



**Fixed Radio Systems;
Parameters affecting the Signal-to-Noise Ratio (SNR)
and the Receiver Signal Level (RSL) threshold
in point-to-point receivers;
Theory and practice**

Reference

DTR/ATTM-04015

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Access, Terminals, Transmission and Multiplexing (ATTM).

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**may not**", "**need**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the [ETSI Drafting Rules](#) (Verbal forms for the expression of provisions).

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Introduction

Digital Fixed Radio Systems (DFRS) had been historically specified in a relatively large number of specific European Norms produced by ETSI. These ENs were prepared separately and, even if the list of standardized parameters was common to all these ENs, their specific values were defined on a case-by-case basis. The content of the old Point-to-Point ENs was further transferred into the multipart standard EN 302 217 [i.4] while in a first time most of the parameters values were kept unchanged.

As a consequence the RSL figures provided in earlier versions up to V1.4.1 of EN 302 217-2-2 [i.2] are an array of values proposed at different times and corresponding to different technology situations.

1 Scope

The present document provides guidance for the definition of a full set of rationalized RSL values based on the most recent technological state-of-the-art and determined using a common set of rules for all P-P systems within the scope of EN 302 217 [i.4].

As part of the rationalization effort of EN 302 217 [i.4], the present document proposes technical parameters to be used as basis in the calculation of the RSL figures.

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

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2.1 Normative references

The following referenced documents are necessary for the application of the present document.

Not applicable.

2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

- [i.1] ETSI EN 302 217-1: "Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas; Part 1: Overview and system-independent common characteristics".
- [i.2] 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".
- [i.3] 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).
- [i.4] ETSI EN 302 217 (all parts): "Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas".
- [i.5] IEEE 802.16: "IEEE Standard for Air Interface for Broadband Wireless Access Systems".
- [i.6] Recommendation ITU-R F.1101: "Characteristics of digital fixed wireless systems below about 17 GHz".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

air interface interoperability: requirement by which DFRS terminals from different manufacturer can be connected inside the same radio systems

NOTE: It requires standardization of the physical radio layer (e.g. modulation format, digital codings, synchronization procedures, etc.) and part or all of the higher network layers protocols.

digital fixed radio systems: comprise the whole family of Point-to-point (P-P), Point-to-multipoint (P-MP) and Multipoint-to-multipoint (MP-MP) radio equipment (see note 2), which may be used in fixed locations as part of public or private core or access networks (see note 3)

NOTE 1: It is equivalent to the ITU-R definition of Fixed Wireless Systems (FWS) and comprises Fixed Wireless Access (FWA) systems and, in specific cases, their optional extension to Nomadic Wireless Access (NWA).

NOTE 2: The two latter generically identified as Multipoint (MP) systems.

NOTE 3: Analogue systems are no longer implemented; therefore, for the purpose of the present document only digital applications are identified as DFRS.

essential phenomenon: radio frequency phenomenon related to the essential requirements under article 3.2 of the R&TTE Directive [i.3] that is capable of expression in terms of quantifiable technical parameters

harmonized radio frequency band: commonly referred to as a portion of the frequency spectrum that CEPT/ECC (formerly CEPT/ERC) allocates to a specific service through a CEPT/ECC Decision (proper definition is currently under study by CEPT/ERC)

NOTE: It should be noted that, presently, radio frequency bands allocated to Fixed Service are not harmonized.

3.2 Symbols

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

dB	deciBels
GHz	GigaHertz
Hz	Hertz

3.3 Abbreviations

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

AWGN	Additive White Gaussian Noise
BER	Bit Error Ratio
CRL	Carrier Removal Loop
CS	Channel Separation
DEG	Signal Degradation
DFRS	Digital Fixed Radio System
EVM	Error Vector Magnitude
FEC	Forward Error Correction Code
FSK	Frequency Shift Keyed
GF	Galois Field

NOTE: RS code is based on its properties.

IM3	3 rd order Inter Modulation
IMD	Inter Modulations Distortion
IPN	Integrated Phase Noise
ITU-R	International Telecommunication Union - Radiocommunications standardization sector

LDPC	Low Density Parity Checking Code
LNA	Low Noise Amplifier
LO	Local Oscillator
MLC	Multi-Level Coding
N_{DEG}	Degraded noise power
NEB	Noise Equivalent Bandwidth
NF	Noise Figure
PLL	Phase Locked Loop
PN	Phase Noise
PSK	Phase Shift Keying
QAM	Quadrature Amplitude Modulation
RF	Radio Frequency
RRC	Root Raised Cosine

NOTE: A common type of channel filter.

RS	Reed-Solomon code
----	-------------------

NOTE: A common type of forward error correction code.

RSL	Receiver Signal Level
-----	-----------------------

NOTE: Given at dBm of signal at the antenna port.

RX	Receiver
S_{DEG}	Power of a degraded signal
S_{ND}	Signal power without any source of degradation
SNR	Signal to Noise Ratio
TCM	Trellis Coded Modulation
TX	Transceiver
VCO	Voltage Controlled Oscillator

4 Proposed technical parameters

The RSL (Received Signal Level) is defined for the following BER points:

- RSL for $\text{BER} \leq 10^{-6}$
- RSL for $\text{BER} \leq 10^{-8}$
- RSL for $\text{BER} \leq 10^{-10}$

4.1 Forward error correction code

Modern P-P digital fixed radio systems use Forward Error Correction (FEC) Coding, also called Channel Coding, to improve BER performance.

