CEPT ECC
Electronic Communications Committee

ECC Report 198

Adaptive modulation and ATPC operations in fixed point-to-point systems - Guideline on coordination procedures

May 2013

0 EXECUTIVE SUMMARY

An overall review of all the variable elements in the use of Adaptive Modulation (AM) point-to-point systems as well as their practical implementation in term of modulation formats and TX power management, which also affect the range of available ATPC and/or RTPC offered by the system.

When adaptive modulation is used, the coordination process and the interference situation is driven only by the “reference modulation”, intended as the one which TX and RX parameters are used for the conventional evaluation of the fade margin corresponding to the target QoS on the network. Switch to higher or lower modulations formats would not impact other links nearby as far as the spectral emission does not exceed the mask of the “reference modulation” and the corresponding licensed e.i.r.p.; this requirement is clearly defined also in the ETSI EN 302 217-2-2 [4].

The report shows that an effective use (in term of users desired benefits) of those systems can be managed only with the detailed knowledge of all the characteristics of the actual system to be deployed on a specific link with given target of nominal capacity and its QoS. Most of the flexibilities offered by AM systems, implies a number of trade-offs between the “ideal” capacity and QoS (i.e. those that would be used in plain fixed modulation systems) and the additional benefits obtained by an AM systems (i.e. possible exploitation of higher capacity with less QoS and lower capacity with higher QoS than the “ideal” one, represented by the actual “reference modulation” used for the link license); this might imply the increase of the modulation level defined as “reference”.

When also the use of ATPC is desired in the network, for reducing interference and/or enhancing network density, the additional required TX power management increases the variables and furthermore the needed trade-offs in the link parameters for best user satisfaction.

While the system parameters are possibly known also by the administration responsible for link planning, only the user may know (and possibly adapt) the acceptable trade-offs on link-by-link basis. From the licensing point of view, the additional benefits of using AM can only be seen as “best effort” on top of the given QoS defined for the “reference modulation”.

A step by step method is described as pre-license approach for the user in order to decide the best trade-offs, between the various flexibilities offered by an AM system, in order to define the modulation format that better suites the link needs to be finally used as “reference modulation” in the license request.

Under the assumptions made in this report, from the administration point of view, only the “reference modulation” of an adaptive modulation systems is used for the coordination process; all other system characteristics might be intended as ancillary information.

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
3G	3^{rd} Generation mobile systems
4G	4^{th} Generation mobile systems
AC	Adjacent Channel
AM	Adaptive Modulation
ATPC	Automatic Transmit Power Control
BBER	Background Block Error Ratio
BER	Bit Error Ratio
BPSK	Binary Phase Shift Key
CC	Co-channel
C/I	Carrier to Interference ratio
CEPT	European Conference of Postal and Telecommunications Administrations
EC	European Community
ECC	Electronic Communications Committee
e.i.r.p.	equivalent isotropically radiated power
EHF	Extremely High Frequency
ETSI	European Telecommunication Standards Institute
GSM	Global System for Mobile communications
IP	Internet Protocol
ITU-R	International Telecommunication Union – Radiocommunication Sector
LTE	Long Term Evolution
N	Noise
NFD	Net Filter Discrimination
PDH	Plesiochronous Digital Hierarchy
P-P	Point to Point
PSK	Phase Shift Keying
QAM	Quadrature Amplitude Modulation
R&TTE	Radio and Telecommunications Terminal Equipment
RBER	Residual Bit Error Ratio
RSL	Receiver Signal Level
RTPC	Remote Transmit Power Control
RX	Receiver
S/N	Signal to Noise ratio
S/(N+I)	Signal to Noise plus Interference ratio
SDH	Synchronous Digital Hierarchy
TDM	Time Division Multiplexing
TX	Transmitter

1 INTRODUCTION

A number of new requirements for mobile networks together with the technological evolution of fixed P-P radio systems used in the infrastructure (backhauling) networks will impact the current usage of fixed radio links and in turn cause some adaptation of the current link-by-link coordination procedures.

The scope of this report is to offer a common understanding of the implementations of recent technical innovations in modern P-P systems, most notably ATPC, RTPC and Adaptive Modulation (AM), and their impact on link design and coordination.

The rationale for this study is as follows:

- The advent of new generations of mobile systems (usually identified as LTE or 4G) where the amount of data traffic to/from the end user terminals would become larger and larger; this would imply that also the infrastructure (backhaul) networks need to evolve towards higher capacity implying also that, for connecting a denser pattern of base stations, the fixed P-P links would also become shorter.
- These new mobile systems will no longer generate TDM traffic (e.g. building up PDH and SDH hierarchies) as mostly used in current mobile systems (GSM and 3G) but directly Packet data traffic (e.g. IP/Ethernet). The new services offered, over IP based platforms, to the end-user are going to evolve with different degrees of quality (pay for quality) from the simplest “best effort” to different increasing degrees of guaranteed traffic availabilities.
- Also the fixed transport infrastructure is migrating to Ethernet traffic transport. In Ethernet, while the electrical interfaces formally presents a 10^n hierarchy, the actual payload capacity varies continuously according the load.
- The introduction of Adaptive Modulation P-P systems perfectly fits the new IP quality requirements of the mobile access. In IP traffic different degrees of quality are defined, according the importance and/or the different fees policies applied to different payload.
- The possible introduction of ATPC can be a method for enhancing the spectrum usage, which implementation is under study by a number of administrations.
- The joint use of AM and ATPC poses some mutual constraints to their operation.

2 DEFINITIONS

Term	Definition
Adaptive modulation	A technology (referred in ETSI standard as “Mixed-mode”) in which the modulation formats are dynamically changed (errorless for the relevant payload fraction) according the propagation conditions; this permits to design a link with a defined availability for a uniquely predefined modulation format (the “reference mode”) and having the payload capacity enhanced during good propagation time and, if desired, further reduced, but with even higher availability, during abnormally adverse propagation.
ATPC (Automatic Transmit Power Control)	Range of transmit attenuation dynamically variable with the propagation effects. Total range(s), activation threshold(s) and attenuation dynamics may also be software programmable.
Linear ATPC	Portion of the ATPC range available for conventional interference reduction purpose. In systems without “Adaptive modulation” feature it is coincident with the total ATPC range.
Step ATPC	Portion of the ATPC range, used only in “Adaptive modulation” systems, for reducing/increasing the output power when the modulation format changes between the “reference modulation” and higher modulation formats. It is a fixed feature always enabled for managing the required linearity needed by each modulation format.
Bandwidth adaptive	A technology similar to Adaptive modulation where, while keeping the modulation format constant, the capacity is changed through the dynamic increase/decrease of the occupied bandwidth. This is mostly used in highest frequency bands where higher modulations index are not practical.
Mixed-mode	Alternative terminology for “Adaptive modulation” adopted in both ETSI EN 302 217-2-2 [4] for P-P systems and in EN 302 326-2 [5] for P-MP systems.
Reference mode	When adaptive modulation systems are concerned, corresponds to the reference modulation format used for identifying the equipment parameters needed for the link coordination with the predefined availability objective (i.e. Spectrum mask, Nominal output power for defining the licensed e.i.r.p. and BER threshold for deriving the nominal link fade-margin, Co-channel and adjacent channel C/I for deriving the NFD. When bandwidth adaptive systems are concerned, the reference mode and its equipment parameters and availability objective correspond to the maximum bandwidth occupancy situation.
Reference modulation	The modulation format used for the reference mode
RTPC (Remote Transmit Power Control)	Range of static transmits attenuation used for software programmable setting of the e.i.r.p. required for the link in the license conditions.

3 ATPC AND RTPC IMPLEMENTATION BACKGROUND

3.1 GENERAL REQUIREMENTS

In most practical applications, Automatic Transmit Power Control (ATPC) and Remote Transmit Power Control (RTPC) are realized by a single hardware function, which is software programmable; therefore, the supplier usually declare how the available range of attenuation should be subdivided (and possibly limited) in order to meet the requirements described below.

It is important to understand that the total available range of attenuation is, in general, subdivided in two sub-ranges, which, in principle, are independent from their “labelling” as RTPC or ATPC ranges:

- “Initial” Sub-range where the required spectrum mask is still fulfilled; consequently the system net filter discrimination (NFD) is still guaranteed;
- “Final” Sub-range where the required spectrum mask is no longer fulfilled; consequently the system NFD can no longer be guaranteed.

Ignoring the RTPC range, which, if any, remains by definition within the initial sub-range where the NFD is guaranteed, the actual ATPC range may be defined according two possible scenarios synthesised by Table 1.

Table 1: ATPC requirements versus licensing conditions

Coordination/licensing conditions	Effect on network	Requirement
No ATPC is imposed in the licensing process, but the user(s) of the link, under his (their) responsibility, apply an ATPC reduction in a homogeneous area for general improvement of the interference situation.	Interference impact on performance and availability is still evaluated with power at nominal level (no ATPC attenuation is considered in the coordination process related to the link license); therefore: ▪ No improvement in the network density ▪ The user, under his own responsibility, might obtain additional margin against the calculated performance and availability objectives.	No need for fulfilling the spectrum mask (and NFD) in the ATPC range, which can indifferently use “initial” and or “final” sub-ranges of attenuation.
ATPC is imposed as pre-condition of coordination and licensing (note 1)	Interference impact on performance and availability is evaluated with power reduced by an ATPC range; therefore: ▪ Improvement in the network density could be obtained under certain conditions (note 2). ▪ No additional margin against the calculated performance and availability objectives (note 3).	Need for fulfilling the spectrum mask (and NFD) in the assumed ATPC range, which shall remain within “initial” sub-range of attenuation.

NOTE 1: The ATPC range is link-by-link dependent, it is usually determined in order to fix the maximum received signal level (RSL) permitted during unfaded periods.
NOTE 2: In general the use of ATPC pre-condition is possible for new links in a network; however, if existing links in already dense networks were coordinated without any ATPC, the possible density improvement might be severely reduced.
NOTE 3: However, in principle and if possible and practical, improvement might still be obtained using the residual ATPC attenuation, under operator responsibility.

Therefore, from the point of view of equipment use in the network, the RTPC and ATPC “labelling” of the available attenuation range is, in principle, different for the two cases considered in Table 1 and Figure 1 summarises this aspect.

It should be noted that, when adaptive modulation is used, the ATPC range is formally subdivided in two sub-rages. The first, here called “Step ATPC”, is a fixed feature permanently enabled for increasing/reducing the output power needed for linearity purpose when the modulation format switch between the reference modulation and higher modulation formats. The second, here called “Linear ATPC”, represents the remaining portion of the total ATPC range additionally available for conventional interference reduction purpose.

