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Technical Report

Fixed Radio Systems (FRS);
Point-to-point systems;
Requirements and bit rates of PtP Fixed Radio Systems with packet data interfaces, effects of flexible system parameters, use of mixed interfaces and implications on IP/ATM networks

Reference

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Foreword

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

1 Scope

Modern digital fixed radio systems extend their capability from a pure transport media towards multiplexing and switching capability, also for packet and cell-based type of user traffic. This type of traffic is no longer solely routed via the well-established PDH and SDH interfaces, but also on typical data interfaces.

Digital modem techniques intend to optimize the link performance by applying sophisticated coding schemes, as well as dynamic adaptation of the modulation.

As a consequence, the established set of standards for digital fixed radio systems requires an extension towards packet data transmission in adaptive modulation modes using systems with incorporated switching and multiplexing, routing or traffic engineering functionalities, use of adaptive modulation/coding for either conventional or packet data systems shall also be considered.

Actually, the set of specifications covered in EN 302 217 v.1.1.3. [1] is based on:

- assessment of DFRS for transport only without switching, data storage or routing capability;
- modulation efficiency based on modulation, impact of coding nearly neglected;
- RIC-values referred to suitable PDH/SDH reference standards, in addition a set of radio interface capacities correlated to these PDH and SDH data rates.

The present document intends to clarify the implications of specifying a full set of RIC (Radio Interface Capacity) values and related modulations applicable to existing RF channel plans recommended by CEPT or ITU. This full set of RIC will cover also values for which radio interface parameters cannot be found in existing fixed radio system standards. A proposed set of missing necessary technical requirements will be reported for frequency bands 7 GHz to 55 GHz and for spectral efficiency classes 2 to 5.

Compliance of adaptive modulation with existing requirements will also be considered.

Additionally possibilities for commonality with multipoint systems e.g. ETSI BRAN HiperAccess bit rates and flexible system features as well as aspects of multiple or mixed network interfaces will be analysed.

As a prerequisite for the full set of RIC, an updated definition of the term "Radio Interface Capacity" has to be established, which would consider the extended capability of a fixed radio system towards switching, storage, routing and multiplexing.

Also the definition of spectrum classes has to be reviewed in order to cope with modern modulation and coding techniques. In order to establish a consisted set of requirements, the modulation efficiency should be considered as the appropriate measure for the spectrum classes.

2 References

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

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long term validity.

A more comprehensive list of references is available in EN 302 217-1 [1].

[1] ETSI EN 302 217 series: "Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas".

[2] ETSI EN 302 326-1: "Fixed Radio Systems; Multipoint Equipment and Antennas; Part 1: Overview and Requirements for Digital Multipoint Radio Systems".

[3] ETSI EN 301 785 (V1.2.1): "Fixed Radio Systems; Point-to-point packet data equipment; Parameters for radio systems with packet data interfaces for transmission of digital signals operating in the frequency range 7, 8, 13, 15, 18, 23, 26, 28, 32, 38, 52 to 55 GHz".

[4] ETSI TS 101 999: "Broadband Radio Access Networks (BRAN); HIPERACCESS; PHY protocol specification".

[5] ITU-T Recommendation I.356: "B-ISDN ATM layer cell transfer performance".

[6] ITU-T Recommendation I.357: "B-ISDN semi-permanent connection availability".

[7] IEEE 802.3 (part 3): "Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications".

[8] ITU-T Recommendation Y.1541: "New Appendix X - An example showing how to calculate IPDV across multiple sections".

[9] ITU-T Recommendation Y.1540: "Internet protocol data communication service - IP packet transfer and availability performance parameters".

[10] T/R 13-01: "Preferred channel arrangements for fixed services in the range 1-3 GHz".

[11] ETSI EN 302 326-2: "Fixed Radio Systems; Multipoint Equipment and Antennas; Part 2: Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive for Digital Multipoint Radio Equipment".

[12] Directive 1999/5/EC of the European Parliament and of the Council of 9 March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity (R&TTE Directive).

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in EN 302 217-1 [1] apply.

3.2 Abbreviations

For the purposes of the present document, the abbreviations given in EN 302 217-1 [1] and the following apply:

ATM	Asynchronous Transfer Mode
ATPC	Automatic Transmit Power Control
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
BRAN	Broadband Radio Access Networks
BRAN-PHY	PHYsical layer (acc. to ETSI BRAN Hiperacess)
C/I	Carrier to Interferer
CBR	Constant Bit Rate
CER	Cell Error Rate
ChS	Channel Separator
CLR	Cell Loss Ratio
CZ	Control Zone
DFRS	Digital Fixed Radio System
DL-BRAN	DownLink (acc. to ETSI BRAN Hiperacess)
DLC	Data Link Control
ECC	Error Correction Coding
EMO	Equivalent Modulation Order
FEC	Forward Error Correction
FWA	Fixed Wireless Access
IP	Internet Protocol
LAN	Local Area Network
MAC	Medium Access Control
NFD	Net Filter Discrimination
PDU	Protocol Data Unit

PtP	Point to Point
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
R&TTE	Radio equipment And Telecommunications Terminal Equipment
RBER	Residual Bit Error Ratio
RBER	Residual Bit Error Ratio
RF	Radio Frequency
RIC	Radio Interface Capacity
RS	Reed-Solomon
RSL	Receive signal Level
SDH	Synchronous Digital Heirarchy
SECBR	Severely Errored Cell Block Ratio
SESR	Severely Errored Seconds Ratio
SFD	Start-of-Frame Delimiter
SNR	Signal to Noise Ration
STM	Synchronous Transfer Module
STM-1	Synchronous Transport Module level 1 (155,520 Mbit/s)
TCM	Trellis Code Modulation
TDMA	Time Division Multiple Access
TS	Terminal Station

4 Packet Data in Fixed Radio Systems - the need to update the standard

4.1 Transmission of packet data in fixed radio systems

4.1.1 Packet data transmission alternatives

Packet data may be transmitted in radio systems by mapping data packets into PDH or SDH frames. The interface to transmission section is PDH or SDH standard interface and the radio system cannot see any difference to PDH or SDH transmission. There may be, however, some difference in transmission quality requirements compared with CBR signal transmission when packet data is transmitted as the payload. Transmission capacities are limited to payload capacities of selected PDH or SDH-frames.

In the PDH or SDH radio system there may be also a special packet data interface e.g. 10 Mbit/s, 100 Mbit/s or 1 000 Mbit/s Ethernet interface or one of the ATM Forum interfaces. At the interface portion of radio system there may be a data processing unit, which can communicate with the data network and adjust the incoming data rate according to available radio system capacity. In principle this kind of system may transmit multiple packet data signals or mixed constant bit rate and packet data signals but the transmitted capacity is typically fixed by some standard PDH or SDH carrier (e.g. 34 Mbit/s or STM-1).

When packet data is transmitted "directly" without standard transport layer structures the transport capacity may be better adjusted to match in an optimum way to the modulation/coding and available RF-channels. Radio system frame can be optimized for the radio transmission and could also be proprietary. The packet data may even be compressed to improve spectral efficiency. The interface towards network would be one of the standard packet data interfaces. In case of multiple packet data interfaces or mixed interfaces there can be benefits from statistical multiplexing of incoming data. There may be also requirement for "transparent transmission" of packet data signal e.g. 100 bT if used as an interconnection line for LANs. Fixed radio systems are typically full-duplex systems and there are no collisions, which would decrease data rate.

Typically in packet data network there is traffic control, which adjusts the traffic where necessary. Radio system interface part may contain a packet data network element, which controls the data source. This element may filter the incoming traffic and adjust it at optimal value for the available radio channel and applied modulation. If adaptive system parameters (transmit power, modulation levels) are in use the traffic control level may be updated according to the valid parameters. If transparent transmission of packet data is required less adaptation of capacity is possible.

4.1.2 Transmission quality aspects

Transmission quality objectives for a radio system planned to carry packet data are expressed in different measures than those for PDH/SDH systems. For ATM there are cell-based measures CLR, CER and SECBR, which lead to requirements for physical level RBER (residual bit error ratio). These parameters are defined in ITU-T Recommendation I.356 [5] as design-parameters over a long enough time period. No requirements for ATM SESR are specified. Availability threshold for ATM is specified in ITU-T Recommendation I.357 [6] but no requirement for availability ratio yet agreed. Therefore SESR and availability objectives for PDH/SDH may be applied.

Similar set of quality objectives is being specified by ITU-T for IP layer traffic (Y.1541 [8], Y.1540 [9]).

4.1.3 Network interface alternatives

Network interface may be single or multiple of similar or different types of interfaces. If one of the interfaces is packet data interface we may call the radio system packet data radio even in case packet data is multiplexed into PDH or SDH frame inside the radio system. Packet data interfaces may be 10 Mbit/s, 100 Mbit/s or 1 000 Mbit/s of Ethernet type. Ethernet frames may contain various types of packet data, typically IP or ATM cells. Packet-network can utilize transmission paths of different capacity.

4.2 Switching and routing functionality

Digital fixed radio systems contain quite often additional functionality on the baseband section:

- pluggable or configurable interfaces provide a variety in data rates and physical layer, which can be configured semi permanent or even dynamically;
- the data stream of a specific port is not automatically designated for transmission via the radio link, but can also be routed and multiplexed to other baseband ports at the same side of the radio link;
- the internal baseband processing can also contain queuing or storage mechanisms.

Consequently the instantaneous data rate at one or more baseband interface ports is no more directly correlated with the data rate via the radio link. Therefore an updated definition of the Radio Interface Capacity is required.

4.3 Flexible system parameters

The radio system may select, adaptively or not, from different modulations/coding alternatives and/or from several coding alternatives in order to:

- cope with variations in input user data;
- adapt to propagation and interference conditions on the radio link and to dynamic variations of user data:
  - PtP-radio link which transmits normally using the highest system mode available may switch to lower modes if propagation conditions get worse due to rain or multipath fading or in case of temporary interference situations. Some part of the traffic would be lost but the availability of the remaining traffic would be higher. The interest of this mode is to allow continuing to transmit at lower bit rates in time periods which would be fully unavailable for conventional equipment.
  - PtP-radio link which transmits normally using some lower mode may increase temporarily transmission capacity by switching to higher modes to offer transmission channel for traffic with lower availability requirements. This mode is particularly adapted to the transmission of data with different priority levels, as will happen in the packet data world.

5 Relevant Parameters

5.1 Radio Interface Capacity

5.1.1 Clarified definition of RIC

The definition of RIC as contained in EN 302 217-1 [1] shall be updated as follows:

- **radio interface capacity (RIC):** net capacity defined at Z/Z' reference points that can be transmitted over the radio interface defined at reference point C'

NOTE: RIC includes additional capacity added for framing and multiplexing/demultiplexing different baseband signals (at X/X' points) into a transport module, eventually integrated in the baseband processing of the radio system, virtually defined at the Z/Z' reference points. It does not include other additional proprietary algorithms and signals used for specific radio systems purposes not intended for customer use (typically error correction codes and radio system service channels).

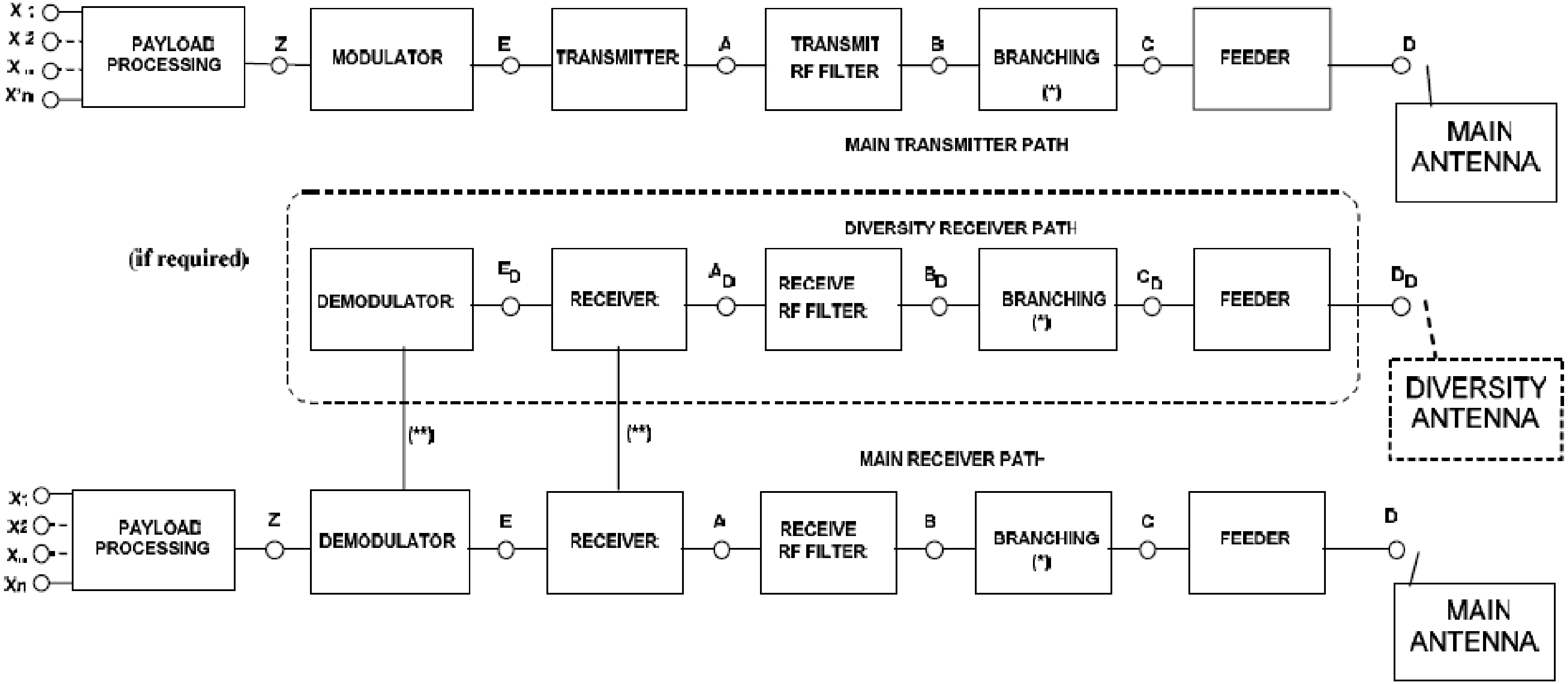


Figure 1: System Block Diagram from EN 302 217-1 (figure 1)

The definition of the RIC at the reference points Z/Z' is still valid also for systems with sophisticated capability of the module "payload processing".

Figure 2 shows the flow of data stream laid over the system block diagram.

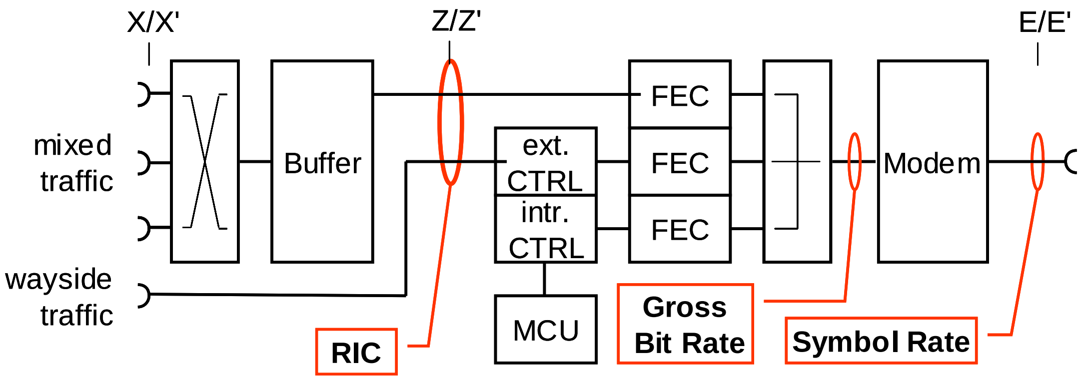


Figure 2: Schematic signal flow

The correlation between the data rates at X/X', at Z/Z' and the symbol rate at E/E' cannot be derived in a straight and generalized approach:

- due to the switching/routing capability, only a portion of the data stream at interface X/X' might be transmitted via the air interface. Other portions of the data stream might directly be routed to other ports X/X';
- besides PDH or SDH, interfaces X/X' might also cover all types of packetized data interfaces or partly filled data streams;
- each data stream might be routed through a buffer for handling low-prioritized or burst data streams;
- control data e.g. for the MAC are generated for radio system internal purposes, but shall not be included in the RIC;
- wayside channels are accessible for the user; traffic on those channels belongs therefore to the RIC;
- traffic data to be transmitted over the radio link and control data will obtain individual forward error correction.

The RIC shall be defined as the maximum average data rate at interface Z/Z' which the system can transmit. All interfaces X/X' and the control interface have to be loaded with the maximum acceptable data rate. The accumulated data rate of all interfaces X/X' shall not be the limiting bottleneck, but the capacity of the radio link. In case that the portion between X/X' and Z/Z' is able to provide control mechanisms for the data stream at X/X', these mechanisms shall be configured such that the radio link capacity determines the accepted data rate at X/X'.

5.1.2 Overview of current RIC-limits

We can regard the data rates and allocated bandwidth of PDH/SDH systems as initial reference for the upper limit of radio interface capacity.