Many types of FECs are available in today's communication world. These codes, specifically when associated to an iterative decoding process, offer unprecedented coding gain, thus enabling new communication schemes to operate closer and closer to the Shannon bound.

The two main categories of FEC are block codes and convolutional codes. Coded modulation is a particular coding scheme where the coding gain results from an expansion of the number of states of the modulation format for a given spectral efficiency rather than by an increase of the transmitted bitrate.

The following coding schemes are currently implemented:

- Block codes, typically Reed-Solomon (RS) codes.
- Coded modulation: Several coded modulation schemes with very similar performance are described in the literature, especially Multi-level coding (MLC) and Trellis Coded Modulation (TCM).

- A combination of an outer code and an inner code, which provides increased BER performance. This combination generally associates a RS code as outer code and a coded modulation scheme as inner code. The benefit of this association is balanced by the higher latency of the transmission system, due to the need to implement an interleaving matrix between the outer and inner codes.
- Turbo codes and/or Low Density Parity Checking (LDPC) codes which, being using iterative decoding techniques, provide results close to the Shannon limit.

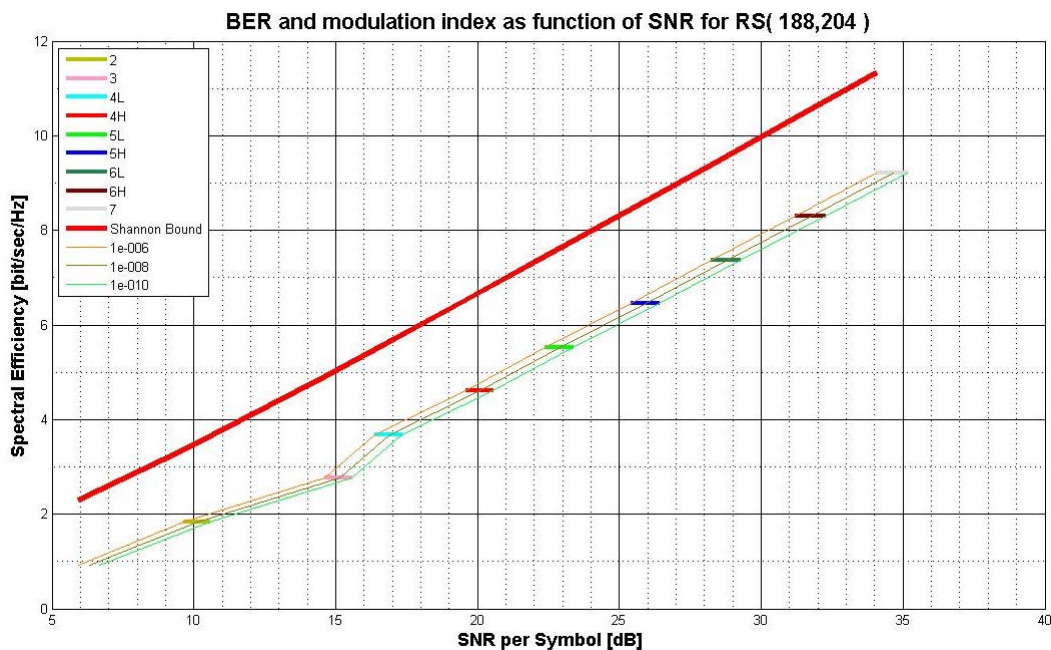
As an example, this clause presents the characteristics in terms of BER of a P-P equipment using two Reed-Solomon codes, RS(204, 188) and RS(200, 190) respectively.

RS(204, 188), which is a Reed-Solomon code over GF(256), has been retained by several standardization bodies. This code has approximately 8 % redundancy and typically corrects up to 8 errored bytes in every block of 204 bytes.

The code RS(204,188) is used in many applications such as DVB-S/T/C, IEEE 802.16 [i.5] and others.

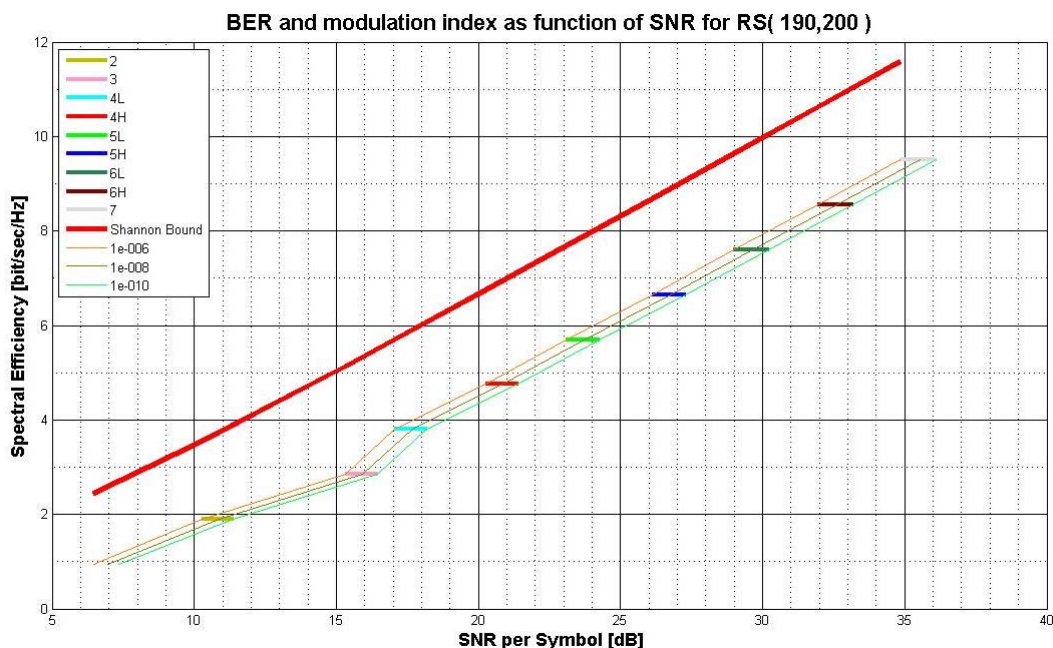
A lower code rate (with approximately 5 % redundancy) is also considered, this code RS(200,190) typically corrects up to 5 errored bytes in every block of 200 bytes.

