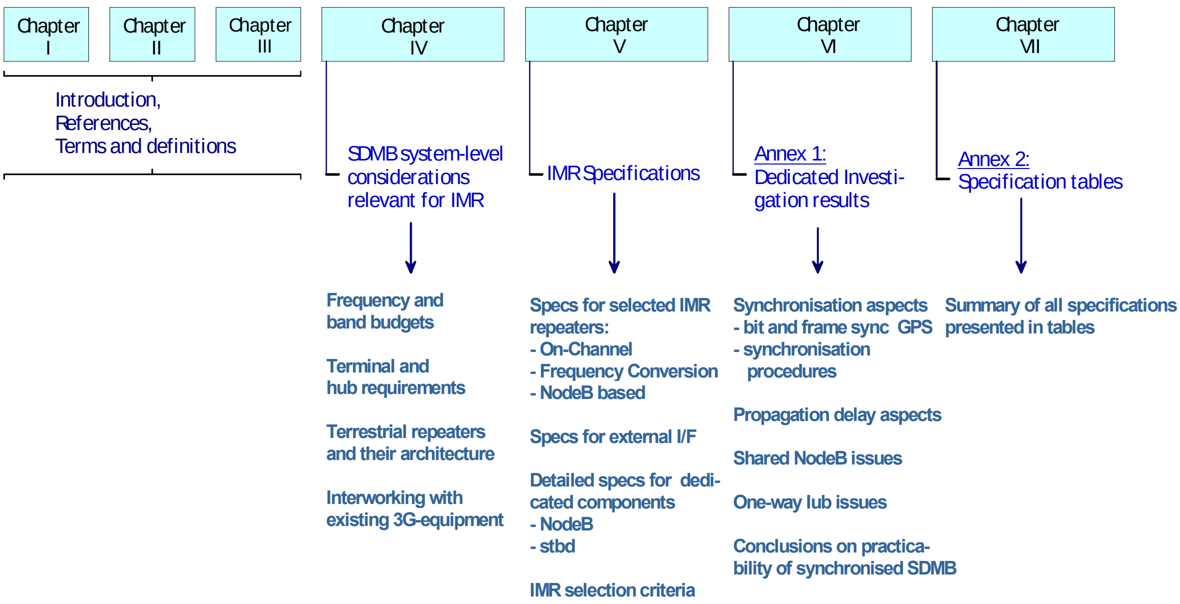


Figure 3: Deliverable D06-4.1 document tree

2 DOCUMENTARY REFERENCE SYSTEM

2.1 Reference Documents Applicable And Applied

- [....] ASP-03-TL/SR/A-9, November 18, 2003
- [....] 3DC 21151 0016 TQZZA, November 2003
- [Mae0] MAESTRO Glossary
- [Mae1] MAESTRO Deliverable D6-1: SDMB System Technical Requirement
- [Mae2] MAESTRO Deliverable D6-2: System Design Definition File
- [Mae3] MAESTRO Deliverable D3-1: S-DMB Access Layer definition
- [Mod1] MoDiS Deliverable N° 1: Dissemination and Use Plan
- [Mod2] MoDiS Deliverable N° 2: Project Presentation
- [Mod3] MoDiS Deliverable N° 3: S-DMB System Specification
- [Mod4] MoDiS Deliverable N° 4: S-DMB Business Model
- [Mod5] MoDiS Deliverable N° 5: Trials specification
- [Mod6] MoDiS Deliverable N° 6: Test-bed definition & specification
- [Mod7] MoDiS Deliverable N° 7: Integration Plan

2.2 Norms And Standards

- [3GP5] 3GPP TS 25.104
- [3GP5] 3GPP TS 25.215
- [3GP1] 3GPP TS 25.402: “Synchronisation in UTRAN Stage 2”
- [3GP2] 3GPP TS 25.433: “UTRAN I_{ub} Interface NBAP Signalling”
- [3GP6] 3Gpp TS 25.923
- [3GP3] 3GPP TS 29.846: “Multimedia broadcast / multicast service; CN1 procedure description”, 1.2.0 (2004-02)
- [3GP4] 3GPP TS 23.246: “Multimedia Broadcast/Multicast Service (MBMS); Architecture and functional description”, V.6.1.0 (2003-12)

3 TERMS, DEFINITIONS, ABBREVIATED TERMS AND SYMBOLS

AAL	:	ATM Adaptation Layer
ACLR	:	Adjacent Channel Leakage Power Ratio
ANRU	:	Alcatel NodeB antenna network
ARPU	:	Average Revenue Per User
BER	:	Bit Error Rate
BFN	:	NodeB Frame Number
BLER	:	Block Error Rate
BM-SC	:	Broadcast Multicast Service Centre
CA	:	NodeB Connection Area
CFM	:	Cell Frame Number
CRNC	:	Controlling RNC
DC	:	Down Converter
DoA	:	Direction of Arrival
DRM	:	Digital Rights Management
DVB	:	Digital Video Broadcast
EIRP	:	Equivalent Isotropic Radiated Power
ETSI	:	European Telecommunications Standard Institute
ETSI TC SES	:	Technical Committee Satellite Earth Stations & Systems
EVN	:	Error Vector Magnitude
FDD	:	Frequency Division Duplex
FDM	:	Frequency Division Multiplexing
FEC	:	Forward Error Correction
FSS	:	Fixed Satellite Service
GSO	:	Geostationary Orbit
GPS	:	Global Positioning System
IBS/IDR	:	Classical Satellite Modem
IMR	:	Intermediate Module Repeater
LNA	:	Alcatel NodeB Low Noise Amplifier
LoS	:	Line Of Sight
MBMS	:	Multimedia Broadcast/ Multicast Service
MBMS	:	Multimedia Broadcast/ Multicast Service
MCPA	:	Multi-Carrier Power Amplifier
MMS	:	Multimedia Messaging Service
MNO	:	Mobile Network Operator
MSC	:	Multiple Scrambling Code
MSS	:	Mobile Satellite Service
NGSO	:	Non GSO
OMA	:	Open Mobile Alliance
OMC	:	Operation and Maintenance
O&M	:	Operation and Maintenance Centre
OCXO	:	Oven Controlled Oscillator

PA	:	Alcatel NodeB Linearised Power Amplifier
PAR	:	Peak to Average Ratio
PCDE	:	Peak Code Domain Error
QoS	:	Quality of Service
QPSK	:	Quadrature Phase Shift Keying
RMA	:	Root Mean Square
RNC	:	Radio Network Controller
SDMB	:	Satellite Digital Multimedia Broadcast
SRI	:	Satellite Radio Interface
SSTD	:	Side Selection Diversity
SUMU	:	Alcatel NodeB Station Unit Board
TDD	:	Time Division Duplex
TM	:	Test Mobile
ToA	:	Time Of Arrival
UC	:	Up-Converter
UE	:	User Equipment
UARFCN	:	UTRA Absolute Radio Frequency Channel Number
USIM	:	Universal Subscriber Identity Module
UTRA	:	UMTS Terrestrial Radio Access
W-CDMA	:	Wide-band Code Division Multiple Access

4 TERRESTRIAL REPEATERS

4.1 Some SDMB System Figures Relevant For The IMR-Design

MAESTRO Frequency Ranges And Performance:

- feeder up-link : 27.5 - 30GHz – FSS-bands
- down-link to terrestrial repeaters : 19.7 - 20.2GHz – HDFSS-bands
- down-link to terminal : 2.17 - 2.2GHz - IMT 2000 MSS bands
- in the same IMT2000 MSS frequency carrier as the satellite-terminal direct link in such a way that the terminal can combine satellite and terrestrial repeater(s) signals
- terrestrial repeaters may be co-sited with 3G base station to minimise deployment cost (---> Shared NodeB and/or Shared RNC)..
- GPS-Synchronisation: 1,575.42MHz
- At least 144kb/s per carrier and spot beam
- Coverage outdoor and indoor
- Spot beam throughput of at least 1Mbits/s.
- Terminal sensitivity better than –114dBm (3GPP TS 25.101)
- Retransmission via terrestrial 2G or 3G network for :
  - 4,5% of users over 90% of service area,
  - 5% of average volume of data selected by a user.

Service Requirement

- Portability of applications in SDMB environment
- Rights to use NodeB sites
- Satellite based broadcast layer in full compliance with the MBMS, from 8 to 384kbit/s with the same granularity as in T-UMTS
- Collect performance & user service data through via 2G / 3G mobile networks
- Service area over the European continent:
  - latitude : from 35°N to 65°N
  - longitude : from 10°W to 30°E.

Terminal Key Features (As Relevant For The IMR):

- 3GPP UTRA FDD W-CDMA standardised technology

- 3GPP standardised handsets reception performances in IMT2000 satellite down-link frequency band (2.170 - 2.200GHz)
- Multimode 3G terminals without additional reception chain: no simultaneous reception or transmission through both modes
- dual mode, GSM, UMTS, MBMS enabled
- recombination of signals received from the satellite and the terrestrial repeaters using rake receiver
- SDMB reception shall not prevent mobile network operations (idle mode: paging, location update; connected mode)
- specific software package to configure the UMTS/MBMS protocol stack and implement media broadcast application enabling technology.
- Standardised interfaces to 2G / 3G networks

Hub Requirements (As Relevant To The IMR)

- controls the broadcast transmission in one or several spot beams
- builds the 3GPP standardised W-CDMA down-link carriers
- fixed Satellite System frequency band 5MHz carrier for direct satellite path.
- the system is designed to allow several hubs to share the system capacity and several BM-SC to share the capacity managed by the Hub

4.2 View On Different Architectures Of Terrestrial Repeaters

The MAESTRO System is intended to apply different types of Terrestrial Repeaters according to the particular terrestrial topology. Nevertheless, hub characteristics in combination with the transmitted UMTS channels may determine only a restricted number of IMR variants; in principle this will become an issue when the decision has to be made up, either to transmit only the U_u via the satellite or the full set of e.g., U_u, I_{ub} and I_{ur} respectively. A final decision might be derived from the economical investigations and the resulting cheapest solution.

4.2.1 Families Of IMRs

Figure 4 depicts three principle IMR architecture solutions. They can be classified into sub groups either operating fully independently of existing environments or making use of it.

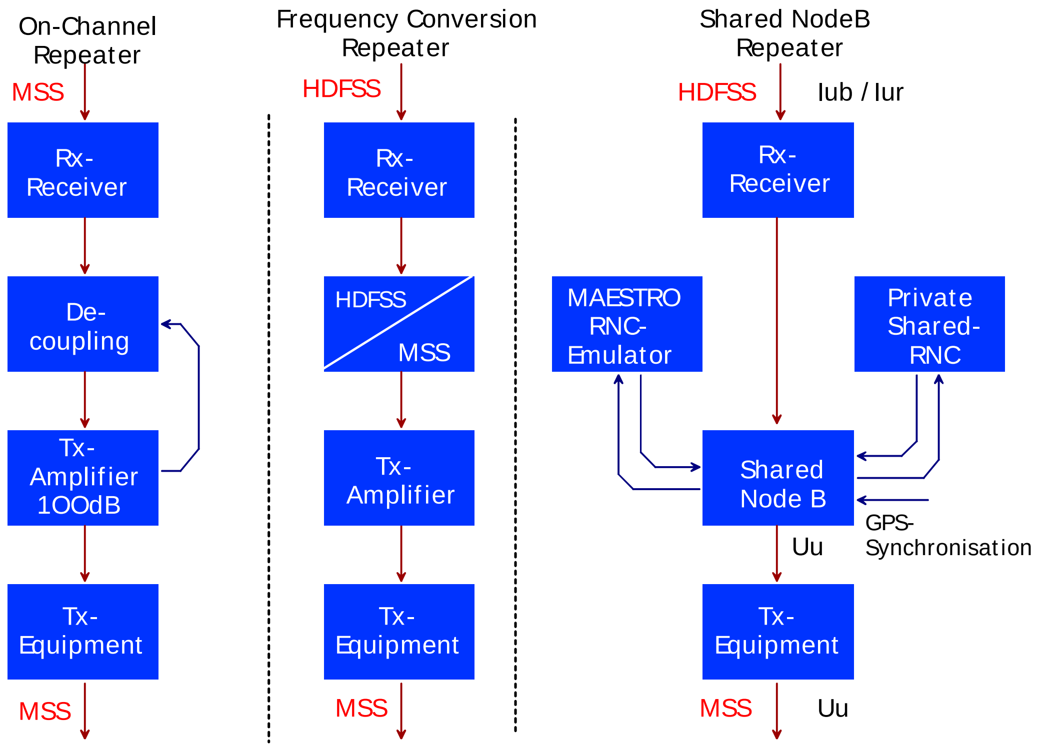


Figure 4: Three IMR-principle architecture types

4.2.2 Stand-Alone Repeaters Without Using Available Infrastructure

This type of repeaters follows the scheme given in Figure 4 on left-hand side and middle. A number of suitable terrestrial repeaters of this type is commercially available and applicable but all types burdened with a set of specific issues by their own with respect to the envisaged SDMB system.

This paragraph will describe very briefly some principle type of repeaters which will described subsequently more detailed in context with their specifications. Due to their technical appearance such repeaters are fairly not suitable to use or re-use existing communication infrastructure (such as NodeBs, RNCs, etc). Two examples may be given to show the principles of such type of terrestrial repeaters:

- **On-Channel Repeater ("Enhancer"):**

This repeater type acts as a simple amplifier for the received signal. Specific measures have to be taken for keeping input and output signals strictly separated in order to avoid strong interference and feed-back. This repeater type is cheap but serviceable only in restricted areas (e.g., indoor application).

- **Frequency Conversion Repeater:**

  This repeater type offers a reasonable technical concept in combination with a high degree of flexibility. Input and output do not conflict; measures need not be taken to avoid feed-back. This type of repeater is of medium cost and its most suitable installation may be in more dens crowded areas.

4.2.3 Repeaters Partly Using Available Infrastructure

This repeater type will make use of available communication infrastructure and follows the scheme given in Figure 4. It can be said that this challenging broadcast system will suffer of – apart from other issues – trip delays, path delays, processing delays, etc. and their balance. Furthermore, system synchronisation will play a strong role in the system which requires precise bit and frame synchronisation across both the satellite link and the supporting terrestrial links, in particular, when NodeBs and RNCs will be used. Consequently, the expected benefits of such a solution are high and must be able to compensate such really complex techniques and technologies. Two examples will stand for this type:

- **Architecture Sub-Variants Based On NodeB:**

Figure 4 and Figure 5 represents the Node-B based IMR functional architecture, reusing an existing terrestrial mobile network base station for to comply with the requirement MAE-D6-1.1-C-REQ-089. In addition to the stand-alone repeaters the following functional equipment has to be added:

- a GPS receiver, providing a time reference to the NodeB
- satellite reception equipment, providing the I_{ub} traffic coming from the hub via a satellite
- an equipment merging the unidirectional satellite I_{ub} traffic and the terrestrial I_{ub} traffic coming from the UMTS PLMN, and providing synchronisation.

Finally, the NodeB needs to be upgraded for to use the IMT-2000 MSS satellite bands and to process the GPS signals.:

- RNS/RNC Based Repeater The decision on a repeater solution based on an RNS/RNC-infrastructure for the time being needs both further study and experience gain.

The IMR logical architecture must match one of the two logical architectures of the SDMB hub, represented in the hub design document:

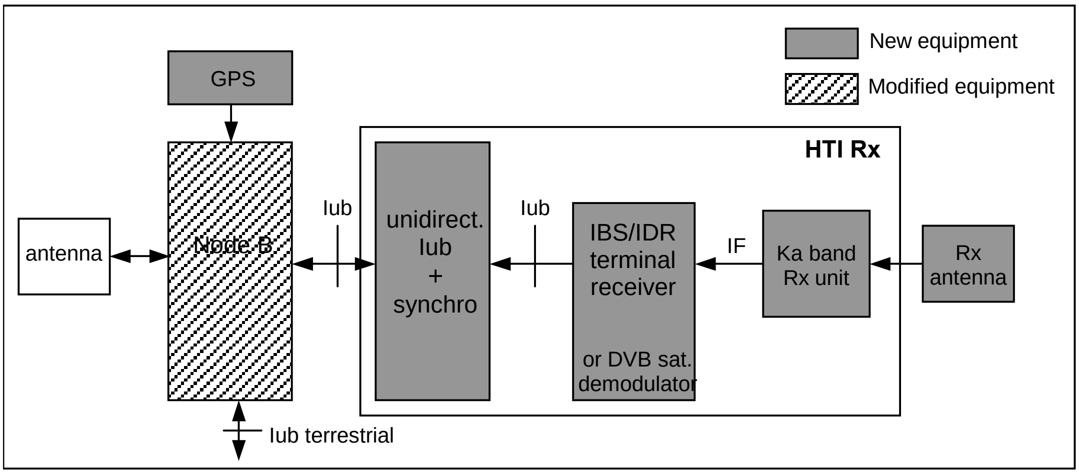


Figure 5: NodeB IMR functional architecture

- the satellite transmits only an U_u interface data signal; therefore, the IMR acts as a repeater of this U_u signal, on-channel or with frequency conversion, as shown in Figure 6.

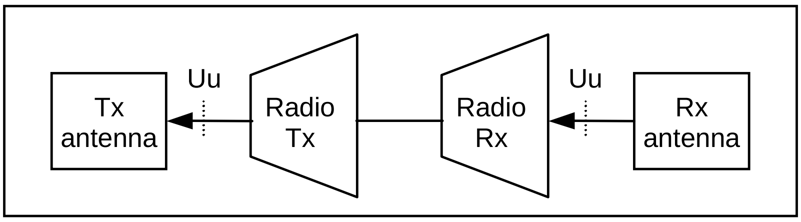


Figure 6: IMR architecture scheme for U_u-repeater

- the satellite transmits an I_{ub} interface signal; therefore, the IMR is NodeB based and contains a HTI Rx (Hub to IMR Receiver), as depicted in Figure 7. Such type of repeaters are required when making use of available communication infrastructure (e.g., NodeBs, RNCs, etc.)