Table 1: PDH/SDH data rates and spectral efficiencies

Levels of modulation		**2**	**4**	**8**	**16**	**32**	**64**	**128**	**256**
Bit rate	**Data Rate**	**Class 1**	**Class 2**	**Class 3**	**Class 4L**	**Class 4H**	**Class 5L**	**Class 5H**	**Class 6**
	(Mbit/s)	(MHz)	(MHz)	(MHz)	(MHz)	(MHz)	(MHz)	(MHz)	(MHz)
E1	2,048	3,5	1,75						
2 x E1	4,096	7	3,5		1,75				
E2	8,448	14	7		3,5		1,75		
2 x E2	16,896	28	14		7		3,5		
E3	34,368	56	28		14		7		
2 x E3	68,736	112	56		28		14		
4 x E3	137,472				56		28		
(0,5xSTM-0)	25,5	28		14		7			
STM-0	51	56		28		14			
2xSTM-0	102			56		28			
STM-1	155				56			28	
(4xSTM-0)	204					56			
2xSTM-1	310							56	40
minimum spectral efficiency (bit/s/Hz)		**0,59**	**1,17**	**1,82**	**2,34**	**3,64**	**4,83**	**5,54**	**7,75**
maximum spectral efficiency (bit/s/Hz)		**0,91**	**1,23**	**1,82**	**2,77**	**3,64**	**4,91**	**5,54**	**7,75**

The transmission rate for packet data can vary and may be controlled by the network itself. Packet data transmission can be adapted in many cases to existing PDH and SDH rates directly.

The multipart standard EN 302 217 [1] annex F specifies how to apply the standard to systems with baseband interfaces other than PDH/SDH interfaces. It applies to systems with packet data interfaces, mixed interfaces or multiple interfaces not covered by PDH/SDH standards directly.

The PtP multipart standard defines the required minimum radio interface capacities (RIC) for different channel widths and spectrum classes bound to selected PDH/SDH bit rates. This selection defines the minimum RIC values 2, 4, 8, 16, 32, 48, 64, 96 and 144 Mbit/s (and Nx144 Mbit/s) and gives reference to applicable PDH/SDH equipment requirements.

The RIC values corresponding PDH/SDH bit rates are summarized in table 2.

Table 2: RIC values in PtP multipart standard (EN 302 217-2-2 annex F)

Equivalent PDH/SDH rate Mbit/s	**Minimum applicable RIC Mbit/s**
2,048	2
2 x 2,048	4
8,448	8
2 x 8,448	16
34,368	32
STM-0	48
2 x 34,368	64
2 x STM-0	96
STM-1	144
N x STM-1	N x 144

Table 3 shows the spectral efficiency for different RIC alternatives with available channel spacing. In addition some possible new alternatives scaled within spectral class have been added. These alternatives are shown in parentheses.

Table 3: Spectral efficiency related to existing minimum RIC values

Levels of modulation		2	4	8	16	32	64	128
Bit rate	**RIC**	**Class 1**	**Class 2**	**Class 3**	**Class 4L**	**Class 4H**	**Class 5L**	**Class 5H**
		(MHz)	(MHz)	(MHz)	(MHz)	(MHz)	(MHz)	(MHz)
2	2	3,5	1,75					
2x2	4	7	3,5		1,75			
4x2	8	14	7		3,5		1,75	
8x2	16	28	14		7		3,5	
16x2	32	56	28		14		7	
32x2	64	112	56		28		14	
(64x2)	128				56		28	
(0,5xSTM-0)	24	28		14		7		
STM-0	48	56		28		14		
2xSTM-0	96			56		28		
STM-1	144				56			28
(4xSTM-0)	192					56		
2xSTM-1	288							56
minimum spectral efficiency (bit/s/Hz)		**0,57**	**1,14**	**1,71**	**2,29**	**3,43**	**4,57**	**5,14**
maximum spectral efficiency (bit/s/Hz)		**0,86**	**1,21**	**1,71**	**2,57**	**3,43**	**4,86**	**5,14**
NOTE: Not all the channel alternatives shown in the table are present for all frequency bands in existing PDH/SDH standards.								

The values shown in table 3 represent the minimum spectral efficiencies of RIC limits based on standard PDH/SDH transmission and may be considered as reference values for new RIC alternatives.

5.2 Bandwidth and Channel Separation

The channel plans as contained in the relevant recommendations from CEPT are based on:

- multiples of 0,025 MHz (T/R 13-01 [10], etc.);
- discrete channels of 1,75 MHz, 3,5 MHz, 7 MHz, 14 MHz etc, i.e. "7-MHz-family";
- discrete channels falling close to those of the "7-MHz-family", such as 27,5 MHz or 29,65 MHz;
- discrete channels of 10 MHz, 20 MHz, 40 MHz, i.e. "10-MHz-family".

In the scope of block allocation, the channel raster can arbitrarily be chosen depending on the capability of the equipment.

Consequently for a generic approach for defining the RIC values, an approach will be more straight-forward and less complex, which defines a certain spectrum efficiency per equipment class.

5.3 Spectral Efficiency

The definition of spectral efficiency is based on the ratio between RIC value and channel separation. It has therefore to be evaluated, whether the limits for the required spectral efficiency of a certain class should be uniform for all values of channel separation and radio frequency.

- The impact of the radio frequency on the correlation of typical RIC values versus gross bit rate is not seen at the moment.

- But there might be some impact from the occupied channel bandwidth. The data rate required for system management might not proportionally depend on the user traffic rate, but could be somehow constant. Therefore for lower bandwidths and lower modulation orders, the ratio between RIC and bandwidth might be set to lower limits.

5.4 Equipment spectrum class

In order to group equipment with similar spectral efficiencies, but for a wide range of channel separations, a classification system has been introduced. From history, this scheme is principally correlated with the type of modulation. Table 1 indicates the schematics.

Exceeding the scope of EN 302 217 [1], the class 4 is subdivided into a class 4L, mainly for 16-level modulation, and a class 4H for 32-level modulation and higher. This subdivision is justified by the wide range of modulation efficiencies from 2,34 bit/s/Hz to 3,64 bit/s/Hz, otherwise correlated with a single class 4.

The simple correlation between spectrum class and modulation scheme becomes less strict with the introduction of higher order coding rates. Systems with high-order modulation schemes enhanced with considerable coding will fall into a lower class than derived only from modulation.

It should be noted that regulating only the minimum RIC the actual system may fulfil requirements for more than one class, provided that they are capable of meeting all the requirements, e.g. the two different spectrum masks.

6 General considerations on criteria and methods for Radio Interface Capacity

6.1 Setting guidelines for new RIC-limits

RIC-limit is the minimum value for the radio interface capacity and it forms the criterion for the spectrum efficiency. Thus setting the limits for the RIC defines the spectrum class of the equipment, and can finally decide whether certain equipment would get allowance for operation or not. Since the spectrum class is originally correlated to PDH and SDH data rates, the relation between these rates and the RIC has to be discussed:

Route 1:

- When selecting the present RIC-limits some allowance was already added compared to SDH/PDH alternatives to allow roughly comparable net transmission capacities for packet data transmission. If additional allowances or discounts are applied the concept of RIC-limit is diluted and loses its value. However being the present standard tailored on PDH/SDH alternatives over discrete numbers of channel separation, this will become the more practical way for the short-term solution required by the market.
- In addition it is understood that the benefit for the networks of packet data transmission goes beyond the simple concept of spectral efficiency introducing more flexibility than the PDH/SDH fixed rates.

Route 2:

- Actual radio designs show an increasing manifold of combinations from various baseband interfaces to the radio interface, show a large variety of modulation states and coding schemes, and use multiple embedding of packet data into other transmission modes, e.g. IP-packets over ATM over STM-1.
- This approach is considered as a guideline for development of a new EN superseding EN 302 217 [1] and dealing with capacity, channel separation and equipment classes in a parametric way.

6.2 Definition of RIC limits

The apparent need for additional minimum RIC values occurs when the requirements imposed by the applicable PDH/SDH standard are difficult to meet with the desired RIC value.

Some basic approaches are seen when evaluating the definition of new RIC values:

- to add case by case new data rates and correlate them with applicable channel separations and equipment classes, i.e. to continue the way already started in EN 301 785 [3] and EN 302 217-2-2 [1] annex F; or
- to relax the applicable radio requirement in question by relaxing the requirements corresponding next lower or next higher RIC and keeping the number of RIC values to enable the application of one of these; or
- to define the RIC in a normalized way depending on equipment class and channel separation.

7 Route 1 - Addition of dedicated RIC values

7.1 Radio requirements for specific RIC values

Radio requirements for radio systems with packet data interfaces shall be selected according to PtP multipart standard EN 302 217-2 (V1.1.3) [1] annex F which relates existing PDH/SDH standards with RIC values. The available minimum RIC values are at present limited to values shown in table 1 for which applicable standards are available.

The apparent need for additional RIC values occurs when the requirements imposed by the applicable PDH/SDH standard are difficult to meet with the desired RIC value. The issue can be solved by either adding new RIC values with corresponding requirements or by relaxing the requirements and keeping the number of RIC values. Which way to go depends on the desired relationship between the requirements and what is economically achievable. To have tight requirements for all RICs, many sets of data rate limits are necessary and those already specified for PDH/SDH will not be enough. If less stringent requirements can be accepted, existing sets of requirements may be sufficient.

This has been proposed for the revision of EN 302 217-2 (V1.2.1) [1].

7.2 Evaluation of the radio interface parameters

In the following example some of the radio interface parameters are compared with typically achievable theoretical values. The most relevant parameters for this comparison are the following:

- receiver threshold level;
- co-channel and adjacent channel interference sensitivities;
- transmitter spectrum port.

7.2.1 Example 1 (28 MHz channel spacing)

To illustrate the situation, the specific example of the 23 GHz frequency band with a channel spacing of 28 MHz has been analysed. The requirements imposed by the PDH/SDH standards for a range of RIC are compared with what is believed to be normal performance with commonly used coding, modulation and noise figure.

Similar analysis was made for other channel spacing at 23 GHz (56 MHz, 14 MHz and 7 MHz) and the corresponding comparison figures are shown in annex D.

7.2.1.1 Assumptions

The theoretical performance curves are based on the following assumptions:

- BER = 10^{-6} at C/N = 25 dB for 6,5 bits/symbol;
- 3 dB increase in C/N for an increase of one bit/symbol (typical for QAM-modulations);
- Noise factor of 8 dB;
- 3 dB degradation of BER = 10^{-6} threshold is assumed to be at a co-channel interference C/I 3 dB above C/N for BER = 10^{-6}.

Table 4: Assumed symbol rates for requirement comparisons

CS (MHz)	Symbol Rate (MHz)
7	5,6
14	11,2
28	23,3
56	46,7

The NFD curves are calculated as the difference between C/I for 3 dB degradation from co- and adjacent channel interference.

The comparison for co-channel interference is shown in figure 3. The C/I for 3 dB degradation of the BER=10^{-6} threshold is used for this example. The figure shows that for RICs around 140 Mbit/s, the requirement is very close to expected performance. An interesting observation is that there is the same requirement over range where the expected performance varies with about 10 dB. The reason is not the lack of specified RIC values but the fact that the requirements for 2 x 34 Mbit/s and 2 x STM-0 are the same. With only one additional RIC limit, the complete range of relevant capacities could be covered with reasonable requirements. The new requirements could easily be derived by scaling existing PDH requirements as already practiced. That will include a Class 5L that is missing in this case.

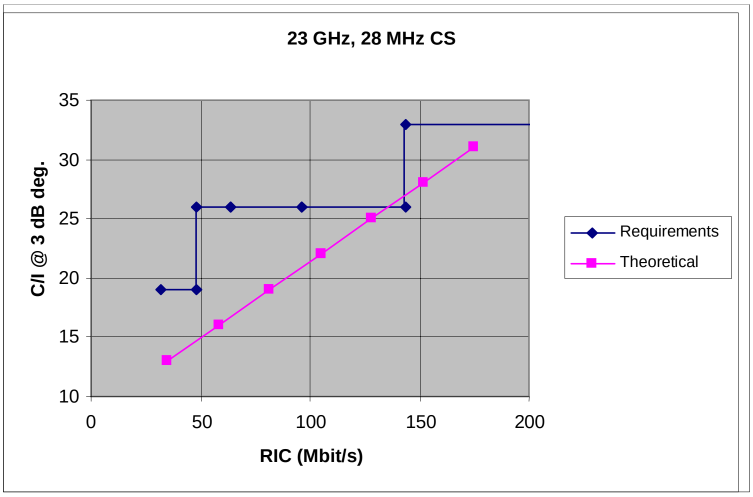


Figure 3: Co-channel C/I for 3 dB degradation of BER = 10^{-6} threshold as a function of Radio Interface Capacity

Table 5: Source data for requirements in figure 3

PDH/SDH requirements		Packet data requirements	
Capacity	C/I requirements (dB)	Applicable RIC range (Mbit/s)	Segment
34 Mbit/s	19	32 to 48	1
STM-0	26	48 to 64	2
2 x 34 Mbit/s	26	64 to 96	3
2 x STM-0	26	96 to 144	4
STM-1	33	144 to -	5

The comparison between requirements for BER=10-6 threshold and expected performance is shown in figure 4. From the figure it seem as the existing requirements can cover the relevant range of RIC and no additional specifications or relaxations are needed.

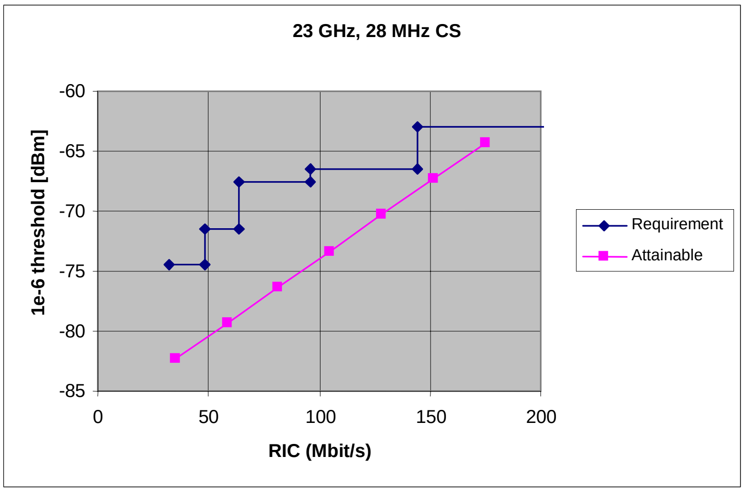


Figure 4: BER = 10^{-6} threshold as a function of Radio Interface Capacity

Figure 5 shows the different spectrum masks specified for 23 GHz with a channel separation of 28 MHz. The mask for STM-0 "misuses" the channel but offers higher compatibility alternative which can be seen also from the high NFD requirement (figure 3).

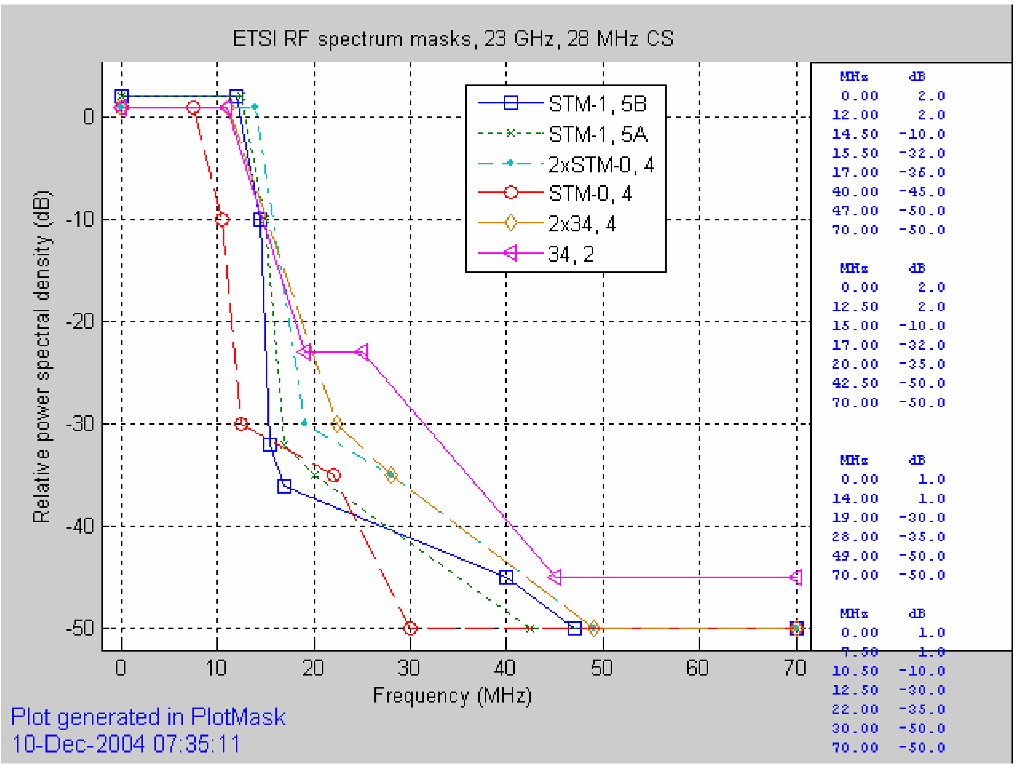


Figure 5: Spectrum masks for different capacities

Figure 6 shows the NFD which is implicitly required by the combination of co- and adjacent channel interference requirements. The NFD is calculated as the difference between required C/I for 3 dB degradation of the BER=10^{-6} threshold for co- and adjacent channel interference.