The performance of RS(204, 188) and RS(200,190) are reported in figure 1 and figure 2 respectively.



NOTE: The spectral efficiency is the "net" one (i.e. divided by 204/188).

Figure 1: BER and modulation index as function of SNR for RS(188,204)



NOTE: The spectral efficiency is the "net" one (i.e. divided by 200/190).

Figure 2: BER and modulation index as function of SNR for RS(190,200)

The Signal-to-Noise Ratio (SNR) for a given BER is a characteristic of the coding and modulation format. The theoretical values of SNR at a BER of 10^{-6} for coded and uncoded systems using modulation formats from 2 PSK to 1 024 QAM are provided in table 1.

Table 1: SNR at BER of 10^{-6} for different modulation and coding formats

Modulation	Uncoded (see note) (dB)	Coded (RS200,190) (dB)	Coded (RS204,188) (dB)
2 PSK	10,5	7,5	6,8
4 QAM	13,5	10,5	9,8
8 PSK	18,8	15,5	14,8
16 QAM	20,5	17,2	16,5
32 QAM	23,5	20,4	19,7
64 QAM	26,5	23,4	22,7
128 QAM	29,5	26,3	25,6
256 QAM	32,5	29,3	28,6
512 QAM	35,5	32,1	31,4
1 024 QAM	38,7	34,8	33,9

NOTE: The values of SNR for uncoded systems from 2 PSK to 512 QAM are taken from Recommendation ITU-R F.1101 [i.6].

Taking into account the proximity of these results a coding gain of 3 dB for all modulation formats has been assumed in the calculations and will reflect "maximal values" of SNR for modern systems implementing coded modulations.

The theoretical SNR values at lower bit rates could also be determined the same way. With the RS error correction code, the $10^{-6}/10^{-10}$ slope is of 1 dB or less.

Nevertheless, such a slope would not reflect properly actual conditions in digital fixed radio systems:

- Even at high C/IM3 ratio, the amount of degradation of different BER thresholds due to C/IM3 ratio is likely not to be the same at different BERs.
- At very low BER, a number of other implementation factors (e.g. scrambling, mapping, clock imprecision, uncoded bytes, etc.) give significant impact to actual SNR that can hardly be simulated.

Therefore, while simulations for BER 10^{-6} , where the thermal noise is the dominant factor, provide appropriate calculation of the degradation, at lower BER a pragmatic approach has been adopted, using a predefined slope between RSL at a BER of 10^{-6} and RSL at lower BER.

Table 2: Derivation of SNR at BER of 10^{-8} and SNR at BER of 10^{-10}

BER	SNR "maximal"
10^{-6}	3 dB coding gain
10^{-8}	SNR at BER of 10^{-6} + 1,5 dB
10^{-10}	SNR at BER of 10^{-6} + 3 dB

4.2 Noise figure and RX duplexer loss

Noise figure and the RX duplexer losses are obviously contributing to the degradation of the sensitivity of the system; they are necessary parameters for defining the RSL threshold.

In common practice, the "system noise figure" is intended as the overall system noise figure composed by the sum of the noise figure of the receiver chain (evaluated from LNA input to the demodulator input) plus the RX side branching loss (duplexer insertion loss).

For a detailed analysis in view of defining a "reference" value for comparison, these two components should be separately analysed.

Practical low noise amplifiers and associated receiver chains for high frequencies have higher noise figure than practical LNAs for lower frequencies. The variation is assumed to be continuously increasing with the frequency. However, the technology impact (mostly for size problems) for lower bands implies that the front-end noise figure may not drop as low as the single active components would permit.

Similarly, also RX side duplexer are subject to a number of factors affecting their losses (evaluated, according to EN 302 217-1 [i.1], at the reference point B or the reference point C when they are coincident). Examples of such factors are:

- Technology: filters may be realized with many technologies for reducing their size and/or their losses and/or their cost. In particular, the change of technology for size constraint tends to compress the variation of the natural increasing of loss with the frequency.
- Channel arrangement: in a number of bands, different channel arrangements with different TX/RX duplex separations are used in different countries. Even if, in most cases, the difference in losses is not a major issue, this fact should be here mentioned and kept in mind.
- Configuration: according to the user needs, different protection configuration or number of channels may be connected to the same antenna port. This implies that the same equipment may be connected to different types of duplexers (e.g. from the simplest 1+0 configuration, to the 1+1 hot-standby, to the N+1 of trunk applications); also outdoor or full indoor mount implies differences from the duplexer point of view.