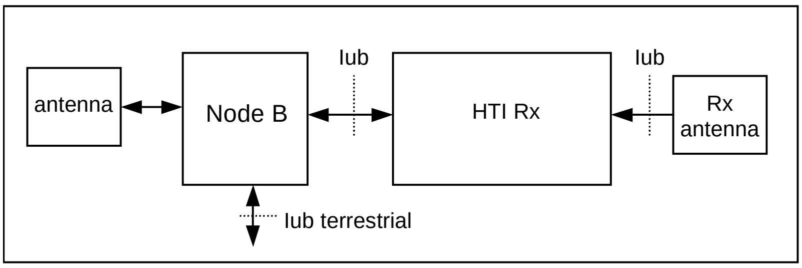


Figure 7: IMR architecture scheme for I_{ub}-repeater

4.2.4 Inter-Working With Existing UMTS-Equipment

In order to reduce the IMR cost, the IMR must be designed as the simplest up-grade of existing UTRAN equipment such, e.g., as the NodeBs. In addition, this hardware upgrade must not reduce the reliability of the existing equipment. For such inter-working two options could be identified:

- **Option 1:** inserting the HTI Rx on the I_{ub} interface;
- **Option 2:** connecting the HTI Rx through an ATM switch.

(a) Option 1: HTI Rx inserted on I_{ub}:

This option is shown in Figure 8. The drawback of this solution is that it might be difficult to be accepted by the network operator, because a failure of the HTI Rx might have an impact on the UMTS terrestrial traffic.

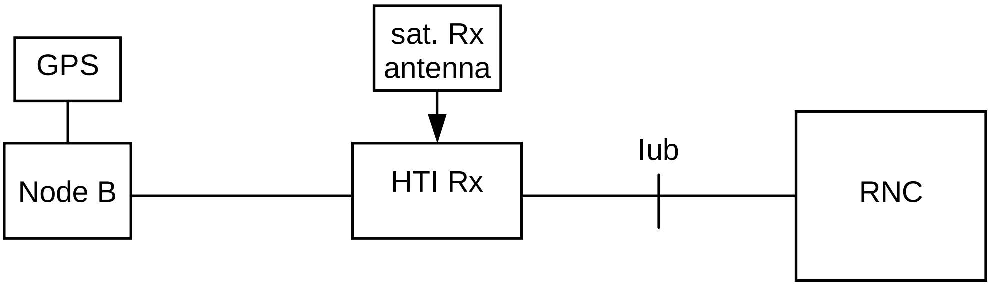


Figure 8: HTI Rx inserted on I_{ub}

(b) Option 2: HTI Rx not inserted on I_{ub}:

To overcome the problem of option 1, the HTI Rx could be connected through an ATM switch, as depicted in Figure 9 in this case, a failure of the HTI Rx has no impact on the UMTS terrestrial traffic.

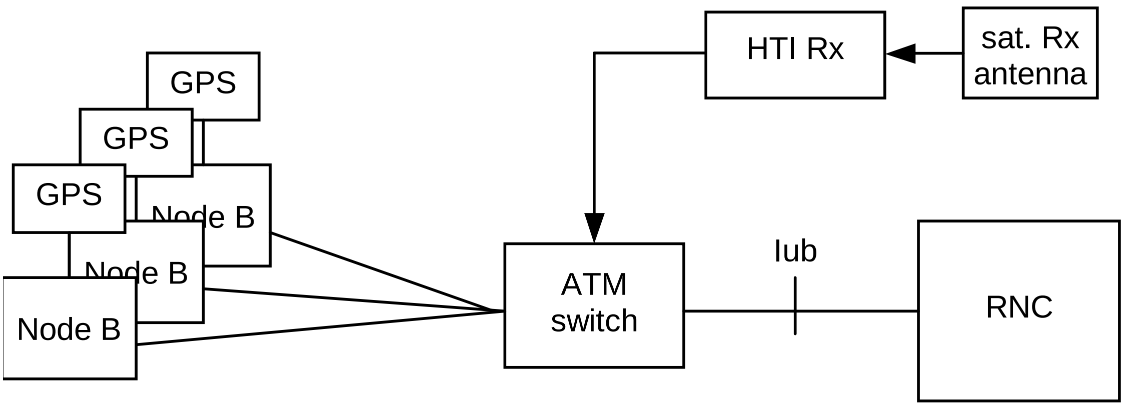


Figure 9: HTI Rx not inserted on I_{ub}

The I_{ub} traffic received from the satellite is fed into the ATM switch connecting the RNC to its NodeBs. This solution is economic, as it is not necessary to add an HTI

Rx, an antenna, etc. in each NodeB. Only one set of these devices need to be integrated in the RNC location. This will provide SDMB capability to the whole NodeBs connected to this RNC.

(c) Option 2 Refinement:

In option 2, the I_{ub} traffic received from the satellite cannot be simply fed into the ATM switch as only one Q.2630 VC exists, and the AAL5 uses one ALCAP VC and one NBAP VC. Concerning the data traffic over AAL2, option 2 works as the ALCAP VCI and VPI can be changed.

As shown in Figure 10, a listening probe close to the RNC could be inserted on I_{ub}. This probe enables the HTI Rx to listen to the I_{ub} traffic exchanged with the RNC. This probe could be either a high-impedance listening probe inserted on E1/I_{ub}, or a feature of the ATM switch.

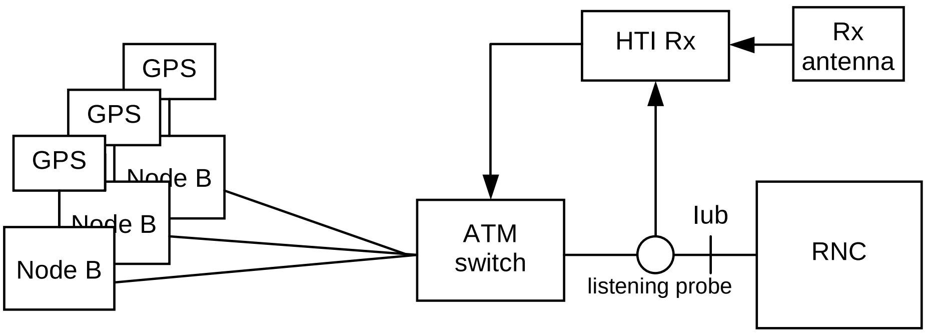


Figure 10: RNC based IMR

Another issue in this case is the synchronisation of the NodeBs connected to one HTI Rx. As the HTI Rx is only capable to synchronise one NodeB, the problem arises how and by what the other NodeBs can be be synchronised, too.

TBC: in Alcatel Node B, check if distinct ATM circuits can be used for common channels.

TBC: check that no problem with AAL5 circuits.

5 IMR SPECIFICATIONS

5.1 Description And Specifications Of The IMR-Variants

5.1.1 Scheme For Embedding IMRs In An SDMB Environment

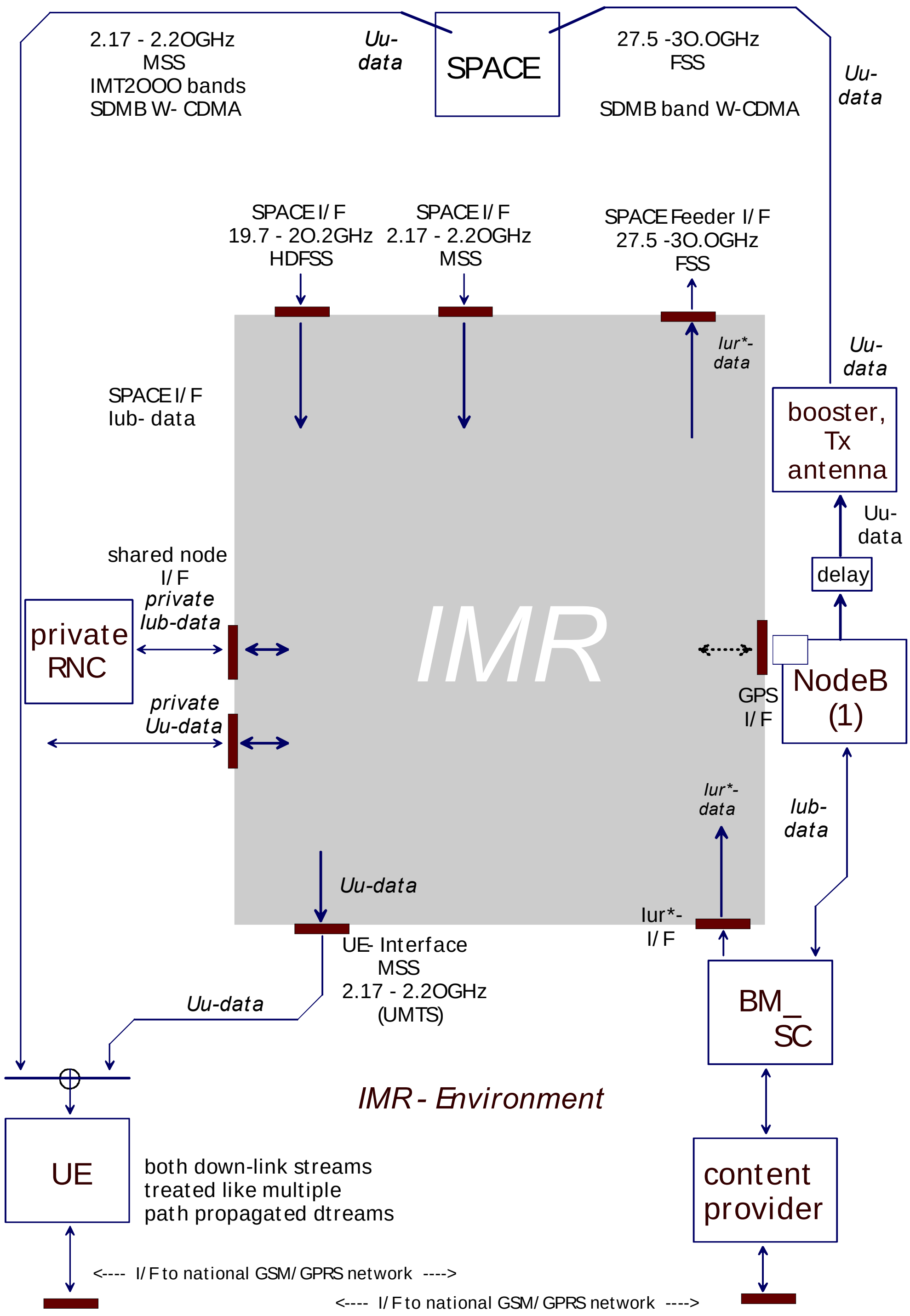


Figure 11: The Basic System – IMR Embedding

Figure 11 gives a rough view on the components of the envisaged SDMB broadcast and communication system, where the grey area will accommodate the different types of terrestrial repeaters. This figure follows the high-level architecture depicted in Figure 2 and Figure 12: .

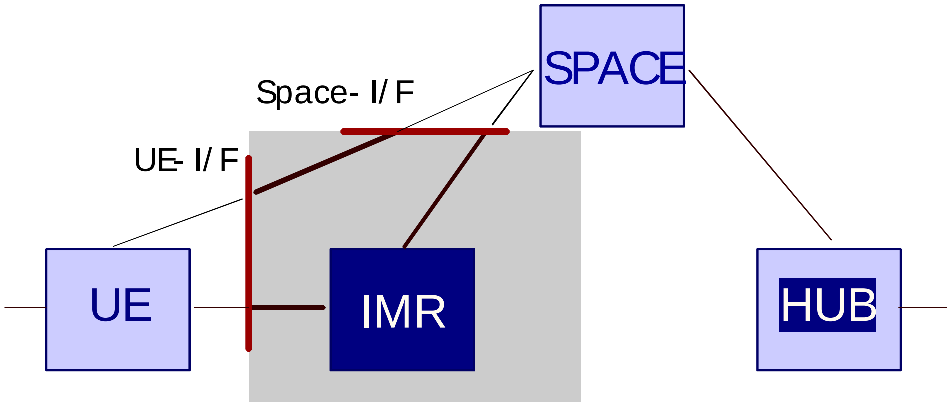


Figure 12: Basic system mapped on SDMB IMR architecture

It was agreed that replacing IMRs by other IMR types should not influence more than absolutely necessary the performance and specified parameters at both interfaces connecting the IMR to the SPACE and the UE respectively. This is one of the preconditions for an economical system deployment; the application of different IMR-architectures, too.

Following this philosophy and the architectural schemes from above, this requires to minimise the total number of interfaces connecting the IMR to the system. Such identified interfaces are the SPACE interface (SP-I/F) and the UE-interface (UE-I/F), the former working in the HDFSS-band (19.7 – 20.2GHz) and in the MSS-band (2.17 – 2.20GHz) respectively, while the latter operates in the SDMB W-CDMA MSS-band only.

Figure 11 represents the most simple SDMB-system solution under the assumption of a fully covered region without any relevant shadow problem zones; the system which can be regarded as basic and which performs the environment of the envisaged IMR items. Though strictly spoken it belongs to the system level, however, it may be described here very roughly, as it performs the basic system all IMR variants and components are embedded in.

Starting up-link the content provider box represents the broadcast data source; it contains a number of service relevant data bases, servers, etc. It may be of interest that the content provider is connected to the national GSM/GPRS network. Such connection is required to offer a terrestrial link from the SDMB users and the content provider.

The content provider box is followed by the module, which mainly includes the RNC-functionality and delivers I_{ub}-data to the subsequent NodeB /1. This NodeB prepares U_u-data which is lead to ground equipment mainly consisting of amplifiers, up-converters and the directed Tx antenna towards the satellite. Feeding transmission occurs in the 27.5 – 30GHz FSS SDMA bands (W-CDMA).

5.1.2 IMR On-Channel Solution – Description And Specs

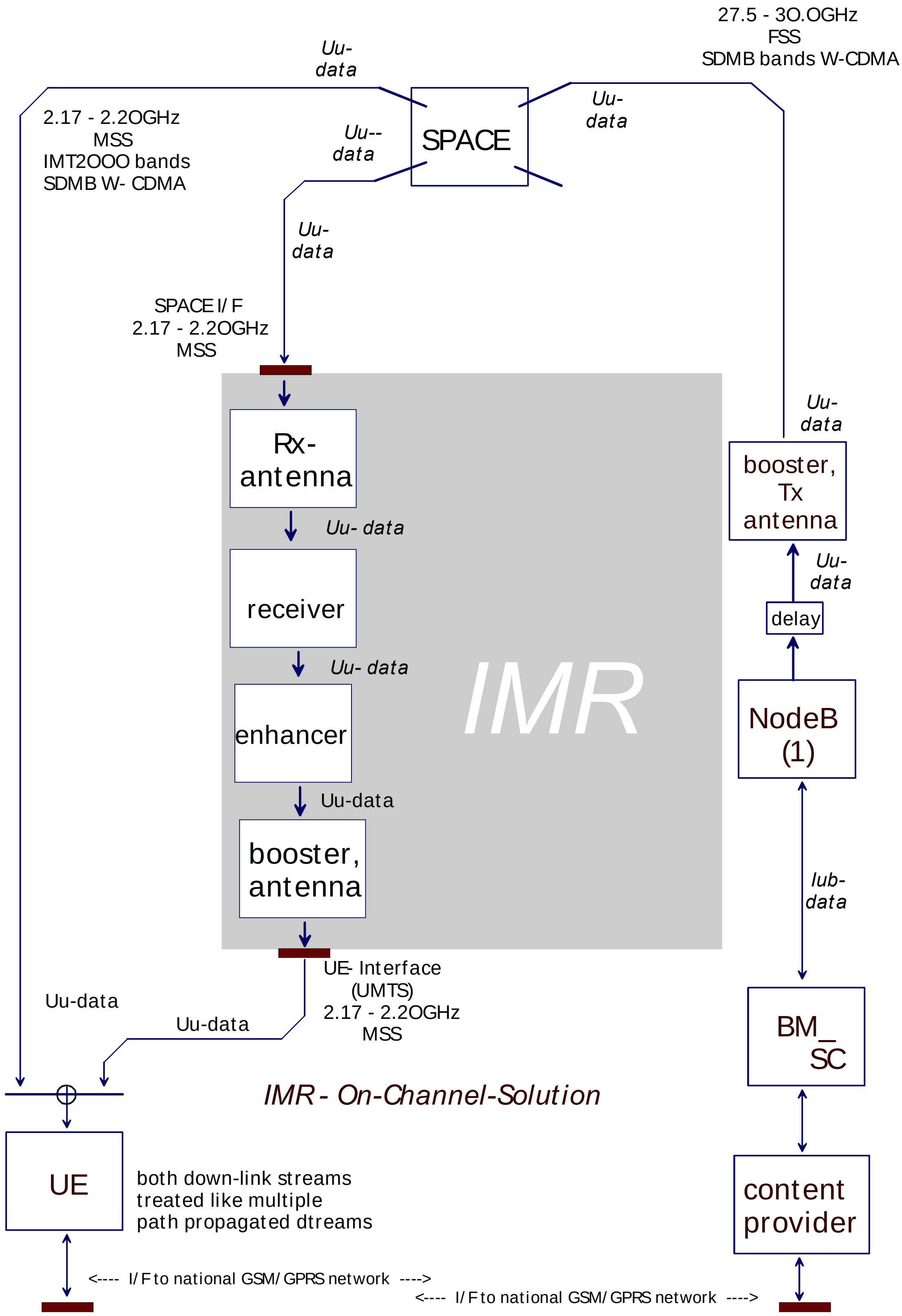


Figure 13: IMR – On-channel based repeater branch

Functions:

This repeater type embedded in the terrestrial repeater link acts as a simple amplifier for the received signal. As the input frequency band (from the satellite) is the same as the amplified output frequency band towards the users, specific measures have to be taken for keeping input and output signals strictly separated either by fibres (only less suitable for this project) and/or by directed antennas in order to avoid strong feedback interference This repeater type is cheap but serviceable only in restricted areas (indoor application).

It is applicable for use in cellular and PCS wireless communication systems. Wireless RF network coverage problems can be addressed quickly and easily. In particular this repeater type is highly suitable for deployment in dense urban environments, tunnels, canyons, and other areas where physical structures cause low field strengths. It can also be used as an efficient and low-cost alternative to base stations in areas where coverage is more critical than additional capacity.

It is also suitable to extend base station coverage to shadow areas where signals can be obstructed. The repeater includes RF-enhancers for large area coverage, capacity, and high speed data. These primary network elements are ideal, too, for the first phase of the network rollout and for any subsequent phase where cost, coverage, and quality need to be optimised. This repeater does not only increase signal strength between a mobile and a base station in areas where high-quality voice or high-speed data service is not available, they also enhance air-interface capacity and increase the network data rate.

Such type of repeaters normally are channelised so that they repeat only the desired signal band without adding excess noise in adjacent bands. They can be used for both single carrier and multiple-carrier applications. Repeater systems are available in a wide frequency range from 450MHz to 2,100MHz and thus support CDMA, W-CDMA, GSM, DCS, UMTS, etc.

Used bands for MAESTRO application:

The table below sub-summarises the applied bands, their adjacent frequencies and the carried UMTS data across the relevant IMR-interfaces.