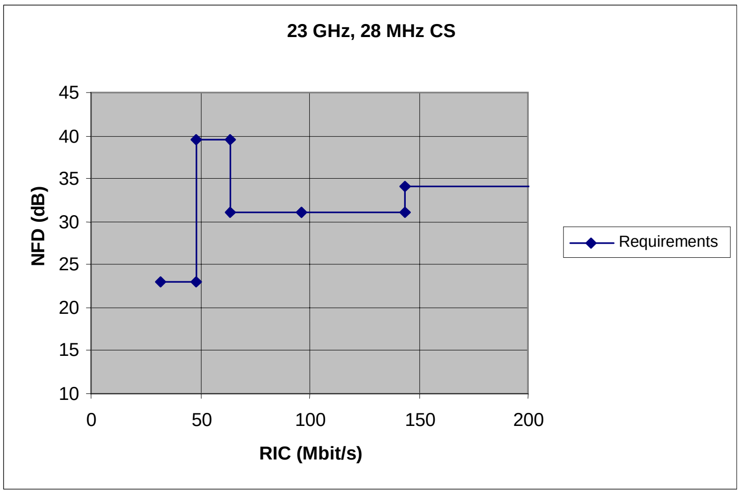


Figure 6: Implicit NFD requirement as a function of Radio Interface Capacity

7.2.2 Other examples

Comments to examples on other channel spacing (see details in annex D:):

- CS = 56 MHz: In receiver threshold and C/I cases there will be problems around 280 Mbit/s. This could be solved by relaxing the requirements for STM-1 or lowering the RIC limit at 288 Mbit/s. However, it is probably better to add a new RIC limit at e.g. 4 x STM-0 and scale the requirements from 2 x STM-0 in 28 MHz channel spacing;
- CS = 14 MHz: C/I requirements at 48 Mbit/s seems to be the most critical point. This may be solved by relaxing the requirement at 48 Mbit/s;
- CS = 7 MHz: C/I requirement for 32 Mbit/s seems to be at the nearest to "attainable" curve. Possibly no actions are required.

7.3 Conclusion and proposals

Based on the above analysis of the 23 GHz band, the following changes might be necessary:

- Add a new RIC limit of 128 Mbit/s for 28 MHz channels, named 4 x 34, with requirements scaled from 2 x 34 in 14 MHz channels.
- Relax adjacent channel interference requirement and spectrum mask for STM-0 in 28 MHz channels.
- Add a new RIC limit of 128 Mbit/s for 56 MHz channels, named 4 x 34, with requirements scaled from 2 x 34 in 28 MHz channels.
- Add a new RIC limit of 192 Mbit/s for 56 MHz channels, named 4 x STM-0, with requirements scaled from 2 x STM-0 in 28 MHz channels. (does not relax co-channel interference requirement).
- Add a new RIC limit of 256 Mbit/s for 56 MHz channels, named 8 x 34, with requirements scaled from 2 x 34 in 14 MHz channels (gives relaxed co-channel interference requirement but more stringent adjacent channel interference requirement).

Table 6: Proposed new requirements for 23 GHz

Capacity	Threshold (dBm)	CCI (dB)	ACI (dB)	Minimum RIC (Mbit/s)	Note
STM-0 in 28 MHz		23	-4		Relax ACI
4 x 34 in 28 MHz	-63	33	-7	128	
4 x 34 in 56 MHz	-64,5	26	-5	128	
4 x STM-0 in 56 MHz	-63,5	26	-5	192	
8 x 34 in 56 MHz	-60	33	-7	256	

In summary, the analysis has shown that by adding only three new minimum RIC values, it is possible to cover all relevant capacities in the 23 GHz band with reasonable requirements. As the new requirements can be scaled from existing requirements this should be a simple task.

Based on this example, also other frequency bands can be amended with new RIC values when following Route 1.

Obviously this approach is strongly bound to a more conventional approach, also when new packet based radio systems are considered, since all new RIC values are connected to establish PDH/SDH data rates. This is an advantage as the classes will have the same meaning for both packet based and PDH/SDH systems. It will also simplify compatibility considerations when mixing the two types of systems.

However, also the relaxation of the present RIC values (as proposed for EN 302 217-2-2 (V1.2.1) [1] will satisfy as well the short term needs.

8 Route 2 - Approach for flexible RIC-values

The term "radio interface capacity" correlates a certain set of user data rates with another set of spectrum classes for various channel separations. In conventional systems with minor coding, well-known contributions for way-side channels, etc. a variety of specifications which sometimes differ when defining quite similar parameters has been established for such correlations.

Before adding new RIC-values, the approach for deriving the transmission capacity from the available spectrum shall be reconsidered in order to see the physical limits.

The following evaluation intends to define a continuous set of RIC values covering all equipment classes at a certain bandwidth. The approach shown in annex E provides an extension also over various channel separations.

8.1 Derivation of reasonable symbol rates versus bandwidth

The upper end of the range of a RIC is given by technical parameters as the ratio between the gross bit rate or the symbol rate and the channel spacing.

This ratio is a crucial point for the design of the modulator, the transmitter and the demodulator. To keep the expenditure balanced for the design and production of fixed radio systems the ratio should be a realistic assumption depending on the spectral efficiency classes. (Specifically the peak factor is concerned, which leads to a larger back-off of the transmit power for higher order modulation, thus requiring a higher power amplifier for the same operational transmit power.)

- For spectrum efficiency class 1 (BPSK) Cosine-roll-off > 40 %.
- For spectrum efficiency class 2 (QPSK) Cosine-roll-off > 35 %.
- For spectrum efficiency class 3 (8QAM) Cosine-roll-off > 30 %.
- For spectrum efficiency class 4L (16QAM) Cosine-roll-off > 25 %.
- For spectrum efficiency class 4H (32QAM & 64QAM) Cosine-roll-off > 20 %.
- For spectrum efficiency class 5 and higher (64QAM, 128QAM, 256QAM) Cosine-roll-off > 15 %.

These numbers are a trade-off between the transmission bit rates and the appropriate channel spacing and the realization of equipment.

Depending on the modulation scheme the maximum RIC can be calculated from the channel spacing and the assumed cosine roll-off factor.

$$RIC = f_1(GrossBitRate; Overhead)$$
$$GrossBitRate = f_2(SymbolRate; ModulationOrder)$$
$$SymbolRate = f_3(ChannelSeparation; RollOff)$$

$$SymbolRate = \frac{CS}{(1 + CosRollOff)}$$

Figure 7 shows the symbol rate versus bandwidth, taking into account the roll-off factors.

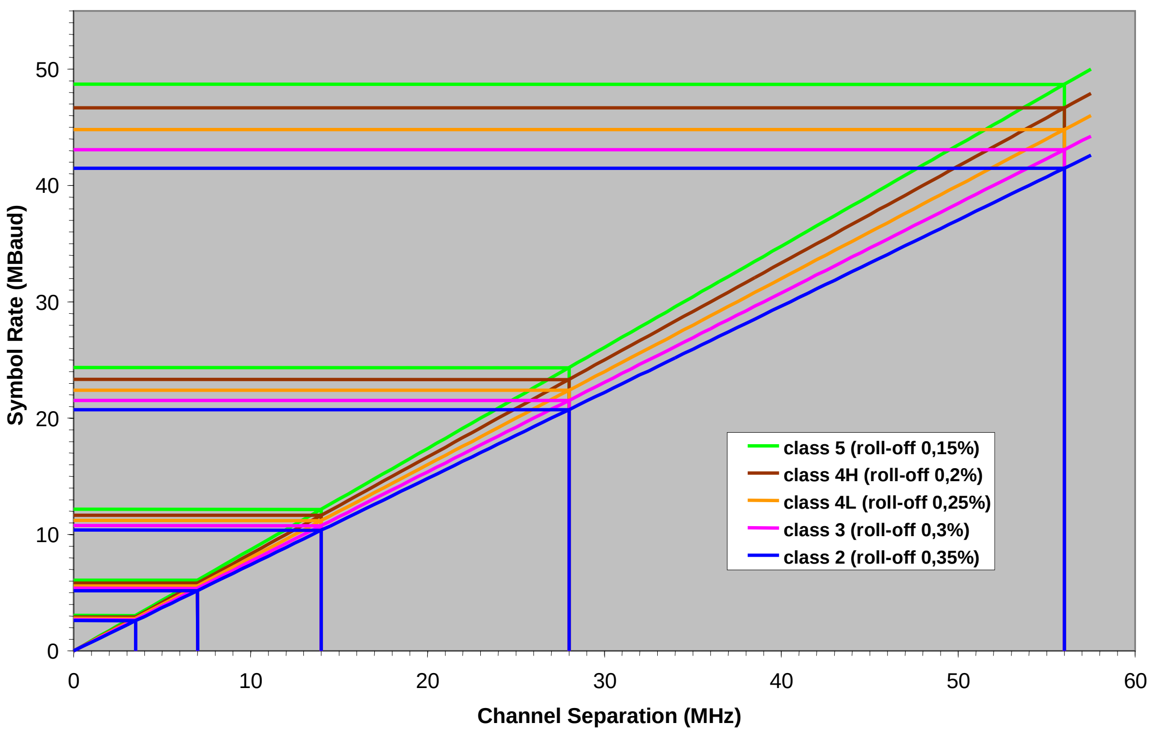


Figure 7: Maximum Symbol Rate versus Channel Separation

8.2 Derivation of maximum radio data rates

The gross bit rate before coding can be calculated as:

$$GrossBitRate = SymbolRate * \log_2(N)$$
$$N = \text{modulation states}$$

This gross bit rate is the maximum one which can reasonably be transmitted over a given channel bandwidth with a given modulation, but it does not contain any coding to improve robustness, no reserve for control channels, no overhead for packet data etc. Figure 8 shows the maximum achievable gross bit rate per bandwidth and modulation order.

NOTE: This evaluation does not directly correlate with the actual definition of "equipment class", where also higher maximum data rates can be used in most cases. There is no explicit limitation on which constellation can be used for a system class. The maximum size will be given by requirements on receiver threshold and co-channel interference.

The basic question for deriving the RIC is to define a reasonable allowance for these contributions.

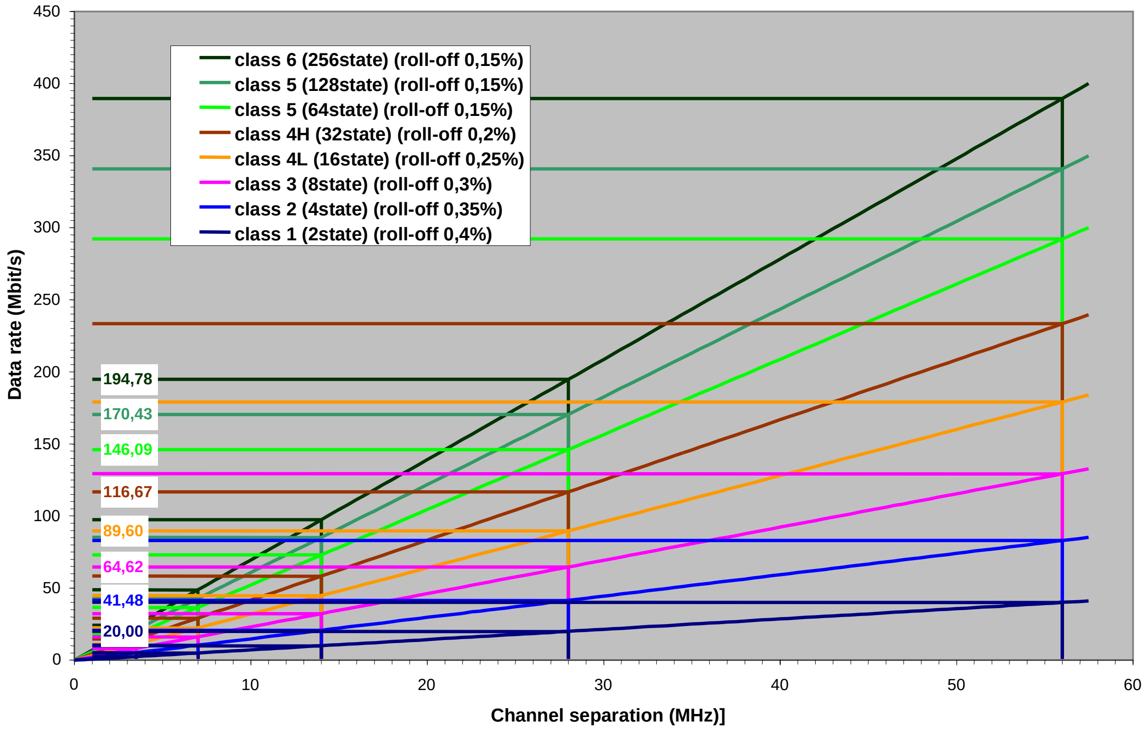


Figure 8: Maximum radio data rates

NOTE: The results presented in figure 8 suggest that e.g. the maximum data rate for Class 3 is 64,62 Mbit/s. Based on the analysis in clause 7, it should be possible to achieve approximately 115 Mbit/s and still meet the requirements of Class 3 in 23 GHz. However in this case it has to be recognized that this is achieved using 64 - TCM 4D + RS (255,239) and 22 MHz symbol rate, which corresponds with class 5L in this approach.

8.3 Definition of RIC-ranges

Obviously in all microwave radio systems the transmit data rate for user data is lower than the maximum radio data rate shown in figure 8. Some coding has to be applied, some data rate has to be reserved for wayside channels and internal data traffic used for monitoring and control, and network protocols require some overhead.

Figure 8 is now scaled in dual logarithmic manner, in order to get a better visualization about relative or absolute portions of data rate reserved for overhead. Besides the maximum radio link capacity as previously derived in figure 7, also some discrete data for PDH/SDH systems are included, extracted from table 2 and marked with squares. In addition, some RIC values as contained in EN 302 217-2-2 [1] annex F are shown as triangles.

The assessment of clause 5.3 about the overhead to be rather an absolute portion than a relative one, seems to be not confirmed. All points for specific PDH/SDH systems of the same class lay at about the same distance from the lines of the ideal radio transmission rate. Due to the logarithmic scale of figure 8, the overhead is therefore rather proportional to the data rate without a constant contribution.

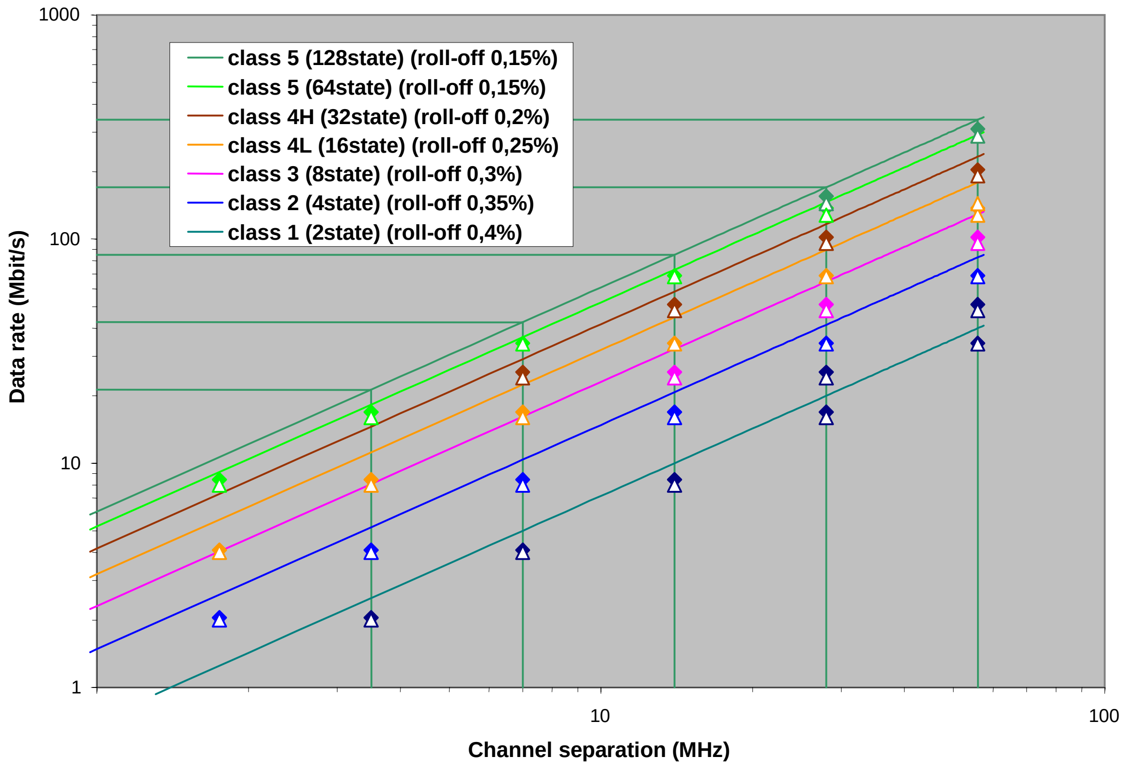


Figure 9: PDH/SDH and annex F data rates

The values of figure 9 are summarized in the first columns of table 7 in terms of spectral efficiency. The "maximum radio spectral efficiency" is derived from the data rate calculated in equation 2 divided by the allocated channel separation. The "spectral efficiency" for PDH/SDH systems is derived from table 1. The "calculated ratio" shows the portion used for user data.