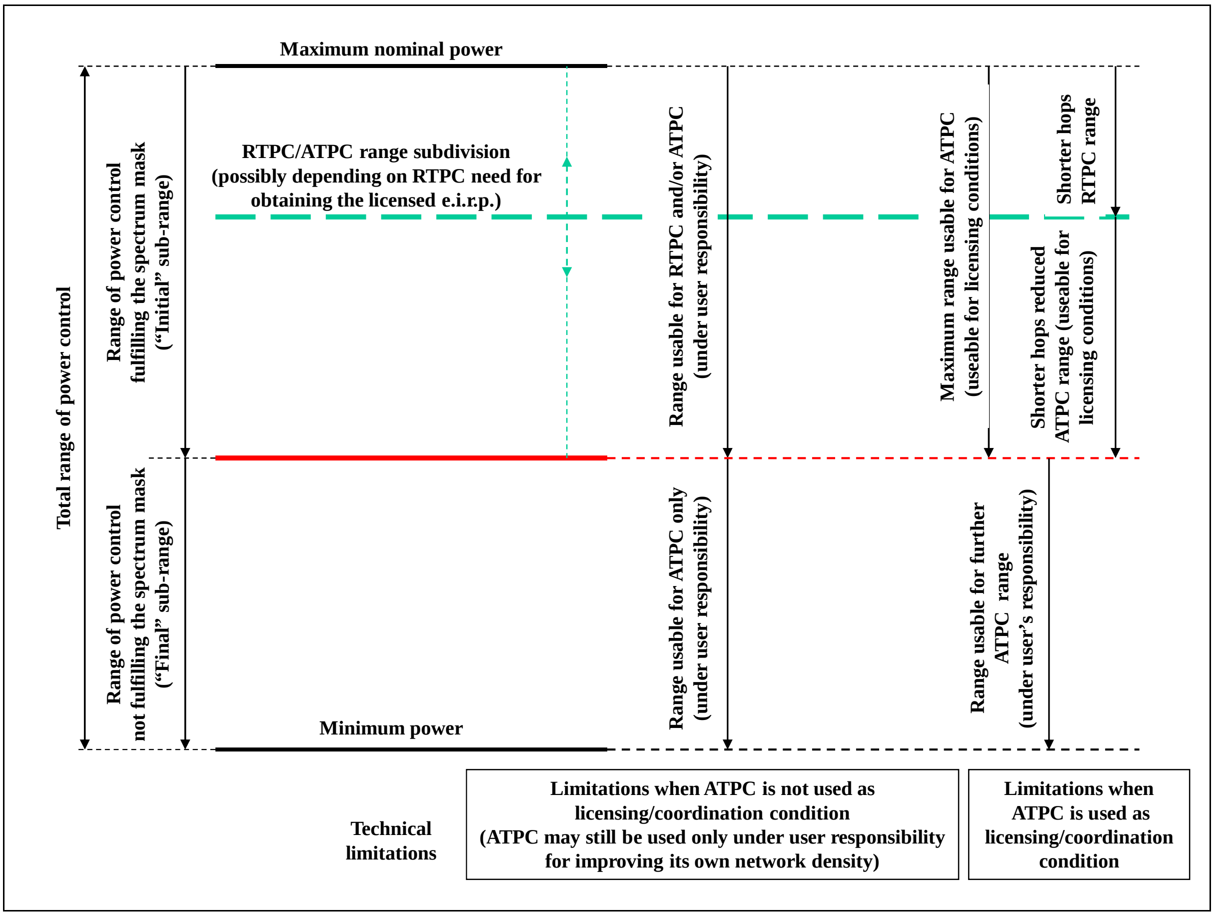

Figure 1: Overview of the output power control range subdivision into ATPC and RTPC with different licensing conditions.

3.2 RTPC IMPACT

When RTPC is used as alternative for conventional RF attenuators (used in the past for a similar purpose) for setting the maximum power established in the network when planning for each single link (P-P) in order to control inter system interference into other links, the NFD should be maintained because it is used for frequency planning and associated with a rated power. Therefore the mask should be met throughout the operating range offered (suppliers should limit the range of RTPC accordingly).

3.3 ATPC IMPACT

3.3.1 ATPC not imposed as licensing/coordination conditions

Figure 2 clarifies the technical background for the ATPC operations; it identifies the relevant power levels and their relationship with the transmitter power density spectrum mask as required by ETSI EN 302 217-2-2 [4] (note) in relation to the Art. 3.2 of 99/05/EC Directive (R&TTE) [1].

NOTE: Presently, the large majority of licensing procedures in Europe do not impose an ATPC range; therefore, the ETSI standard requirement for fulfilling the R&TTE Directive is tailored to this situation; more stringent requirements (see next section 3.3.2) are left to voluntary implementation of the manufacturer.

In Figure 2 different power levels, possible during ATPC operation, are identified as follows:

- Maximum Nominal Power (ATPC operating): This is coincident with the e.i.r.p. defined in the coordination process for the required link availability (excluding the antenna gain);
- Minimum Power (ATPC operating): This is the lower power reached in unfaded (clear sky) propagation conditions. This level is defined on the basis of a minimum receiver signal level (RSL) guaranteeing stable “error free conditions” (including safeguard allowance for tolerances in both TX power setting and RSL detection);
- Intermediate Power (ATPC operating): Any intermediate power condition adapted to the instantaneous propagation condition;

The rationale for the requirement related to respecting (e.g. in green) or not (e.g. in red) the ETSI power density spectrum mask is that while the ETSI mask is a "relative attenuation", the actual interference potential is given by the absolute power spill over into adjacent channels (defined by the green mask). Therefore the NFD should be guaranteed when transmitters operate at maximum nominal power (i.e. when maximum absolute power is produced in adjacent channels), which are the conditions commonly used for frequency planning. In all lower power conditions, even where the NFD may be degraded by the (apparent in the red mask) increase of the noise floor (due to the actual drop in carrier power), resulting in the mask level being exceeded (see Figure 2), however the absolute interference power on adjacent channels will, in any case, be equal to or less than the green mask used for planning (i.e. the planned C/I on adjacent channels will not be exceeded).

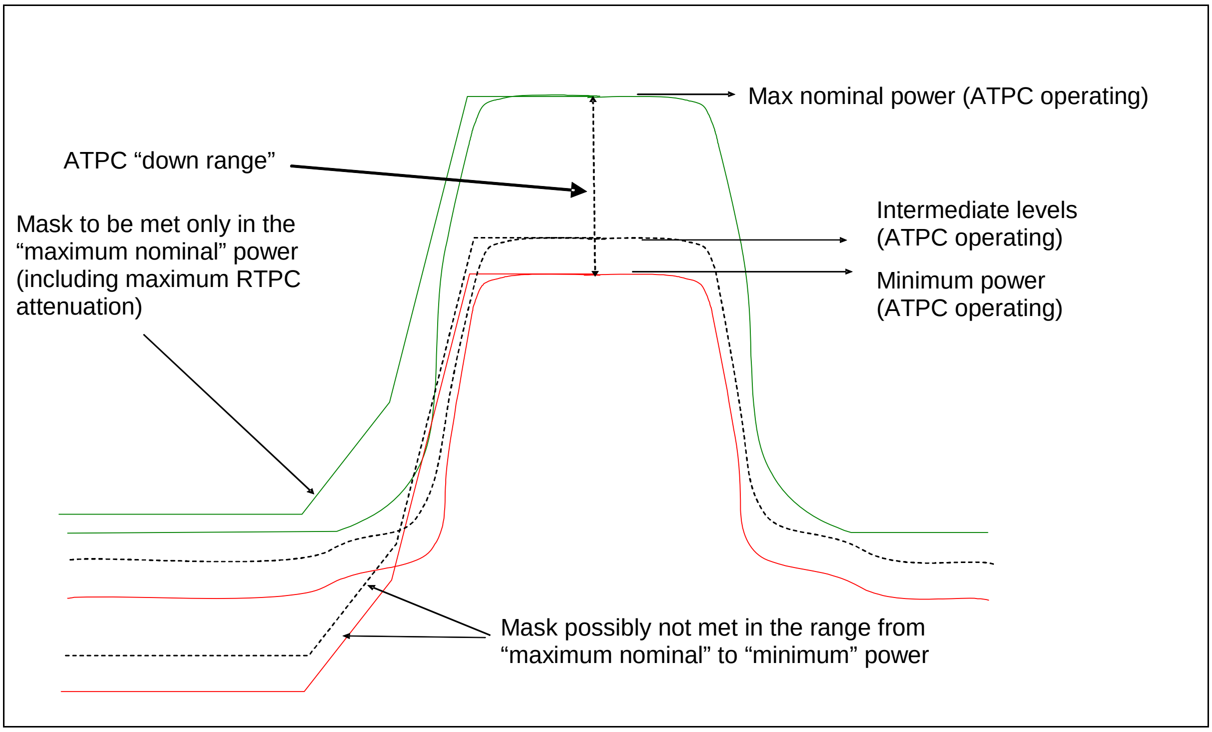

Figure 2: Relationship between spectrum mask requirement and not regulated ATPC operation

However, it has to be considered that the manufacturer, besides the inter-system operation guaranteed by the above behaviour of the equipment, should take into account in the system design also of the intra-system constraints for maintaining a suitable RBER; during ATPC operation, the "noise floor" of the emission should remain sufficiently low for maintaining a signal to noise ratio (S/N) suitable for RBER fulfilment[1].

3.3.2 ATPC used as licensing/coordination conditions

Recently, the frequency congestion in some bands and areas has stimulated new studies on the potential density increase if ATPC would be imposed by the licensing conditions.

When it is desired to use ATPC for a real increase of the network density, the following steps should be considered:

- When existing links in an already relatively dense network do not implement any ATPC, the density improvement of imposing ATPC for new links is very limited, unless, very unlikely, an investment for ATPC retrofits and new re-coordination is planned;
- Take into account that links of different length and propagation conditions would require different fade margin; consequently, the ATPC range would also possibly be different; the ATPC range should be calculated on the basis of a suitable fixed RSL in “clear sky” conditions valid for any link, rather than considering fixed transmitter attenuation. Sufficient margin between RSL BER threshold and the required “clear sky” RSL in ATPC conditions should also be provided for guaranteeing “error free” condition; relatively short links might not permit any ATPC range but would rather require some “extra margin” in term of e.i.r.p. higher than that calculated for availability;
- In order to guarantee the NFD also in the minimum ATPC power condition, used for coordination, the spectral density mask (green one in Figure 2) should never be exceeded, as shown by the red line of Figure 2 when ATPC is not used as planning assumptions, but should be respected in the whole ATPC range (note);
- The links coordination of new links for the desired performance and availability objectives would be done with transmitter output power reduced by the link-specific ATPC range necessary for the link to reach the desired fixed RSL in “clear sky” conditions;
- Existing links with no ATPC can still be coordinated with their nominal output power;
- A practical ATPC range should be defined considering also the possible implementation limitation described in section 4;
- When “Adaptive modulation” systems are used, further constraint to ATPC range might be taken into account. See section 4.4 for more details.