For providing a homogeneous guidance and the "total reference noise figure", the duplexer losses are defined according the following assumptions:

- a) The technology should not result in inhomogeneous figures. The optimization of cost and performance is a common target; therefore, this should imply that in each band the same technology is likely to be used.
- b) For the channel arrangement variants only the lowest duplex separation, implying the expected highest losses in the band, are considered.
- c) For the configuration only the simplest 1+0 configuration (generally available for all equipment on the market) are considered (see note).

NOTE: Also in link budget analysis the more complex and lossy configurations are often taken into account as "additional losses" over the 1+0 configuration; therefore, this seems the best choice for a homogeneous definition of "reference values".

Table 3 contains the band-by-band information and the suggested "reference values" for the total noise figure, without industrial margin.

Table 3: Typical values for BER threshold determination

Frequency Band (GHz)	"Reference" Total Noise Figure Duplexer Loss + Noise figure (dB)
1,5 (1,350 to 1,517)	4
2 (2,025 to 2,290)	4
L4 (3,4 to 4,2)	5
U4 (4,4 to 5)	5
L6 (5,925 to 6,425)	5
U6 (6,425 to 7,125)	5
7 (7,110 to 7,725)	5
8 (7,725 to 8,500)	5
10,5 (10 to 10,68)	5
11 (10,7 to 11,7)	5
13 (12,7 to 13,25)	5
15 (14,4 to 15,35)	5
18 (17,7 to 19,7)	6
23 (21,2 to 23,6)	6
26 (24,5 to 26,5)	7
28 (27,5 to 29,5)	7
32 (31,8 to 33,4)	7
38 (37 to 39,5)	8
42 (40,5 to 43,5)	8
50 (48,5 to 50,2)	9
52 (51,4 to 52,6)	10
55 (55,78 to 57,0)	10
70 (71 to 76)	13
80 (81 to 86)	13

4.3 Channel Separation (ChS)

The thermal noise density at 300 K is -174 dBm/Hz.

For an errorless communication link, the signal's RSL is expected to be at a certain level above the integrated noise over the bandwidth of the signal.

A receiver that was optimally designed for a signal with root-raised-cosine (RRC) shaping filter has an RRC also as the channel filter.

The Noise Effective Bandwidth (NEB) of an RRC filter is narrower than the ChS by a rolloff factor of the RRC which is assumed to be 90 % of the ChS.

EXAMPLE: A system with ChS of 28 MHz has NEB of $28 \text{ MHz} \times 0,9 = 25,2 \text{ MHz}$.

The integrated thermal noise over 25,2 MHz is equal to $-174 + 10 \times \log_{10}(25,2 \times 10^6) \text{ dBm} = -100 \text{ dBm}$.

4.4 Phase noise

The calculation of the phase noise contribution can be estimated with a model based on some simple assumptions on oscillator phase noise and carrier recovery loop.

Both topics could be more deeply detailed but the following simple assumptions are taken:

- the shape of the round trip phase noise of the complete system drops 20 dB / decade;
- the carrier recovery loop is based on a type II second order PLL.

These assumptions are reasonably taken as common practice.

In order to perform the phase noise contribution calculation, the following four parameters are requested:

- K_{lo} and f_m for the end-to-end phase noise;
- f_c and F_s respectively for recovery loop bandwidth and symbol rate.

Assuming that the phase noise shape is described as in the equation below:

$$L(f) = \frac{K_{lo}}{f^2}$$

The offset frequency f_m and the associated phase noise value K_{lo} identify the curve shown in figure 3.

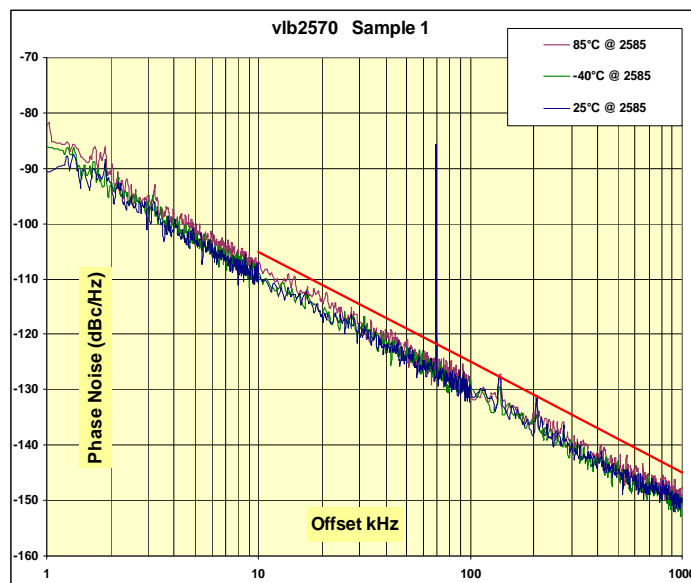


Figure 3: Offset frequency f_m and its associated phase noise value K_{lo}

If the end-to-end phase noise at f_m frequency offset is X_{dB} then:

$$K_{lo} = f_m^2 \times 10^{X_{dB}/10}$$

The carrier recovery loop can be modelled as depicted in figure 4.