The maximum spectral efficiency given in table 7 is based on the assumption that the class limits the modulation order. In current standards, modulation is not specified and the real limit on spectral efficiency is determined by the specified performance requirements. It is possible to achieve considerable higher spectral efficiencies than those given in table 7 (as illustrated by the example in clause 8.2).

Obviously the lower class systems are less stringent concerning the usage of the theoretically available data rate for user traffic, since the ratio comes closer to 100 % for higher class systems.

Table 7: Recommended limits for spectral efficiency

System Class	Maximum Radio Spectral Efficiency (bit/s/Hz)	Spectral Efficiency for PDH/SDH systems (bit/s/Hz)	Calculated Ratio	Recommended Ratio	Spectral Efficiency Limit (bit/s/Hz)
2	1,48	1,17 to 1,23	78,99% to 82,85%	82%	1,21
3	2,31	1,82	78,93%	84%	1,94
4L	3,20	2,34 to 2,77	73,14% to 86,50%	86%	2,75
4H	4,17	3,64	87,43%	88%	3,67
5L	5,22	4,83 to 4,91	92,53% to 94,10%	90%	4,9
5H	6,09	5,54	90,94%	92%	5,6
6	6,96			92%	6,4

In the column "recommended ratio" one value per system class, increasing from 82 % to 92 %, is proposed. This recommended ratio is intended to cover most of the PDH/SDH cases (with exception of class 5L).

In the last column, the resulting new limit for the spectrum efficiency is shown.

8.4 Application of RIC-ranges

The "limits of spectral efficiency" in conjunction with the allocated channel separation shall define the maximum RIC required for a certain system class. The lower limit of this class is given by the spectral efficiency limit of the next lower class.

The advantage of this approach is obvious and supported by visualization of figure 10:

- every potential new data rate can uniquely be allocated to a specific RIC;
- all reasonable channel separations can be correlated to a specific RIC;
- each class covers about the same range, as long as the sub-classes 4L and 4H are taken into consideration.

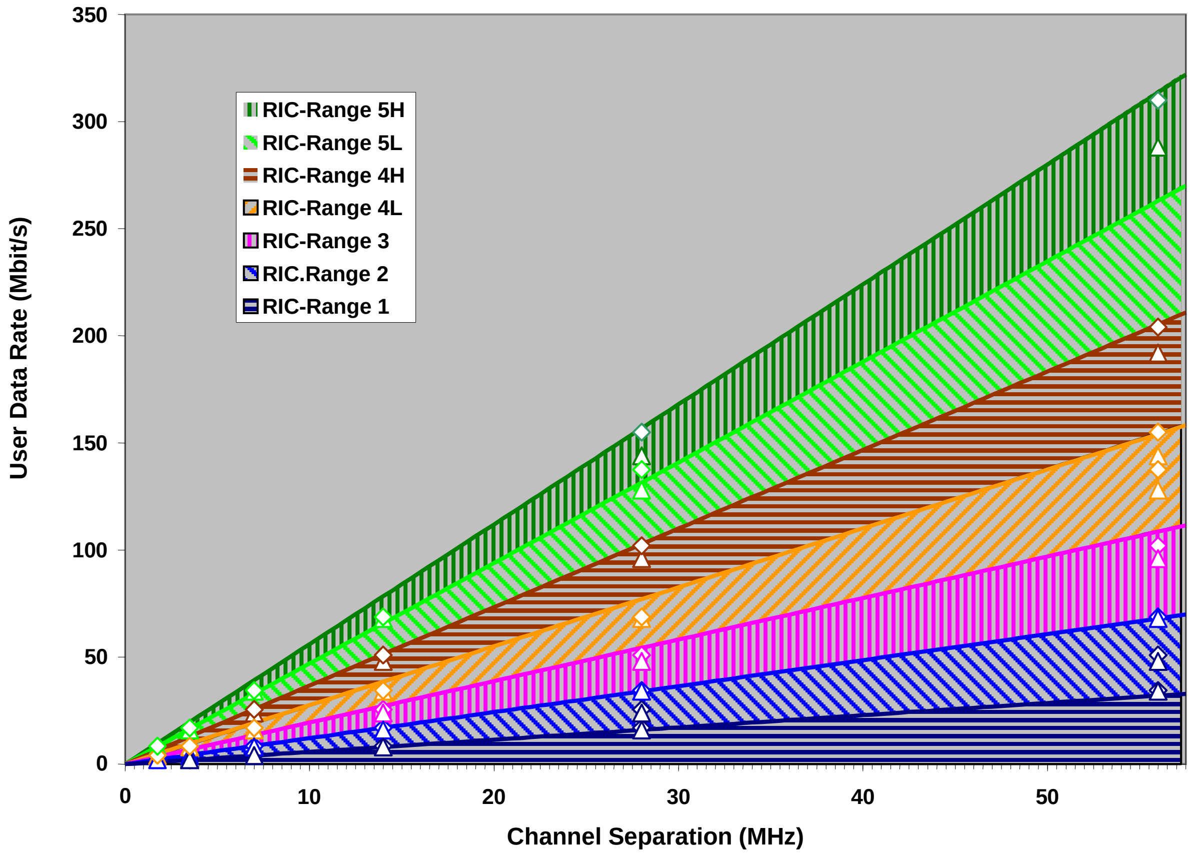


Figure 10: Definition of RIC-Ranges

8.5 Possible Extension EN 302 217-2-2 annex F

The correlation of figure 10 with table F.1 of EN 302 217-2-2 [1] results in an update shown in table 8, where the range of the applicable RIC is identified together with the applicable system type. This table 8 allows allocating packet data radios as long as a corresponding system type (B.1 to E.7) has been allocated for PDH/SDH systems.

Table 8: Update of table F.1 of EN 302 217-2-2 (depending on actual channel separation)

ChS (MHz)	Class	PDH/ SDH rate (actual EN302217)	min. RIC (Mbit/s) (proposal WR)	additional PDH/SDH (proposal Nera)	(proposal Ofcom CH)	min RIC (Mbit/s)	nom RIC (Mbit/s)	max RIC (Mbit/s)	B.1	B.2	B.3	C.1	C.2	C.3	D.1	D.2	D.3	D.4	D.5	D.6	D.7	D.8	E.1	E.2	E.3	E.4	E.5	E.6	E.7
1,75	1				2-state	0,6	1	1,2																					
	2	2,048	1,00		4-state	1,1	2	2,4	X						X														
	3		2,13		8-state	1,6	3	4																					
	3&4(L)	2 x 2,048	3,39		16-state	2,2	4	5	X						X														
	4(H)				32-state	2,5	5	6																					
	5(L)				64-state	5	8	9																					
	5(H)				128-state	5	9	10																					
	6(L)				256-state	6	11	12																					
	6(H)				512-state	7	12	13																					
3,5	1	2,048	below 2		2-state	1,1	2	2,45																			X		
	2	2 x 2,048	2,00		4-state	2,2	4	5	X						X								X	X	X		X	X	X
	3		4,25		8-state	3,3	6	8																					
	3&4(L)	8,448	6,78		16-state	4,5	8	10	X						X								X	X	X			X	X
	4(H)	9,792	9,63		32-state	5	10	12								X													
	5(L)	14,4	12,83		64-state	8	16	18								X													
	5(H)				128-state	10	19	21																					
	6(L)				256-state	12	22	24																					
	6(H)				512-state	13	25	27																					
7	1	2,048	below 2																								X	X	X
	1	2 x 2,048	2,00		2-state	2,2	4	5																				X	X
	2	8,448	4,00		4-state	4,5	8	10	X						X								X	X	X		X	X	X
	3		8,50		8-state	7	12	15																					
	3&4(L)	2 x 8,448	13,57		16-state	9	16	20	X						X								X	X	X			X	X
	4(H)		19,26		32-state	10	20	25																					
	5(L)				64-state	16	33	36																					
	5(H)				128-state	20	38	42																					
	6(L)				256-state	23	44	48																					
	6(H)				512-state	26	50	54																					
11,662	2	8,448	6,66						X																				

ChS (MHz)	Class	PDH/ SDH rate (actual EN302217)	min. RIC (Mbit/s) (proposal WR)	additional PDH/SDH (proposal Nera)	(proposal Ofcom CH)	min RIC (Mbit/s)	nom RIC (Mbit/s)	max RIC (Mbit/s)	B.1	B.2	B.3	C.1	C.2	C.3	D.1	D.2	D.3	D.4	D.5	D.6	D.7	D.8	E.1	E.2	E.3	E.4	E.5	E.6	E.7
13,75	1	2 x 2,448	below 4																								X		
14	1	8,448	4,00		2-state	4,5	8	10																				X	X
14,5	2	2 x 8,448	7,86		4-state	9	16	20	X						X														
15	3		16,70		8-state	13	24	30																					
	3&4(L)	34,368	26,65		16-state	18	34	40	X						X								X	X	X			X	X
	4(H)	STM-0	37,84		32-state	20	40	50										X					X	X	X			X	X
	5(L)	2 x 34,368	50,42		64-state	33	66	72	X						X								X	X	X				
	5(H)				128-state	40	77	84																					
	6(L)				256-state	46	88	96																					
	6(H)				512-state	52	100	108																					
20	4(L)	STM-0	38,77						X																				
21	4(L)	STM-0	40,71						X																				
23,324	4(L)	STM-0	45,21						X																				
27,5	1	8,448	below 8																								X		
28	1	2 x 8,448	8,00		2-state	9	16	20																				X	X
29	2	34,368	15,71		4-state	19	34	40	X						X								X	X	X			X	X
29,65	3	STM-0	33,41		8-state	26	42	60	X								X											X	X
30	3&4(L)	2 x 34,368	53,31		16-state	36	51	80	X						X								X	X	X			X	X
	4(H)	2 x STM-0	75,68		32-state	40	80	100	X									X					X	X	X			X	X
	5(L)			4 x 34,368	64-state	66	132	144																					
	5(H)	STM-1	100,83		128-state	80	155	168	X	X	X								X	X	X		X	X	X				
	6(L)				256-state	92	177	192																					
	6(H)				512-state	104	200	216																					
40	5(L)	STM-1	146,67									X																	
	5(H)	STM-1	187,83										X																
	6	2 x STM-1	224,00											X															
55	1	34,368	below 32		2-state	19	34	40																				X	X
56	2	STM-0	32,00		4-state	38	51	80															X	X	X			X	X
	3		68,03		8-state	47	84	120																					
	3&4(L)	STM-1	108,55	4 x 34,368	16-state	62	155	160																					
	4(H)	STM-1	151,36		32-state	80	160	200													X		X	X	X			X	X
	5(L)			4 x STM-0																									
	5(L)			8 x 34,368	64-state	132	264	288																					
	5(H)	2 x STM-1	205,33		128-state	160	310	336														X	X	X	X	X		X	X
	6(L)				256-state	184	354	384																					
	6(H)				512-state	208	400	432																					

9 PtP-systems with mixed-mode system parameters

A system with mixed-mode system parameters may select adaptively from different modulations/coding alternatives based on the transmission needs and the quality of the received signal at a given time (e.g. 4QAM, 16QAM or 64QAM or more and/or from several coding alternatives). According to characteristics of available adaptive modulation techniques, existing P-P ETSI standards are not directly applicable to this type of systems. Therefore it is necessary to discuss how to use existing standards or to develop standards that can be used in this context. If parameters of systems with adaptive modulation comply with existing standard (EN 302 217) [1], it might be easy to introduce this option in the standard, in the harmonized standard EN 302 217-2-2 [1] mainly, and the amendment would be implemented without delay.

It should be noted that use of mixed-mode system parameters are not limited to packet data radio systems only but may in principle be used in PDH/SDH systems as well. In these systems some part of the traffic may be categorized as lower priority and can be dropped out when necessary.

9.1 Benefits of adaptivity

There are at least three ways P-P radio system can benefit from adaptive system parameters:

1) To increase the availability of a smaller portion of the capacity, during period with very unfavourable propagation conditions, by the use of modulation formats lower than that used for defining the link budget and related frequency co-ordination constraints at the conventional availability objective (e.g. 99,99 %). This will result in lower capacity with higher availability (according the statistic of propagation phenomena, multipath or rain) due to enhanced link budget (according the lower BER threshold and, as far as permitted by ATPC overdrive mode, TX power increase without exceeding the spectrum mask of the highest allocated modulation scheme).

   It is anticipated, that those systems will keep the transmit power at a level which is always compliant with the transmit spectrum mask of the highest allocated modulations scheme also during momentary use of lower order modulation. In this case, the assumptions for the frequency planning and coordination of the link as done for the highest order modulation are always applicable. i.e. the system has to fulfil the spectrum mask of the highest order modulation also for the lower order modulation states.

   This scheme might even be extended in a way, that the actually used bandwidth of the system will be reduced, e.g. from 28 MHz via 14 MHz to 7 MHz. Applying the maximum transmit power over a smaller bandwidth would increase the power spectral density, thus improving the link budget.

   The RIC limits shall be applied only for the highest mode.

2) To increase the available capacity over the same radio frequency channel, during period with favourable propagation conditions, by the use of modulation formats higher than that used for defining the link budget and related frequency co-ordination constraints at the conventional availability objective (e.g. 99,99 %). E.g. maintaining about the symbol rate fixed, this will result in the same channel occupancy and in a higher capacity even if with lower availability (according the statistic of propagation phenomena, multipath or rain) due to reduced link budget (according the higher BER threshold and reduced TX power for improving linearity).

   The RIC limits shall be applied only for the lowest mode!

3) P-P radio links configured permanently for one of the possible modulation formats. In this case, the benefits are found in the reduced amount for logistics. The applicable requirements of the specific system type have to be met for each potential modulation state.

9.2 General considerations

When considering how to specify requirements for adaptive systems, the essential aspects are how to cover regulatory and frequency planning issues. Adaptive systems are highly likely to co-exist with fixed rate systems and it is therefore essential to have specifications that can help to ensure compatibility between those systems.

Also for mixed-mode systems, the requirements of the EN 302 217 [1] are applicable, but have to be amended concerning link control and the dynamic behaviour of the transmitter, which shall be verified against the required emission characteristics.

A more detailed consideration of multi-rate systems has been included as annex F of EN 302 326-1 [2] (Point to Multipoint multipart standard). This is contained as annex F of the present document.

10 Conclusion and next steps

The concept for parameters standardized over all bands of the EN 302 217 [1] should also be followed for other parameters than just the RIC, e.g.:

- spectrum masks (with noise floor stepwise relaxed with higher frequency bands);
- RSL versus spectrum efficiency class and occupied bandwidth;
- co- and adjacent channel interference.

It is regarded as appropriate to evaluate this approach in a possible new standard superseding the EN 302 217 [1].

Annex A: RIC-values for Ethernet signal transmission

According to IEEE 802.3 [7] specification Ethernet-frames consist besides of data octets also of some octets for addresses, synchronization, error checking and other control functions. P-P radio system operates always in full duplex mode where no collisions can happen.

From [7] the following Ethernet MAC-frame data can be obtained:

Table A.1: Ethernet MAC-frame data

	Minimum frame length	**Maximum frame length**	
Preamble	7	7	octets
SFD	1	1	octets
Destination address	6	6	octets
Source address	6	6	octets
Type	2	2	octets
Data	46	1 500	octets
FCS	4	4	octets
sum	72	1 526	octets
	576	12 208	bits
Inter frame gap	96	96	bit times
sum	**672**	**12 304**	**bit times**

The maximum bit rates that can be transmitted by different Ethernet systems in full-duplex system are calculated from the previous data. Data rate1 excludes preamble and SFD from the data stream and data rate 2 includes all the octets in the data stream.

Table A.2: Ethernet data rates

	data rate1		**data rate 2**	
Mbit/s	**Min**	**Max**	**Min**	**Max**
10	7,62	9,87	8,57	9,92
100	76,19	98,70	85,71	99,22
1 000	761,90	987,00	857,14	992,20

For instance 100 Mbit/s Ethernet can carry up to 98,7 Mbit/s if preamble and frame limiter (SFD) fields are excluded from the net data and up to 99,2 Mbit/s if they are included.