	Band	Frequency	Data
feeder	F_{FSS}	27.5 – 30GHz	U_u
direct down-link to UE	F_{MSS}	2.17 – 2.2GHz	U_u
down-link to repeater	F_{MSS}	2.17 – 2.2GHz	U_u
down-link from repeater to UE	F_{MSS}	2.17 – 2.2GHz	U_u

Performance:

frequency	down-link (available)	2,110 – 2,170	MHz
	down-link (required)	2,170 – 2,200	MHz
CDMA-carriers	adjacent per module	1 – 3	
down-link output power	1 UMTS carrier	43.0	dBm
	2 UMTS carriers	40.0	dBm
	3 UMTS carriers	38.0	dBm
	output power step size	1	dB
	output power accuracy	±1.5	dB
down-link power	minimum at full output	-60	dBm
antenna isolation	min. for max gain	83 min.	dB
delay	w/o echo cancellation	stbd	us
	with echo cancellation	< 6,4 / < 8.0	us
gain	maximum	103 /automatic setting	dB
	adjust range	53 – 103	dB
return loss		> 15	dB
adjacent channel leakage	1st adjacent channel	-45	dBc
	2nd adjacent channel	-50	dBc
out of band gain (rejection)	opt.1	-40dB in 200	kHz
	opt.2	-70dB in 200	kHz
far-off selectivity		70	dB

Interfaces:

Remarks:

pros for this repeater type:

- cheap; "plug´n´play"
- simple and cheap indoor solution
- stand-alone capability

cons for this repeater type:

- antenna set required
- difficult input/output de-coupling
-

5.1.3 Frequency Conversion IMR Solution - Descriptions And Specs

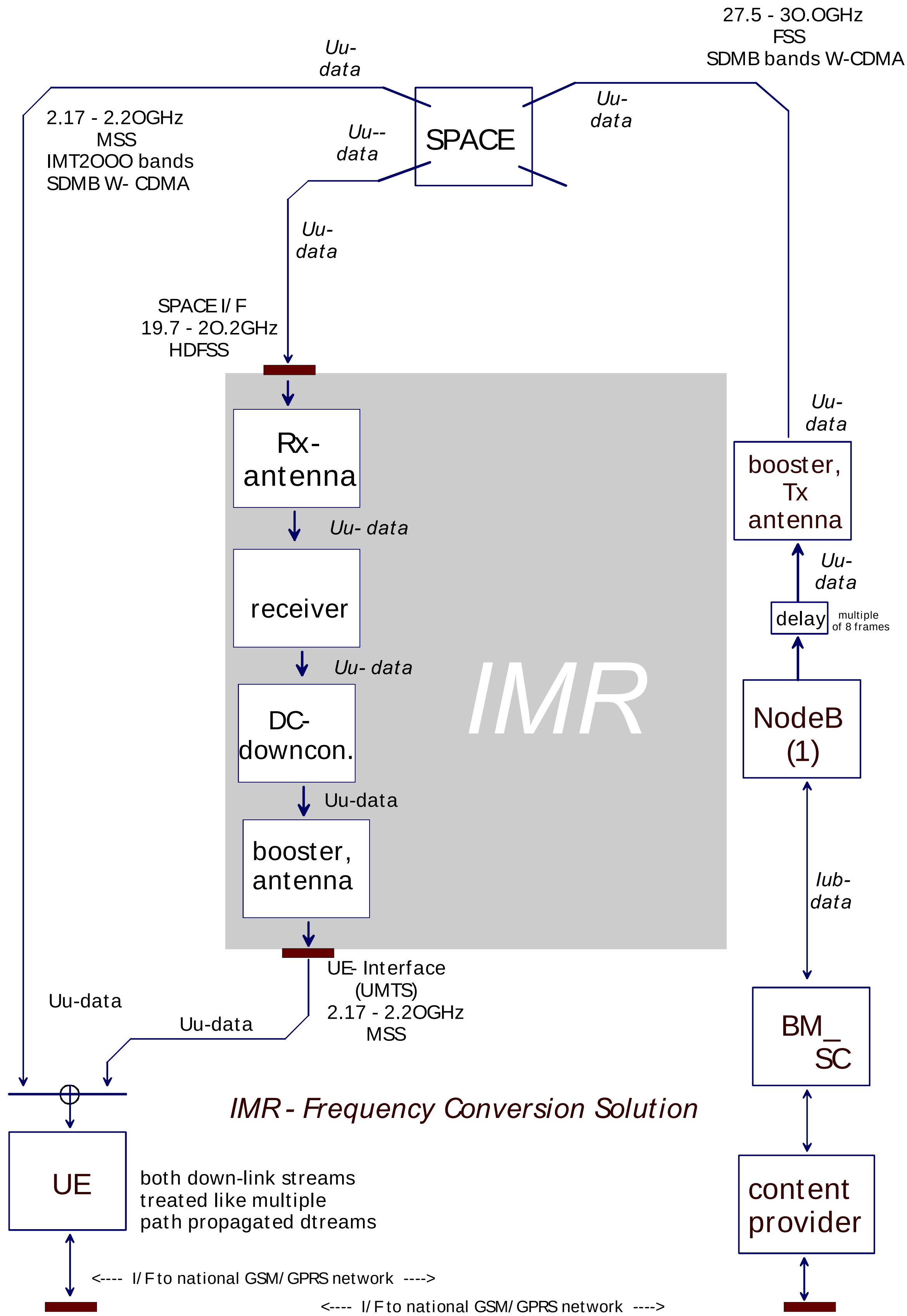


Figure 14: IMR – frequency conversion based repeater branch

Function:

This repeater type embedded in the terrestrial repeater link obviously offers a reasonable technical concept in combination with a high degree of flexibility. This repeater type is divided into an up-converting part (normally within the satellite) (FSS to FSS) and an down-converting part (from FSS to MSS) on the ground. The incoming high frequency band (FSS) from the satellite thus does not conflict with the down-converted MSS band transmitted to the users UE. No specific measures must be taken to avoid feed-back. This type of repeater is of medium cost and its most suitable installation may be in more dens crowded areas.

Performance:

pros for this repeater type:

- clear technical concept allowing less effort for antenna design
- simple input/output decoupling
- simple and cheap indoor and out-doorsolution
- stand-alone capability

cons for this repeater type:

- installation cost
- availability
-
-

Interfaces:

The table below sub-summarises the applied bands, their adjacent frequencies and the carried UMTS data across the UE and SPACE interface.

	Band	Frequency	Data
feeder	F_{FSS}	27.5 – 30GHz	U_u
direct down-link to UE	F_{MSS}	2.17 – 2.2GHz	U_u
down-link to repeater	F_{FSS}	27.5 – 30GHz	U_u
down-link from repeater to UE	F_{MSS}	2.17 – 2.2GHz	U_u

5.1.4 NodeB Based IMR Solution - Descriptions And Specs

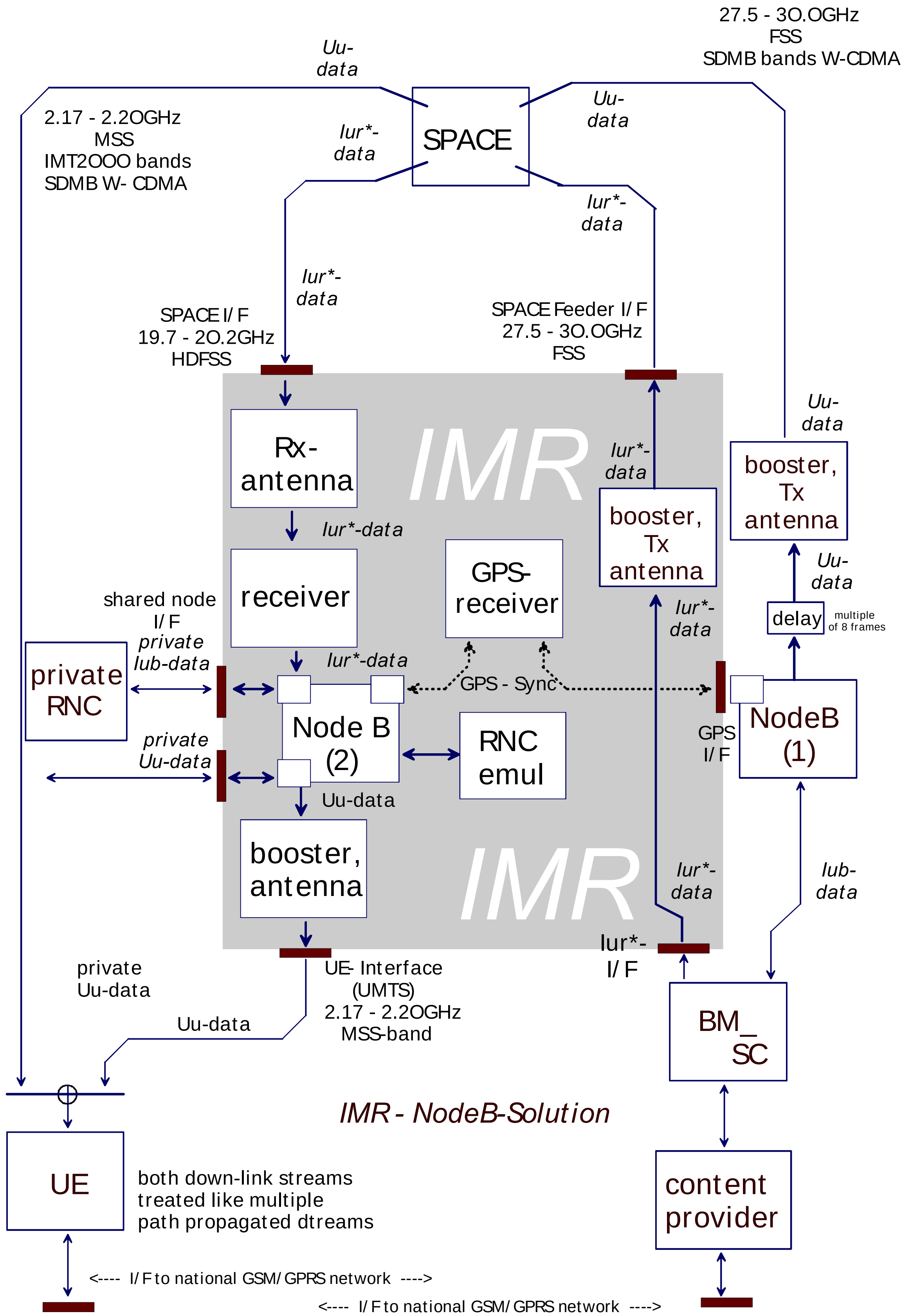


Figure 15: IMR - NodeB based repeater branch

Function:

Figure 15 represents the NodeB based IMR functional architecture, reusing an existing terrestrial mobile network base station in the IMR-branch to comply with the requirement MAE-D6-1.1-C-REQ-089. Though the ambitious topic, Maestro to share an installed private NodeB with a private network provider, sounds reasonable for making use of the existing communication infrastructure, in equal measure this enlarges the number of additional issues sizabely.

In order to simplify and concentrate the technical discussion in an initial step it is assumed to base all subsequent considerations on an Alcatel NodeB V2.

This repeater solution to apply a standard NodeB burdens the system concept with numerous technical issues, mainly in the area of synchronisation, propagation time delays and processing time delays. This is illustrated in Figure 15 in form of a GPS receiver assigned to the repeater branch catering for bit synchronism and frame synchronism. between Hub and the repeater NodeB/2. This also requires a specific synchronisation access to the SUMU on the I_{ub} – side. Such access is planned and prepared but not implemented yet an needs further HW and SW adaptation development.

Unfortunately, such synchronism is not sufficient, as propagation delay has to be balanced, too, in the repeater NodeB/2. This balance can only be executed correctly by sending both U_u-data and I_{ub}-data via satellite either to the UE directly as well as processed. The reason for this is that the U_u data has to be delayed within the Hub in order to meet later-on at the UE interface frame number and assigned frame content timely correct. The required delay steps may be adjusted with steps of multiples of 8 frames duration.

On the Iub – side of the repeater NodeB/2 provisions have to be made to synchronise both the received data from the satellite as well as the data streams in the private part of the NodeB/2. Additionally private Iub-data have to be multiplexed, at least functional, with the Maestro Iub-data. As Maestro is a broadcast system, i.e., one-way I_{ub}-data, supplementary measures have to be taken to allow the NodeB/2 dialogues for cell set-up, common channel set-up, mismatch balance for UMTS frame synchronisation, ARM cell transmission, etc.

Performance:

Interfaces:

The table below sub-summarises the applied bands, their adjacent frequencies and the carried UMTS data.

	Band	Frequency	Data

feeder	F_{FSS}	27.5 – 30GHz	U_u+I_{ub}
direct down-link to UE	F_{MSS}	2.17 – 2.2GHz	U_u
down-link to repeater	F_{FSS}	27.5 – 30GHz	I_{ub}
down-link from repeater to UE	F_{MSS}	2.17 – 2.2GHz	U_u

pros for this repeater type:

- Re-use of NodeB infrastructure (power supply, etc,)
- Suitable NodeB locations and positions
-

cons for this repeater type:

- Rake requirements (20us window)
- System synchronisation required
-
-

5.1.5 IMR I/F To Outside World – Space I/Fs

5.1.6 IMR I/F To Outside World – UE I/F

5.2 Detail Specification Of Dedicated Components

In this chapter it is intended to describe some complex specifications (just like this one fore NodeB), which hardly fit into a integral table work and additionally require illustrations.

5.2.1 Transmit Path OF NodeB

(a) UMTS (UTRA FDD) NodeB General Radio Parameters:

- Tx-power : 20W +/- 1dB, 43dBm (3GPP TS25.104)
- Reference sensitivity : -123dBm at 12.2kb/s, SF = 64, BER less or equal10-3
- Channel bandwidth : 5MHz
- Frequency range : UTRA FDD
- Combiner type : wide-band combining

(b) Frequency Bands:

- transmit frequency band : 2,110MHz – 2,170MHz (terrestrial UMTS)
- Tx-mid-frequency : 2,140MHz (terrestrial UMTS)
- transmit frequency band : 2,170MHz – 2,200MHz (UMTS-satellite band)
- Tx-mid-frequency : 2,185MHz (UMTS-satellite band)

The local oscillators within the Tx-block are adjustable to support UMTS carriers within these RF bands. The adjustable oscillators will settle within 10ms after a frequency change command. The RF filters within the Tx module support the full 60MHz RF bandwidth without any tuning.

(c) Capacity Per Cell:

Within the NodeB should be no limitation in order to support up to 120 users and 1,920kb/s per cell. This cell capacity cannot be achieved today but will be target for the next future.

Also the restricted capacity for base-band processing on NodeB-level in the future could be set to a maximum of 18 cells (6x3) thus with 75% load and 75% voice users in total. Fully equipped the Node may handle up to 1,215 users (18 x 0.75 x 0.75 x 120users) and 25,920kb/s. The today base-band processing per cell allows support up to 75 users and 1,536kb/s per cell. For traffic mix models the following rough estimation for Basis Band Processing-module dimensioning can be drawn up:

- $K + L + M + N \leq 75$ user channels
- K x 12.2kb/s + L x 64kb/s + M x 128kb/s + N x 384kb/s ≤ 1,536 kb/s

where:

- K = number of AMR users

- L = number of 64kb/s channel users
- M = number of 128kb/s channel users
- N = number of 384kb/s channel users

Base-band processing capacity serves as pooled resource for the whole platform. So the distribution of users in the BB-pool is independent from the number of the carriers or sectors. The limit for one basis band processing board is the support of a 6x2 configuration in the future. BB dimensioning is independent from the RF configuration with the following limits per Node:

- min. configuration: up to 16 users and 384kb/s + necessary CCH
- max. configuration: up to 675 users and 13 824kb/s + necessary CCH
- (---> assuming max 12 cells, 75 % load)

<u>NodeB Tx-Channel Capacity And/Or Range Extensions:</u>

- Tx Antenna Diversity (STTD-mode, TSTD-mode, Feedback mode 1 and 2)
- Multiple Scrambling Codes (MSC)
- SSDT (Side Selection Diversity TPC)

(d) Channel Arrangement

<u>Channel Spacing And Channel Raster:</u>

The Node´s RF modules support a nominal channel raster of 5MHz. In order to optimise performance in a particular operator scenario also other channel spacing shall be supported, up to a minimum of 4.6MHz. Anyway, performance measurements should be done using the nominal channel spacing.

The Node´s RF modules support a channel raster of 200kHz, i.e., the centre frequency of a channel must be an integer multiple of 200kHz. The local oscillators within Tx-module have tuning steps required to support this channel raster.

<u>Channel Number:</u>

The UTRA absolute radio frequency channel number (UARFCN) is obtained by multiplying the corresponding Tx channel centre frequency by five.

<u>Multiple Carrier Capabilities And Restrictions:</u>

The multiple-carrier capability of the Tx-module ensures to process up to four UMTS frequency channels simultaneously within any consecutive 20MHz sub-band of the UMTS Tx frequency band. Because the multiple-carrier synthesis / analysis is done in the digital part on Tx-module the analogue up and down-converters have to support a 20MHz bandwidth in their IF stages.

(e) Transmit Chain Budget Allocation

The reference point for transmitter performance measurements is the NodeB antenna connector. The following measurements should be executed there:

- base station output power tests,
- occupied bandwidth test,
- adjacent channel leakage power ratio tests (ACLR),
- spurious emissions tests,
- transmit inter-modulation test.