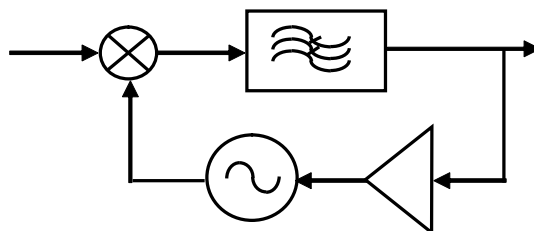


Figure 4: Simplified model for the carrier recovery loop

where $L_{pf}(f)$, $F_{pll}(f)$ and $LO(f)$ are the phase transfer functions of demodulation low pass filter, PLL loop filter and vco. These transfer functions are respectively listed below:

$$L_{pf}(f) = Kl \frac{1}{j2\pi f + F_s/2}$$

$$F_{pll}(f) = K_g \frac{j2\pi f + f_z}{j2\pi f}$$

$$LO(f) = K_{vco} \frac{1}{j2\pi f}$$

The open loop gain results:

$$G_{loop}(f) = L_{pf}(f) F_{pll}(f) LO(f)$$

and the closed loop transfer function is:

$$G(f) = \frac{L(f)}{1 + G_{loop}(f)}$$

The phase variation transfer function of such recovery loop is a high pass filter with slope of 40 dB / decade from 0 Hz to the frequency f_c and no gain until $F_s / 2$.

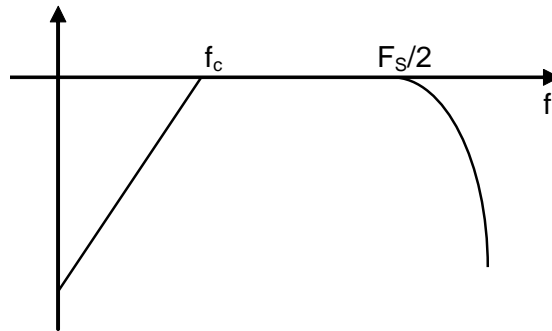


Figure 5: Typical characteristic of Phase Noise transfer function

The integrated phase noise IPN is given by:

$$IPN = 2 \left(\int_0^{F_s/2} L(f) |G(f)|^2 df \right)$$

resulting in the closed formula:

$$IPN = 4K_{lo} \left(\frac{1}{f_c} - \frac{1}{F_s} \right)$$

The calculation is given in rad^2 .

In figure 6 the effect of the recovery loop is graphically shown with two different bandwidths.

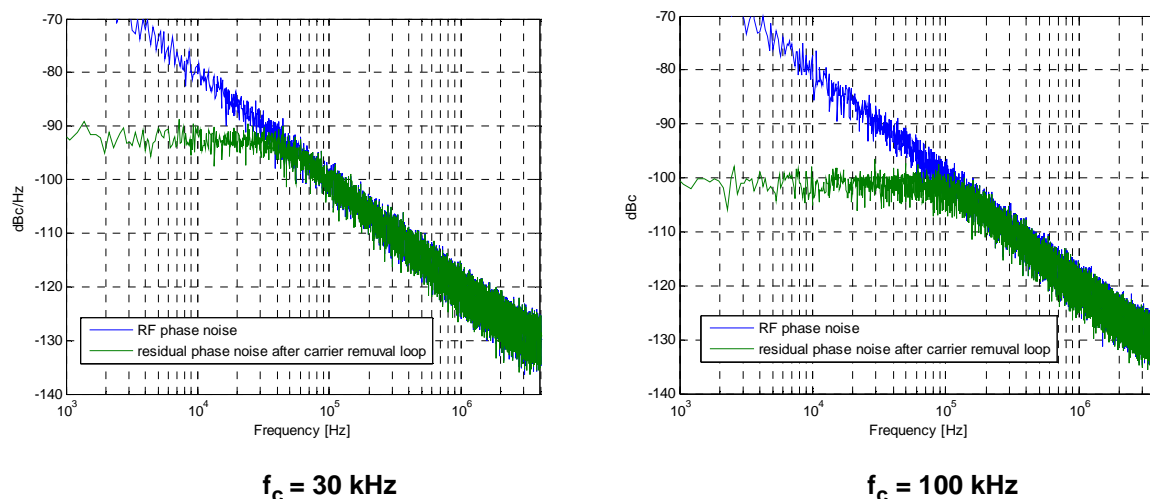


Figure 6: Simulation of Phase Noise for a CRL with different values of f_c

It should be noted that communication links with higher baud rate have higher f_c frequencies and thus proportionally lower integrated phase noise. Furthermore, the residual phase noise is flat up to the recovery loop bandwidth f_c after which it decays at a rate of 20 dB / decay. This is in line with the expectation in the IPN formula derived above.

Additional observation is that the IPN formula gives consistence values for CS greater than 56 MHz. For lower CS (e.g. 28 MHz, 14 MHz and 7 MHz) additional degradation beyond the usual 3dB (industrial margin) occurs. For this purpose the formula in the RSL calculation spreadsheet given in annex B is modified to include a ceiling which provides a maximum of 2 dB degradation.

It should also be mentioned that practical local oscillators tend to have higher K_{LO} normalization factor as the LO frequency is higher.

A simple way to provide the information about a LO characteristics is to give its noise density at +100 kHz and at -100kHz offset to the nominal carrier frequency. Table 4 provides maximal and typical values of phase noise at ± 100 kHz for currently used LO synthesizers.

Table 4: Typical phase noise figures

Frequency band (GHz)	Nominal Phase noise at 100 kHz (two sided spectrum) (dBC/Hz)
1,4 to 2,7	-97
3 to 5	-97
5,9 to 8	-97
10,5 and 11	-94
13 to 15	-94
18	-94
23	-94
26 to 28	-94
32	-91
38 to 42	-91
48 to 50	-88
52 to 55	-88
71 to 86	-80

Maximal phase noise values are assumed to be the end-to-end phase noise, i.e. include the contributions of the synthesizers in both Tx and Rx sides.