NOTE: Presently, in ETSI standards, even if most of the equipment on the market implement it, ATPC is not considered a mandatory feature and its requirements are not tailored on the basis of its use as planning assumptions; this because, up to now, few administrations considered this possibility. For this reason, if this regulatory use of ATPC would become more and more popular, the RTPC/ATPC ranges subdivision should be specifically re-defined by the manufacturers because possibly not coincident with the general case considered in section 3.1 (where the spectrum mask matching is not required in the ATPC range), on which basis the equipment characteristics are generally declared. Review of the ETSI standard in this direction (ATPC mandatory for coordination) might be considered if the market force would require it.

4 ADAPTIVE MODULATION (MIXED MODE) OPERATION IMPACT

4.1 BASIC CONCEPTS

Adaptive modulation systems can dynamically (on the basis of receiver signal level and other built-in quality parameters) smoothly switch between different modulation formats, increasing/decreasing the payload capacity accordingly. At the same time they can manage the TX power output, reducing it for the higher complexity formats that require higher linearity. Therefore, adaptive modulation systems have also a built-in ATPC functionality.

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[1] The S/N in the transmitter chain would depend on the proprietary implementation; however, a conservative indication may be drawn assuming that the ratio between the in-band power density and the noise density ("transmitter S/N") should be:

$$\text{Transmitter S/N (dB)} > (\text{Cochannel C/I@1dB}) + (\text{RSL@RBER} - \text{RSL@BER}10^{-6})$$

Where:

Co-channel C/I@1dB is the C/I ratio that degrades the BER 10^{-6} by 1 dB; its maximum limit is usually defined in ETSI standards.

The factor (RSL@RBER - RSL@BER10^{-6}) is conservatively defined as ≤ 10 dB in ETSI EN 302 217-2-1 [3].

This technology might be combined with variable (more or less redundant) coding techniques whilst maintaining the modulation format. In addition, further bandwidth adaptive functionality could be, in principle, be used as described in section 5 (e.g. after reaching the simplest modulation format, the system bandwidth is reduced) for further enhancing the link availability for a very limited portion of payload (beyond the minimum modulation format). However; the possible use of this feature is irrelevant for the technical descriptions in this section.

The variable capacity of the AM systems in various propagation conditions implies that part of the maximum payload is gradually lost. This also requires that mechanism for defining different priority steps to portion of the payloads should be provided and the AM system should be able to detect it in order to gradually eliminate lower priority parts.

4.2 LINK AVAILABILITY

When assigning a radio frequency channel of a certain width over a link of defined length, the use of adaptive modulation in PP links, occupying the same channel and switching between the modulation formats, can offer more efficient operative conditions dictated by two different objectives:

1. **To increase the available capacity over the same radio frequency channel:** During period with <u>favourable</u> propagation conditions, this is obtained by the use of modulation formats higher than the one of the “reference mode” used for defining the link budget and related frequency co-ordination constraints at the conventional availability objective (e.g. 99,99 %). Maintaining the symbol rate about the same, 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).

   EXAMPLE 1: On a link designed and frequency coordinated for the 99.99 % availability for 'K' Mbit/s capacity with 4 QAM format, the system, maintaining the same symbol rate, will also operate for:

   - '2×K' Mbit/s capacity with 16 QAM format for lower time % due to the ~10 dB reduction in link budget (i.e. ~6 dB S/N and ~4 dB TX back off) resulting, in Raleigh multipath propagation, in ~99.9 % (note 1).
   - '3×K' Mbit/s capacity with 64 QAM format or '4×K' Mbit/s capacity with 256 QAM for even lower time %, due to the ~8 dB or ~ 15 dB further reduction in link budget (as a mixture of consequent S/N increase and further TX back off) resulting, in Raleigh multipath propagation, in ~99.4 % and ~98.8 %, respectively (note 1).

   NOTE 1: These are ideal examples; in real systems operation, the availability for the capacity related to a specific modulation format should be evaluated on the basis of the actual switching thresholds (see section 4.3).

2. **To increase the availability of a smaller portion of the capacity:** During period with very <u>unfavourable</u> propagation conditions, this is obtained by the use of modulation formats lower than the one of the reference mode 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). In principle, also the TX power might be increased, as a consequence to reducing linearity requirement; however, this would result in higher interference generated to nearby links due to both the nominal e.i.r.p. increase and the NFD degradation; therefore, the possible increase of TX power (see note 2) should be carefully considered together with true occurrence probability of activation of lower modulation formats (see also section 4.3) with respect to the unavailability objective used for network coordination.

   NOTE 2: It should be considered that ETSI has introduced the specific requirement “Dynamic change of modulation” under art 3.2 of the R&TTE Directive [1] for adaptive modulation systems. They should demonstrate the capability of not increasing the TX power, and consequently the spectrum mask, beyond that used for the reference mode. Deviations from this general behaviour, as described above, are not considered in the scope of the ETSI standard.

   EXAMPLE 2: On a link designed and frequency coordinated for 99,99 % availability for 'K' Mbit/s capacity and 64 QAM format, the system, maintaining the same symbol rate, will also operate for:

- '2/3*K' Mbit/s capacity and 16 QAM format for higher time % due to the increase in link budget (i.e. ~6 dB S/N and, if permitted, ~4 dB TX back off) resulting, in Rayleigh multipath propagation, in ~99,997 % and, if possible, ~99,999% (see note 3).
- '1/3*K' Mbit/s capacity and 4 QAM format for an even higher time %, due to the further increase in link budget (as a mixture of consequent S/N increase and, if possible, TX back off) resulting, in Rayleigh multipath propagation, up to ~99,9999% (see note 3).

NOTE 3: These are ideal examples; in real systems operation, the availability for the capacity related to a specific modulation format should be evaluated on the basis of the actual switching thresholds (see section 4.3).

Intermediate situations are possible; e.g. a link designed and coordinated with 16 QAM format might dynamically change to 64 QAM or higher for lesser % objectives as in option 1) and to 4 QAM or lower for higher % objectives as in option 2).

In practical backhauling networks operation according example 1 or mixed examples 1 and 2 are generally more appropriate for the links collecting payload from the base stations, which contains a mixture of high and low priority traffic; typically, these links are deployed in the higher frequency bands (e.g. at or above 15 GHz). Operation according Example 2 becomes more appropriate in higher network layers connections between larger exchange centre, where longer high capacity hops with higher priority payload is treated; this option may better fit in lower frequency bands, where also some licensing constraint on minimum spectral efficiency might be present. Adaptive modulation systems, being in general fully software programmable in term of desired *reference modulation format*, would respond to both demands.

It is to be noted that go and return channels may operate independently, being driven by different propagation situation; therefore TX and RX modulation formats, at a certain time, may not be the same.

In addition, it should be noted that adaptive modulation systems will likely need highly reliable exchange of information between TX and RX, necessary for managing the change of format dynamically with propagation. For this purpose, it might be advisable that service channels for internal system management (e.g. within the headers of the radio frame, similarly to preambles in PMP systems) are always transmitted with symbols of the less sensitive format (e.g. 4 QAM or even BPSK) even when the remaining radio frame (payload) is transmitted with symbols of higher order formats.

4.3 LINK FADE MARGIN

When error free switch (on the surviving higher priority traffic) between various formats is desired, the switching towards lower formats (downshift thresholds) should be activated well above the RSL threshold (typically BER=10-6 or higher); conversely, the switching towards higher formats (upshift thresholds) should be activated above the downshift ones (hysteresis is needed). If the whole set of available formats is desired, a minimum value of unfaded RSL is needed for permitting their activation;

Figure 3 and Figure 4 graphically show the typical switching process for two examples of different Reference modes. These figures detail a switching process for all possible formats between 4QAM and 256QAM, but in practical implementations only some of them might be used.

When applied to the same link with the same availability, the required fade margin is a constant and does not depend on the chosen Reference modes. When using higher format reference modes, the drop of output power for linearity and spectrum mask needs should also be considered. This could be recovered through RTPC and/or antenna gain.

Figure 3 and Figure 4 show the ideal principle; however, standing the limited difference in RSL between contiguous formats (~3 dB), in real implementation the upshift of one format might even exceed the downshift of the next higher format.

In addition, when higher class Reference modes is chosen and lower classes modes are still used, the actual fade margin applicable to the whole capacity of the reference mode will be reduced and defined approximately by the mean RSL between the down and up shift thresholds of the reference modulation; see example in Figure 4. If it is not possible or desired to block the downshift to classes lower than the “reference” one, this effect might be traded off with an “extra margin” in the link design and its coordination process; the user can obtain it by applying for the coordination of an higher “reference mode”, which would imply for the same fade margin higher e.i.r.p. and consequently higher RSL range overcoming the above problem (see section 6).

Similar situation may arise when relatively short hops and low rain intensity zones are concerned, because of the consequently low required fade margin. In these cases some “extra margin” might be considered (see section 6).