Base Station Maximum Output Power:

The maximum output power is the mean power level per carrier measured at the reference point when the carrier power is set to maximum available power. For the multiple-carrier Tx the available output power could be distributed to up to four carriers. In the tables below the sum of all carriers is given. In case of only one carrier the total output power should be available for this carrier. The following requirements Table 1 are applicable for the applied NodeB:

Table 1: NodeB power budget

NodeB output power		normal condit.	extreme condit.
minimum value	[W]	14.79	12.88
typical value	[W]	20.89	20.65
maximum value	[W]	29.51	33.11
minimum value	[dBm]	41.70	41.10
typical value	[dBm]	43.20	43.15
maximum value	[dBm]	44.70	45.20
tolerance	[+/- dBm]	1.50	2.50

Tx-module output power		normal condit.	extreme condit.
nominal output power	[W]	29.5	29.5
extreme output power	[W]	44.7	44.7
output power tolerance	[+/- dB]	1.0	1.5
minimum output power	[dBm]	43.7	43.2
typical output power	[dBm]	44.7	44.7
minimum output power	[dBm]	45.7	46.2

NodeB module insertion loss		normal condit.	extreme condit.
minimum loss in Tx-band	[W]	0.20	0.20
typical loss in Tx-band	[W]	0.60	0.65
maximum loss in Tx-band	[W]	1.00	1.10

RF-cable insertion loss		TRx-→ANT	ANT -→BTS

minimum loss in Tx-band	[dBm]	0.30	0.50
typical loss in Tx-band	[dBm]	0.35	0.55
maximum loss in Tx-band	[dBm]	0.40	0.60

(f) Frequency Error:

All frequencies and clocks within the Node shall be derived from the same source. The modulated carrier frequency is measured over a period of one power control group (one radio timeslot of 666.6us). The following effects may contribute to the modulated carrier frequency error:

- stability of the common frequency source (master oscillator of the Node, which determines the long-term stability of the carrier frequency. If the master oscillator is locked to the clock from the I_{ub} interface, then clock stability will refer to the stability of the I_{ub} clock.
- clock distribution within the platform´s cabinet. Low frequency noise and spurs up to several kHz contribute to the frequency error. To minimise these effects, a clock cleanup circuit shall be used within the Tx-module with a loop bandwidth of less than 10Hz.
- TEU internal effects like noise and spurs on the TEU internal clock distribution, low frequency local oscillator phase noise or spurs and power amplifier

Table 2below allocates the allowed overall frequency error to the different sources.

Table 2: Tx frequency error budget

Tx frequency error budget	error [+/- ppm]	error at RF [+/- Hz]
platform master oscillator	0.020	29.5
clock distribution inside cabinet	0.005	44.7
Tx-module	0.025	1.5
calculated platform frequency error	0.050	43.2
required platform frequency error	0.050	44.7

(h) Output RF-Spectrum Emissions

From budget allocation point of view, the RF spectrum emission requirements can be divided into two categories:

- requirements inside the UMTS transmit band (2,110 – 2,170MHz) and close to the band edges. In this frequency band Tx has to fulfil the requirements because the Tx filter within ANT does not provide any additional suppression beside the normal in-band insertion loss.
- for the MAESTRO application the Tx filter requires a shift of the filter mid-frequency from 2,140 to 2,185MHz.

- requirements outside the UMTS transmit band. Here the Tx filter of the Antenna Network provides additional suppression of unwanted frequencies.

Occupied bandwidth is a measure of the bandwidth containing 99% of the total integrated power for transmitted spectrum and is centred on the assigned channel frequency. The occupied channel bandwidth shall be less than 5MHz at Tx output.

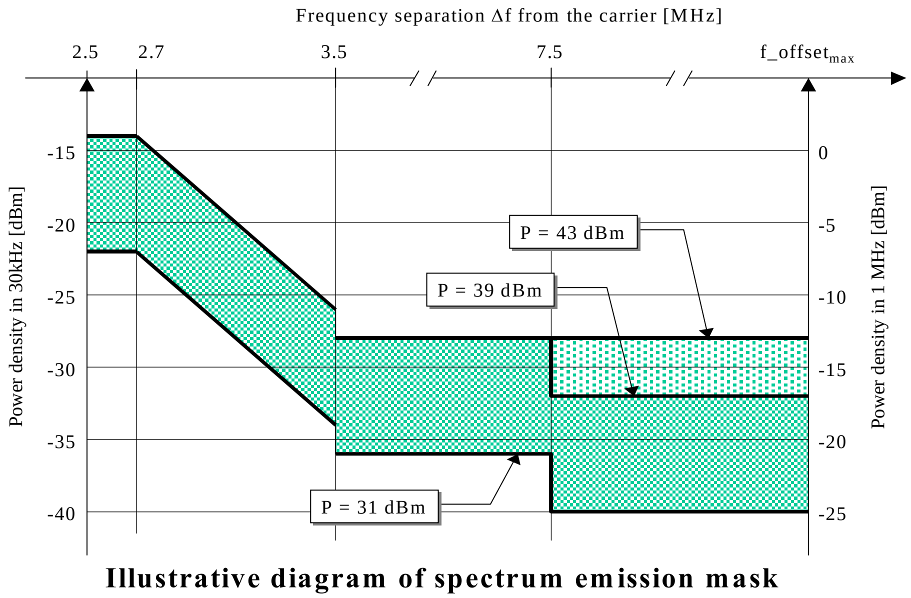


Figure 16: Spectrum emission mask at reference point

The platforms Tx emissions shall not exceed the maximum level specified in Table 3 and also shown in Figure 16 for the appropriate maximum output power, in the frequency range from Δf = 2.5MHz to $f_{\_offsetmax}$ from the carrier frequency, where:

- Δf is the separation between the carrier frequency and the nominal -3dB point of the measuring filter closest to the carrier frequency.
- $f_{\_offset}$ is the separation between the carrier frequency and the centre of the measuring filter.
- $f_{\_\ offsetmax}$ is either 12.5MHz or the offset to the UMTS-Tx band edge.

Table 3: Spectrum emission mask values for different output power

spectrum emission mask values for output power P<43dBm				
frequency offset of measurement filter –3dB-point, Δf	**frequency offset of measurement filter centre frequency f_offset**	**maximum level at TRx-output**	**maximum level at antenna output**	**Measure. bandwidth**
2,5 < Δf <2.7MHz	2.515 < f_offset < 2.715MHz	-13.15dBm	-14dBm	30kHz
2,7 < Δf <3.5MHz	2.715 < f_offset<3.515MHz	-13.15 - 15	-14 - 1.5	30kHz

		(f_offset-2.715)dBm	(f_offset-2.715)dBm	
see note below	3.515 < f_offset<4.000MHz	-25.15dBm	-26dBm	30kHz
3.5 < ∆f MHz	4.000 <f_offset<f_offset max	-12.15dBm	-13dBm	1MHz

spectrum emission mask values for output power P>43dBm				
2,5 < ∆ f < 2.7MHz	2.515 < f_offset < 2.715MHz	-13.15dBm	-14dBm	30kHz
2,7 < ∆f < 3.5MHz	2.715 < f_offset < 3.515MHz	-13.15-15 (f_offset-2.715)dBm	-14-1.5 (f_offset-2.715)dBm	30kHz
see note below	3.515 < f_offset < 4.000MHz	-25.15dBm	-26dBm	30kHz
3.5 <∆f < 7,5MHz	4 < f_offset < 8MHz	-12.15dBm	-13dBm	1MHz
7.5 <∆f MHz	8 < f_offset < f_offset max	P - 55.15dBm	P - 56dBm	1MHz

spectrum emission mask values for output power 31 < P < 39dBm				
2,5 < ∆f <2.7MHz	2.515 < f_offset < 2.715MHz	P - 52.15dBm	P - 53dBm	30kHz
2,7 < ∆f < 3.5MHz	2.715 < f_offset < 3.515MHz	P - 52.15-15 (f_offset-2.715)dBm	P-14-1.5 (f_offset-2.715)dBm	30kHz
see note below	3.515 < f_offset < 4.000MHz	P - 64.15dBm	P - 65dBm	30kHz
3.5 < ∆ f < 7,5MHz	4 <f_offset < 8MHz	P - 51.15dBm	P - 52dBm	1MHz
7.5 < ∆f MHz	8 < f_offset < f_offset max	P - 55.15dBm	P - 56dBm	1MHz

spectrum emission mask values for output power P < 31dBm				
2,5 < ∆f < 2.7MHz	2.515 < f_offset < 2.715MHz	- 21.15dBm	- 22dBm	30kHz
2,7 < ∆f < 3.5MHz	2.715 < f_offset < 3.515MHz	P - 52.15-15 (f_offset-2.715)dBm	P-22-1.5 (f_offset-2.715)dBm	30kHz
see note below	3.515 < f_offset < 4.000MHz	-33,15dBm	- 34dBm	30kHz
3.5 < ∆f < 7,5MHz	4 <f _offset < 8MHz	- 20.15dBm	P 21dBm	1MHz
7.5<∆f MHz	8 < f_offset < f_offset max	- 24.15dBm	- 25dBm	1MHz

<u>Note:</u> a minimum insertion loss of 0.85dB is assumed for the TX to antenna connector

(i) Adjacent Channel Leakage Ratio (ACLR):

Adjacent Channel Leakage power Ratio (ACLR) is the ratio of the average power centred on the assigned channel frequency to the average power centred on an adjacent channel frequency. In both cases the average power is measured with a filter that has Root Raised Cosine (RRC) filter response with roll-off factor 0.22 and a bandwidth equal to the chip rate. The requirements below shall apply for all configurations of TRx (single carrier or multiple carrier) and for all operating modes foreseen.

Table 4: Adjacent channel leakage ratio at TX and platform output

adjacent channel offset below the first or above the last carrier frequency used	**ACLR limit**	**ACLR typ**
5MHz	45dB	48dB

10MHz	50dB	53dB

(k) Transmit Inter-Modulation And Transmit Modulation

Transmit Intermodulation:

The transmit inter-modulation performance is a measure of the capability of the transmitter to inhibit the generation of signals in its non linear elements caused by presence of the wanted signal and an interfering signal reaching the transmitter via the antenna.

The transmit inter-modulation level is the power of the inter-modulation products when a W-CDMA modulated interference signal is injected into the antenna connector at a level of 30dB lower than that of the subject signal. The frequency of the interference signal shall be ±5MHz, ±10MHz and ±15MHz offset from the subject signal.

Transmit Modulation:

Transmit modulation is specified in three parts, Frequency Error, Error Vector Magnitude and Peak Code Domain Error. These specifications are made with reference to a theoretical modulated waveform.

The theoretical modulated waveform is created by modulating a carrier at the assigned carrier frequency using the same data as was used to generate the measured waveform. The chip modulation rate for the theoretical waveform shall be exactly 3.84Mcps. The code powers of the theoretical waveform shall be the same as the measured waveform, rather than the nominal code powers used to generate the test signal. In the platform the modulation is performed within the digital part of Tx. Modulation errors are due to:

- truncation effects in the digital signal processing part of Tx (limited number of bits and transmit pulse shape filter length). These effects are minor.
- the clipping algorithm within Tx which is needed to improve the signal peak to average ratio (PAR) of the unclipped signal. A low PAR is required in order to have a good power amplifier efficiency. Most of the allowed modulation errors should be allocated to the clipping process.
- the D/A, up-converter and power amplifier imperfections within the Tx module.
- the transmit filter imperfections like amplitude ripple and group delay variations within the Antenna Network ANT/ANRU module.

Transmit Pulse Shape Filter:

The transmit pulse-shaping filter is a root-raised cosine (RRC) with roll-off $\alpha = 0.22$ in the frequency domain. The impulse response of the chip impulse filter RC0(t) is:

$$RC_0(t) = \frac{\sin\left(\pi \frac{t}{T_C}(1-\alpha)\right) + 4\alpha \frac{t}{T_C}\cos\left(\pi \frac{t}{T_C}(1+\alpha)\right)}{\pi \frac{t}{T_C}\left(1-\left(4\alpha \frac{t}{T_C}\right)^2\right)}$$

where the roll-off factor α = 0.22 and the chip duration:

$$T_c = \frac{1}{chiprate} \approx 0.26042\mu\text{s}$$

Error Vector Magnitude (EVM):

The error vector magnitude (EVM) is a measure of the difference between the reference waveform and the measured waveform. This difference is called the error vector. Both waveforms pass through a matched Root Raised Cosine filter with bandwidth 3.84MHz and roll-off α = 0.22.

Both waveforms are then further modified by selecting the frequency, absolute phase, absolute amplitude and chip clock timing so as to minimise the error vector. The EVM result is defined as the square root of the ratio of the mean error vector power to the mean reference power expressed as a %. The measurement interval is one timeslot as defined by the C-PICH (when present) otherwise the measurement interval is one timeslot starting with the beginning of the SCH.

Table 5: Error vector magnitude (EVM) requirements

EMV_{TRX}	EMV_{ANT}	EMV_{total}
16.80%	4.1%	17.3%

For the platform on Node B basis the total allowed EVM is allocated to the different modules as shown in Table 5 above. It is assumed that the EVM of the individual modules is independent so that the overall EVM is the RMS-value of the individual contributions.

Peak Code Domain Error (PCDE):

The Peak Code Domain Error (PCDE) is computed by projecting the power of the error vector onto the code domain at a specified spreading factor. The Code Domain Error for every code in the domain is defined as the ratio of the mean power of the projection onto that code to the mean power of the composite reference waveform.

The PCD Error (ratio expressed in dB) is defined as the maximum value for the Code Domain Error for all codes. The measurement interval is one timeslot as defined by the C-PICH (when present) otherwise the measurement interval is one timeslot starting with the beginning of the SCH. The requirement is valid over the total power dynamic range.

Table 6: Peak code domain error (PCDE) requirements

EMV_{TRX}	$PCDE_{ANT}$	$PCDE_{total}$
16.80%	4.1%	17.3%

The spreading factor for the peak code domain requirement is 256. The table below lists the PCDE requirements for the experimentation platform. It is assumed that individual contributions are independent, so that their powers can be added.

5.2.2 Stbd

5.2.3 stbd

5.2.4 stbd

5.3 System Variants Evaluation Process

5.3.1 Selection Criteria (PRO&CON Matrix) [under construction]

Remark: The subsequent evaluation table may be regarded as an attempt to find objective selection criteria as a pre-step for the later economical considerations. Unfortunately all addressed parameters have a close relationship to either each other or to the other IMR components; pros might balance cons and so far. The application of e.g On-Channel repeaters may be advantageous as far as satellite and Hub are concerned; it might be not to be the optimal solution, when the use of directed antenna configurations will be discussed.

Selection criteria			**OCR**	**fcv**	**NdB**
Required infrastructure (e.g., power supply)			–	–	+
Operation and maintenance			0	0	0
Installation			++	+	–
MTBF			+	+	++
Installation cost factor			++	0	– –
Synchronisation issues (general):			++	++	– –
	in particular:	GPS-coverage	++	++	–
	In particular;	GSM (GPRS) / UMTS Environment	++	++	– –
System complexity			+	+	– –
System flexibility			+	+	– –
Robustness against regularity			0	0	0
Robustness against standards changes			+	++	–
Privacy and security			– –	+	++
Future safe:			–	0	++
	in particular:	extendable	++	++	+
	in particular:	adapted capacity /scalable	++	++	+
	in particular:	re-usability	–	–	++
	in particular:				
Acceptance by external providers			0	0	– –
Acceptance by public			0	0	0
Availability			+	–	+

Possible adaptation development effort	++	0	

OCN = On-Channel Repeater **– – = extremely unfavour-able**

FCV = Frequency Covnertion Repeater **– = unfavourable**

NdB = NodeB based Repeater **0 = neither nor**

+ = advantageous

++ = very advantageous

Efficiency (based on individually tailored concepts)

Adaptation development effort

Availability Of Suitable Equipment

Satellite (Features, Equipment

Repeaters

Antennas

RNC / NodeB network

Synchronisation extension

Communication Environment

6 ANNEX 1 – DEDICATED INVESTIGATION RESULTS

6.1 Synchronisation Issue Studies Between HUB And IMR

6.1.1 Usage Of UMTS Repeaters For Synchronisation

It is obvious that applying a NodeB to the IMR-branch and, additionally, to use it for shared traffic causes higher-than-average problems. It is not clear yet, whether this solution will increase cost and effort (instead decrease those ones). It is also not clear from the technical point of view, whether the co-use of the supplying environment of an established NodeB compared with stand-alone repeater solutions will be advantageous.

(a) Summary On Existing Procedures

In any case (option 1 or option 2) the SFNs of both NodeBs are not synchronous. This is the main difference to the synchronisation of radio links in the soft handover situation, where corresponding CFNs are equal. As the terminal does not see the frame numbers, it is the RNC which could recalculate the appropriate BFN/SFN for the 2nd NodeB, so that the content is delivered time-synchronous over different SFNs of the two NodeB's S-CCPCH.

Furthermore the application of the existing procedures would require for the UE to provide a greater window for the processing of the two signals.

(b) UMTS Repeaters

The simplest solution would be to apply real UMTS-repeaters instead of the "terrestrial repeater-" NodeBs. Repeaters would provide in general a slight delay of the signal (less than 6us according product information), which could be helpful to select the better signal and to reduce interference.

If the Repeaters are used inside buildings only, the repeaters could send on the same frequency as the "satellite" NodeB.

If the repeaters are used in urban regions, the "satellite" NodeB has also to be simulated by a repeater and all repeaters have to use the same sending frequency, which should be different from the frequency, which is provided by the "source NodeB". Repeaters sending on the same frequency as the received signal, would also receive and amplify their own signal. In this case the signals of the source NodeB would not be received by the terminal. Attenuation can only be achieved by suitable antenna configurations.

(c) Impact On The Final System

Repeaters would be a good solution for the final satellite system. The UMTS signal could be split in a direct and an indirect (for the repeaters) link either by the Hub NodeB, the Satellite transmitter or even by the satellite. The satellite sends the UMTS wave form signal directly and over the 12MHz band to the repeaters, which convert it to the frequency of the direct link .

Further on there is no need in sharing terrestrial NodeB's capacity between their RNC and the Hub RNC. This sharing would cost a considerable capacity of the NodeB, especially because it requires the down-link. Additionally it is difficult to use the SDMB reserved frequencies, if an UMTS operator uses only the lower bands of terrestrial UMTS (linearity of amplifier). It is also a question, whether we have UMTS NodeBs exactly in those locations, where we have no line-of-sight to the satellite. Repeaters at these locations would be quite cheaper than NodeBs.

To be continued

6.1.2 Usage Of NodeB For Synchronisation

Synchronisation of and by means NodeBs aims at the achievement of common timing references among different nodes. Though normally not required, for some specific applications (like IMR inter-working / inter-operation) such synchronisation may be helpful and necessary.

In order to avoid buffer-times and thus speeding up the transmission delay, it could be suitable to estimate the timing differences between RNC and NodeB without the need to compensate the phase differences within the NodeB´s internal counters. This is the reason why UTRAN provides three synchronisation mechanisms over I_{ub}:

- synchronisation between the RNC and its NodeBs;
- synchronisation of NodeBs among each other;
- frame synchronisation.

The synchronisation between the RNC and its NodeBs is shown in Figure 17. The Round Trip Delay (RTD) is calculated [3GP1]:

RTD = T2 ... T1 and T4 ... T3

where:

- T1 RNC specific frame number (REN) that indicates the time when RNC sends the down-link Node Synchronisation control frame through the SAP to the transport layer.
- T2 NodeB specific frame number (BFN) that indicates the time when NodeB receives the correspondent down-link Node Synchronisation control frame through the SAP from the transport layer.