The integrated residual phase noise is degrading the signal to noise ratio, the degradation applies only to the dimension of the phase error and does not affect the radial dimension.

Under low BER conditions the phasoric element of the error is the dominant element, given that unlike the phase noise the white thermal noise is evenly spread on both the phasoric and the radial error, the residual phase noise contribution is equivalent to an AWGN noise with twice the power (3 dB higher power).

These two noise sources are used to calculate the combined noise of the signal.

4.5 Non-linear distortion

Practical radio systems are not perfectly linear, their non-linearity is evaluated by the IMD (Inter Modulation Distortion).

The main contributor for IMD is the power amplifier in the transmitter, but in many cases the receiver RF chain is also contributing to the distortion, especially at high RSL levels. The non-linearity of the receiver chain determines the upper bound of the RSL range, the determination of which is outside the scope of the present document.

Since the third order inter modulation products are always the dominant distortion phenomenon (relative to higher odd order inter modulation products, e.g. 5th, 7th, etc.) at achievable output power for a given amplifier, the IMD is practically identical to IM3. The effect of this inter modulation results in an Error Vector Magnitude (EVM) which has been used in the calculations.

Nevertheless, the non-linear contribution cannot be treated as a fixed C/IM3 valid for all BER thresholds, this result may not be valid for each BER. This has been taken into account by deriving RSL at BER of 10⁻⁸ and RSL at BER of 10⁻¹⁰ from the calculated RSL at BER of 10⁻⁶ using a rule of thumb.

For a given power amplifier the EVM is directly dependant of its output level. As by nature the sensitivity of a modulated signal to IM3 is increasing with the number of states of its modulation format, the transmitter is designed so that the non-linear distortion is decreasing as the modulation format is increasing. This is ensured either by decreasing the output Tx level, and/or by designing a more performing pre-distorter associated to the power amplifier. EVM values for various modulation formats are indicated in table 5.

Table 5: EVM for various modulation formats

Modulation format	EVM (dB)
2 PSK, 2 FSK	-20
4 QAM	-23
8 PSK	-26
16 QAM	-29
32 QAM	-32
64 QAM	-35
128 QAM	-38
256 QAM	-42
512 QAM	-46
1 024 QAM	-50

4.6 Internal distortion

The internal distortion is modelled by -54 dBc for all modulations and channel bandwidth settings less than 112 MHz.

For CS greater than 112 MHz, distortion values are given in table 6.

Table 6: Distortion values for CS greater than 112 MHz

CS (MHz)	Quantization Noise (with 10 x log degradation)	Total Distortion
112	-60	-54,0
250	-56,5	-52,8
500	-53,5	-51,3
750	-51,7	-50,1
1 000	-50,5	-49,2
1 250	-49,5	-48,5
1 500	-48,7	-47,8
1 750	-48,1	-47,3
2 000	-47,5	-46,8

Internal distortion includes the internal degradations and/or distortions such as receiver non-linearity, quantization noise, I and Q unbalance, group delay variations and amplitude variations that are inherent in all systems. With high order modulations (class 7 or higher) this degrading effect cannot be omitted.

In the calculations an assumption of having at least four independent contributions of approximately -60 dBc is given. This will end up in 6 dB higher power and therefore -54 dBc is used in the calculations. There is a minor impact on the calculated values but it serves to make the model more complete for future analysis.

4.7 Industrial margin

The performance of various system elements tend to vary over temperature, voltage, aging and production spread.

At higher frequencies the variance is usually higher, because the technology is less mature and pushed closer to its limits. Industrial margin values used in the evaluation of the RSL model are indicated in table 7.

Table 7: Industrial margin for all frequency bands

Frequency band (GHz)	Industrial Margin (dB)
1,4 to 15	3
18 to 28	3
32 to 42	3
48 and 55	3
71 to 86	4

4.8 Evaluation of the RSL

The evaluation of RSL at different BERs for the P-P systems of different classes (i.e. using different modulation formats) within different frequency bands from 1,5 GHz to 90 GHz should take into consideration the following parameters:

- the equivalent noise level at receiver input, resulting from the Noise Equivalent Bandwidth assumed to be equal to 90 % of the CS (see clause 4.3);
- the Noise Figure and Duplexer Loss as reported in clause 4.2;
- the SNR, characteristic of the coding and modulation format (see clause 4.1);
- the industrial margin, as provided in clause 4.7, table 4;
- the residual integrated Phase Noise as described in clause 4.4;
- the Internal Distortion, as evaluated in clause 4.6;
- the Non-linear distortion as described in clause 4.5;
- the formula for RSL calculation used in the spread is described below:

$$RSL[dBm] = -114[dBm] + 10 \times \log_{10}[CS[MHz] \times 0,9] + Noise\ Figure + Industrial\ margin + Required\ SNR\ after\ impairments[dB]$$

while

$$Required\ SNR\ after\ impairments[dB] = -10 \times \log_{10}(10^{-1 \times coded\ SNR\ before\ impairments} - 10^{\frac{internal\ distortion}{10}} - 10^{\frac{Tx\ linearity}{10}} - 10^{\frac{TX\ IPN}{10}} - 10^{\frac{RX\ IPN}{10}})$$

Note that in case required SNR after impairments is more than 2 dB greater than coded SNR before impairments, the required SNR after impairments will be limited to only 2 dB greater than coded SNR before impairments and not according to formula in the spreadsheet given in annex B.