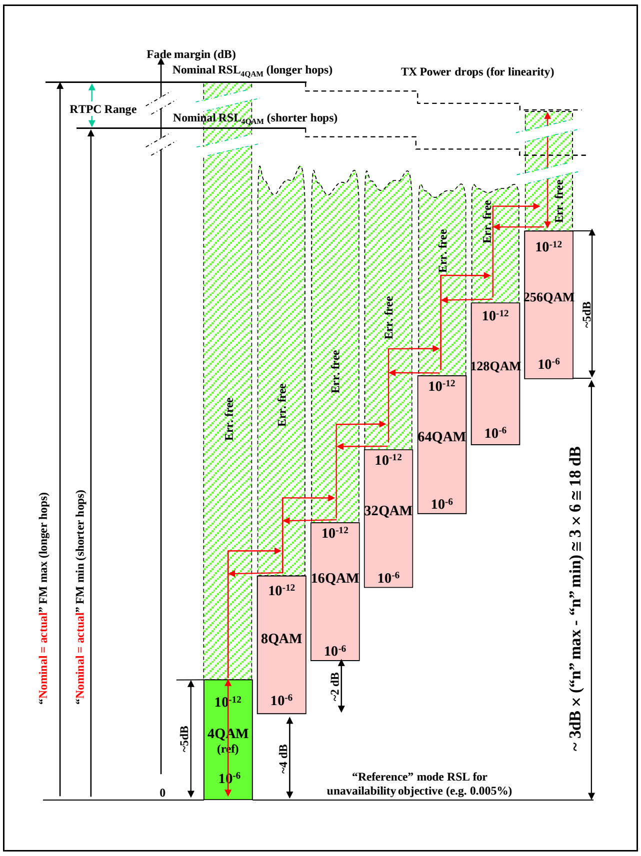

Figure 3: Class 2 (4 QAM) reference

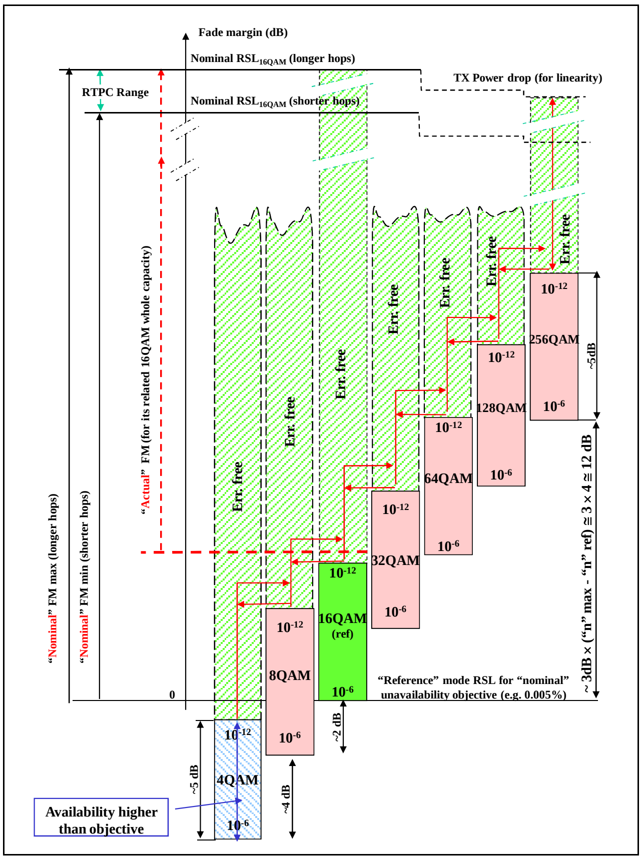

Figure 4: Class 4L (16 QAM) reference

4.4 ATPC RANGE

When Adaptive modulation systems are used in conjunction with ATPC (in either cases identified in Table 1), the definition of the operative ATPC range used for coordination purpose (i.e. the one relative to the *reference modulation format* power) should also take into consideration the minimum unfaded RSL necessary for permitting the activation of the highest mode desired (see clause 4.3).

In addition, due to the unavoidable tolerances of a number of parameters the overall switching process (for BER/RSL detection, up/downshift threshold pre-setting, ATPC pre-setting, environmental conditions,..), significant safeguard over the uppermost class upshift threshold should be taken. The principles for this evaluation are shown in Figure 5 examples drawn for 4 QAM or 16 QAM case and showing, for simplicity, only three other modulation formats up to 256 QAM (but higher QAM formats are also possible without changing the principle background).

It should be noted that the “clear sky” RSL remains constant whichever reference mode is used (it depends only on the highest modulation format). This means that the possible ATPC range might be higher if higher efficiency classes are used as Reference mode, so requiring a higher “nominal” RSL; however, this depends also on the selected antenna gain, which might be forcefully higher for a 16 QAM link due to its intrinsic lower TX power.

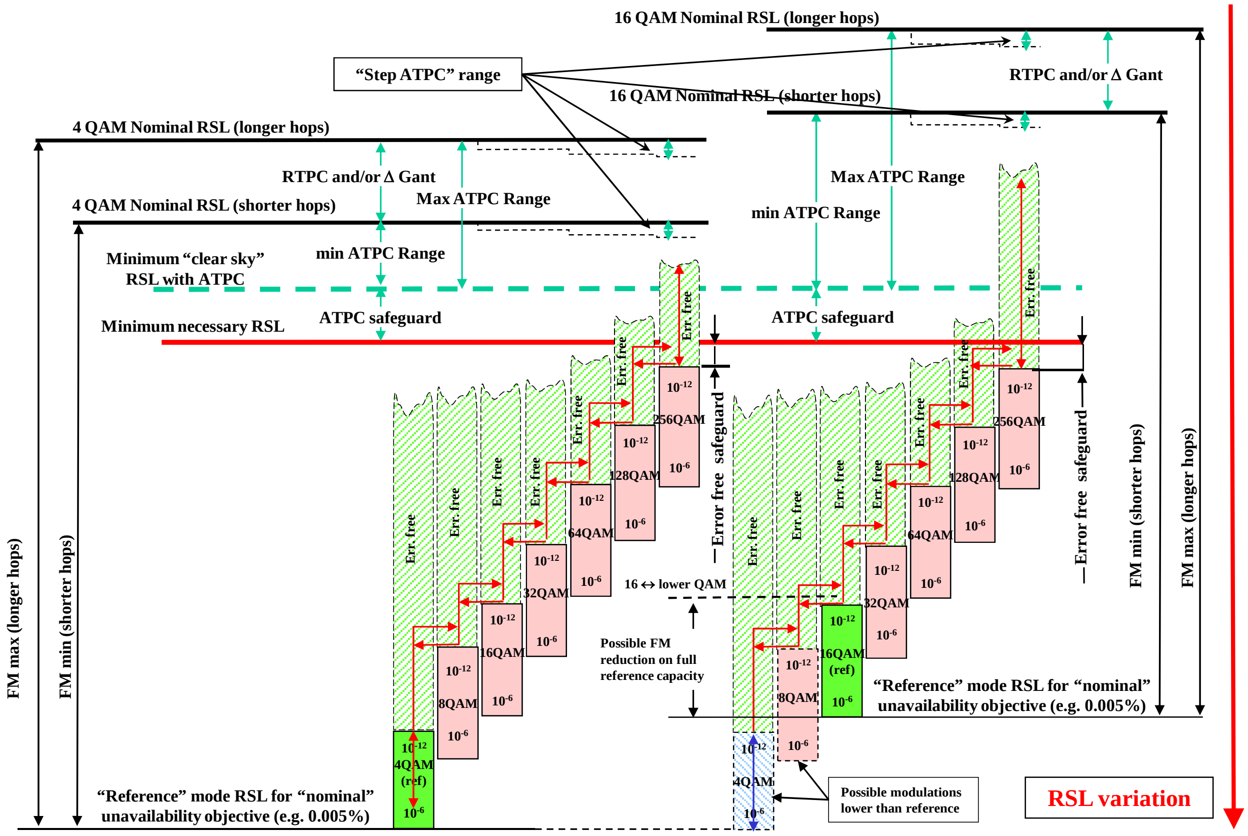

Figure 5: Impact of fade margin and Reference mode on ATPC range

Table 2: Legend of Figure 5

Horizontal lines legend	
4 QAM nominal RSL (longer hops)	Nominal RSL (clear sky, ATPC disabled) on hops, designed with 4 QAM reference mode, requiring the highest fade margin (for high length and/or high rain rate) (note 1)
16 QAM nominal RSL (longer hops)	Nominal RSL (clear sky, ATPC disabled) on hops, designed with 16 QAM reference mode, requiring the highest fade margin (for high length and/or high rain rate) (note 1)
4 QAM nominal RSL (shorter hops)	Nominal RSL (clear sky, ATPC disabled) on hops, designed with 4 QAM reference mode, requiring the lower fade margin (for short length and/or low rain rate) (note 1)
16 QAM nominal RSL (shorter hops)	Nominal RSL (clear sky, ATPC disabled) on hops, designed with 16 QAM reference mode, requiring the highest fade margin (for short length and/or low rain rate) (note 1)
Minimum "clear sky" RSL with ATPC	Minimum "clear sky" RSL that may support the complete up-shift of all formats higher than the "reference" one. It is constant and does not depend on which reference (e.g. 4QAM or 16QAM) the link has been designed. This level may be intended as the lower RSL bound for the definition of the ATPC power reduction (note 2).
Minimum necessary RSL	This is the real "nominal" minimum "clear sky" RSL permitting the exploiting of all modulation formats in "error free" operation. However, the large number of variables and related tolerances involved in the ATPC operation imply that a safeguard margin

	(see ATPC safeguard) should be taken into account for defining the above minimum "clear sky" RSL with ATPC enabled.
Reference mode RSL for nominal unavailability objective	RSL at which correspond the BER threshold (typically BER = 10^{-6}) of the chosen reference mode. It is used for defining the necessary fade margin for fulfilling the link availability objective (e.g. 99.995 %) for the system capacity associated to that reference mode.
16 ←→ lower QAM	Average RSL below which the 16 QAM modulation (reference in the example) is shifted to lower format (8 QAM in the example), unless formats lower than reference are disabled.
Vertical lines legend	
Step ATPC range	Minimal ATPC range always enabled when adaptive modulation systems operate with reference mode lower than the maximum QAM format available (256 QAM in the example). It is necessary for operating the TX with the required back-off and linearity for guaranteeing the error free transmission.
FM max (longer hops)	Maximum fade margin required in the network (typically for the longer hops) (note 3) (note 4).
FM min (shorter hops)	Minimum fade margin required in the network (typically for the shorter hops) (note 3) (note 4).
RTPC and/or Δ Gant	Difference between the maximum and the minimum fade margin possible with a given radio system. Corresponding to the difference in e.i.r.p. possibly licensed for the longer and shorter links. This difference is usually recovered with different antenna size/gain and/or RTPC setting.
Error free safeguard	Safeguard RSL margin above the nominal equipment error free threshold for taking into account tolerances in the link design (antenna, feeders, ….) and possible unpredictable channel distortions. It defines the "minimum necessary RSL for safely exploiting all modulation formats in error free mode.
ATPC safeguard	Additional margin on to be considered when ATPC operation is foreseen. It defines the "minimum clear sky RSL with ATPC" to be considered when ATPC operation is required in the coordination process (note 2).
Maximum ATPC range	Maximum range of ATPC attenuation (including the "step ATPC") available on the system, which can be used on a link by link basis as function of actually needed FM, for setting the desired "clear sky RSL with ATPC" (note 5).
Minimum ATPC range	Minimum practical ATPC range (i.e. giving a not negligible improvement on the network coordination) (note 5).
Possible Reference FM Reduction on full capacity	When the operator enables also the operation in modulation formats lower than the reference one, it reduces, de facto, the payload available with the "reference" availability (e.g. 99.99%). This is traded off with an even higher availability (of the 4QAM format) for a portion of that payload.
RSL variations	Received signal level axis.