- T3 NodeB specific frame number (BFN) that indicates the time when NodeB
  sends the up-link Node Synchronisation control frame through the SAP
  to the transport layer.
- T4 RNC specific frame number (RFN) that indicates the time when the RNC
  receives the up-link Node Synchronisation control frame.

Each T1, T2 and T3 covers a range between 0 – 40,959.875ms with a step size of 0.125ms; T4 is not standardised yet.

The Node Synchronisation between the RNC and NodeB can be used to detect differing timing references between the UTRAN nodes (RFN in RNC and BFN in NodeB); in particular, synchronisation is required for the transport channels between RNC and their connected Nodes both for determination of up-link and down-link offset values.

Measured values of timing relationships between those nodes are gained by the RNC-NodeB Synchronisation Procedure. This procedure is defined in the user plane protocols for I_{ub} (DCH, DSCH, and FACH/PCH) and I_{ur} (DCH).

When used from RNC over the DCH user plane, this procedure also allows to detect the actual round-trip-delay, as the Node Sync Control Frames are transferred the same way as the DCH frames).

The procedure may also be carried out over a high priority transport bearer. Measurements of node offsets can be made at start or restart as well as during normal operation to supervise the stability of the nodes.

Though an **accurate** Reference Timing Signal is used, there still might remain a low frequency deviation between the nodes.

If **no accurate** Reference Timing Signal is available, the local node reference oscillator must be relied upon. In such cases the RNC-NodeB Node Synchronisation procedure can be used as a background process for detecting the frequency deviation between the nodes.

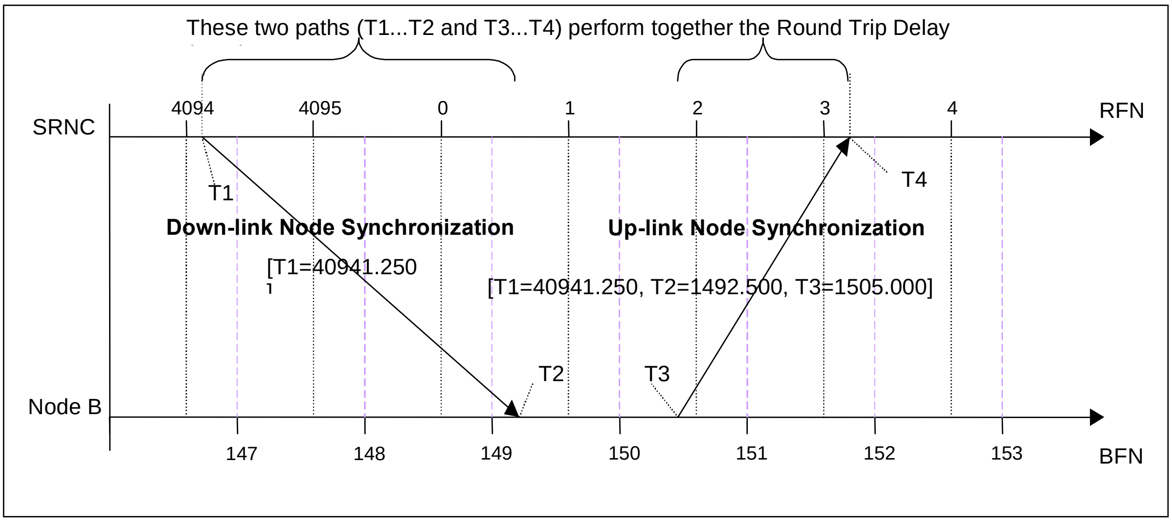
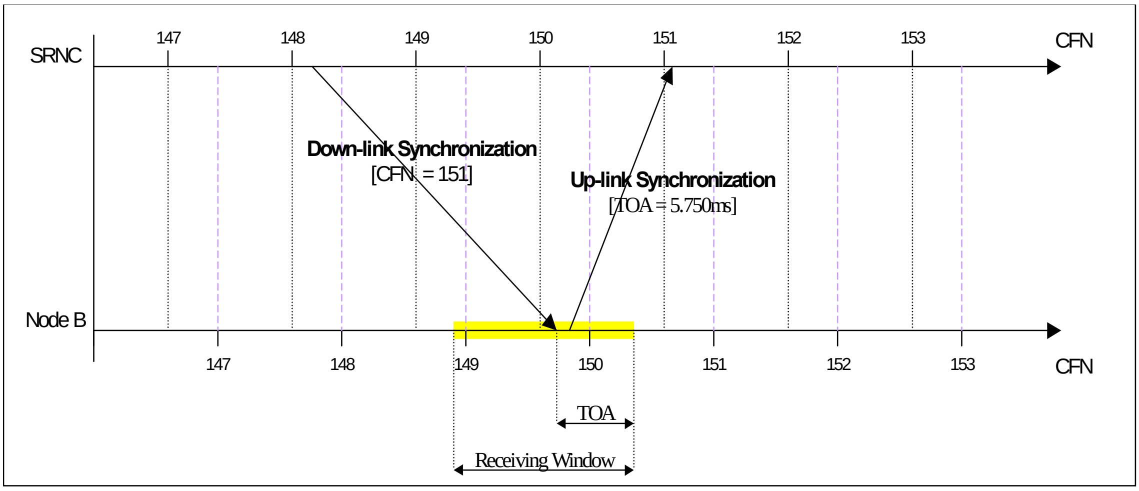


Figure 17: RNC-NodeB synchronisation

In the RNC-NodeB Node Synchronisation procedure, the RNC sends a down-link Node Synchronisation control frame to NodeB containing the parameter T1. Upon reception of a down-link Synchronisation Control Frame, the NodeB shall respond with up-link Synchronisation Control Frame, indicating T2 and T3, as well as T1 which was indicated in the initiating down-link NodeB Synchronisation Control Frame (Figure 17).

In order to monitor the TOA when no down-link data frames are sent, a synchronisation procedure is defined in the I_{ub}/I_{ur} frame protocols ([4],[5]). This procedure makes use of up-link and down-link Synchronisation Control Frames (see Figure 18).

The SRNC sends down-link Sync Control frame containing the CFN in which the control frame should be received by the NodeB. When the NodeB receives the down-link Synchronisation Control Frame (SCF), it always replies with an up-link Synchronisation Control Frame containing the TOA, even if the down-link Control Frame is received within the receiving window as shown in Figure 18.



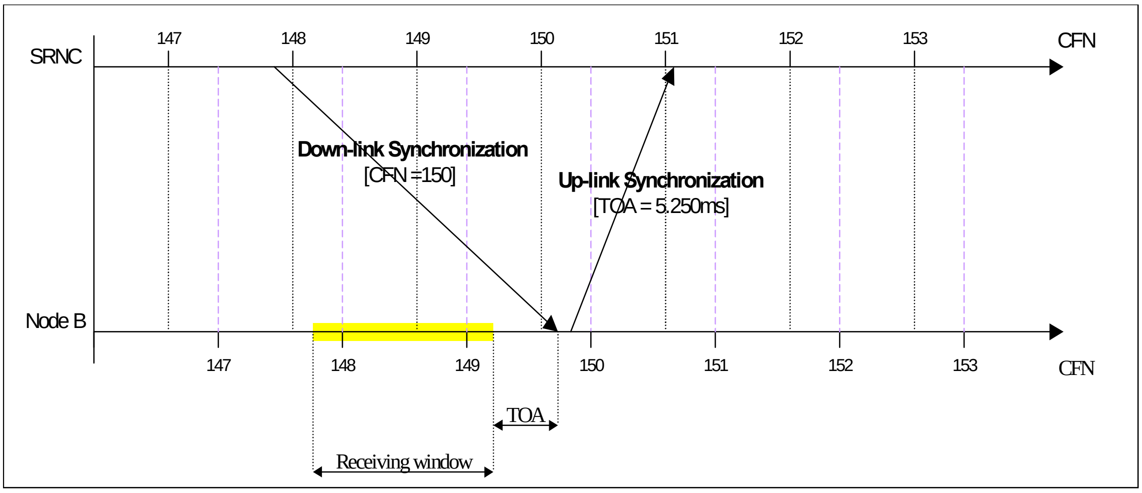


Figure 18: TOA monitoring

TOA-monitoring is executed through Frame Protocol Synchronisation procedure (TOA >0, TOA <0 as shown in Figure 18.

6.1.3 Features Provided In UMTS For Timing Adjustment

The channels used for SDMB are shown in Figure 19.

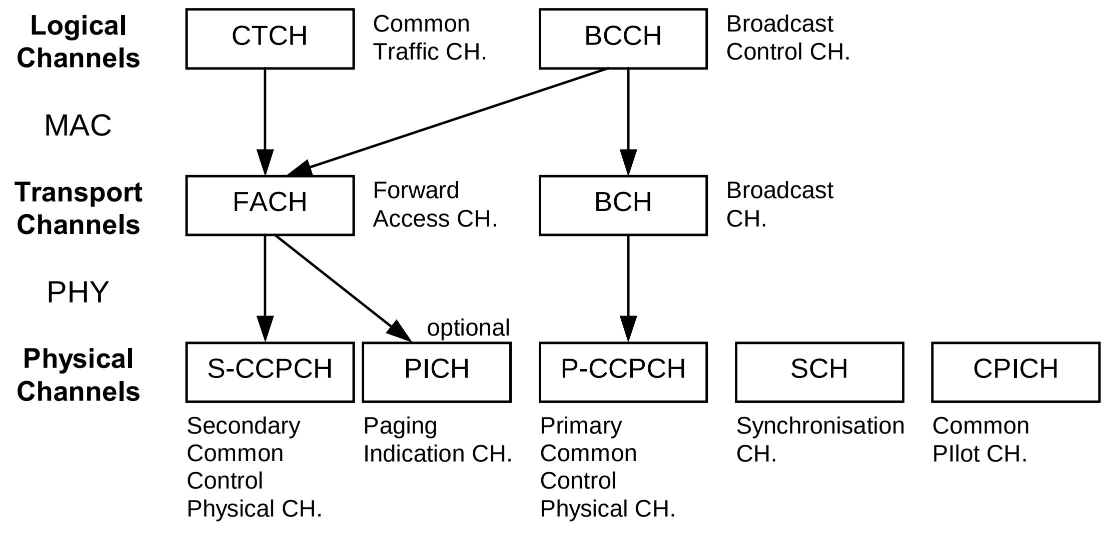


Figure 19: Channels used in SDMB

The Secondary Common Control Physical CHannel (S-CCPCH) is the only common physical channel that can be aligned on a multiple of 256 chips, as shown in Figure 20 The other common physical channels are aligned on the 10ms frame structure.

As one radio frame takes 10ms and contains 15 slots of 2,560chips, 256chips last 10ms / 15 /10 = 66.6µs. Therefore, the S-CCPCH can be aligned with a granularity of 66.6µs only. But aligning the S-CCPCH alone is not enough: the other physical channels must also be aligned (SCH, CPICH and P-CCPCH).

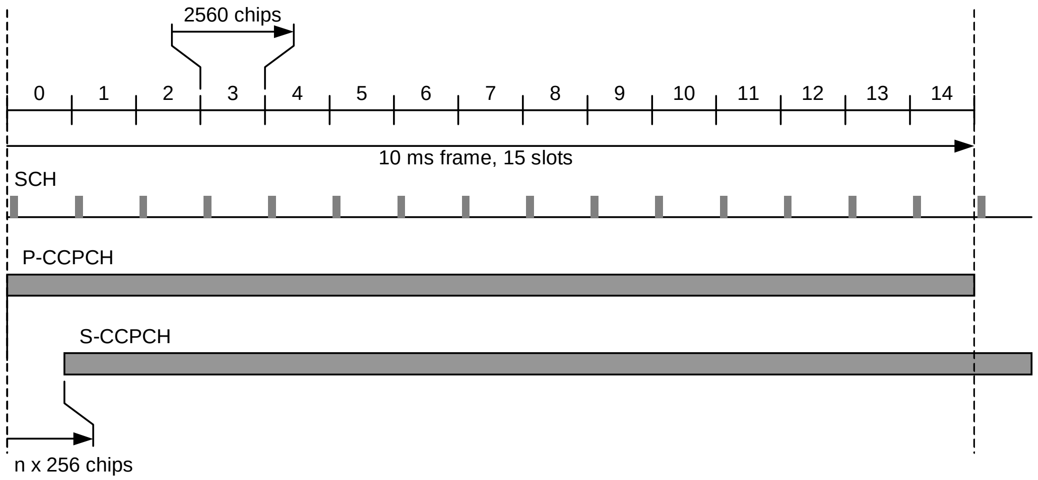


Figure 20: Timing of P-CCPCH and S-CCPCH

In NBAP T_{CELL} is the timing delay used for defining start of SCH, CPICH and the down-link scrambling code(s) in a cell relative BFN. The resolution of T_{CELL} is 256 chips.

6.1.4 Compensation Of HTI And IMR NodeB Processing Time

All further considerations are made under the assumption of having a NodeB as IMR. This is reasonable, as for configurations without NodeB synchronisation and delay compensation issues are not relevant.

Figure 21 architecture illustrates the different links within the SDMB system where propagation delay is produced and thus be compensated.

The hub (SDMB RNC) in relation with the IMR (HTI Rx) ensures that both satellite W-CDMA signal and terrestrial repeater's W-CDMA signal are received by the SDMB enabled handset (UE) within its rake window (20us) to ensure coherent recombination.

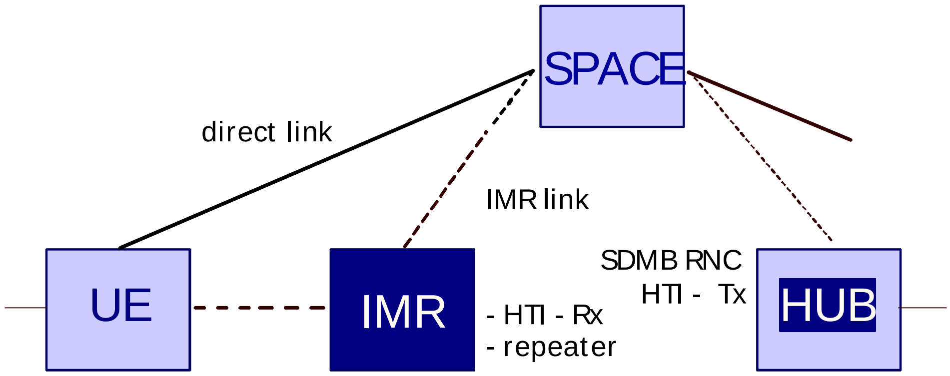


Figure 21: Direct link and IMR link

The SDMB RNC shall delay the information/signal transmitted by the SDMB NodeB to take into account the maximum processing time of the HTI Tx + HTI Rx + ‘enabled S-DMB’ NodeB (repeater), illustrated in Figure 21.

The HTI Rx will synchronise the information/signal transmitted by the ‘enabled SDMB’ NodeB to achieve time alignment between both signals from the satellite and from the terrestrial repeater at the UE side. For that, a cache memory is needed to absorb the worst case time difference [500ms].

The use of a common clock reference in the hub and in the IMR is required to adjust the IMR’s nodeB modem time reference with regards to time reference sent by the HTI Tx/SDMB RNC.

6.1.5 Alignment Of The Satellite And IMR Signals

(a) Synchronisation Considerations:

The synchronisation issues may be fairly solved by applying a GPS receiver to the NodeBs. This synchronisation is intended to control both clock frequency and phase. Unfortunately this synchronisation mechanism, as described in [3GP1], section 6.1.2.1, is intended only for TDD mode and cannot applied here one-to-one.

The Alcatel NodeB V2 used in MAESTRO, however, is already equipped with add-on synchronisation ports but the software does not handle it yet. One solution could be an upgrading adaptation development of the NodeB software.

The RNC should itself be synchronised, too, e.g., by implementing a procedure to loop-back the NodeB´s GPS-synchronised clock - see [3GP5] section 5.2.9, used for LCS - Location Services - described in [3GP6]

Additionally, the standard UMTS granularity to adjust the timings is not sufficient: it is of 66µs only, and the UE rake receiver accepts 20 µs maximum. Therefore, the 3GPP specifications should be upgraded to enable time adjustments with a granularity below 66µs.

For a given frame, the BFN (NodeB frame number) in the Hub NodeB and the BFN in the IMR NodeB must be equal (the BFN is used to transmit the SFN to the UEs). The BFN depends on each NodeB start-up time, and cannot be controlled; therefore, the BFN in the Hub and in the IMR will be different. One solution could be to upgrade the 3GPP specifications and thus enabling BFN setting through the I_{ub}.

(b) Distance Considerations (direct link vs IMR link):

In addition to the compensation of HTI and IMR NodeB processing time described in the previous section, which is performed at frame level, the signal coming directly from the satellite must be aligned with precision with the signal coming through the IMR.

As shown in, Figure 22 the geo stationary satellite being at dd = 36,000km from the earth, it can be estimate that:

- di1 - dd < di2;
- di1 - dd induces a fixed reception delay (or advance) D1, of maximum 10 / 300,000 = 33µs, if di2 = 10km.
- D1 is constant and depends on the location of the IMR relatively to its satellite.

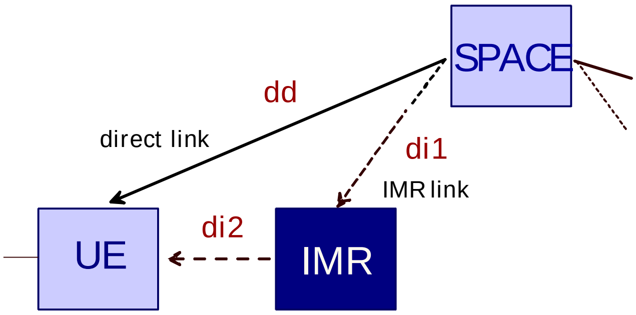


Figure 22: Distances through direct link and IMR link

In addition, a variable delay D2 is provoked by the distance between the UE and the IMR. The reception of two identical signals with a time difference more than the rake window duration (20us) causes interference and then degrades the reception performance. Considering that the rake receiver in the UE can recombine signals received with a time difference of up to 20 µs, the IMR transmission power should be limited to cover a maximum distance.

The approximate cell size can be calculated by:

DRake = 20 µs x 300,000km/s = 6km.

DRake seems compatible with the fact that the IMRs will be installed in dense urban areas, where the goal is not to cover a very large cell.