Annex B:
Table F.1 from EN 302 217-2-2

Table B.1: Applicable PDH/SDH specifications for accumulated capacities using a combination of interfaces

Frequency Bands	Equivalent PDH/SDH rate (Mbit/s)	Minimum applicable RIC (Mbit/s) V1.1.3	Minimum applicable RIC (Mbit/s) V1.2.1	Reference to annex and System
4 GHz to 11 GHz (excluding 40 MHz Channel separation)	2,048	2	1,3	B.1
	2 × 2,048	4	2,7	
	8,448	8	5,5	
	2 × 8,448	16	11,1	
	34,368	32	22,2	
	STM-0	48	33,3	
	2 × 34,368	64	44,4	
	2 × STM-0	96	66,6	
	STM-1	144	100	B.2, B.3
	N × STM-1	N × 144	n x 100	
4 GHz, 5 GHz, 6U GHz and 11 GHz (40 MHz Channel Separation only)	STM-1	144	100	C.1, C.2, C.3
	N × STM-1	N × 144	n x 100	
13 GHz, 15 GHz, 18 GHz	2,048	2	1,3	D.1
	2 × 2,048	4	2,7	
	8,448	8	5,5	
	2 × 8,448	16	11,1	
	34,368	32	22,2	
	2 × 34,368	64	33,3	
	STM-0	48	44,4	D.3, D.4
	2 × STM-0	96	66,6	
13 GHz	STM-1	144	100	D.5, D.6
	N × STM-1	N × 144	n x 100	
15 GHz	STM-1	144	100	D.5, D.6, D.8
	N × STM-1	N × 144	n x 100	
18 GHz	STM-1	144	100	D.7 or D.8
	N × STM-1	N × 144	n x 100	
23 GHz to 38 GHz	2,048	2	1,3	E.1 (23 GHz band) E.2 (26 GHz and 28 GHz bands) E.3 (32 and 38 GHz bands)
	2 × 2,048	4	2,7	
	8,448	8	5,5	
	2 × 8,448	16	11,1	
	34,368	32	22,2	
	STM-0	48	33,3	
	2 × 34,368	64	44,4	
	2 × STM-0	96	66,6	
	STM-1	144	100	E.1, E.4 (23 GHz band) E.2, E.4 (26 GHz and 28 GHz bands)
	N × STM-1	N × 144	n x 100	E.3, E.4 (32 and 38 GHz bands)
50 GHz	2,048	2	1,3	E.5
	2 × 2,048	4	2,7	
	8,448	8	5,5	
	2 × 8,448	16	11,1	
	34,368	32	22,2	
52 GHz and 55 GHz	2,048	2	1,3	E.6 (52 GHz) E.7 (55 GHz)
	2 × 2,048	4	2,7	
	8,448	8	5,5	
	2 × 8,448	16	11,1	
	34,368	32	22,2	
	STM-0	48	33,3	
	2 × 34,368	64	44,4	
	2 × STM-0	96	66,6	
	STM-1	144	100	

Annex C: System details on HiperAccess user data rate evaluation

C.1 BRAN HiperAccess

ETSI BRAN HiperAccess Technical Specification (TS 101 999 [4]) defines Point to Multipoint system with flexible system parameters. The system may select adaptively from three QAM modulations: 4QAM, 16QAM or 64QAM and from four coding sets. There are four specified physical modes in downlink and three in uplink.

The same system concept and technology can be applied to (packet data) PtP-radio links (however, without the need for MAC). PtP-radio link would transmit using the highest system mode available and switch to lower modes only temporarily if propagation conditions get worse due to rain or multipath fading. System may also in case of packet data adapt to instantaneous input data rate and choose temporarily a lower mode.

The following tables give some information to the RIC values for the transmission of ATM based packets for Point-to-Point fixed radio systems derived from ETSI BRAN HiperAccess.

C.2 HiperAccess parameters

The single broadband 28 MHz, 14 MHz or 7 MHz carrier establishes a connection between two points, both uplink and downlink are symmetric and support adaptive modulation as well. 4QAM, 16QAM and 64QAM levels are supported. The transparent transmission of ATM cells is realized in a continuous TDM mode. There are two coding schemes in HIPERACCESS:

- inner code is convolutional with coding rates 2/3, 5/6, 7/8 or 1/1; and
- outer code RS block code with selectable coding rates.

In this example CC (2/3) is used and only for QPSK. For maximum frame length the RS coding rate is 216/232. The (Max) user data rates in table 6 were calculated using these figures. The available user rate is lower if shorter frames are used (<4 PDU´s). See annex B for more details.

Table C.1: Selection of user data rates and its system characteristics using flexible modulation and coding scheme based on HIPERACCESS parameters (with CC and RS coding, and some complementary overhead)

System mode	Physical mode set[2]	Symbol rate (MBd)	Channel spacing (MHz)	Max User Data Rate (Mbit/s)	RIC-limit (Mbit/s)
QPSK(2/3) [1]	2	22,4	28	25,4	<25,4
QPSK(1/1)	2	22,4	28	38,5	<38,5
16QAM(1/1)	2	22,4	28	77,6	<77,6
64QAM(1/1)	2	22,4	28	116,2	<116,2
QPSK(2/3) [1]	2	11,2	14	11,9	<11,9
QPSK(1/1)	2	11,2	14	18,2	<18,2
16QAM(1/1)	2	11,2	14	36,5	<36,5
64QAM(1/1)	2	11,2	14	54,7	<54,7
QPSK(2/3) [1]	2	5,6	7	5,9	<5,9
QPSK(1/1)	2	5,6	7	9,1	<9,1
16QAM(1/1)	2	5,6	7	18,2	<18,2
64QAM(1/1)	2	5,6	7	27,3	<27,3
NOTE 1: The user data rate is applied only temporarily to the described for short time intervals, not for operation with fixed modulation scheme. There may be no practical need for RIC limits for these temporary values. NOTE 2: Refers to ETSI HiperAccess mode sets (1 or 2).					

C.3 BRAN HiperAccess data rates

The measurement reports are ATPC messages and are assigned to the management information. The packet cell includes internal information of the system. The header of the ATM cell is assigned to the user data rate.

For reasons of clarity only the applied physical mode is presented. The characteristics of the user data rate are shown below:

- Symmetrical TDM (DL-BRAN).
- Frame length 1 ms to 2 ms (depending on the frequency bandwidth, for 28 MHz only 1 ms).
- PDU-Length = 54 Bytes.
- Preamble length = **32 symbols**.
- Control Zone (CZ): 3 x FEC = 3 x [RS(46,30)+CC1/2, 6-tail bits, QPSK] = **1 122 symbols.**
- BRAN-PHY Modes with 4 x PDUs.
- Number of channel symbols (without CZ & Preamble) per frame.
  - 28 MHz with 1 ms frame duration = **21 246 symbols**.
  - 14 MHz with 1 ms or 7 MHz with 2 ms frame duration = **10 046 symbols.**

Overheads

- 1 byte per ATM Cell (53/54).
- DLC Protocol (e.g. power control) & Mgmt signalling.
- Padding symbols / bits (frame / symbol).

Table C.2: Data Rates for PtP @ 28 MHz channel (1 ms frame length = 22 400 symbols)

Set	Outer code	Inner code	Modulation	# of symbols / FEC block	No of PDU per Frame	Maximum data rate in Mbps (including DLC & Management overhead)
Set 2	RS (232, 216)	CC2/3	4QAM	1 397	60	**25,440**
	RS (232, 216)	no	4QAM	928	91	**38,548**
	RS (232, 216)	no	16QAM	464	183	**77,592**
	RS (232, 216)	no	64QAM	310	274	**116,176**

Table C.3: Data Rates for PtP @ 14 MHz channel (1 ms frame length = 11 200 symbols)

Set	Outer code	Inner code	Modulation	# of symbols / FEC block	No of PDU per Frame	Maximum data rate in Mbps (including DLC & Management overhead)
Set 2	RS (232, 216)	CC2/3	4QAM	1 397	28	**11,872**
	RS (232, 216)	no	4QAM	928	43	**18,232**
	RS (232, 216)	no	16QAM	464	86	**36,464**
	RS (232, 216)	no	64QAM	310	129	**54,696**

Table C.4: Data Rates for PtP @ 7 MHz channel (2 ms frame length = 11 200 symbols)

Set	Outer code	Inner code	Modulation	# of symbols / FEC block	No of PDU per Frame	Maximum data rate in Mbps (including DLC & Management overhead)
Set 2	RS (232, 216)	CC2/3	4QAM	1 397	28	**5,936**
	RS (232, 216)	no	4QAM	928	43	**9,116**
	RS (232, 216)	no	16QAM	464	86	**18,232**
	RS (232, 216)	no	64QAM	310	129	**27,348**

Annex D: Radio requirements for 23 GHz

The objective of this paper is to identify transmission capacities where the current requirements are not appropriate. With packet data transmission, the transmission capacity can be more freely chosen than in tradition PDH/SDH systems. The standards should therefore have appropriate requirements for all relevant capacities. Current standards are tailored to PDH/SDH capacities and may not fully cover relevant capacities for packet data systems. The present document is an attempt to draw attention to issues where amendments are necessary. The analysis is based on examples from the 23 GHz band.

D.1 Need for new RIC limits

The apparent need for additional RIC limits occurs when the requirements imposed by the applicable PDH/SDH standard are difficult to meet with the desired RIC value. The issue can be solved by either adding new RIC limits with corresponding requirements or by relaxing the requirements and keeping the RIC limits. Which way to go depends on the desired relationship between the requirements and what is economically achievable. To have tight requirements for all RICs, many sets of requirements are necessary and those already specified for PDH/SDH will not be enough. If less stringent requirements can be accepted, existing sets of requirements may be sufficient. If tight requirements are desired for the whole range of RIC, an alternative approach could be to have requirements that scale with capacity.

To illustrate the situation, the specific example of the 23 GHz frequency band with different channel spacing has been analysed. The requirements imposed by the PDH/SDH standards for a range of RIC are compared with what is believed to be expected normal performance with commonly used coding, modulation and noise figure.

D.2 Assumptions

The expected performance curves are based on the following assumptions:

- BER = 10^{-6} at C/N = 25 dB for 6,5 bit/symbol.
- 3 dB increase in C/N for an increase of one bit/symbol.
- Noise factor of 8 dB.
- 3 dB degradation of BER = 10^{-6} threshold is assumed to be at a co-channel interference C/I 3 dB above C/N for BER = 10^{-6}.

The following symbol rates are assumed:

CS (MHz)	Symbol Rate (MHz)
7	5,6
14	11,2
28	23,3
56	46,7

The NFD curves are calculated as the difference between C/I for 3 dB degradation from co- and adjacent channel interference.

D.2.1 Example 1 (28 MHz channel spacing)

The comparison for co-channel interference is shown in figure D.1. The C/I for 3 dB degradation of the BER=10^{-6} threshold is used for this example. The figure shows that for RICs around 140 Mbit/s, the requirement is very close to expected performance. An interesting observation is that there is the same requirement over range where the expected performance varies with about 10 dB. The reason is not the lack of specified RIC values but the fact that the requirements for 2 x 34 Mbit/s and 2 x STM-0 are the same.

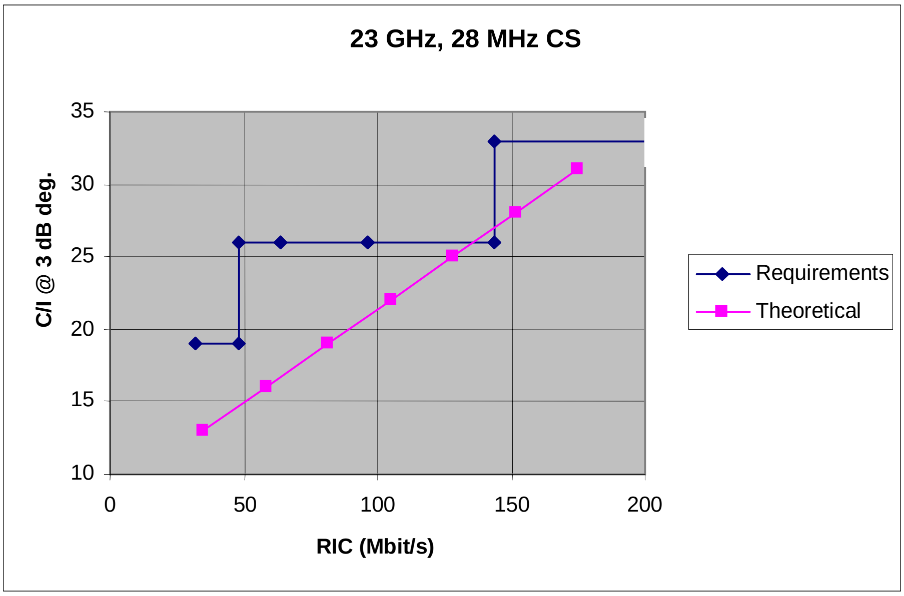


Figure D.1: Co-channel C/I for 3 dB degradation of BER=10^{-6} threshold as a function of Radio Interface Capacity

Table D.1: Source data for requirements in figure D.1

PDH/SDH requirements		Packet data requirements	
Capacity	**CCI requirements (dB)**	**Applicable RIC range (Mbit/s)**	**Segment**
34 Mbit/s	19	32 to 48	1
STM-0	26	48 to 64	2
2 x 34 Mbit/s	26	64 to 96	3
2 x STM-0	26	96 to 144	4
STM-1	33	144 –	5

The comparison between requirements for BER = 10^{-6} threshold and expected performance is shown in figure D.2. From the figure it seem as the existing requirements can cover the relevant range of RIC and no additional specifications or relaxations are needed.

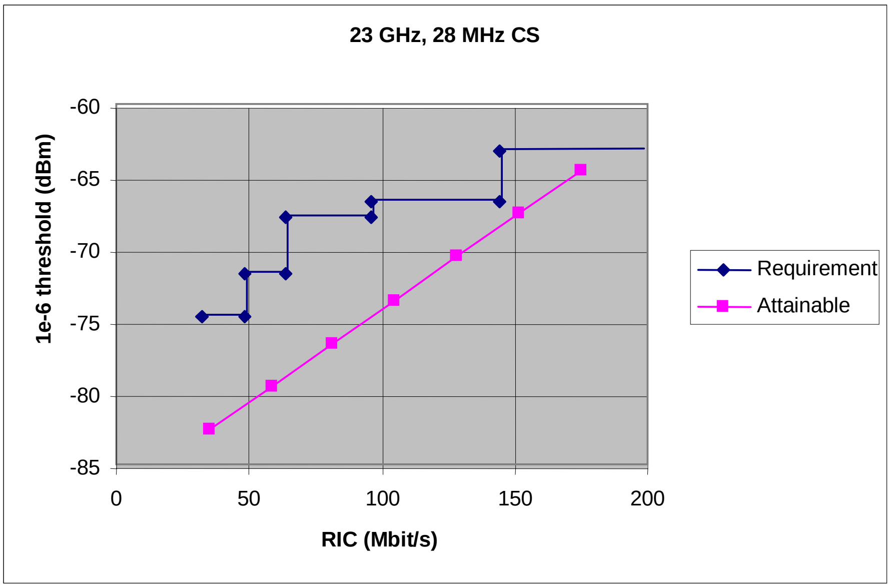


Figure D.2: BER = 10^{-6} threshold as a function of Radio Interface Capacity

Figure D.3 shows the different spectrum masks specified for 23 GHz with 28 MHz channel spacing.

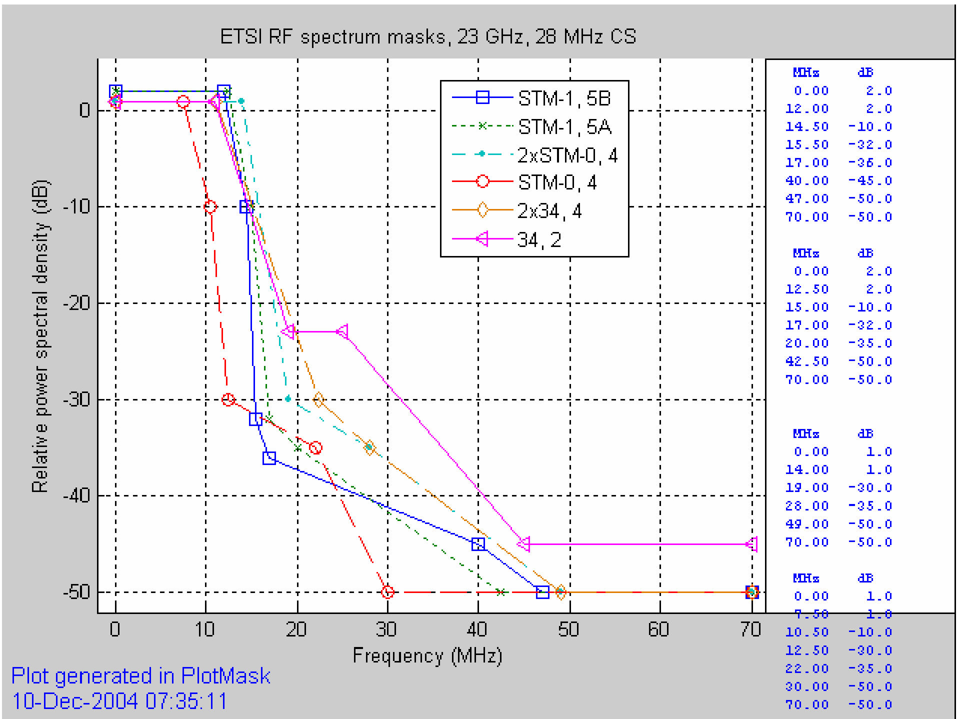


Figure D.3: Spectrum masks for different capacities

Figure D.4 shows the NFD which is implicitly required by the combination of co- and adjacent channel interference requirements. The NFD is calculated as the difference between required C/I for 3 dB degradation of the BER = 10^{-6} threshold for co- and adjacent channel interference.