Note 1: When higher QAM reference mode is used on the same hop, these values would increase accordingly for keeping a constant flat fade margin (assuming negligible the dispersive component).

Note 2: It should be taken into account that, when the adaptive modulation operation is considered "best effort", the network planning might not consider this aspect as mandatory; in some cases of mandatory ATPC usage, the planning rules might still impose a RSL (with ATPC enabled) lower than this limit. In this case, the most complex modulation format(s) might not be operating.

Note 3: These values are independent from the used QAM reference mode (assuming constant flat fade margin and negligible dispersive component).

Note 4: The shown "reference" margin is the one usually corresponding to the "conventional" availability at BER 10^{-6} threshold (99.995% in the example). However, fade margins for all formats (e.g. for their nominal average down/up shift threshold) could be defined with their corresponding (lower or higher) availability.

Note 5: The possible ATPC range depends on the used QAM reference mode, but also on the combination of nominal TX power and antenna gain used on the hop; it should be calculated link-by-link.

It might also be useful, for the overall comprehension of the joint mechanisms of adaptive modulation and ATPC (including both "step ATPC" and "linear ATPC" ranges), to consider the contemporaneous variations of transmit power and RSL when an ideal deep fading affects the whole fade margin beyond the lowest modulation threshold and back to normal propagation. The examples (4, 32, 256 QAM only shown) in

Figure 6 and Figure 7 show the levels variation and their required hysteresis during the time duration of the fading phenomenon; 4QAM and 32 QAM are assumed as reference modulation, respectively.

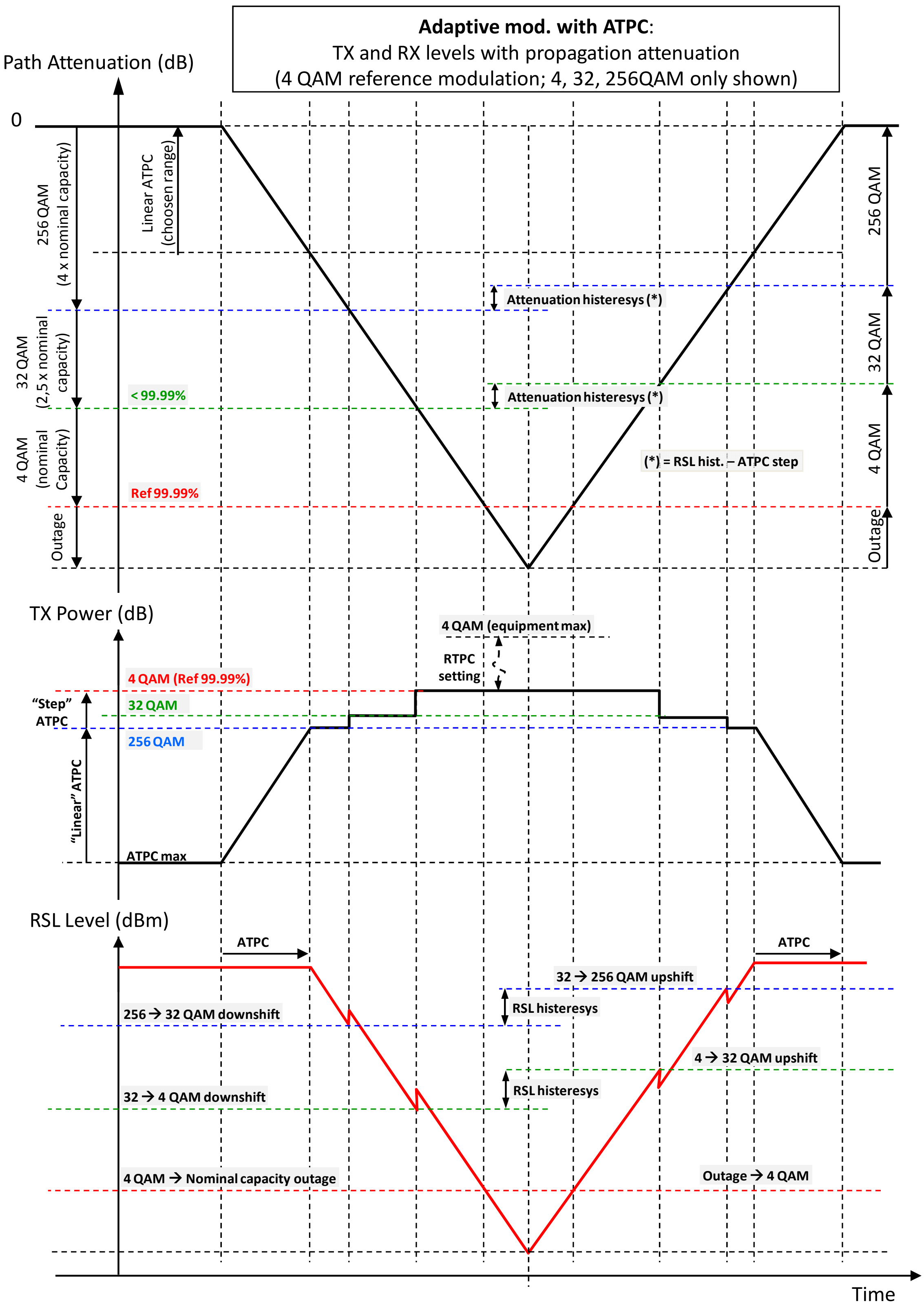

Figure 6: Transmit power and RSL variations with fade attenuation (ideal example with 4 QAM reference modulation)

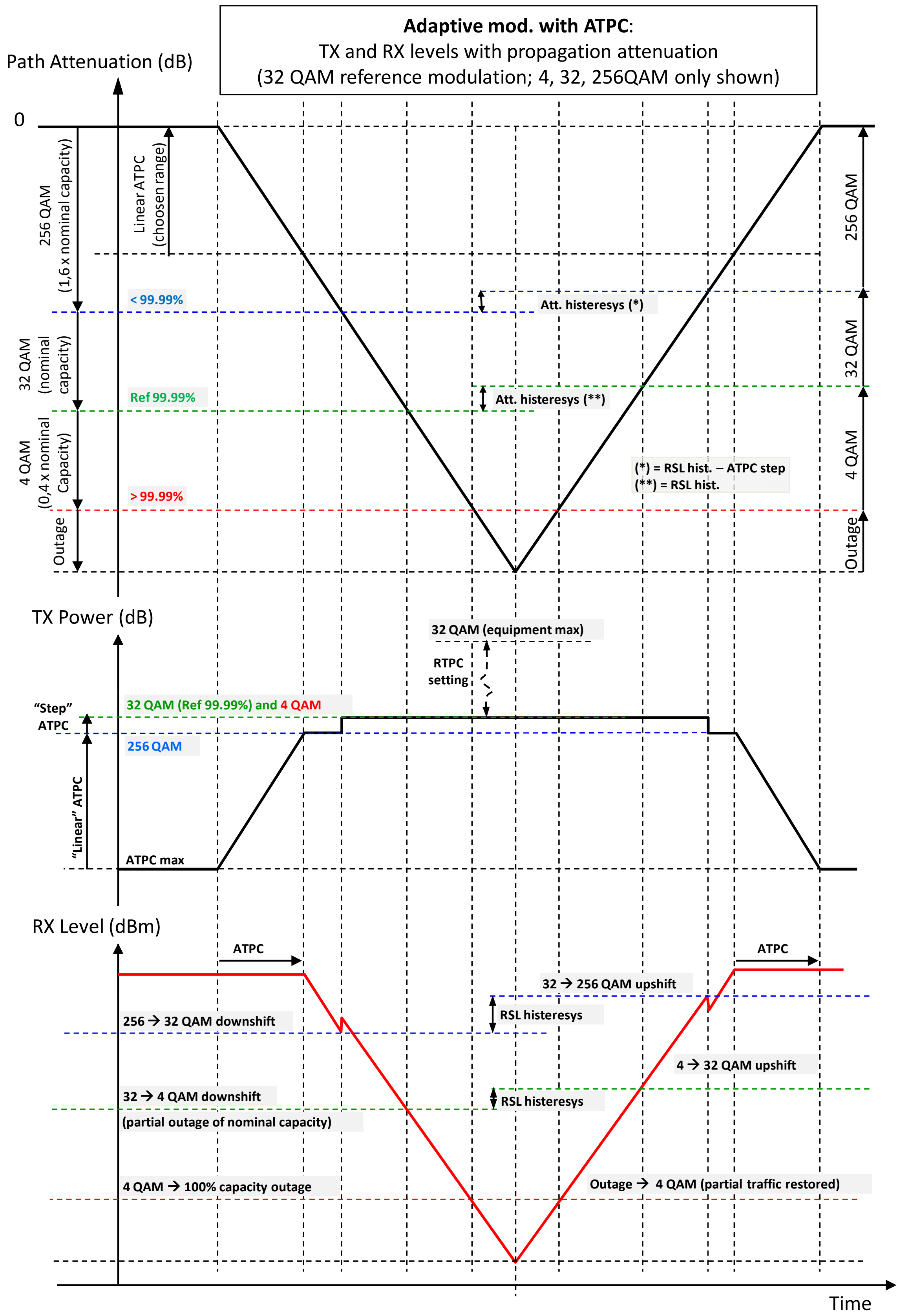

Figure 7: Transmit power and RSL variations with fade attenuation (ideal example with 32 QAM reference modulation)

5 BANDWIDTH ADAPTIVE OPERATIONAL IMPACT

5.1 BASIC CONCEPTS

Bandwidth adaptive systems can dynamically (on the basis of RSL and other built-in quality parameters) smoothly switch between different bandwidth with the same modulation formats, increasing/decreasing the payload capacity accordingly. In principle, the output power is kept constant because no different linearity requirements are present; therefore, differently from adaptive modulation systems, bandwidth adaptive systems might not have ATPC built-in functions.

These systems are mainly used for high capacity systems in EHF bands (e.g. 70/80 GHz) where the radio frequency technology does not (yet) permit:

- The use of high level modulation formats (simplest 2 or 4 levels could only be practical);
- Enough TX power and RX sensitivity for producing a sufficient fade margin for operating the maximum capacity on relatively long hops in geographical areas with sensible rain-rate.