(c) Distance Considerations (between north and south beam limits):

This briefly explained issue is only relevant for a synchronised IMR application. In this concept the RNCs and NodeBs together with the GPS cater for bit- and frame synchronism and additional artificial frame content delays. This fact requires a fully synchronised network of RNCs and NodeBs, i.e., a time delayed satellite beam meets a fully synchronised network. Depending on the actual delay time – as calculated below – the propagation delay time of the beam may fit into those time constraints or not.As these different propagation delay is a physical phenomena and can only be adjusted (in the hub) once for the whole system no additional balance can be applied.

It is now subject of the subsequent considerations to find out whether propagation delay variants will support/skip the synchronous system concept.

Simplified Model By Neglecting The Longitude:

In order to give a first overview on the delay problem an initial simplification is applied. The restriction is made by calculating only in a two dimensional sphere which might be sufficient for the first batch. Depending on the outcome results a three-dimensional calculation can be added, if necessary. Subsequent Figure 23 gives a view on the relevant parameters and distances.

The satellite SAT is assumed to be positioned in orbit on the equatorial line in a distance D of 36,000km. Its Cartesian co-ordinates are [xSAT | 0]. The earth radius R is assumed to 6,366km.

The satellite´s beam covers an latitude area between 35 (α1)and 65 (α2) degrees north represented by the Surface Points SF1 and SF2 with its co-ordinates [x1 | y1] and [x2 | y2]. Caused by the deflection of the earth surface the distances between satellite and SF1 (d1) differ to that between satellite and SF2 (d2).

It is now matter of this investigation to prove that all UEs on the curve between SF1 and SF2 receive the broadcast data stream within the Rake´s tolerance frame of about 20us. Increasing this value would mean that the UEs cannot combine the received signals; they will be regarded as non-correlated signals.

The simplification is made by neglecting the longitudinal angles 10 to 30 degrees and thus not calculating in a three-dimensional space.

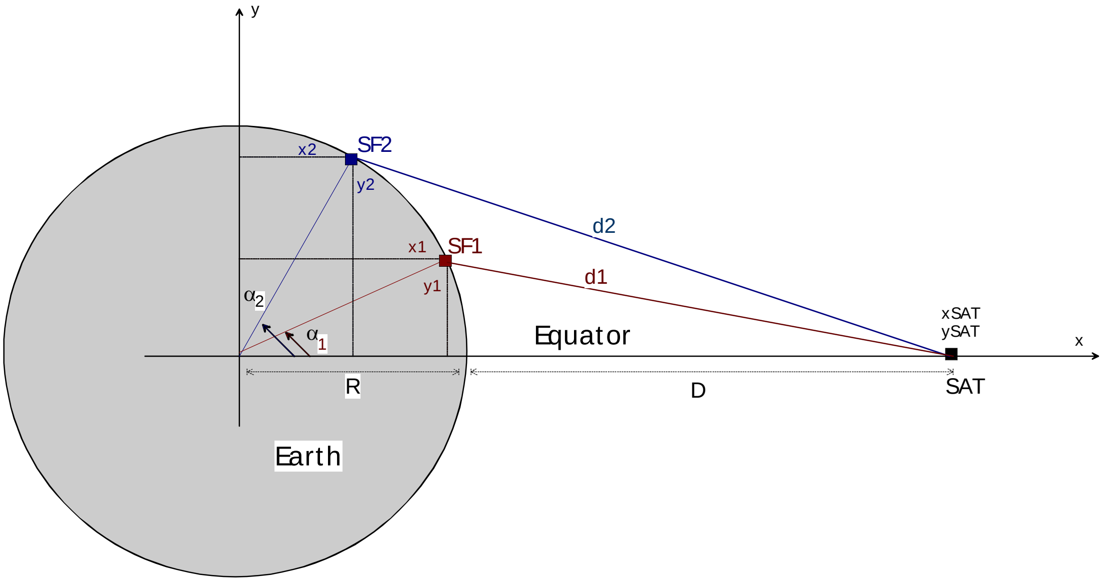


Figure 23: Propagation delay variants

Assumptions And Calculations:

- Earth radius R = 6,366km
- Satellite distance D = 36,000km
- Latitude α_1 = 35°

α_2 = 65°

- Co-ordinates SAT = [R+D | 0]

SF1 = [R cosα_1 | R sinα_1]

SF2 = [R cosα_2 | R sinα_2]

Taking the figures from above the distance difference between most south (*d*1 from SAT to SF1) and most north (*d*2 from SAT to SF2) surface points can be calculated by:

$$d1 = \sqrt{(R + D - R\cos\alpha_1)^2 + (R\sin\alpha_1)^2}$$

$$d2 = \sqrt{(R + D - R\cos\alpha_2)^2 + (R\sin\alpha_2)^2}$$

Inserting the parameters from above the distances will result in:

$$d1 = 37{,}331 km$$

$$d2 = 40{,}090 km$$

The two-dimensional distance between the both north and south surface points can thus be calculated to:

$$\delta d = d2 - d1 = 40{,}090 km - 37{,}331 km = 2{,}759 km$$

This results in a time delay of 9.2ms, which might be too large to enable broadcast in an area of synchronised NodeBs.

This results in 460 cells along the borderline (6km cell size assumed) or, for the whole three-dimensional area 211,600 cells.

6.1.6 HTI Rx Functional Block Diagram

Figure 24 represents the HTI Rx functional block diagram.

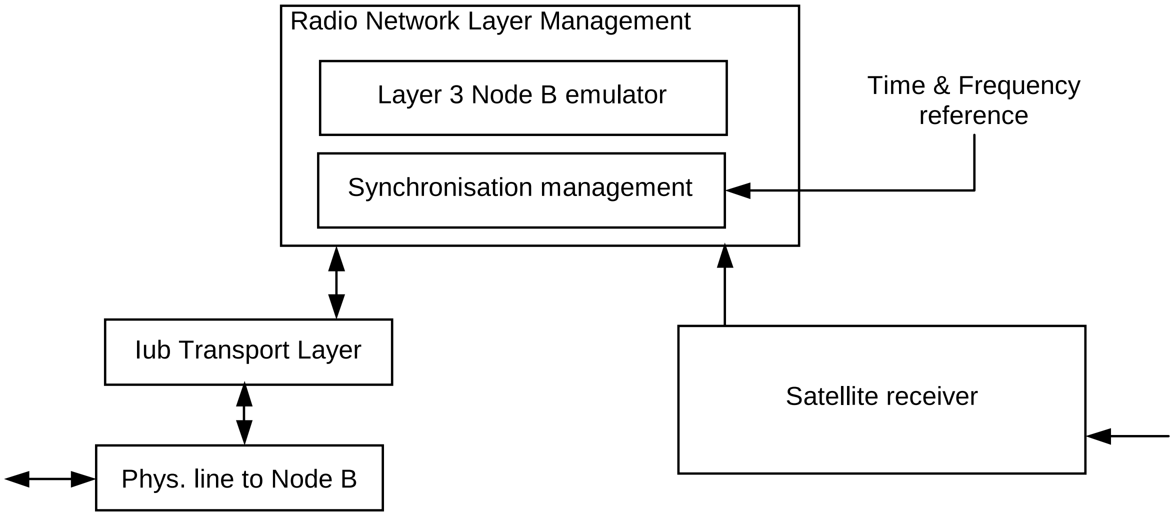


Figure 24: HTI Rx functional block diagram

6.1.7 Conclusions

6.2 NodeB-I_{ub} And U_u Synchronisation Considerations

6.2.1 Issue Description

If the concept considerations lead to the application of a NodeB in the terrestrial repeater branch, then significant synchronisation problems will emerge; synchronisation problems between the Hub-NodeB ("satellite NodeB") and the potentially co-sited repeater NodeB. ("terrestrial NodeB"). Still more, the UMTS standard does not provide synchronisation rules and applications for absolute synchronisation in FDD.

The situation will grow worse when the "terrestrial" NodeB has to be shared with a private provider, who may not like to be touched by specific MAESTRO requirements and potential QoS issues.

Taking into account the standard I_{ub}/NBAP procedures for common channels, the only achievable synchronisation can be gained on frame level which may not be sufficient. The NodeB uses the frame number received from the RNC to transmit the data block at the indicated time (1 frame = 10ms).

To achieve a synchronisation on chip or bit level, a radio interface sync-procedure is required similar to the one defined for dedicated channels and soft handover feature. Though not standardised, a similar procedure for common channels should be implemented for SDMB. The synchronisation mechanisms used for the Alcatel NodeB are compliant to the 3GPP specifications, as far as they exist.

6.2.2 Node Synchronisation

The Node synchronisation procedure is used to get a timing reference of the NodeB in the C-RNC. Node Synchronisation relates to the estimation and compensation of timing differences among UTRAN nodes. The procedure is as follows:

- The CRNC sends a **down-link Node Synchronisation Control Frame** to the NodeB reporting an RNC frame number when it was sent.
- The NodeB replies with an **up-link Node Synchronisation Frame**, indicating a NodeB frame number at the reception of the down-link frame, and another frame number at sending back the up-link frame.

This procedure is supported on the specific high priority VC on which only one AAL2 connection is established for this purpose.

Here only the "RNC - NodeB" Node-synchronisation is considered. This Node synchronisation allows to get knowledge of the timing differences between RNC and its NodeBs, and thus to estimate the phase difference between RFN and BFN of these nodes. The estimated phase difference is used in the down-link data transmission (i.e., Tx direction) in order to minimise the transmission delay and the buffering time.

For the Alcatel NodeB this procedure is performed at NodeB restart, and periodically (e.g. once a day) after that.

6.2.3 Network Synchronisation

(a) General

Network Synchronisation relates to the distribution of synchronisation references to the UTRAN Nodes and the stability of the clocks in the UTRAN (and performance requirements on UTRAN internal interfaces).

The distribution of an accurate frequency reference to the network elements in the UTRAN is related to the main issue to provide a synchronisation reference with a frequency accuracy better than 0.05 ppm at the NodeB in order to properly generate signals on the radio interface.

For the time being this synchronisation is achieved for the Alcatel NodeB by synchronisation to the (ATM) transport network.

(b) Synchronisation Under Normal Conditions

If the transmission network can provide the required frequency accuracy, the NodeB V2 is synchronised on it. In case of e.g. an ATM network unable to provide this accuracy, the NodeB will switch to the free run mode.

Normally the NodeB is basically synchronised on the transmission network, if the network can provide the required frequency accuracy (in normal conditions better than 0.05 ppm). The NodeB´s local oscillator permanently monitors the quality of the clock delivered by the network. For the case of a loss of incoming signal or if a clock drift is detected, the NodeB then switches to its local clock mode. After the fault has disappeared the NodeB will switch back to the transmission line synchronisation source.

When the I_{ub} is supported on several E1 links, the NodeB performs its synchronisation on the first E1, and in case of failure of this E1, it switches to the second one and so on.

The Alcatel NodeB V2 clock is compliant with 3GPP TS 25.104 (0.05 ppm) [3GP5]. The NodeB synchronises:

- **on I_{ub} link** when the clock delivered by this link is of good quality,
- **on the OCXO** (Oven Controlled Oscillator) when the clock delivered by the I_{ub} link has bad quality.
- **Future option: on an external GPS** clock, as the NodeB architecture allows to synchronise the OCXO via an external GPS clock.

6.2.4 Down-Link Transport Channel Synchronisation

The Transport Channel Synchronisation mechanism defines synchronisation of the frame transport between RNC and NodeB, considering radio interface timing.

This procedure is used by CRNC to adjust the transmission time for data frames on FACH and PCH FP. The C-RNC sends a down-link Synchronisation Control

Frame indicating the target CFN value. The NodeB replies with an up-link Synchronisation Frame indicating the ToA for the down-link frame, and the CFN value received in the down-link frame.

6.2.5 Down-Link Timing Adjustment

The Time Alignment Handling procedure over Iu relates to the control of the down-link transmission timing in the CN nodes in order to minimise the buffer delay in SRNC. This procedure is controlled by SRNC.

This procedure is used by the NodeB to report to the CRNC an incorrect arrival time of a down-link data frame in the NodeB. It is initiated by the NodeB when a down-link frame arrives outside of the defined arrival window.

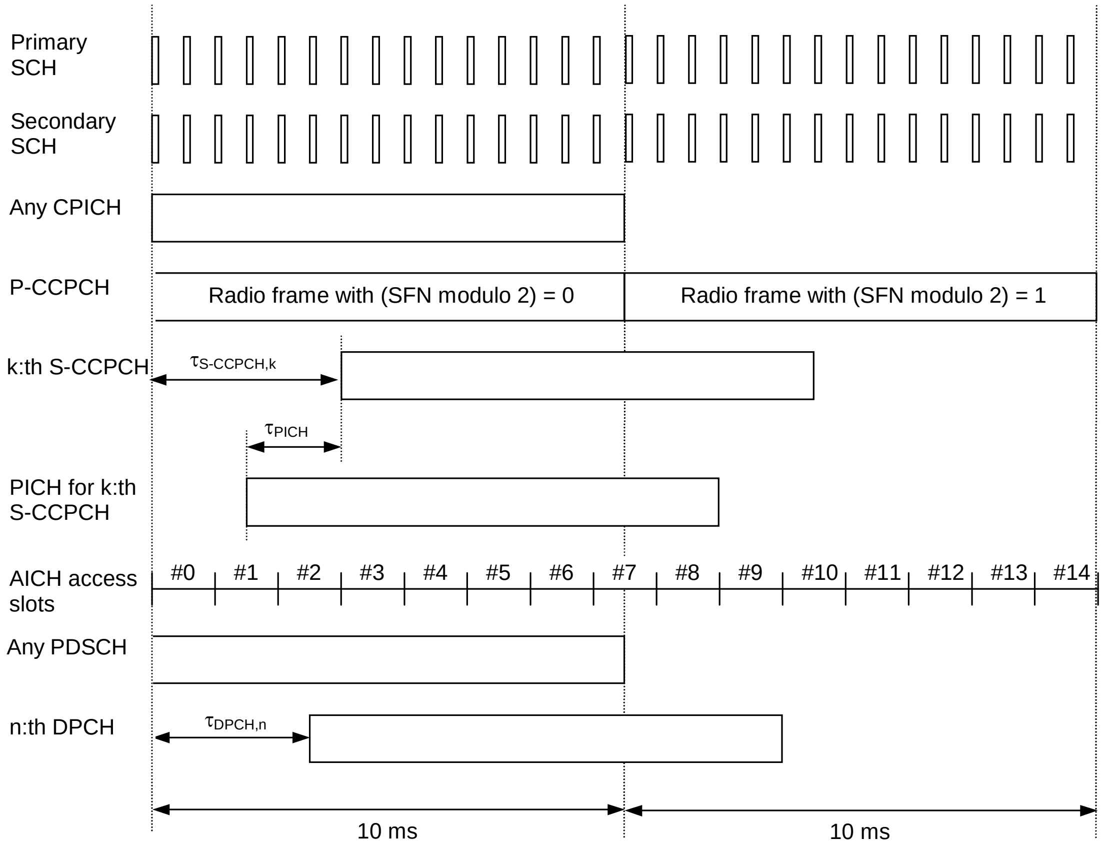


Figure 25: Down-link physical channels - radio frame timing and access slot timing

6.2.6 MAESTRO Synchronisation Requirements

The SCCPCHs bearing the broadcast FACHs of the different NodeBs should be synchronised, i.e., the FACH of the "terrestrial NodeB"s should be started synchronously with the FACH of the "satellite- NodeB".

The terminal should see the FACH channels like ordinary dedicated channels being in a macro diversity (softer handover situation). This is necessary, if the terminal has to synchronise signals in its rake window of 80 chips (20µs).

Subsequent Figure 25 was taken from 3GPP TS 25.211 and describes summarising the timing relationships between the down-link channels of one NodeB as required for the MAESTRO concept.

6.2.7 Radio Interface Synchronisation (U_u)

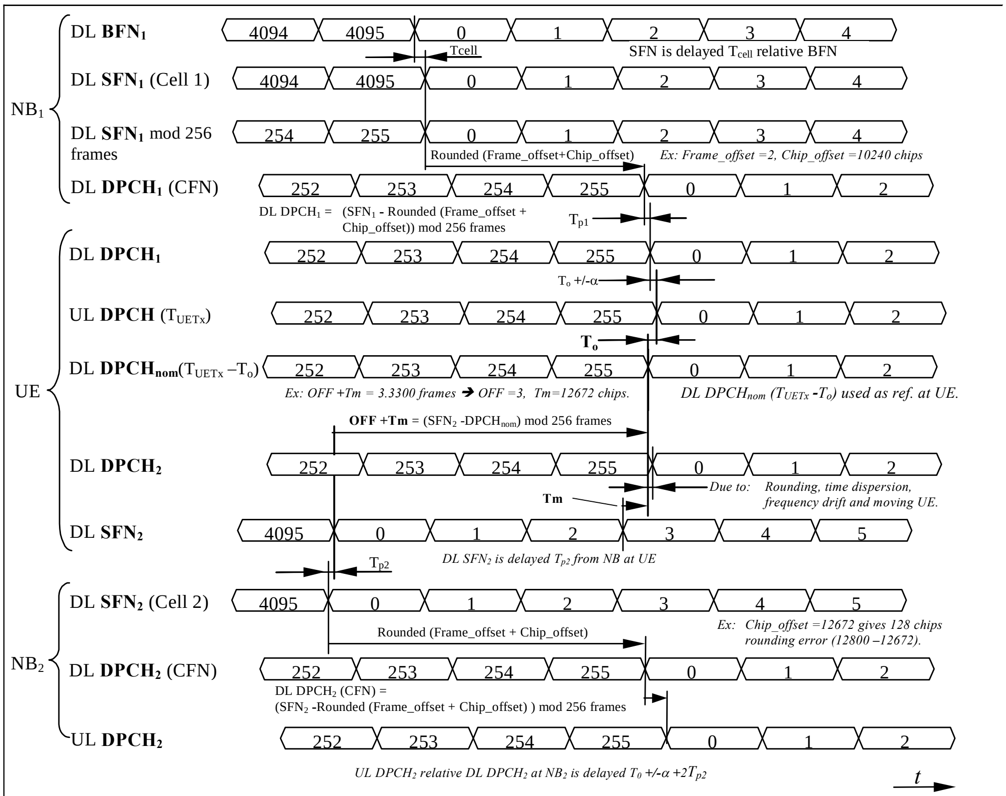
The radio Interface synchronisation relates to the timing of the radio frame transmission in down-link [FDD]. In FDD Radio Interface synchronisation is necessary to assure that the terminal receives radio frames synchronously from different cells, in order to minimise terminal buffers.