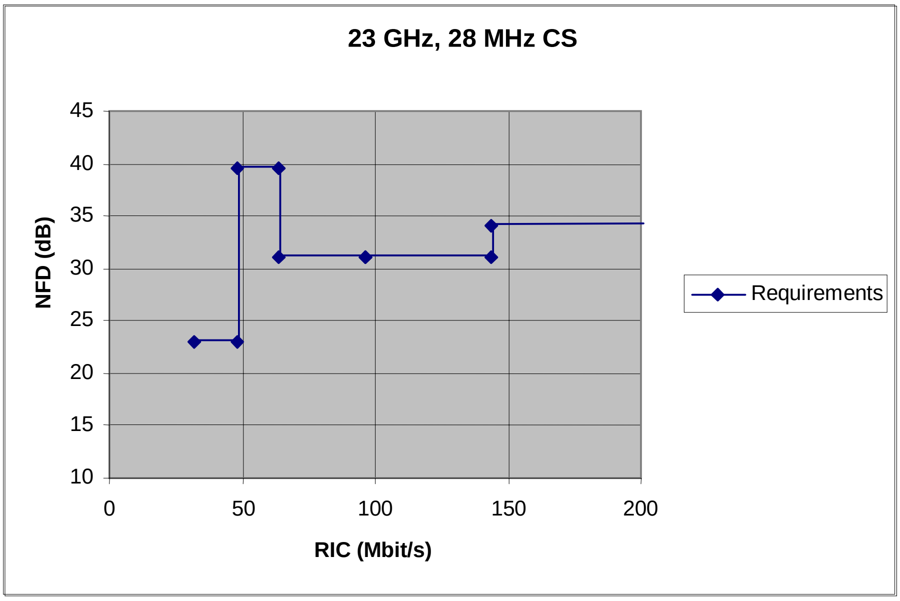


Figure D.4: Implicit NFD requirement as a function of Radio Interface Capacity

D.2.2 Example 2 (56 MHz channel spacing)

Another example is the 23 GHz frequency band with 56 MHz channel spacing. Figures D.5 and D.6 show the comparison between requirements and expected performance for receiver threshold and co-channel interference, respectively. In both cases there will be problems around 280 Mbit/s. This could be solved by relaxing the requirements for STM-1 or lowering the RIC limit at 188 Mbit/s. However, it is probably better to add a new RIC limit at e.g. 4 x STM-0 and scale the requirements from 2 x STM-0 in 28 MHz channel spacing.

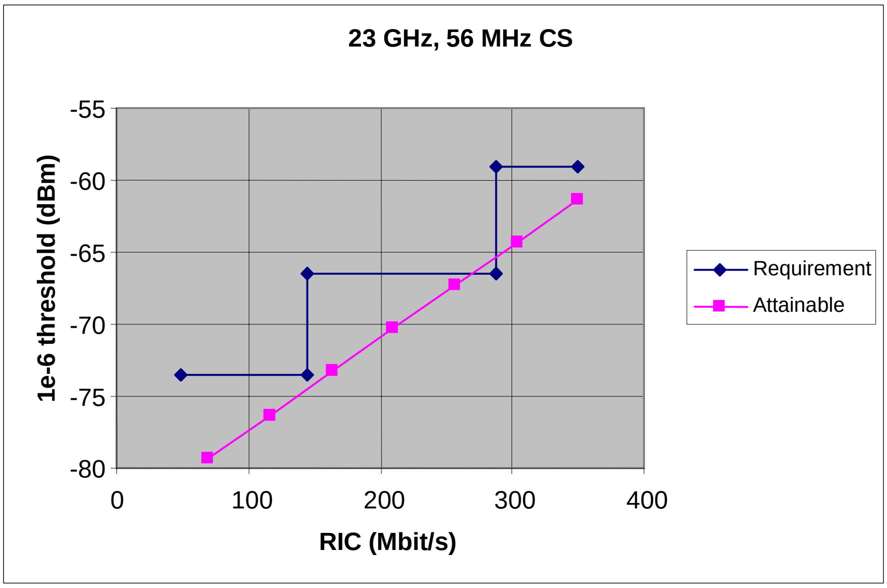


Figure D.5: BER = 10^{-6} threshold as a function of Radio Interface Capacity

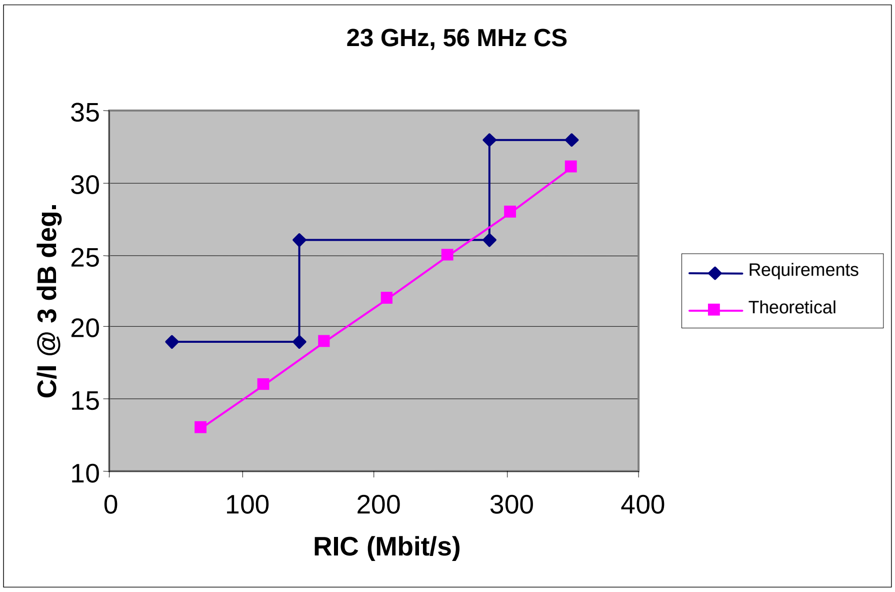


Figure D.6: Co-channel C/I for 3 dB degradation of BER = 10^{-6} threshold as a function of Radio Interface Capacity

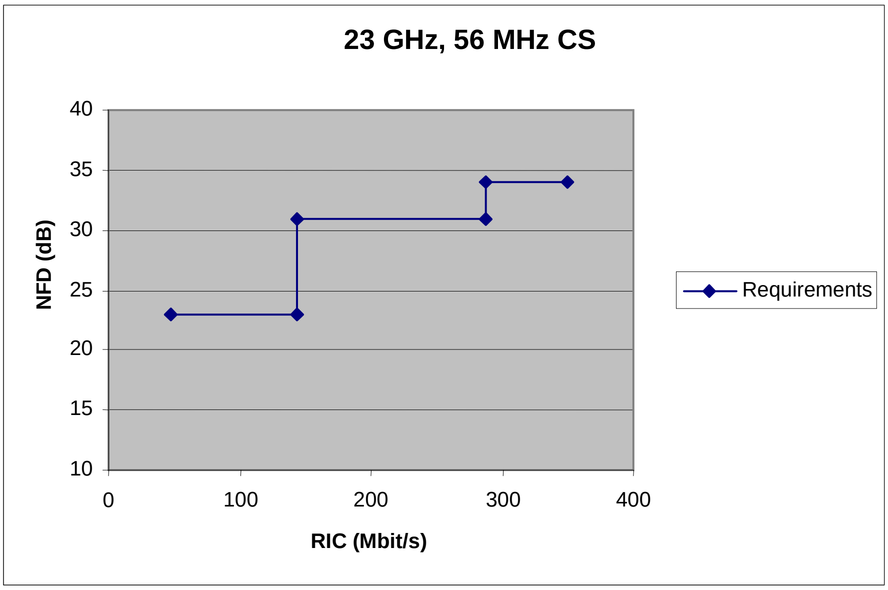


Figure D.7: Implicit NFD requirement as a function of Radio Interface Capacity

D.2.3 Example 3 (14 MHz channel spacing)

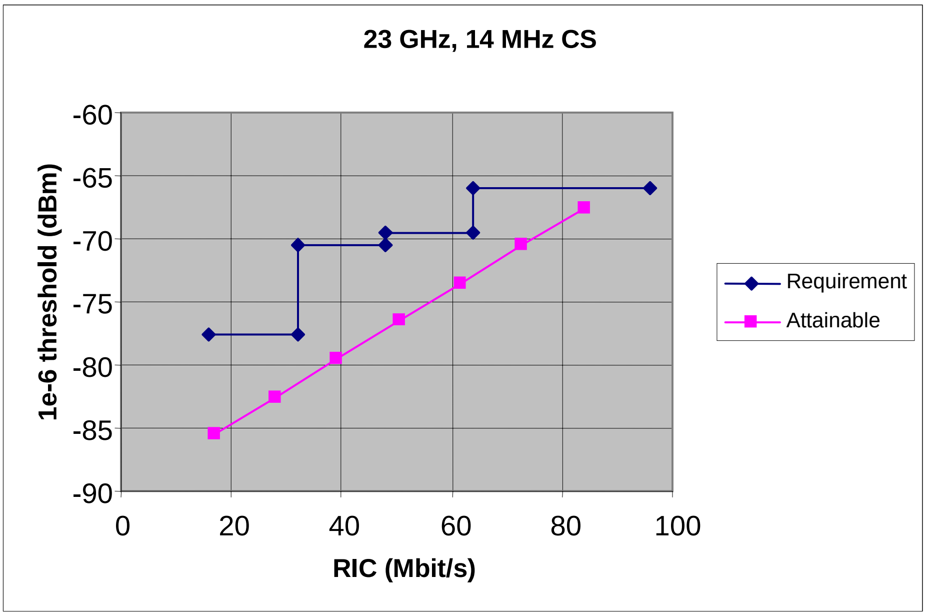


Figure D.8: BER = 10^{-6} threshold as a function of Radio Interface Capacity

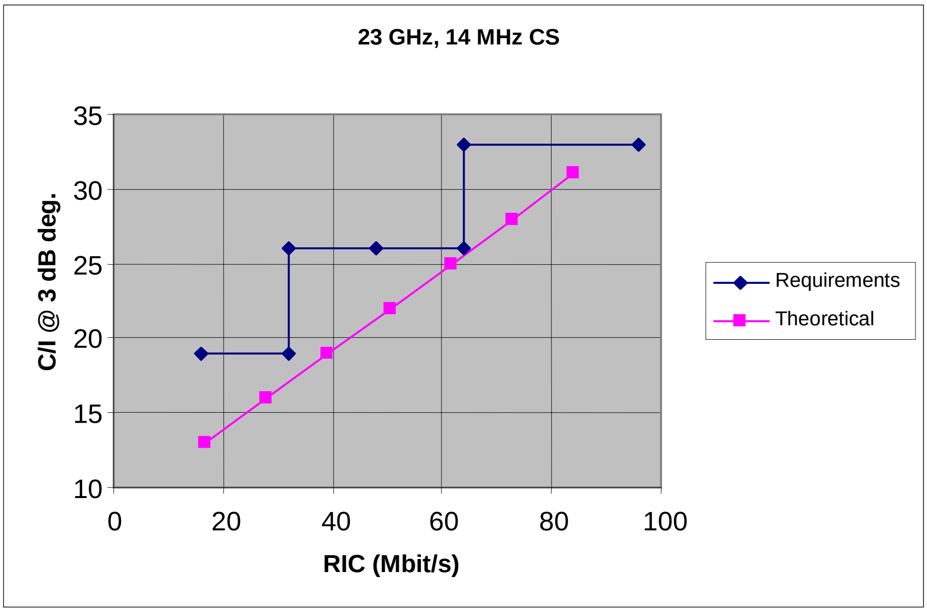


Figure D.9: Co-channel C/I for 3 dB degradation of BER = 10^{-6} threshold as a function of Radio Interface Capacity

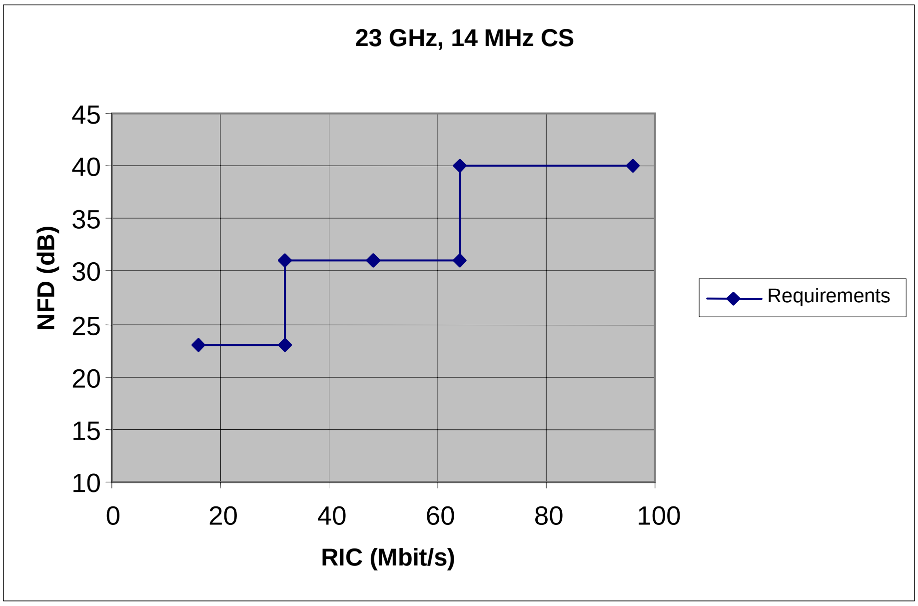


Figure D.10: Implicit NFD requirement as a function of Radio Interface Capacity

D.2.4 Example 4 (7 MHz channel spacing)

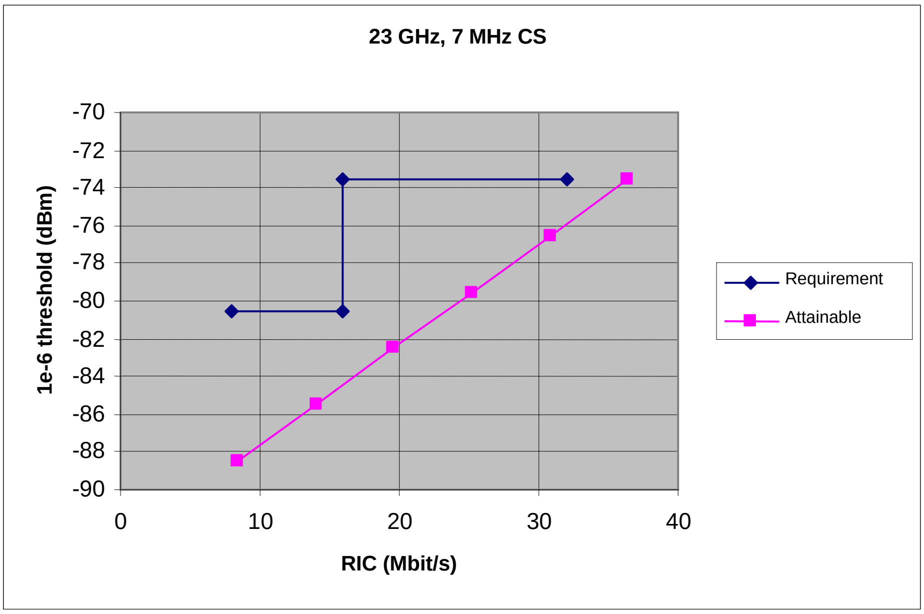


Figure D.11: BER = 10^{-6} threshold as a function of Radio Interface Capacity

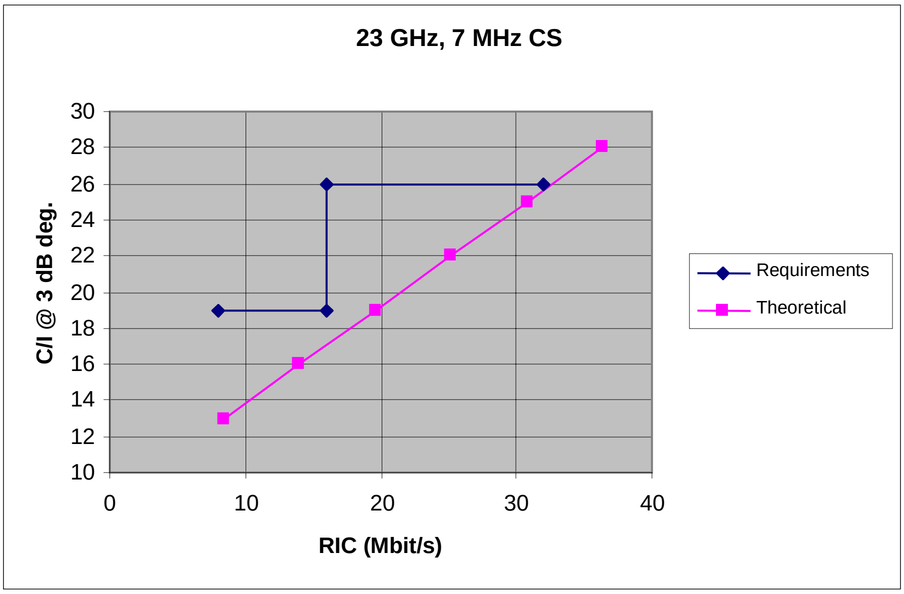


Figure D.12: Co-channel C/I for 3 dB degradation of BER = 10^{-6} threshold as a function of Radio Interface Capacity