This evaluation process, as well as the equations used in the calculation, are described in annex B.

The evaluation of the total degradation in term of $S / [N + \Sigma(\text{degrading elements})]$ needs careful attention. Annex A shows some visual representation of the formulas used in annex B.

Annex B also includes a limitation on the maximum permitted degradation (currently set to 2 dB). Rational is that the theoretical simulations of phase noise impact relies on "conventional" approach, while nowadays a number of advanced techniques which can hardly be simulated by simple formulas are used. Higher degradation on practical equipment is generally avoided.

Values for RSL at BER of 10^{-8} and RSL at BER of 10^{-10} can be derived using table 2.

The results of the calculations are presented in annex B.

5 Conclusion

The present document provides evaluations of the different phenomena which affect the performance of Point-to-Point Fixed Wireless Systems in order to provide the basis for a unified approach to derive RSL limits.

The results of the calculations reflect a simplified approach which introduces doubts on the feasibility of systems with lower channel separation and high modulation format operating at high frequency bands. However, the theoretical simulations of phase noise impact rely on "conventional" approach, while nowadays a number of advanced techniques which can hardly be simulated by simple formulas are used. Higher degradation on practical equipment is generally avoided by those techniques.

In any case, narrow band systems with channel separation less than or equal to 7 MHz and using modulation format of 1 024 QAM (or higher) is not practical for conventional commercial production of equipment with frequency ranges equal to or greater than 18 GHz.

Annex A: Illustration of Signal to Noise degradation

The general model for S / N degradation illustrating constant BER Reference model is shown in figure A.1 to figure A.3.

The evaluation of the RSL degradation at constant BER requires attention for adding up "C/DEG constant" degradation (i.e. due to EVM and IPN distortion) to "S / N variable" ratio; it is based on the following definition of ratios:

S_{ND} / N : basic S / N at certain BER (10^{-6} in the spreadsheet) without any source of degradation. It has been derived at BER = 10^{-6} from uncoded values given in Recommendation ITU-R F.1101 [i.6] minus conservative 3 dB of coding gain.

S_{DEG} / N_{DEG} : final S / (N + DEG) at same BER (10^{-6} in the spreadsheet)

Being related to the same BER, they are linked by the equations:

$$S_{ND} / N \text{ (dB)} = S_{DEG} / N_{DEG} \text{ (dB)};$$

$$S_{ND} / N_{DEG} \text{ (dB)} = S_{ND} / N \text{ (dB)} - \text{DEG (dB)};$$

where DEG is the degradation in dB of the Noise floor assumed to be = -114 + NF (dB).

Figure A.1 graphically shows the above concepts.

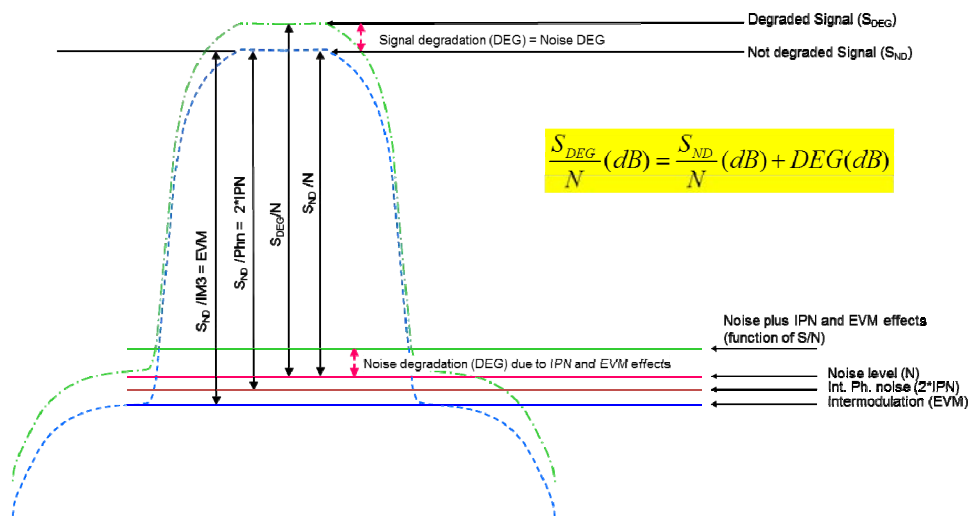


Figure A.1: S / N degradation - Constant BER Reference model (general model)

First step is to evaluate the total S / Σ(DEG) derived, in absence of noise contribution (i.e. in clear sky propagation) from IM3 parameter (EVM) and phase noise (IPN). Figure A.2 shows the mathematical passages.