6.2.8 Conclusions:

6.3 Standard Synchronisation Procedures In Detail

6.3.1 Parameters And Functionality

The subsequent Figure 26 gives a view over the radio interface timing synchronisation details:



α	1st received DL DPCH finger relative DL $DPCH_{nom}$	T_{cell}	Specifies the SFN delay relative BFN
BFN	Node B Frame Number (counter)	T_m	Measured by UE at HO, T_m has a range from 0 to 38399 chips.
CFN	Connection Frame Number (DPCH related)		
DPCH	Dedicated Physical Channel (CFN related)	T_o	Is a constant of 1024 chips, is the nominal difference between first received DPCH finger (DL $DPCH_{nom}$) and T_{UETx} at UE.
HO	Handover		
NB_x	Node B (x: 1=source, 2=target)		
OFF	Offset with a range from 0 to 255 frames	T_{pX}	Propagation delay (one way), UE to Cell X
RFN	RNC Frame Number (counter)	T_{UETx}	The time when UE transmits an UL Dedicated Physical Channel.
RNC	Radio Network Controller		
SFN	System Frame Number (counter)		

Figure 26: FDD Radio interface synchronisation timing diagram

The k<u>th</u> S-CCPCH has a timing offset of T_k * 256chips in relation to the P_CCPCH, where T_k is an integer of {0, 1, ..., 149} and may differ for different S_CCPCHs. The offset is set by the Common_Transport_Channel_set-up with the parameter SCCPCH_Offset.

The offset for a cell (in magnitudes of 256chips) in relation to the NodeB frame number BFN is defined in the parameter T_Cell of the Cell_set-up procedure (3GPP 25.402). Thus the offset of a S-CCPCH in relation to the BFN is (T_Cell + SCCPCH_Offset) * 256 (chips) or (T_Cell + SCCPCH_Offset) * 66,7us.

If the difference between both SFNs can be measured, synchronisation of the S_CCPCH of the second (terrestrial) NodeB is possible by calculating the right

T_Cell parameter for the Cell_set-up and the right SCCPCH Offset parameter for the S_CCPCH-set-up.

For the synchronisation of dedicated channels a procedure is described in 3GPP TS 25 402 chapter 8. This procedure is based on the measurements of the terminal on the time difference between its DPCH and its SFN, which is calculated by the RNC in terms of Frame Offset and Chip Offset and communicated to the NodeB.

In MAESTRO´s case there is no up-link from the terminal to the RNC. In addition, the interest is in synchronising the common channel. For this we require the time difference between the SFN and the S_CCPCH (which is the SCCPCH_Offset value from the S_CCPCH set-up). From the Node synchronisation the RNC knows the BFN of both NodeBs and also the phase difference of both NodeBs since NodeB restart.

On the basis of the existing capabilities of the NodeB there are two approaches to set up a S_CCPCH on a second NodeB, which is nearly synchronous to the S_CCPCH of the first NodeB. Nevertheless, the NodeB synchronisation is not sufficient for the MAESTRO application, neither for option 1 (on I_{ub} link) nor 0ption 2 (on the OCXO).

6.3.2 Using NodeB - RNC Synchronisation

Based on the knowledge of the phase differences PD:

$$\mathbf{BFN = [RFN + PD]\ modulo\ 4096}$$

between both NodeBs, it is possible to map the BFN of one cell on a BFN of the other cell:

$$\mathbf{BFN_{Ter} = [BFN_{Sat} + PD_{Ter} - PD_{Sat}]\ modulo\ 4096.}$$

It is also possible to do the same calculation for the SFNs:

$$\mathbf{SFN_{Ter} = SFN_{Sat} + [PD_{Ter} - PD_{Sat} - TCell_{Sat} + TCell_{Ter}]\ modulo\ 256}$$

Please note, that in both cases the calculations are simplified; they do not take into account, that the phase differences do not represent whole frames, but also offsets, which normally are discarded by rounding. This can be used to calculate the SCCPCH_Offset.

This approach can only be applied, when the NodeBs are controlled by the same RNC. As basis for calculation of the phase difference, the BFN and the RFN at sending / response time are taken. The quality of the measurements depends also on the delays of the used ATM network. The granularity of the measured time is given in ms with 125us-steps. This is twice as much as the granularity of the SCCPCH_Offset between two S_CCPCH channels. If the two S_CCPCHs would be synchronised using this information, the terminal must provide a rake window of about 125us.

6.3.3 Conclusions

6.4 Synchronisation Based On GPS

6.4.1 GPS Application On The SDMB Core System

The synchronisation of the Hub NodeB (NodeB/1) becomes mandatory for the case that the IMR´s core will consist of a NodeB (NodeB/2), independent whether this Node will be shared by a private user. This synchronisation could be done by synchronisation to the same transport network. Formerly initial consideration were made for this problem but restricted to a test-bed application only, where the NodeB/2 played the role of a satellite emulator.

The actual problem for the MAESTRO application is now the supplementary synchronisation of the NodeB/1 (Hub NodeB) in the Hub branch and, additionally, the extreme precise handling of the required propagation delay balance of the I_{ub} and U_u data streams.

For the case that no significant attempt is planned and made to enhance the current functionality of the NodeB and the surrounding network, the GPS alternative seems to be suitable for the first to tackle the most exigent synchronisation issues. Synchronisation by GPS means on I_{ub}-side bit-synchronisation and frame (-begin) synchronisation.

6.4.2 GPS Receiver Connection To The NodeB

The NodeB´s Connection Area (CA) provides remote access to the Station Unit´s (SUMU) external interface and thus the later connection of an optional GPS receiver module. This module delivers the time and position data which is used for alarm and performance measurement time stamping, OCXO clock and frame number synchronisation.

The GPS receiver itself has no own BCB terminal but it can be connected to the SUMU´s BCB terminal. It provides an EEPROM where RI data is stored. The GPS receiver has a RS232 link line for message exchange purposes. This feature is not yet part of the commercial product.

The Alcatel GPS receiver consists of two parts, a proprietary printed board to connect the GPS receiver to the SUMU module and the GPS receiver itself, a commercial product from Trimble (Lassen SK II) and Wharton. The Wharton 488GPS receiver system is designed to allow 482 series master clocks to be automatically synchronised from the GPS satellite time transmissions

The Alcatel´s proprietary connection boards are available for MAESTRO and the existing receiver HW provides interfaces to deliver clock and absolute time.

6.4.3 The GPS Receiver Components

(a) Antenna Module

The satellites transmit highly accurate, real time world-wide, navigation information at a frequency of 1,575.42MHz that anyone can receive and thus use to identify their position together with a precise local time.

The active antenna module is a low-profile disc shaped unit, 10cm diameter and 3.5cm high, specifically designed for GPS use. GPS signals are received by the antenna, amplified within the antenna assembly and then relayed to the GPS receiver for processing.

The antenna should be horizontally mounted with a clear view of 75% of the sky. If the sky view is reduced, the interval between ‘switch-on’ and system time synchronisation will be considerably increased.

The antenna module transmits the received GPS signals and receives power (5V DC @ 25mA) from the GPS receiver/decoder module via a single 6m RG58 coaxial cable. A post mounting clamp is supplied to enable the antenna to be fixed to a suitable horizontal or vertical post of up to 2m diameter.

(b) GPS Receiver/Decoder Module

The GPS receiver/decoder module contains an advanced 6-Channel parallel receiver, a power supply and a microprocessor based communications interface. This module should be mounted in a protected location within 6m of the antenna.

To ensure ease of operation and to remove the possibility of operator error the 488GPS system is designed to self initialise without the necessity of operator data input.

When the accurate satellite time information is available synchronising time signals are transmitted every minute from the receiver/decoder module to the master clock using W482 time code. This code provides UTC time and date information and may be used to synchronise any 482 series master clock.

The 482 series master clock will automatically convert the UTC time to local time using operator pre-programmed time offset conditions. When the 482 master clock is synchronised with the GPS receiver/decoder module, all transmitter signals are accurate to within ± 1ms. Higher accuracy is available on request.

6.4.4 GPS-Clock Based Synchronisation Procedure

The introduction of the GPS into the MAESTRO system would increase the capabilities of the NodeB with a reasonable effort. This approach would synchronise both NodeBs on the same BFN. It has to be defined, how both NodeBs select (or are provided with) the same absolute time to start with BFN = 0:

- The BFN is reset to 0 after 4096 * 10ms = 40,960s.
- The absolute time sent by GPS is given in weeks and seconds of weeks after Jan 6th 1980. So a possible synchronisation would be, if the BFN counter is reset to 0, when GPS_time_in_seconds modulo 4096 (or 1024) equals 0.
- The BFN could also be set to (GPS_time_in_seconds *100) modulo 4096.

- The roll-over period of the weeks can be neglected, because this again is 1024 and thus does not influence the calculation.
- Furthermore mechanisms have to be defined, how a NodeB can synchronise after recovery. Essentially the same method to calculate a re-synchronisation time can be applied here.

It will still be a problem, that the recovery with GPS synchronisation means a longer NodeB outage than an un-synchronous recovery.

For the NodeB synchronisation a number of questions and open points still remain:

- How can the new BFN be assigned to the FPGAs (without disturbing the Telecom applications)?
- The BFN should be assigned before telecom application are set up and before the connection to the RNC is established.
- Can the use of the transport network clock or the use of the GPS clock provide better synchronisation?
- What will happen, if for any reasons GPS is not available over some time ?
- In contrary to the MoDis field trial the MAESTRO requires synchronisation and re-synchronisation mechanism
- Is it sufficient, if the clock is also synchronised via GPS.
- The distance of about 1km (cell size) between two NodeBs should not cause a delay between the GPS signal reception at both NodeBs.
- If one of these NodeB synchronisation methods is applied, the cells and SCCPCHs for both NodeBs have to be set-up with the same T_Cell and SCCPCH_FrameOffset values.

6.4.5 Identified State Of Realisation

- HW, the GPS receiver Lassen SK II from trimble has been used for GSM. A board which can be used to connect the GPS receiver to the Station Unit (SUMU) is available.
- SW to support GPS synchronisation is not yet implemented.

6.4.6 Identified Problems For The GPS Synchronisation

- It is necessary to start the GPS receiver independently from the NodeB, because the GPS receiver needs about 15 minutes to calculate its position and the actual time from the GPS signals (the whole GPS information is transmitted in 12.5min. The GPS time in seconds is repeated every 6 seconds.). After this time the GPS time can be used to deduce the BFN for the NodeB.

- The modification of the BFN will generate a NodeB restart caused by the telecom application, if already active. Only for the purpose of the field trial, this should not be a problem.
- When a NodeB has to be restarted in an already deployed network, there will be a delay of availability depending on the availability of the exact GPS time and the delay to start frame synchronisation with a new calculated BFN.

6.4.7 Required SW Implementations

- Implement an interface (including alarm handling) to the GPS receiver.
- Implement an algorithm for the definition of the BFN from the GPS time.
- Implement a "GPS/nonGPS timing" selection mechanism and menu for the NEMB
- Implement alarm handling for the new module.
- Implement the BFN setting and clock deduction from the GPS receiver for the SUMU transmission HW (see suggestion above :to be set to (GPS_time_in_seconds *100) modulo 4096.)
- Implement clock synchronisation from GPS clock.

The enhancements could not be implemented and tested in the development environments of the UMTS development centre. Separate development environments would have to be set-up for this purpose. The modification would concern different SW platforms of the NodeB including FPGA firmware and the Network Management Tools. Therefore it is unlikely to develop this feature within the MAESTRO timeframe.

6.4.8 Conclusions

6.5 Shared NodeB Physical Issues

6.5.1 General Considerations

In order to install and operate the MAESTRO – System at a minimum of cost, it seems plausible to make use of nationally installed (e.g., NodeB) telecommunication equipment; in particular, if it is under-utilised or, for expansion purposes, the rack only partly equipped and in use. It should be noted that in context of NodeB application as terrestrial repeater it makes only sense to share a NodeB with another network or service provider (in the following called owner). Pure stand alone NodeB solutions will fail because of its cost.

For all further considerations in this paragraph it is assumed that only Alcatel NodeB V2 base stations will be applied. This reduces the number of other potential candidates strictly. Furthermore, it is assumed, too, that commercial network providers have established an UMTS network with UMTS NodeBs, which do not operate at full capacity with both data traffic and physical expansion states. This means, Maestro might be cordially invited to share the base station and:

- bring the equipment of its own (e.g., additional boards, SW extensions, etc.);
- does not touch (i.e., modify) the equipment of the owner;
- does not touch and influence sections operated by the owner;
- modifies the base station only by add-ons.

The issues on physical level additionally emerging from the NodeB sharing philosophy can be grouped into 4 problem areas:

- U_u-side antenna connection and antenna configuration;
- I_{ub}-side GPS bit and frame synchronisation;
- I_{ub}-side RNC response emulator;
- I_{ub}-side RNC-data multiplexer and/or timely control of different I_{ub} data flows.

6.5.2 Shared NodeB RF Analogue Front End

(a) The RF-Front-End In Brief:

The subsequent Figure 27 depicts the radio part of a NodeB and is to facilitate a better understanding of the shared NodeBs U_u-side issues. The figure shows two radio modules capable of 2-antenna diversity operation. The boxes left hand side and right hand side accommodate the linearised power amplifier (PA), its controlling feed-back and pre-distortion path, clipping, up-converter and transmission (Tx) filters.

The down-link path is capable to handle up to four UMTS frequency channels. They may be accommodated within any consecutive 20MHz sub-band of the overall 60MHz UMTS transmit frequency band. The antenna network (ANRU) module allows the connection of two transmitters in case of transmit diversity.

Table 7: U_u - UMTS radio interface functionality

<u>supports:</u> FDD mode air interface to 3GPP-R-99 and R4 compliant transport channels	RACH, FACH, DCH DSCH (all combinations involving DSCH supported) P-SCH, S-SCH (sync channels, primary and secondary) CPCH, BCH, PCH, DCH (DRAC)
<u>supports</u>: physical channels	DPDCH, DPCCH, PDSCH, P-CCPCH, S-CCPC (carries PCH and FACH)H CPICH, AICH, CSICH, PRACH (physical RACH) PCPCH, AP-AICH, CA/CD-AICH, PICH (paging indicator)
<u>supports:</u> channel coding (turbo or convolutional) up to 384kb/s	▪ one transport bearer per CCTrCH ▪ multiple transport bearer per CCTrCH

(b) The U_u UMTS Radio Interface:

Connection to the mobile terminal is done across the U_u - interface (for UMTS FDD). This UMTS radio interface backs up the FDD mode air interface for transport channels compliant to 3GPP-R-99 and R4. It also supports channel coding up to 384kb/s with turbo-coding or convolutional coding/decoding and all layer 1 error indication mechanisms as well, summarises the U_u I/F functionality.

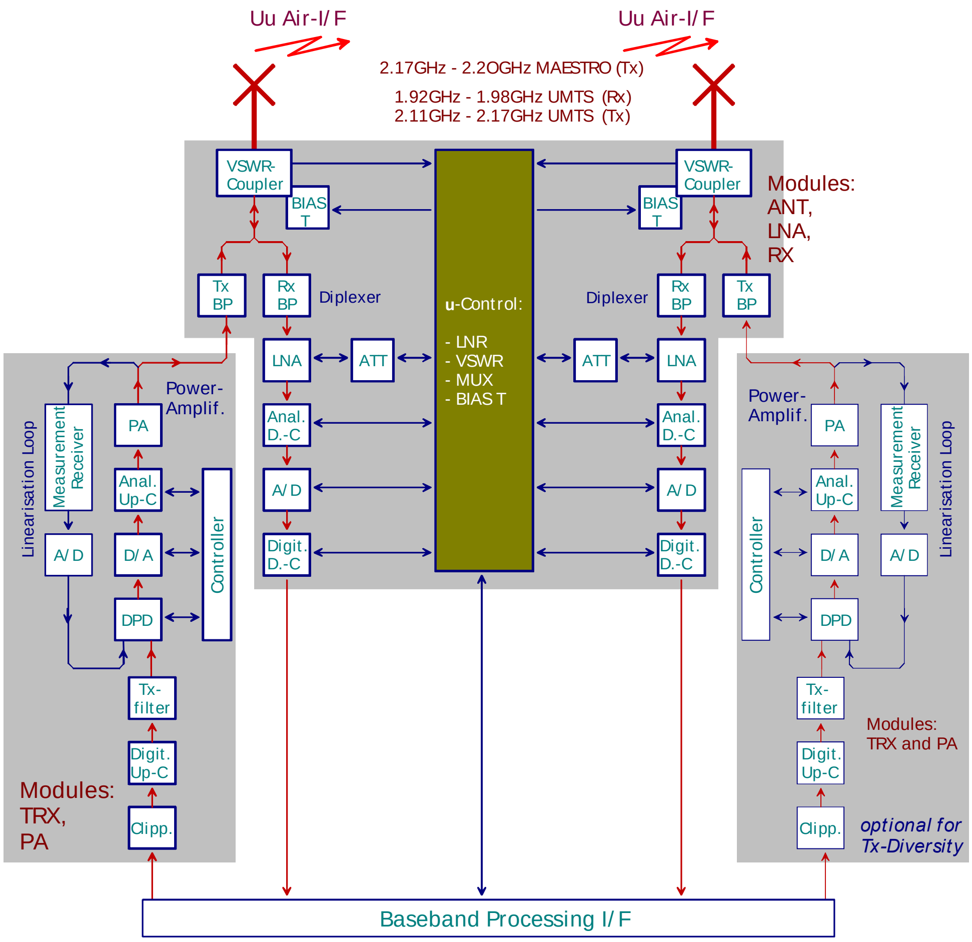


Figure 27: NodeB´s radio front-end

(c) MAESTRO U_u Interface Add-On (1)

Sharing a NodeB commonly with a private network provider can be done in different ways. One of those is depicted in Figure 28 This way is only possible for the case that the base station does not operate at full capacity, in particular, when the racks and sub-racks are not fully equipped. Making use of sharing the Node means, for the first solution, to install a complete Tx-branch from the Base-band interface up to the antenna.