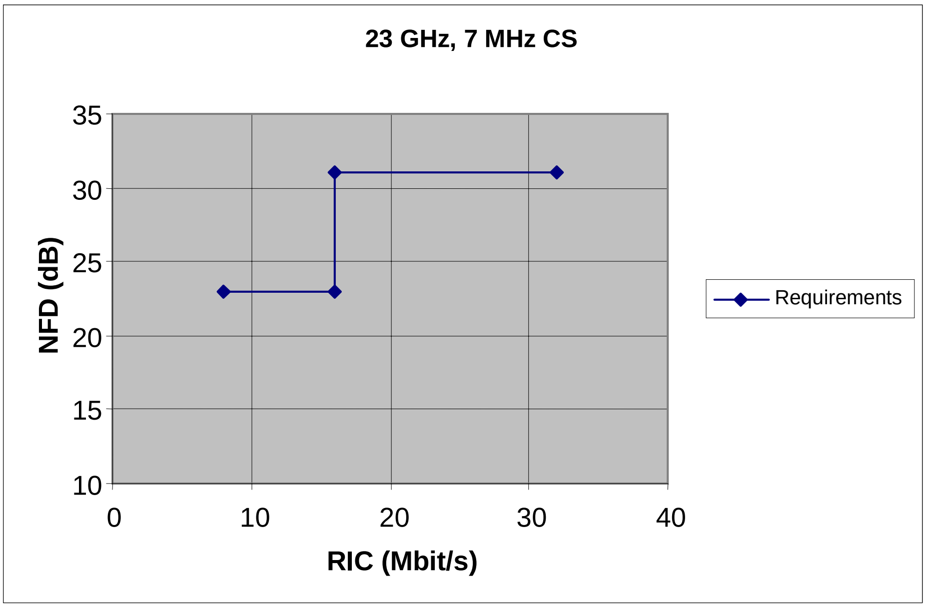


Figure D.13: Implicit NFD requirement as a function of Radio Interface Capacity

D.3 Proposed changes to EN 302 217

Table D.2: Overview of existing specifications in some frequency bands

CS	RIC	7 GHz	15 GHz	23 GHz	18 GHz	38 GHz
7	4	n	n	n	n	n
7,5	8	y	y	y	n	y
	16	y	y	y	n	y
	32	n	n	n	n	n
14	8	n	n	n	n	n
13,75	16	y	y	y	y	y
	32	y	y	y	y	y
	48	y	y	y	y	y
	64	y	y	y	y	y
28	16	n	n	n	n	n
27,5	32	y	y	y	y	y
	48	y	y	y	y	y
	64	y	y	y	y	y
	96	y	y	y	y	y
	144	y	y	y	y	y
56	32		n	n	n	n
55	48		n	y	n	y
	64		n	n	n	n
	96		n	n	n	n
	144		n	y	y	y
	288		y	y	y	y

Based on the above analysis of the 23 GHz band, the following changes are proposed:

- Add a new RIC limit of 128 Mbit/s for 28 MHz channels, named 4 x 34, with requirements scaled from 2 x 34 in 14 MHz channels.
- Relax adjacent channel interference requirement and spectrum mask for STM-0 in 28 MHz channels.
- Add a new RIC limit of 128 Mbit/s for 56 MHz channels, named 4 x 34, with requirements scaled from 2 x 34 in 28 MHz channels.
- Relax co-channel interference requirement and spectrum mask for STM-0 in 14 MHz channels.
- Relax co-channel interference requirement and spectrum mask for 2 x STM-0 in 28 MHz channels (consistent with 4 as the requirement was inherited from 14 MHz channel spacing).
- Add a new RIC limit of 192 Mbit/s for 56 MHz channels, named 4 x STM-0, with requirements scaled from 2 x STM-0 in 28 MHz channels. (5 is required to have reasonable co-channel interference requirement).
- As an alternative to 4, add a new RIC limit of 256 Mbit/s for 56 MHz channels, named 8 x 34, with requirements scaled from 2 x 34 in 14 MHz channels (gives relaxed co-channel interference requirement but more stringent adjacent channel interference requirement).

Table D.3: Proposed figures for 23 GHz

Cap.	Thresh. (dBm)	CCI (dB)	ACI (dB)
STM-0 in 28		23	-4
STM-0 in 14		29	
2xSTM-0 in 28		29	
4x34 in 28	-63	33	-7
4x34 in 56	-64,5	26	-5
4xSTM-0 in 56	-63,5	29	-5
8x34 in 56	-60	33	-7

Annex E: Filling the "Gaps" within a certain class

This proposal shows another idea on how to assign the radio interface capacity to the different channel width and modulation scheme.

Because today there is always the possibility to increase the typical RIC by about 10 % to 20 % (e.g. by decreasing overhead, roll off factor, etc.) the minimum RIC of the next higher channel width should start at about 110 % of the former channel width in order to cover the whole range of RICs between two consecutive channel widths. The start at ~1,1 x typical RIC of the former channel width prevents to use a wider channel by a typical RIC of the narrower channel.

Calculation method:

For classes 1 to 4:

Minimum RIC at channel width x:~1,1 x (typical RIC at channel width x-1), e.g.: channel width x-1: 3,5 MHz → typical RIC = 4 Mbit/s

channel width x: 7 MHz → minimum RIC = 4,5 Mbit/s

For classes 5 and 6:

Minimum RIC at channel width x:~1,08 x (typical RIC at channel width x-1), e.g.: channel width x-1: 28 MHz → typical RIC = 155 Mbit/s
channel width x: 56 MHz → minimum RIC = 168 Mbit/s

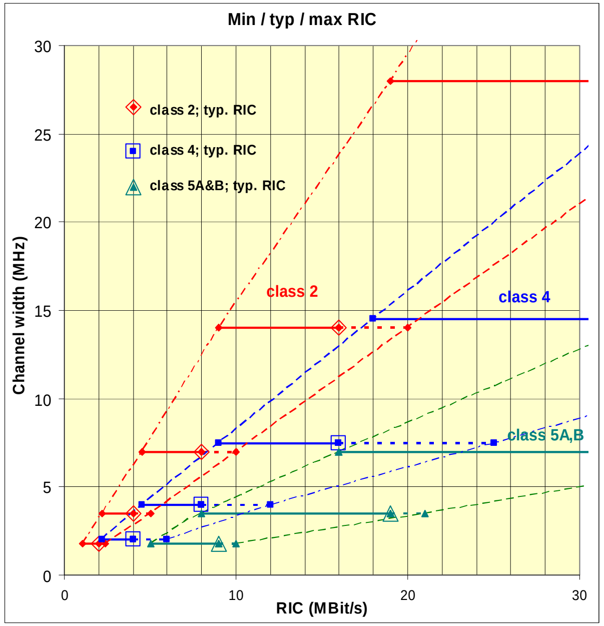
The spectral efficiency for the different classes (see table below) is calculated as:

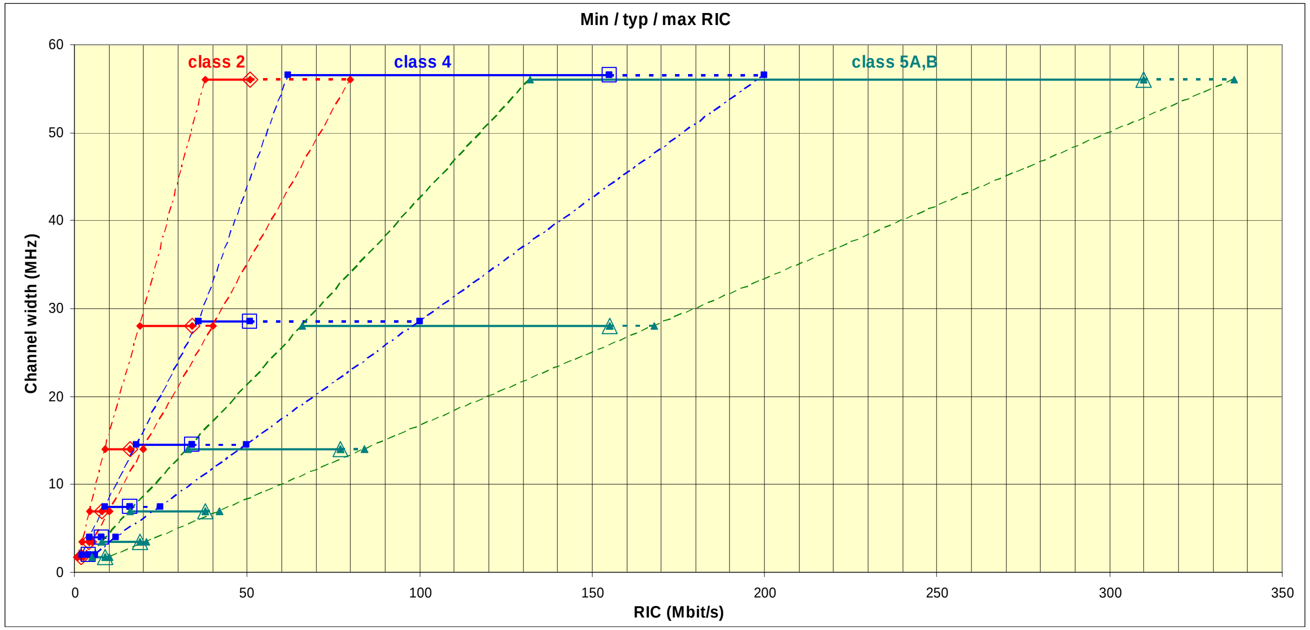
Class 2:	~0,65 to ~1,45 bit/s/Hz;	typical: 1,14 bit/s/Hz
Class 4:	~1,30 to ~3,14 bit/s/Hz;	typical: 2,28 bit/s/Hz
Class 5:	~2,85 to ~6,00 bit/s/Hz;	typical: 5,54 bit/s/Hz

NOTE: The max. RIC was estimated with about 20 % over the typical RIC. The maximum RIC may not be the real maximum achievable with real equipment. This depends also on overhead and roll off factor.

Table E.1: Minimum / typical / maximum values of Radio Interface Capacity (RIC)

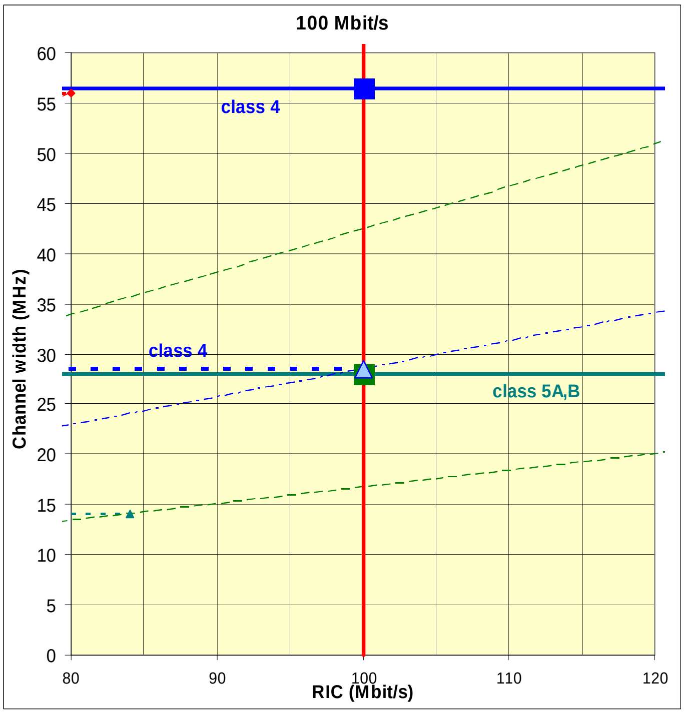
										Class 4						Class 5A						Class 6A					
	Class 1			Class 2			Class 3									Class 5B						Class 6B					
Modulation	2-state			4-state			8-state			16-state			32-state			64-state			128-state			256-state			512-state		
bit/step	1			2			3			4			5			6			7			8			9		
	Mbit/s			Mbit/s			Mbit/s			Mbit/s			Mbit/s			Mbit/s			Mbit/s			Mbit/s			Mbit/s		
Channel width (MHz)	min.	typ.	max.	min.	typ.	max.	min.	typ.	max.	min.	typ.	max.	min.	typ.	max.	min.	typ.	max.	min.	typ.	max.	min.	typ.	max.	min.	typ.	max.
1,75	0,6	1	1.2	1,1	2	2,4	1,6	3	4	2,2	4	5	2,5	5	6	5	8	9	5	9	10	6	11	12	7	12	13
3,5	1,1	2	2.4	2,2	4	5	3,3	6	8	4,5	8	10	5	10	12	8	16	18	10	19	21	12	22	24	13	25	27
7	2,2	4	5	4,5	8	10	7	12	15	9	16	20	10	20	25	16	33	36	20	38	42	23	44	48	26	50	54
14	4,5	8	10	9	16	20	13	24	30	18	34	40	20	40	50	33	66	72	40	77	84	46	88	96	52	100	108
28	9	16	20	19	34	40	26	42	60	36	51	80	40	80	100	66	132	144	80	155	168	92	177	192	104	200	216
56	19	34	40	38	51	80	47	84	120	62	155	160	80	160	200	132	264	288	160	310	336	184	354	384	208	400	432


Min / typ / max RIC
class 2; typ. RIC
class 4; typ. RIC
class 5A&B; typ. RIC
class 2
class 4
class 5A,B
Channel width (MHz)
RIC (MBit/s)
0
5
10
15
20
25
30
0
10
20
30


Min / typ / max RIC
class 2
class 4
class 5A,B
Channel width (MHz)
RIC (Mbit/s)
0
10
20
30
40
50
60
0
50
100
150
200
250
300
350

Examples:

<table>
<tr>
<td>
For 100 Mbit/s the following combinations may be used:

28 MHz with class 5 A or B
or
28 MHz with class 4
or
56 MHz with class 4
</td>
<td>


</td>
</tr>
<tr>
<td>
40 x 2 Mbit/s the following combinations may be used:

14 MHz with class 5A or B

or

28 MHz with class 5A or B
or
28 MHz with class 4
or
56 MHz with class 4
</td>
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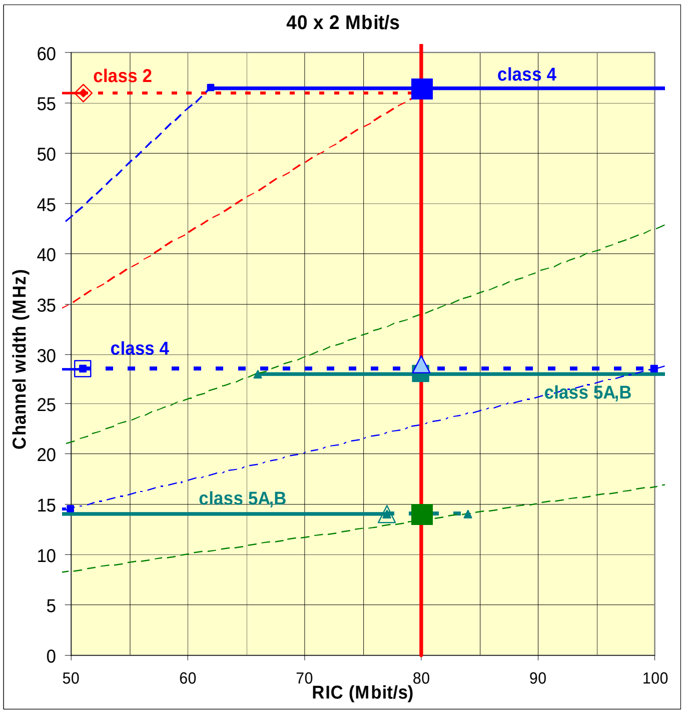

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Annex F: Mixed-mode operation (Annex F of EN 302 326-1)

F.1 Introduction

This annex is intended to offer guidance on the application of spectrum density masks and receiver interference immunity (defined in EN 302 326-2 [11]) in the context of mixed-mode systems. The guidance is considered necessary due to the fact that, at the time of publication of the present document, there are no ECC harmonized frequency planning assumptions and coexistence rules valid in all FWA frequency bands, nor for all system options currently standardized and available on the market (e.g. system modulation orders, access methods and channel separations).

F.2 General description of mixed-mode systems

Systems applying mixed-mode technology use different modulation orders according to the actual network needs (e.g. according to the range of Terminal Stations, assigned capacity, and severity of propagation channel distortion).

The different modulation order might be selected by a simple presetting, statically defining which modulation order is to be used by a particular CS or TS; in this case it is more appropriate to refer to preset-mode systems, for which spectrum mask and other requirements are already considered in EN 302 326-2 [11]. Preset-mode (or "multi-format") systems also have the capability to change the modulation order through remote controls according to the Operator and Customer needs.

The term "mixed-mode systems" is appropriate when the modulation order can be changed dynamically, for example:

- A TDMA CS might use different modulation orders on a slot-by-slot base according to the TS addressed by that slot. An FDMA CS might use different modulation orders on a carrier-by-carrier basis. The modulation order might also be changed to adapt to varying propagation channel impairments, or for a change in service profile.
- The corresponding TS would use one modulation order until the network situation changes due to either propagation channel impairments, or a change in service profile (e.g. a different service profile might be achieved using a more robust modulation or higher spectral efficiency).

F.3 Historical derivation of transmit spectrum masks

Earlier ETSI ENs for Fixed Radio Systems generally defined a set of masks, one for each standardized emission class (related to a typical modulation order, e.g. 4QAM, 16QAM and 64QAM). The transmit spectrum masks defined in EN 302 326-2 [11] are derived from similar masks specified in earlier point-to-point standards.