In principle, this technology might be combined with adaptive modulation functionality (e.g. switching also between PSK and QPSK). Still in principle, this technology might also be added to (full) adaptive modulation systems described in section 4 for further enhancing the link availability for a very limited portion of payload (beyond the minimum modulation format).

5.2 BANDWIDTH (CHANNEL) OCCUPANCY

When operated in a network requiring coordination (either under administration or user responsibility) the occupied bandwidth or the channel occupancy (when a channel arrangement is provided) and their relevant system characteristics for coordination (Reference mode) should be defined for the maximum bandwidth that will be used (and then permitted) for the link under consideration.

5.3 LINK AVAILABILITY AND FADE MARGIN

Over a certain hop, the fade margin becomes, in principle, linearly variable with the bandwidth used.

Therefore, with this technology, the target availability (e.g. a commonly used 99.99%) in the longer hops might be obtained for a limited portion of the payload (e.g. 100 Mbit/s) transmitted, with sufficient fade margin, over a relatively small bandwidth (e.g. 100 MHz), while, during most of the time, the full capacity (e.g. 1 Gbit/s) is transmitted over a corresponding larger bandwidth (e.g. 1 GHz) and reduced fade margin (e.g. 10 dB less).

In the above example, assuming that the rain induced attenuation occurrence follows ~ 10 dB/decade slope, the 1 Gbit/s payload would be transmitted with ~ 99.9% availability.

However, provided that the maximum bandwidth occupancy will define the coordinated interference situation with other links nearby, the link in the above example should be designed and coordinated for Reference mode corresponding to the maximum bandwidth; therefore, with its lowest availability target (in the above example for 1 Gbit/s transmission and only for 99.9% availability).

5.4 ATPC RANGE

As mentioned above ATPC function is not necessary in the design of bandwidth adaptive systems; therefore, it might not be available in all systems.

However, when ATPC operation is desired, considering that the “reference mode” is generally identified as that with the largest bandwidth operation, ATPC problematic is very limited and, in practice, is related to “short hops” with limited fade margin (see section 6.2).

6 IMPLICATIONS ON FREQUENCY CO ORDINATION AND POSSIBLE REGULATORY BACKGROUND (LICENSING)

6.1 BASIC CONCEPTS

For an effective use of the operative conditions described above, which in general implies from time to time the change of modulation format and TX output power, on the link by link frequency coordination process, should consider the constraints deriving from the conventional licensed use of the spectrum.

These constraints are consequence of three possible reasons:

- Frequency coordination is made on the basis of system parameters (i.e. TX spectrum mask and RX sensitivity) in a fixed size radiofrequency channel; therefore, while changing format and power, the system should not worsen the coordination assumptions (i.e. those of the Reference mode) for not impairing coordination assumptions. However, different considerations are applicable to TX and RX parameters:
  - TX emission should not exceed that of the Reference mode for not exceedingly affect neighbour systems in same or adjacent channels.
  - Receiver sensitivity to interference of different modulation formats is not an issue in nodal PP links coordination (provided that noise figure is kept constant) because it is made on the basis of fixed channel separation and of a constant limited amount of interference (e.g. as defined in ECC/REC/(01)05 [2] for 'x' dB constant degradation of the noise floor on noise limited links) from interfering channels into a fixed receiver bandwidth designed for that radio frequency channel. Therefore, whichever is the system mode of the receiver, the originally planned threshold degradation for the Reference mode will remain unchanged for all modes. Figure 8 and Figure 9 show the rationale for this principle.
  - In some cases and for some valuable bands, administrations might require a minimum spectral efficiency (e.g. minimum 16 states formats).
  - In the use of Adaptive modulation over a link coordinated in a specific Reference mode higher modulation formats may be seen as “best effort” operation, unless administrations wish to consider in more detail the specific needs of *mixed mode* systems for exploiting all operating modes other than the reference one as described e.g. in clause 4.3 and 4.4.
  - In some cases, the national administrative policy might foresee licensing fees depending also on the carried payload.

For suitably responding to these constraints in the simplest way, while leaving operative flexibility to the operator, administrations should consider the following items in defining the coordination and licensing for suitable and safe deployment of adaptive modulation systems on the same network with other conventional (fixed modulation) links:

- Their license and coordination process (i.e. in term of system and link parameters) should be made in a fixed width radio frequency channel, for the format and capacity identified by the Reference mode (system type), with the desired "reference availability objective" (i.e. the typical 99,99 % or any other generally used by the administration concerned for the frequency coordination).
- The licensee should be left free, by licensing conditions, of using more complex formats and higher capacity, provided that they do not exceed the "Reference mode" spectral emission, in term of both output power density and spectrum mask and (e.g. as in the 4 QAM or 16 QAM "reference format" examples shown in Figure 8 and Figure 9) (see note).
- The licensee should be left free, by licensing conditions, of using also less complex formats[2] and lower capacity, provided that they do not exceed the "Reference mode" spectral emission, in term of both output power density and spectrum mask (e.g. as in the 16 QAM "reference format" example shown in Figure 9).

[2] The further possibility during ATPC operation of using the overdrive power conditions, described in 3.1, standing its critical applicability, is not considered of general use and, if still desired, is left for specific study by national administrations.

- Consider that, in adaptive modulation operation, the actual RSL thresholds for “dynamic” transitions among different modes of operation are defined as appropriate, by manufacturer or operators, independently from the “static” RSL of the BER thresholds defined in ETSI standards for the assessment of article 3.2 of the R&TTE Directive [1]. Only the “static” threshold of the reference mode is relevant for coordination and licensing process; once activated in “dynamic” operation, this threshold might no longer be reached due to earlier down shift to lower modulation format, see Figure 4. In this case, when practical, the user may follow the preliminary iterative link planning in section 7 in order to define the reference modulation that better suits its needs in order to compensate the effect (see note).
- Consider that bandwidth adaptive systems should be coordinated with their reference mode, corresponding to maximum bandwidth occupancy and its relevant lowest availability objective.

NOTE: In such case, the user can also autonomously manage the problem; these lower formats could either be excluded from dynamic operation, or, when their higher availability is also desired, some “extra margin” on the link for compensating the effect might be recovered through the license application of the link with an even higher *reference mode* than that initially assumed for matching the desired minimum link capacity with required availability. This would automatically imply a higher fade margin without any specific administration intervention.

6.2 SHORT HOPS PROBLEMATIC

The networks of new and future mobile access systems (4G, LTE, …) are evolving towards denser and denser deployment of the Base stations collecting considerable amount of IP/Ethernet packet data traffic composed by different services with possible higher or lower quality. The adaptive modulation technology in P-P equipment has been mostly developed for their backhauling networks; therefore, also their link length tends to become shorter.

This evolution poses additional challenges to the engineering of the network on both sides of the operators and regulators due to the significantly lower fade margin needed for the required availability, which implies to take into account also the following considerations:

- The fade margin, usually calculated for the availability objective at BER@10^{-6}, could drop to few decibels.
  1. It could likely become lower than the safeguard clear sky margin for guaranteeing the BBER objective, conservatively set in present ETSI EN 302 217-2-1 [3] to be 10 dB.
  2. Conventional frequency planning procedure usually fix the maximum transmit e.i.r.p. for matching the fade margin needed for “availability objective” (ITU-R F.1703 [6])[3]. In such short hops, this obviously means that, for fulfilling also the other “error performance objectives” (ITU-R F.1668 [7]), an “extra e.i.r.p. margin” should be assigned in the coordination process.
- Use of adaptive modulation systems for increasing data capacity in clear sky conditions (desired by the operators for obvious economic reasons) and of ATPC for improving the spectrum usage (sometimes considered in the licensing/coordination process).
  1. This even more increases the difference between the minimum fade margin for implementing these techniques (see Figure 5 in section 4.4), and the actual calculated for “availability” only.
  2. This would imply an even higher “extra e.i.r.p. margin” to be possibly assigned in the coordination process, unless all these hops are designed considering only the topmost modulation formats.
  3. The “extra e.i.r.p. margin” would imply an higher interference situation; however, it might be tolerable due to larger fade margin permitting in the coordination process a C/I impact larger than usual[4].
- The very low fade margin, in addition to the continuously more demand for low visual impact, imply the use of low antenna gain (small size).
  1. Low gain antennas physically imply a lower directivity (ETSI antenna classes 3 and 4 could not be practical).

[3] It is usually assumed that other ITU-R “error performance objectives” are automatically met.
[4] ECC/REC/(01)05 [2] provides the possibility that “higher threshold degradation could be accepted (e.g. for dense network deployment), if performance and availability objectives can still be met and increased degradation can be compensated in the link budget”.

2. Low directivity antennas imply a reduced nodal frequency reuse rate.
3. The apparent drawbacks of small antennas should, however, be considered in the light of other possible characteristics of the new network scenario (higher links density, “extra margin”, larger C/I tolerance,).