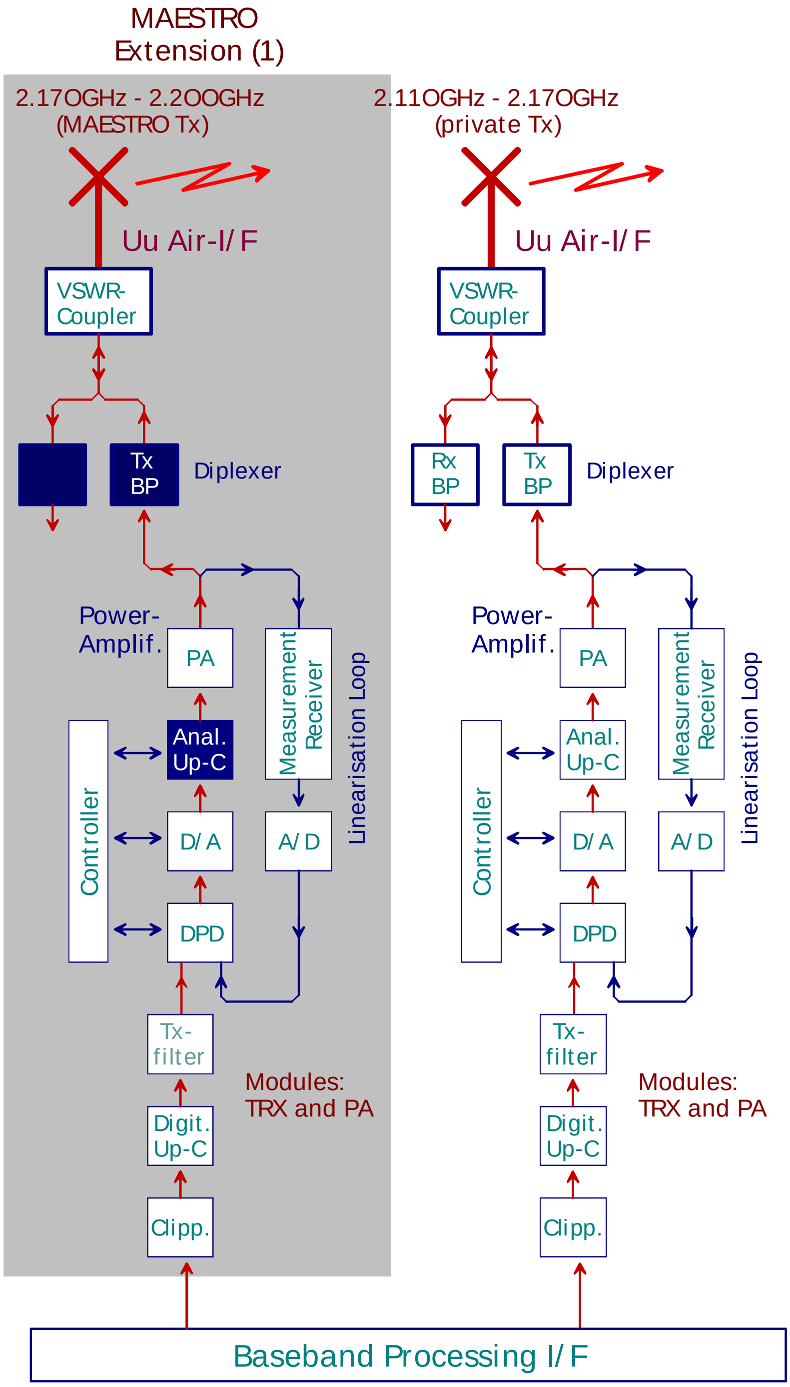


Figure 28: MAESTRO add-on (1) for NodeB sharing

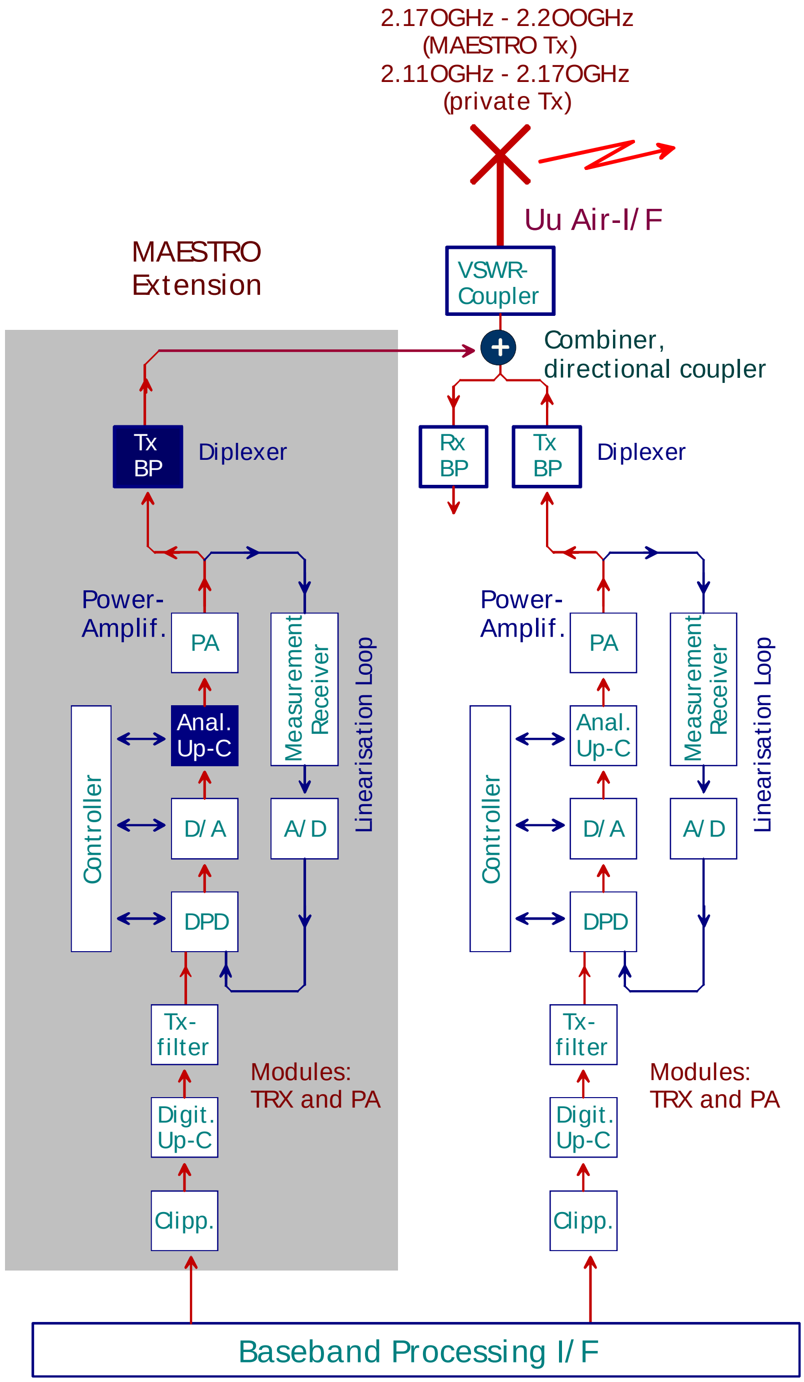


Figure 29: MAESTRO add-on (2) for NodeB sharing

Caused by the slightly differing transmission frequency band (instead UMTS 2.11 – 2.17GHz now the MAESTRO 2.17 – 2.20GHz) some additional measures have to be taken (marked in by dark blue boxes):

- The Diplexer Receiver Band-Pass (Rx BP) has to be removed in order to avoid UMTS noise reception;
- The Diplexer transmission band-pass (Tx BP, mid-frequency 2.14GHz) has to be replaced by one with a mid-frequency of 2.185GHz);

- The local oscillator in the Analogue Up-Converter has to be replaced by one operating at a 20MHz higher frequency; the same with the Tx-filter in this block.

(d) MAESTRO U_u Interface Add-On (2)

The add-on (2) for the U_u interface is depicted in Figure 29. In order to save cable and installation cost (e.g., approximately 150 € per meter) it is possible, too, to re-use the installed UMTS-antenna together with the private network provider. However, in this case the MAESTRO Tx-branch as shown in Figure 29 and Figure 28 has to be connected to the UMTS-antenna by a Combiner or directional coupler. Both connection types will attenuate both the UMTS and the MAESTRO signals by 3dB. This is either to be accepted or can be balanced by power amplifiers with higher power figures. This means in both cases additional effort and cost for the private network provider.

(e) MAESTRO U_u Interface Add-On (3) - Shared Antenna Systems

Instead of sharing a complete NodeB with all issues and effort described above, it may be sufficient to share only the antenna system [3GPP TS 25 867]. The subsequent technical proposal is based on summarised results of a feasibility study about inclusion of Wideband Distribution Systems (WDS) as part of third generation networks in 3GPP standards. It seems applicable in the MAESTRO project, as re-use of existing telecommunication environment is foreseen.

Issue Description:

Bearing in mind re-use of already existing telecommunication environment, re-use may be made of installed ancillary equipment like masthead amplifiers or remote radio heads, that may add flexibility and reduce cost of installation. These solutions are embedded in the NodeB as ancillary RF amplifiers and are therefore seen as integral part of it in a single-vendor deployment scenario.

In order to improve flexibility of radio access network solution and decrease installation cost of a second (i.e., MAESTRO) system, a new type of equipment is proposed, here called Wideband Distribution System (WDS)..

WDS are altogether similar devices, capable of remotisation of NodeB RF.front-end interface, but offering flexible and multiple RF interface to one or more NodeBs or sub-equipped base-stations. The so-defined WDS shall include one or multiple RF front-ends, RF transmission, and interfaces capable of supporting one or multiple BS.

The degree of performance impact shall be assessed in this chapter to understand the effect on multiple-carrier W-CDMA signals in order to maintain compliance to the relevant standard in the coverage area. The test and simulation scenarios in this report are made with the assumption that of no impact from any passive distribution system. Therefore the results are of an ideal nature and may need to be adjusted to suit the class of base station utilised for deployment.

Figure 30: Wide-Band distribution system (WDS)

The specifically tailored solution for NodeB described in (e) became matter of standardisation in a slightly differing configuration [3GPP TR 25 867].

6.5.3 Shared I_{ub}-Interface

(a) The Original I_{ub}:

On network side the NodeB is inter-linked to the radio network controller (RNC) via the I_{ub} interface. The physical part of this interface supports I_{ub} redundancy, ATM protection switching and ATM protocol termination management as well as transmission protocols (such as IP and ATM)

Table 8 summarises the I_{ub} I/F functionality.

The bi-directional I_{ub} interface is accommodated in the Station Unit board. In standard NodeBs this interface is of E1-type. For interconnection with a fibre optic STM1 configuration an additional adaptation unit will be required. Data transmission across this interface occurs with ATM cells supporting AAL2 or AAL5.

Table 8: I_{ub} interface functionality

supports: physical interfaces	I_{ub} redundancy with load sharing (optional)
	ATM protection switching according to ITU-T Rec. I.630
	ATM termination mgmt according to ATM Forum UNI3.1 specs
supports: transmission protocols	IP with MLPPP on E1/T1 (HW ready, SW upgrade needed)
	ATM with IMA on E1/T1
	IP over Ethernet10/100 (HW ready, SW upgrade needed)
	ATM or IP over STM1/OC3 or E3/T3/J2
supports: platform configurations	Chain
	Ring
	Star

(b) Shared I_{ub} Issues :

Sharing the I_{ub} interface with a private provider causes some more serious issues than sharing the U_u. For sharing the I_{ub} additional functional blocks will be required as shown in Figure 31.

Crucial point is that the normal I_{ub} is a bi-directional interface for data exchange with the assigned RNC. Data content can be cell set-up, correction of erroneous frame positions, mismatch of frame synchronisation, different I_{ub}-data flow, common channel set-up etc. This function is performed in the MAESTRO RNC-Emulator. This block terminates the up-link cells and generates response for down-link control.

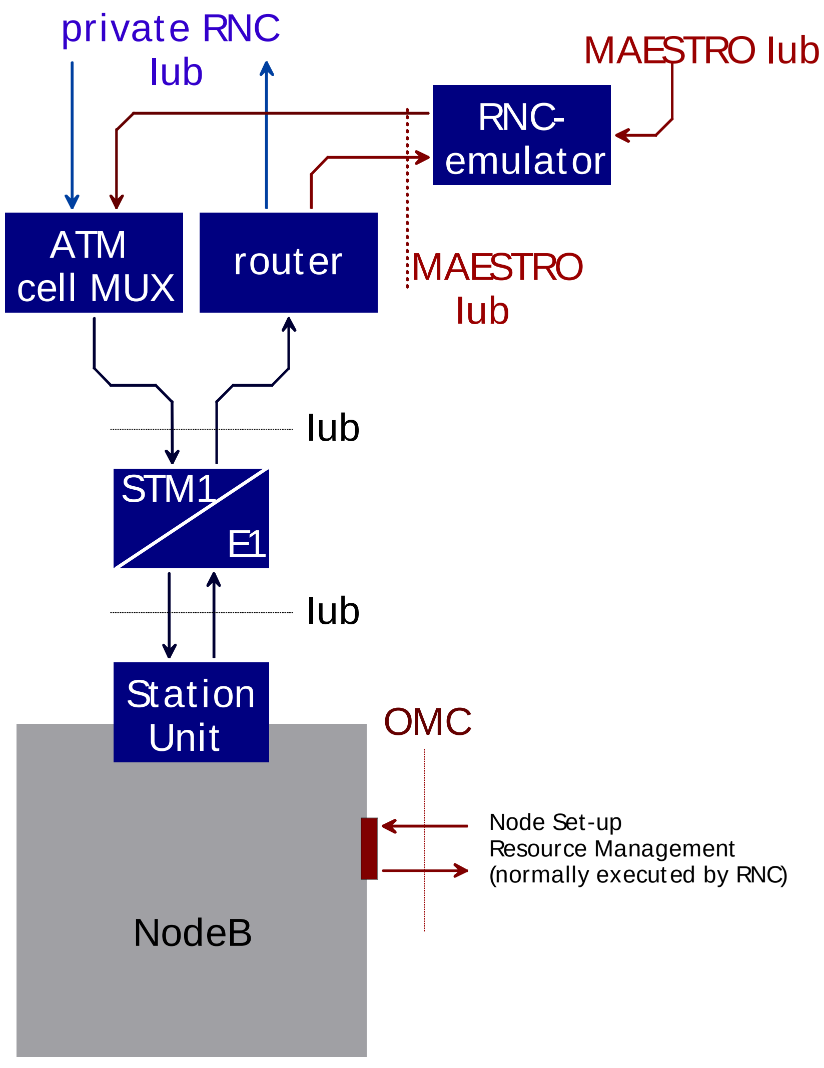


Figure 31: Addendums for I_{ub}-sharing

In a next step RNC-Emulator generated ATM cells will be multiplexed with cells originated in the private RNC, subsequently modified from STM1 format to E1 and fed into the Station Unit block SUMU.

The other way round is similar; here a cell router caters for cell distribution depending on their header addresses. Cells will be routed either to the private RNC or to the MAESTRO RNC Emulator.

6.5.4 Shared I_{ur} Interface

It is still under study whether the I_{ub} allows direct access to relevant channels, as assumed in Figure 31. If this is not possible, access has to be provided to the I_{ur} interface as depicted in Figure 32.

In this case the private RNC operates as C-RNC and enables data exchange with the RNC-Emulator via the I_{ur} interface. The RNC-Emulator and the protocol termination is required to serve the C-RNC with the expected bi-directional I_{ur}.

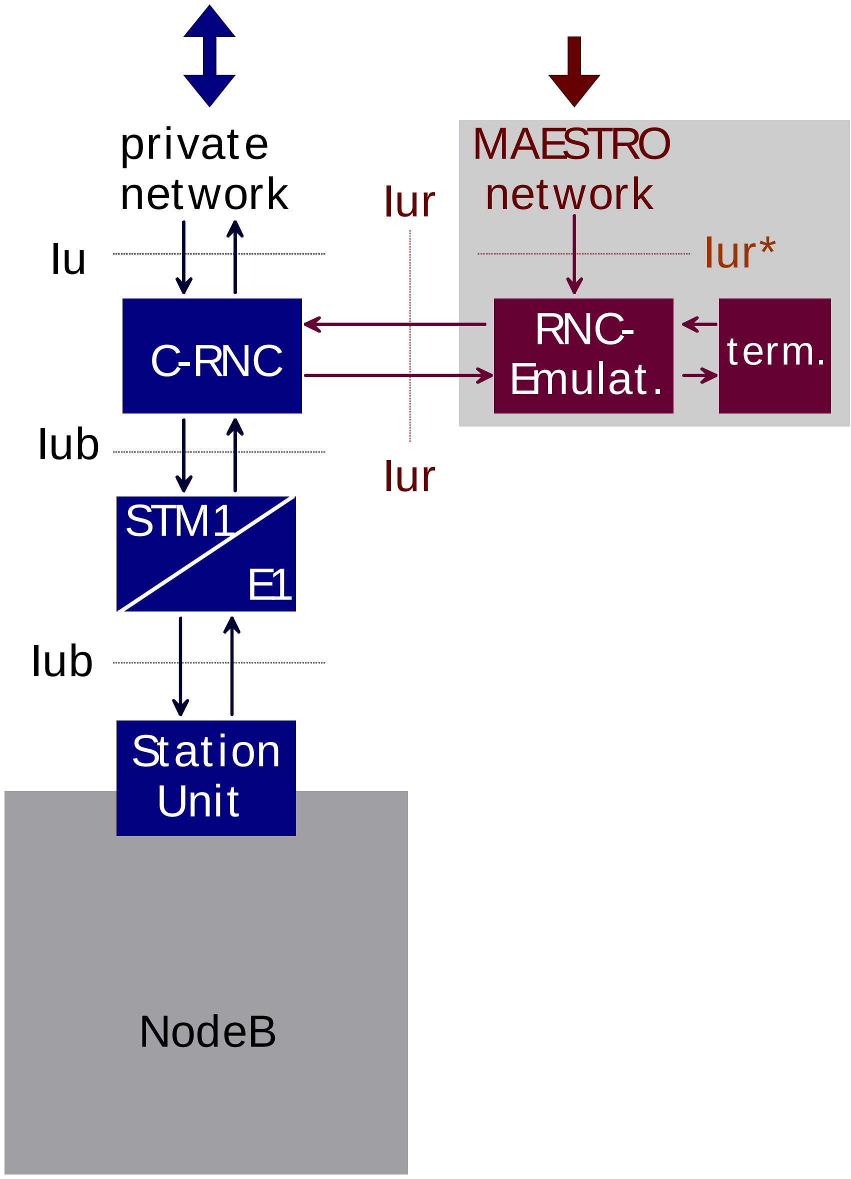


Figure 32: Addendums for I_{ur}-sharing

In principle both of the introduced sharing schemes are – roughly spoken – applicable. While I_{ub} sharing requires the NodeB management (e.g., resource management, node set-up, etc.) executed from outside via the OMC interface, the I_{ur} sharing administration can be executed by the RNC module.

6.5.5 Conclusions

7 ANNEX 2 - SPECIFICATION TABLES