These historical masks were specified for two reasons:

a) In order to permit planning of point-to-point systems operating on adjacent or near adjacent channels over the same physical link and potentially using equipment from different manufacturers and with a different air interface specification. In defining the masks in this way, the assumption was made that the channel filtering was equally divided between transmitter and receiver and that the NFD could thus be calculated on the assumption that the receive mask would match the transmit mask. It was also assumed that the permissible carrier to interference ratio was determined by the modulation type and order and without specifically taking into account possible forward error correction improvement.

b) In order to permit planning of link parameters to ensure coexistence of geographically separated links.

F.4 Rationale for Multipoint transmit masks

F.4.1 Introduction

The transmit spectrum masks should be determined only by the requirements of inter systems planning (reason "b" in clause F.3), for differing systems that are separated geographically or in frequency. Such determination should be technology neutral. The determination of the transmit spectrum mask as a means of achieving intra system adjacent channel performance (reason "b" in clause F.3) is no longer considered relevant to multipoint systems for reasons given below and hence the determination of transmit spectral masks and co-channel and adjacent channel interference sensitivity should be completely decoupled.

The following clauses explain the detailed reasons for this decoupling.

F.4.2 Irrelevance of ETSI transmit spectrum mask in determining adjacent channel requirement for intra-system planning

An operator using multipoint systems will typically plan the deployment in a given geographical area or frequency range based on actual manufacturers' data. The TX spectrum mask cannot be assumed to be directly related to the receive selectivity mask.

F.4.3 Applicability of the transmit spectrum mask to inter-system planning

It is essential that regulators should have sufficient data to ensure the compatibility of different operators' systems, given that the operators adhere to the licence conditions. This may be achieved by definition of geographical areas and co-ordination zones, provision of guard bands, power limitations and specification of modulation type and lowest permitted equivalent modulation order (i.e. the EqC EMO specified in the present document).

Similarly, it may be expected that operators using mixed-mode systems will deploy the same equipment throughout their licensed block or, alternatively, introduce guard bands between sub blocks within their licensed block which are used for different equipment.

In order to ensure spectral efficiency and optimal guard band allocation, administrations might choose to specify, in their interface notification under article 4.1 of the R&TTE Directive [12], a minimum declared EMO (as defined in annex E) which may be used. So, for example, a mixed-mode system providing EMOs 2, 4 and 6 might be constrained to use EMOs of 4 and 6 only, to meet the requirements of an administration. It therefore follows that, in order to permit efficient guard band planning, the system must, at all times, meet the transmit spectral mask of the lowest EMO enabled, but, correspondingly, need not meet the adjacent channel performance with an interfering signal of any lower order than that which may be enabled.

The following is a practical example of the above concepts:

Assuming a mixed-mode system operating with EMO = 2, 4 and 6 (e.g. 4QAM, 16QAM and 64QAM formats) is deployed in a situation where the administration has decided to limit the licence to a declared EMO equal to 4 or higher; the 16QAN and 64QAM formats only should be enabled (fulfilling the EMO = 4 mask). The 4QAM format should be disabled or, if agreed by the administration, used only for special conditions enhancing the effective use of the spectrum but still remaining within the EMO = 4 spectrum mask.

However, provided that the same licensing rule is adopted for all operators, the system will not be subject to co-channel or adjacent channel interference from systems with transmit emission worse than EMO = 4 mask.

F.4.4 Minimum traffic capacity imposed by the regulator

It should be noted that regulators (administrations) sometimes, in the interests of spectral efficiency, restrict licences to modulation orders (i.e. EMOs in the present document) at or greater than a specified limit or, alternatively and preferably, specify a spectral efficiency lower limit in a way which is technology independent. Under these circumstances it should be noted that a mixed-mode system which can meet such constraints when operating at the minimum licensed EMO or above, might switch to a lower modulation order only to improve geographical coverage, interference immunity, or frequency re-use. Such switching would therefore improve the overall spectral efficiency of a deployed system and the regulator (administration) should be encouraged to permit mixed-mode switching to a modulation order lower than the EMO that would have otherwise have been set in the licence conditions.

For these reasons, consideration should be given to 3 points:

1) Minimum capacity in FWA systems is not directly related to the modulation format (e.g. start-up operators may be burdened by the restriction (in the licensed EMO) of using only a higher modulation order when in fact they may not achieve sufficient geographic coverage due to power limitations). The capacity should thus remain only as a long-term objective. It may be achieved by other regulatory means than requiring a minimum EMO.

2) In the event that the planning assumptions are made based on the highest EMO defined in the present document, nevertheless, for short periods (e.g. during a rain fade), the system should be allowed to activate the lower actual modulation orders whilst still maintaining the same spectrum mask, in order to provide service.

3) In the event that a frequency band is "channelized", and frequencies are assigned on an individual channel basis, then the regulator might wish to impose the more stringent requirement on the transmit spectrum mask, in order to improve adjacent channel performance. In that case, the mixed-mode systems would be restricted to use the most stringent mask, for declared EMOs, applicable to the actual modulation orders offered. However, this is not considered an essential requirement under article 3.2 of the R&TTE Directive [12].

F.5 Essential requirements for transmitters and receivers operating in mixed-mode

F.5.1 Requirements summary

The sole requirement for a transmit spectrum mask should be to ensure that planning can be undertaken such that no interference occurs between systems in adjacent geographical blocks or frequency blocks (considered to be the frequency ranges assigned to different operators). The co-channel and adjacent channel performance of systems deployed by an operator within a block may be achieved by whatever means the manufacturer adopts. It is noted that technically, in the limit, a block may currently be as small as one channel, although this is not expected normally to be the case.

The essential requirement should therefore be a mask or set of masks which allows inter-system coexistence to be planned and a set of co-channel and adjacent channel interference C/I values (one for each modulation mode implemented) to be met by the victim receiver (operating in one mode only at the time) with an interfering transmitter operating in any modulation mode implemented.

F.5.2 Transmit spectrum masks for mixed-mode

The manufacturer should declare which combination of modulation orders (in terms of declared EMOs) the equipment offers, and for each actual modulation order should be compliant with the appropriate mask of the declared EMOs. Planning decisions may then be taken on the basis of the least stringent mask which may be selected (the subset of those supported by the equipment, which are also permitted by the licence).

These requirements apply only for the assessment of essential requirements under article 3.2 of the R&TTE Directive [12]. It is assumed that, when operational, the system should meet only the mask of the lowest licensed EMO, in terms of absolute power density in dBm/MHz, (e.g. in order to optimize service, the system is able to adjust the power of the more complex modulation formats even if exceeding their own mask, provided that the least stringent absolute power density mask is always met in all static and transient conditions, including any training bursts or reference signals). It should be noted that a possible overlapping of EMO masks would occur if the same peak power is used for all EMOs, due to the first roll-off point P(1) of the EMO = 6 mask lying outside the envelope of the EMO = 2 and EMO = 4 masks. However, the less stringent masks do not need to be further relaxed because the overlapping condition is unlikely to occur in deployed mixed-mode systems, for the following reasons:

1) There is a significant power drop with higher modulation orders (due to power amplifier back off) that automatically "solves" the overlapping problem, as shown in figure F.1.

2) For frequency coordination purposes, a mixed-mode system will not be worse than a single-mode system employing the lowest licensed EMO.

An example is shown in figure F.1, where the output powers of the actual higher modulation orders are increased slightly to optimize service, but are always maintained at a sufficient margin below the absolute EMO = 2 (e.g. 4QAM) power so that all portions of their spectrum masks remain below the lowest EMO = 2 TX spectrum mask.

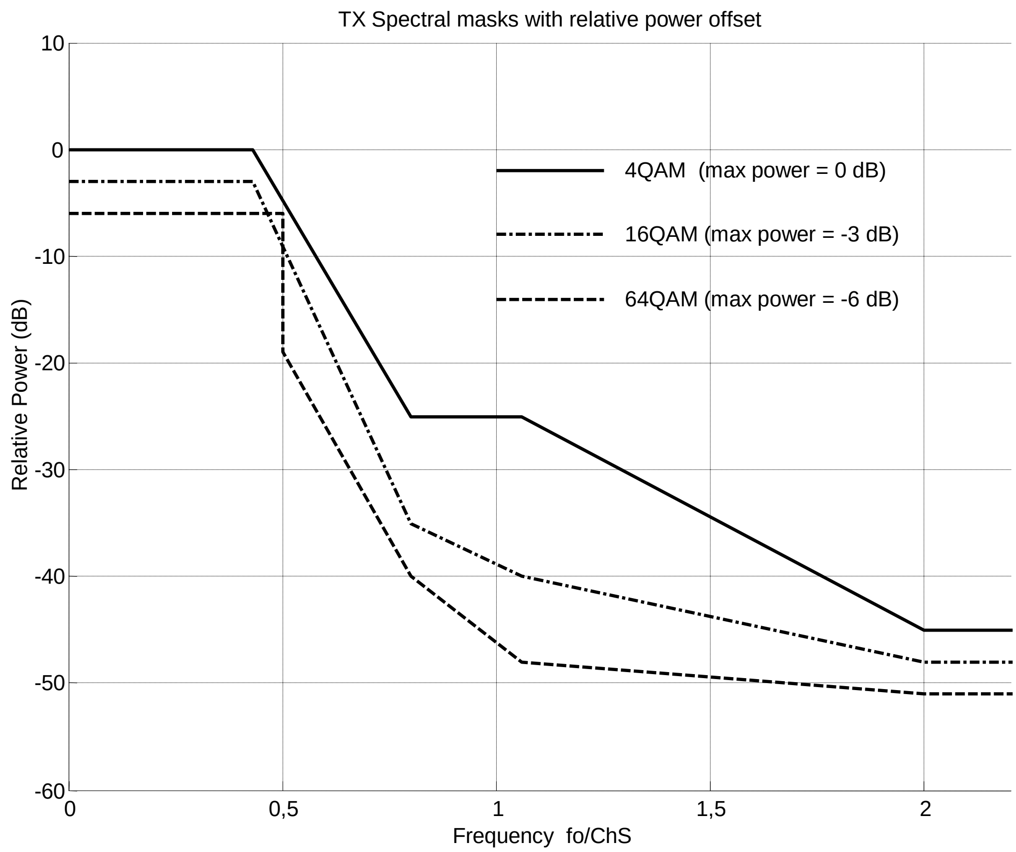


Figure F.1: TX spectral masks of 16QAM and 64QAM with powers adjusted to remain below the 4QAM mask

F.5.3 Adjacent channel interference

In order to achieve satisfactory spectrum utilization within the frequency range (block) assigned to the Operator, particularly where the capacity of a cell is increased by the use of more than one channel per sector, mixed-mode systems should be required to operate in adjacent channels over the same physical link in precisely the same way that single-mode systems are required to operate. It thus follows that a mixed-mode system should be required, for each actual modulation order used, to meet the related EMO (or manufacturer's defined) adjacent channel performance specification, with all combinations of interfering actual modulation order (including training bursts).

For example, in a mixed-mode TDMA system offering QAM states of 4, 16 and 64 (EMO = 2, 4, and 6 respectively), a time slot which is operating at 64QAM should meet the adjacent channel performance specification for 64QAM with an adjacent channel interfering signal of 4QAM, 16QAM or 64QAM. Similarly, a timeslot which is operating at 4QAM should meet the adjacent performance specification for 4QAM with an adjacent channel interfering signal of 4QAM, 16QAM or 64QAM.

F.5.4 Co-channel interference

Co-channel interference will occur where the interfering and victim systems are geographically separated or operating on different sectors. In both cases it is extremely unlikely (and spectrally inefficient) that the TDMA frames of the two systems would be synchronized and that the timeslots within each system's frames would operate on identical modulation orders. It therefore follows that the co-channel specification for each victim modulation order offered should be met with an interfering signal of any modulation order offered (including training bursts), in the same way as for adjacent channel performance. However, unlike the adjacent channel case, the co-channel interference performance would not generally depend on the interfering transmitter modulation.

Annex G: Future Steps

G.1 Further discussion items

- Optimum way to specify scalable radio interface parameters to guarantee more equally stringent requirements.
- Requirements for systems with adaptive radio parameters to guarantee sufficient spectrum efficiency and compatibility.
- How to select requirements for systems with flexible system parameters based on existing standards and for guidance on how to test these systems in their normal operation mode.
- Limits of spectral efficiency numbers of systems and the related classes should be agreed upon for future standardization work.
- Requirements for systems with frequency block allocations (different from channel by channel allocation).
- Problems by adaptive systems (from the regulative point of view, informative annex to standard to warn about problems) (consult with CEPT/SE).
- Licence conditions for adaptive systems (consult with CEPT/SE).
- Plan for time scale modifications in standards (short term, long term) (TM4 work plan scheduling).

G.2 Future targets for PtP-standardization

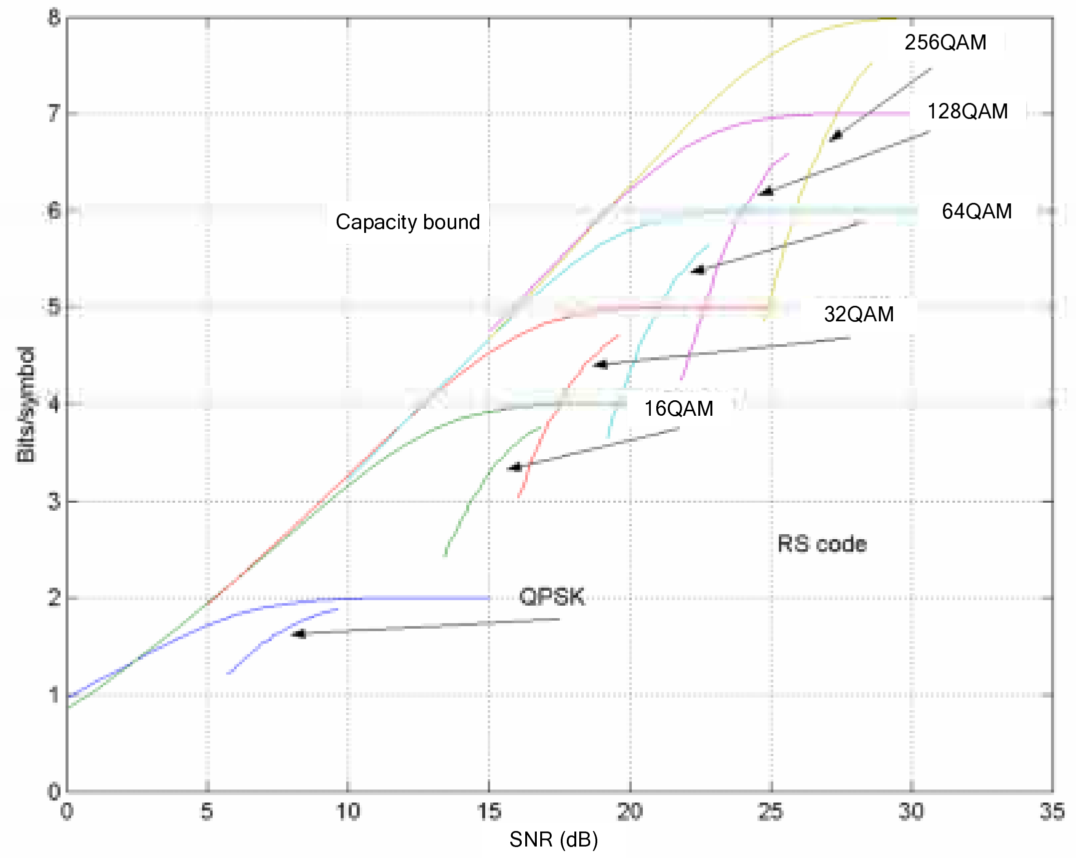
- The future coexistence PtP-standards should be in general independent from the specific digital hierarchies such as SDH or PDH and should be based on RIC limits which define the minimum spectral efficiency.
- The same requirements should apply in constant bit rate and packet data transmission.
- The basis for the requirements should be the RF-channelling and the required compatibility levels.
- The crucial point to be agreed on is how to specify the radio interface capacities for different systems.
- The radio interface requirements should be scalable with RIC to avoid unnecessary differences in requirement level.
- The standardization should also make possible the coexistence between systems with flexible system parameters and give guidance on how to evaluate the performance of such systems.

Annex H: Spectral Efficiency and System Threshold

The following graph presents the Bits/Symbol as a function of the system SNR.

The left plots in the graph represent the theoretical Shannon bound.

The right plots in the graph are an example of using RS coding (at different coding rates) for different modulation schemes (QPSK to 256QAM).



From the graph it is clear that one can achieve the same spectral efficiency with different modulation schemes, by using more overhead for coding thus achieving more coding.

This is actually the technical reasoning behind the proposal to have a continuous radio interface capacity with no compromise on the spectral efficiency.

When we set the minimum capacity for "Class5" (since we generally sometimes regard high modulation schemes at high class systems although it is not specifically defined in the harmonized standard) to 95 Mbit/s we actually get a "Class4" actual performance and also the spectral efficiency is the same.

So using an RIC value of 96 Mbit/s utilizing "high modulation and low rate coding" or "lower modulation and high rate coding" will yield the same spectral efficiency results.

Since the class actually defines a sensitivity threshold, we can derive for that class also a realistic spectral efficiency number (that can be achieved with various combinations of coding schemes and modulations).

Thus the concern for compromising the spectral efficiency actually does not exist.

History

Document history		
V1.1.1	February 2007	Publication