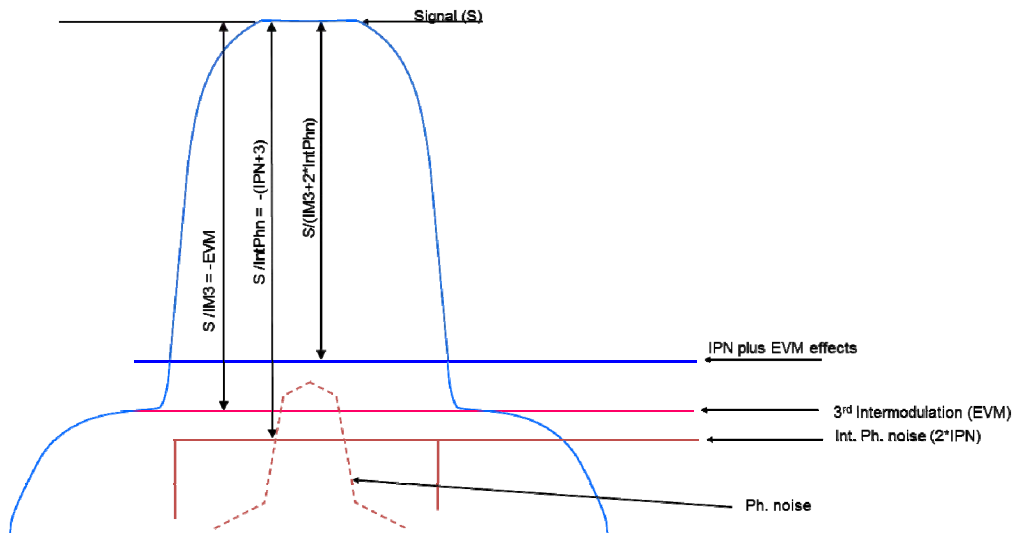


Figure A.2: S / N degradation : S / Imprecisions (1st step clear sky)

Second step is to evaluate the total S_{DEG} / N at constant BER at threshold, which reflects the RSL degradation being looked for. Figure A.3 shows the concept and the mathematical passages.

$$\frac{S}{Imprecision} = \frac{S}{IM3 + 2 \times IntPhn} (dB) = 10 \times \log\left(\frac{1}{10^{10} + 2 \times 10^{10} \frac{EVM}{IPN}}\right)$$

In the second step the noise imprecision is taken into account as illustrated in figure A.3 and the equation below.

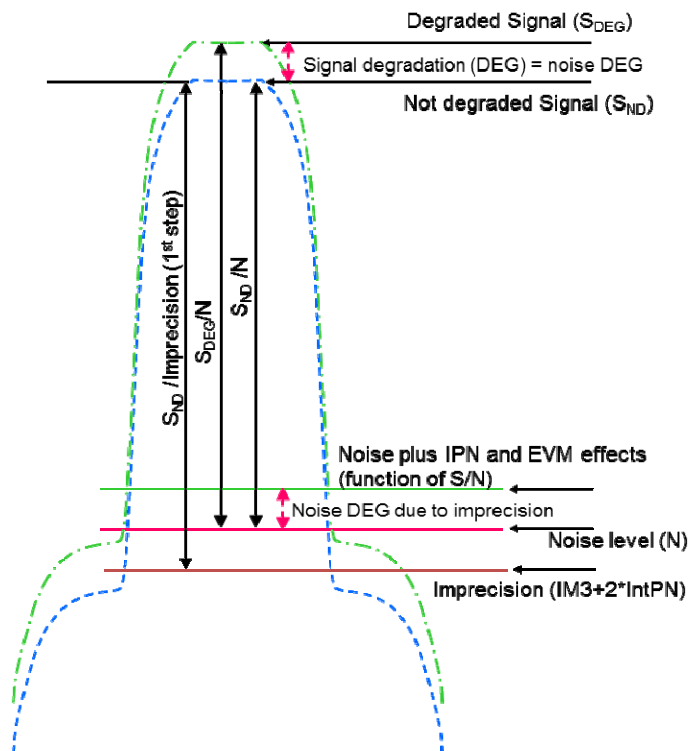


Figure A.3: S / N degradation : S_{DEG} / N at constant BER (second step at threshold)

General model :
$$\frac{S_{DEG}}{N} (dB) = \frac{S_{ND}}{N} (dB) + DEG(S/N; EVM; IPN)(dB)$$

$$DEG(dB) = 10 \log \left(\frac{N + Imp}{N} \right) = 10 \log \left(\frac{\frac{N}{S_{ND}} + \frac{Imp}{S_{ND}}}{\frac{N}{S_{ND}}} \right) = 10 \log \left[\frac{S_{ND}}{N} * \left(\frac{N}{S_{ND}} + \frac{Imp}{S_{ND}} \right) \right]$$

$$DEG(dB) = \frac{S_{ND}}{N} (dB) + 10 \log \left(10^{\frac{\frac{S_{ND}}{N}}{10}} + 10^{\frac{\frac{S_{ND}}{Imp}}{10}} \right) = \frac{S_{ND}}{N} (dB) + 10 \log \left(10^{\frac{\frac{S_{ND}}{N}}{10}} + 10^{\frac{EVM}{10}} + 2 * 10^{\frac{IPN}{10}} \right)$$

\Rightarrow **2nd step** \Rightarrow **1st + 2nd step** \Rightarrow

$$\frac{S_{DEG}}{N} (dB) = \frac{S_{ND}}{N} (dB) + \frac{S_{ND}}{N} (dB) + 10 \log \left(10^{\frac{\frac{S_{ND}}{N}}{10}} + 10^{\frac{EVM}{10}} + 2 * 10^{\frac{IPN}{10}} \right)$$

$$\frac{S_{DEG}}{N} (dB) = 2 * \frac{S_{ND}}{N} (dB) + 10 \log \left(10^{\frac{\frac{S_{ND}}{N}}{10}} + 10^{\frac{EVM}{10}} + 2 * 10^{\frac{IPN}{10}} \right)$$

Annex B: Evaluation of the RSL spreadsheet

The spreadsheet describing the evaluation process as well as the equations used in the calculation is contained in archive tr_103053v010101p0.zip which accompanies the present document.

History

Document history		
V1.1.1	September 2014	Publication