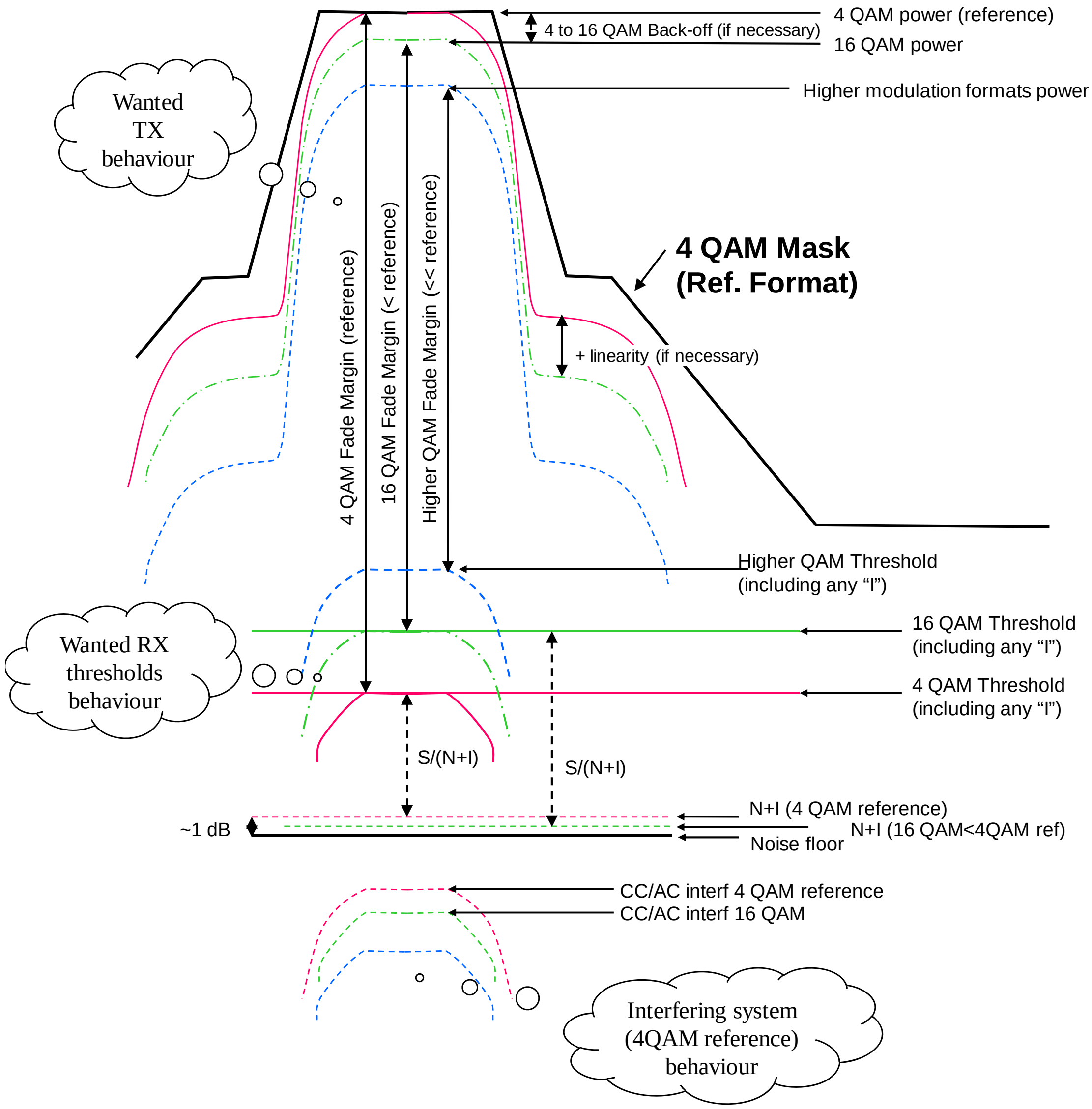

Figure 8: Example of adaptive modulation systems operation and nodal co-channel interference (reference modulation format 4 QAM)

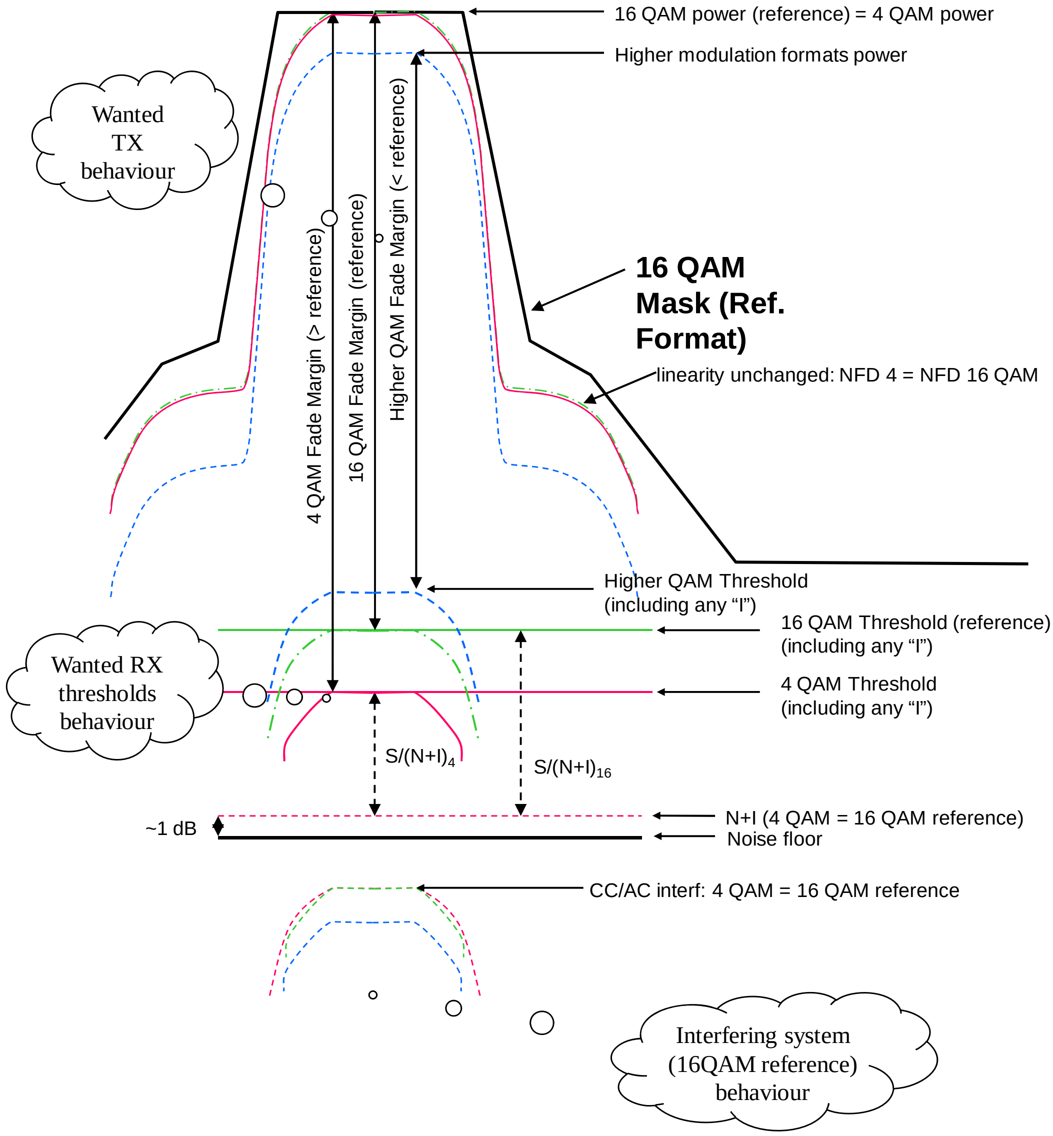

Figure 9: Example of adaptive modulation systems operation and nodal co-channel interference (reference modulation format 16 QAM)

7 FINAL GUIDELINES FOR LINK COORDINATION ACTIVITY

7.1 BASIC CONCEPTS

From the above technical description, a typical process for finalising the coordination and the consequent licensing of links using AM imply that the link user should make a preliminary iterative evaluation of its needs in term of:

- Nominal capacity (i.e. for which the desired availability should be fulfilled)
- Required availability for that capacity (e.g. 99.99%)
- Potential channel spacing and reference modulation suitable for the above requirements.

These are the starting points also used for all "fixed modulation" links.

Then the user may wish to apply the iterative process in order to fully exploit the improved network resources offered by the flexibilities of AM equipment. Next paragraph shows a typical iterative link planning process.

7.2 ITERATIVE LINK PLANNING

The guidelines given in this ECC report are focused to maintain the minimum impact for the administrations with respect to the planning normally used for fixed modulation systems (i.e. the benefit of using the adaptive modulation is considered a best effort for the user).

Therefore, the use of adaptive modulation suggests additional “preliminary” steps in the planning procedure compared to the fixed modulation case. Based on the link requirements, the user, before formally filling the link license request, should carry on an iterative step by step link design in order to take full advantage of the features offered by adaptive modulation.

The user, having fixed the geographical site coordinates and the suitable frequency band, should usually consider the following steps for final definition of the reference modulation to be presented in the license request:

1. Fix the traffic requirements in terms of desired capacity (e.g. 80 Mbit/s) and associated QoS (e.g. availability 99.99% or any other value to be used for the license request).
2. Based on current fixed modulation experience, define a preliminary suitable trade-off for the channel width and reference modulation format as function of the frequency band, hop length and desired spectral efficiency (e.g. 28 MHz, 80 Mbit/s, 16QAM).
3. Based on the characteristics established in steps 1 and 2 above, hop length and propagation characteristics, calculate the needed fade-margin (e.g. FM = 35 dB) and assess, on the basis of actual equipment characteristics and desired antenna size/gain (e.g. Gant = 37 dBi) its feasibility in term of the needed e.i.r.p. (e.g. e.i.r.p. = 50 dBm).
   If the user do not wish to exploit further the adaptive modulation also with modulation formats lower than that defined in step 2 (i.e. lower than 16QAM in the example), the chosen modulation will be used for carrying on, if applicable, the ATPC range assessment in next step 5, to which the process can directly jump.
4. If the user, for keeping the possibility of even higher availability for smaller portion of nominal traffic (as described in section 4.3 and figure 5), wishes to exploit also the downshift to modulation formats lower than the preliminary defined modulation in step 2 he should consider the following process: Based on actual equipment characteristics, increase the levels of the modulation preliminary defined in step 2 (e.g. from 16QAM to 64QAM); this will correspond, for maintaining the same fade margin (35 dB in this example) , to an higher nominal capacity at same QoS (i.e. from previous 80 Mbit/s to 120 Mbit/s) and higher e.i.r.p. needed (e.g. e.i.r.p. = 56 dBm). In this way, the target of 80 Mbit/s with 99.99% availability will still be fulfilled. This principle is graphically shown in Figure 10 and detailed in the example below.

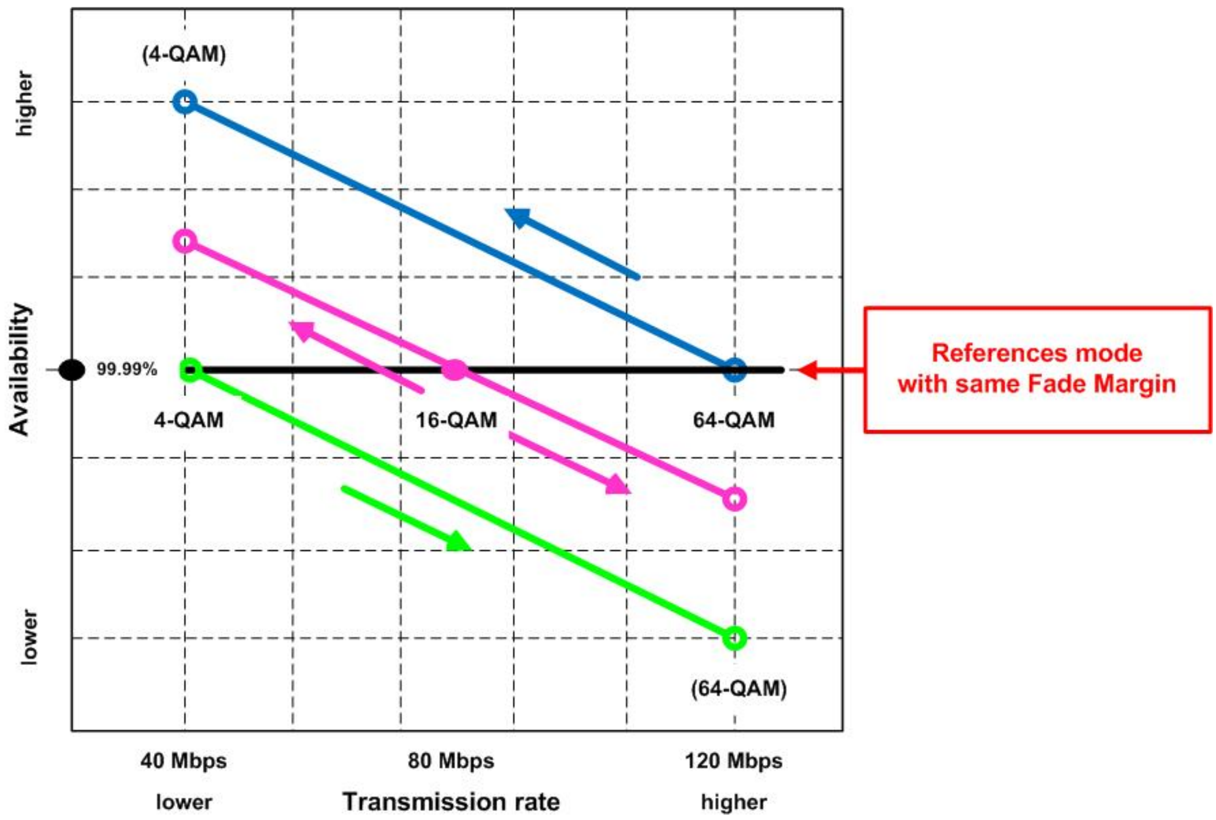

Figure 10: Checking for keeping higher availability for smaller portion of nominal traffic

Example of Step 4 :
We assume that the downshift threshold from 16QAM to lower modulation format (the 4QAM in this example) is about 6 dB higher than the actual BER 10^{-6} threshold at which the needed link fade margin is calculated.

Raising the reference modulation format from 16 QAM to 64 QAM imply that:

a. The nominal reference capacity is raised from previous 80 Mbit/s to 120 Mbit/s;

b. The nominal BER 10^{-6} reference threshold, at which the needed link fade margin is calculated, will also be raised by about 6 dB;

c. The nominal e.i.r.p. for keeping the required 35 dB fade margin will also be raised by about 6 dB;

d. The nominal 64 QAM BER 10^{-6} RSL reference threshold (at which the wanted QoS is obtained) will be about coincident with the actual 16 QAM RSL downshift threshold (at which the originally desired capacity of 80 Mbit/s will start to shrink), taking into account that the assumed 6dB downshift RSL difference from 64QAM to 16QAM is balanced by the other 6dB difference in the nominal RSL threshold mentioned in b).

1. Validate the new preliminary reference format needs, revising the initial assumptions in term of TX output power (i.e. lesser RTPC, if possible) and/or higher antenna size. The new format so defined (64QAM in the example) will be used for carrying on, if applicable, the ATPC range assessment in next step 6.

   NOTE: If this new TX / e.i.r.p. parameters are not practical, the initial assumptions in term of desired capacity and/or channel size and/or exploitation of lower modulations should be revised.

2. If ATPC is not to be used, this step is not applicable and the process can jump to step 7.
   In case ATPC is also to be implemented, either for user desire or regulatory requirement, the ”clear sky” RSL in presence of the desired ATPC attenuation should be compared with the possible ATPC range, i.e:

a. it should be calculated for the actual hop under consideration and obviously be within the max ATPC range (longer hops) (see note 1) and min ATPC range (shorter hops),

b. for fully exploiting the highest modulation format available, the maximum possible ATPC for the reference modulation format should result, considering the actual equipment characteristics, in a RSL greater than the level designed by "minimum clear sky RSL with ATPC" (see figure 5).

NOTE 1: In some nodes, where both long hop and short hop are converging, the max ATPC (longer hops) might not be applicable due to possible overloading of the shorter hops receivers when fading affect only the longer hop. In such cases trade off should be found by reducing the possible ATPC range of the longer hop, consequently raising the "clear sky" RSL and reducing the benefit in the nodal planning.

This may require a trade-off between the maximum capacity/modulation possible in unfaded conditions and (if permitted by regulatory environment) the chosen ATPC attenuation.
It should be noted that, in principle, the higher is the levels of the reference modulation, the lesser is the possible conflict with the chosen ATPC range, due to the fact that the max possible ATPC attenuation decreases (see example); therefore, unless renouncing to ever reach the maximum available modulation format/capacity, this comparison may lead to a further increase of the levels of the preliminary modulation defined in step 3 or in step 5.
The new format so defined (see example) after assessing the feasibility of consequent further e.i.r.p. increase, will be confirmed as reference modulation in the license request.

Example of Step 6 :
According the previous example in step 4, the 35 dB fade margin is applied to nominal 64 QAM BER 10^{-6} RSL reference threshold and the system permits an higher modulation of 512QAM, which have a nominal BER 10^{-6} RSL typically 9 dB higher. The ATPC range validation can be made as follows:

- Adding a global 9 dB of "error free safeguard" plus "ATPC safeguard" (see Figure 5), the minimum clear sky RSL for 512QAM will become 9 + 9 = 18 dB higher than the nominal 64 QAM BER 10^{-6} RSL reference threshold defined in step 5 and the corresponding maximum ATPC attenuation possible on the hop is decreasing to 35 – 18 = 17 dB.
- If these ATPC parameters are not satisfactory (e.g. the minimum clear sky RSL should be only 15 dB, instead of the 18 dB above calculated, higher than the nominal BER 10^{-6} RSL reference threshold for 64QAM) the missing 3 dB can be recovered by increasing the reference modulation to 128QAM.
- The new nominal 128 QAM BER 10^{-6} RSL threshold will rise by 3 dB.
- The new minimum clear sky RSL for 512QAM will now become, as desired, 6 + 9 = 15 dB higher than the nominal 128 QAM BER 10^{-6} RSL reference threshold and the corresponding maximum ATPC attenuation possible on the hop is 35 – 15 = 20 dB;
- The nominal e.i.r.p. for keeping the required 35 dB fade margin will also be raised by 3 dB.

1. Confirm the final desired reference modulation defined, as appropriate, in the steps above (in the examples 16QAM, if the process stopped at step 3, 64QAM if stopped at step 5 and 128QAM if stopped at step 6. Furthermore, based on actual equipment upshift/downshift threshold levels, the user may now re-calculate, for his own records, the available fade margin for each other modulation possible during dynamic operation, higher and lower than that reference, and their corresponding capacities and availabilities.
2. The user can fill the license request to the administration for the link with the desired reference modulation confirmed in step 7 and its relevant characteristics according the actual equipment data.

At the end of the above process, the administration may proceed to the final link planning according the requested reference modulation characteristics (*) and assign the actual channel frequency and associated e.i.r.p. and ATPC range (**) (or, if foreseen by the national procedure) confirm those proposed by the user).

(*) In principle, according the technical background presented in this report, the administration does not need any further data relevant to the adaptive modulation operation; however, they may be requested for due information.

(**) In general the e.i.r.p. calculated by the administration will coincide with that calculated by the user for the final reference modulation and antenna size chosen for that link under the same propagation conditions; slight variation may be possible when the user cannot take into account the local interference situation (e.g. because unknown to him). The e.i.r.p. assigned should always be the minimum necessary for giving the required quality of service for the licensed reference modulation.

8 CONCLUSIONS

An overall review of all the variable elements in the use of Adaptive Modulation (AM) point-to-point systems as well as their practical implementation in term of modulation formats and TX power management, which also affect the range of available ATPC and/or RTPC offered by the system.

When adaptive modulation is used, the coordination process and the interference situation is driven only by the “reference modulation”, intended as the one which TX and RX parameters are used for the conventional evaluation of the fade margin corresponding to the target QoS on the network. Switch to higher or lower modulations formats would not impact other links nearby as far as the spectral emission does not exceed the mask of the “reference modulation” and the corresponding licensed e.i.r.p.; this requirement is clearly defined also in the ETSI EN 302 217-2-2 [4].

The report shows that an effective use (in term of users desired benefits) of those systems can be managed only with the detailed knowledge of all the characteristics of the actual system to be deployed on a specific link with given target of nominal capacity and its QoS. Most of the flexibilities offered by AM systems, implies a number of trade-offs between the “ideal” capacity and QoS (i.e. those that would be used in plain fixed modulation systems) and the additional benefits obtained by an AM systems (i.e. possible exploitation of higher capacity with less QoS and lower capacity with higher QoS than the “ideal” one, represented by the actual “reference modulation” used for the link license); this might imply the increase of the modulation level defined as “reference”.

When also the use of ATPC is desired in the network, for reducing interference and/or enhancing network density, the additional required TX power management increases the variables and furthermore the needed trade-offs in the link parameters for best user satisfaction.

While the system parameters are possibly known also by the administration responsible for link planning, only the user may know (and possibly adapt) the acceptable trade-offs on link-by-link basis. From the licensing point of view, the additional benefits of using AM can only be seen as “best effort” on top of the given QoS defined for the “reference modulation”.

A step by step method is described as pre-license approach for the user in order to decide the best trade-offs, between the various flexibilities offered by an AM system, in order to define the modulation format that better suites the link needs to be finally used as “reference modulation” in the license request.

Under the assumptions made in this report, from the administration point of view, only the “reference modulation” of an adaptive modulation systems is used for the coordination process; all other system characteristics might be intended as ancillary information.

ANNEX 1: LIST OF REFERENCE

[1] 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).
[2] ECC Recommendation (01)05: “List of parameters for digital point-to-point fixed radio links used for national planning”.
[3] ETSI EN 302 217-2-1: “Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas; Part 1: Overview and system-independent common characteristics”.
[4] ETSI EN 302 217-2-2: “Fixed Radio Systems; Characteristics and requirements for point to point equipment and antennas; Part 2 2: Digital systems operating in frequency bands where frequency co ordination is applied; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive”.
[5] 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”.
[6] ITU-R Recommendation F.1703: “Availability objectives for real digital fixed wireless links used in 27 500 km hypothetical reference paths and connections”.
[7] ITU-R Recommendation F.1668: “Error performance objectives for real digital fixed wireless links used in 27 500 km hypothetical reference paths and connections”.