RTT TECHNOLOGY TOPIC
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3 G demodulation budget

This article continues the theme of September's Hot Topic in which we considered the influence of the receiver bandwidth on the noise generated in the receiver front end. The bandwidth was derived from considering the modulation characteristics.

Output Signal (Baseband) Quality

As part of the process in determining the receiver sensitivity it is necessary to consider the minimum acceptable output quality.

This will be considered initially in terms of the demodulation characteristics and without reference to any coding gains.

This minimum acceptable output quality (SINAD in analogue systems, BER in digital systems) will be produced by a particular RF signal input level at the front end of the receiver. This signal input level defines the sensitivity of the receiver.

Demodulator Characteristics

To achieve the target output quality (1×10^{-3} and 1×10^{-6}) a specified signal (or carrier) quality will be required at the input to the demodulator.

The quality of the demodulator signal is defined by its E_b/N_o value, where

E_b is the energy per bit of information
N_o is the noise power density – ie the thermal noise in 1 Hz of bandwidth.

The demodulator output quality is expressed as an output BER.

The Bit Error Rate (BER) or Probability of Bit Error (P_b) against E_b/N_o dB is derived from the expression:

$$P_b = \tfrac{1}{2} Q[(E_b/N_o)^{1/2}]$$

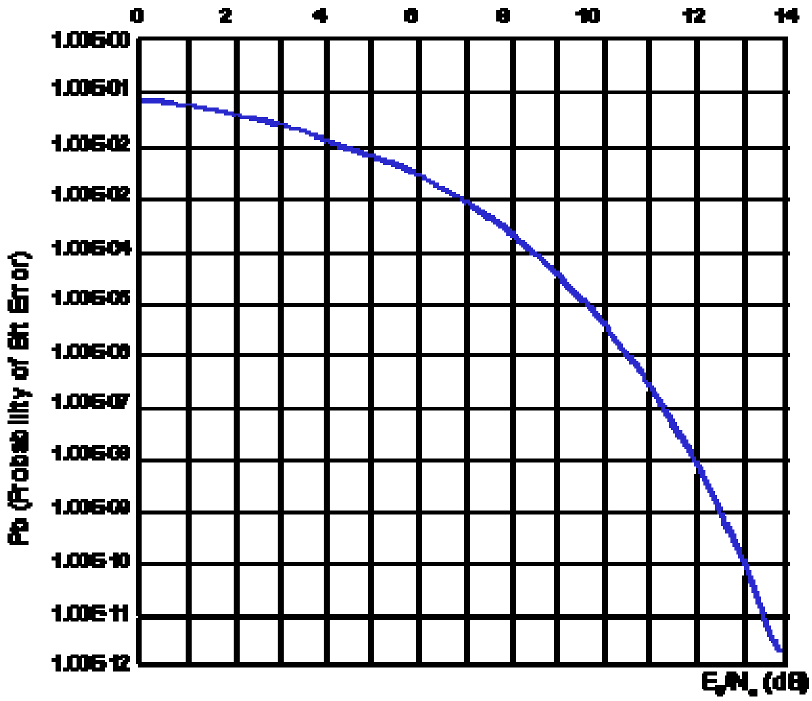
Where:

Q(x) = complementary error function

E_b = energy required per bit of information

N_o = noise power density (thermal noise in 1 Hz of bandwidth)

This maybe shown graphically:



Bit Error Performance of a Coherent BPSK/QPSK System

From the curve

BER 1×10^{-3} = 6.8 dB (E_b/N_o)

= 4.78 (Ratio)

BER 1×10^{-6} = 10.5 dB (E_b/N_o)

= 11.22 (Ratio)

E_b/N_o is that value of energy per noise power spectral density required to yield a specified error probability. Note that it is independent of the system data rate.

To evaluate receiver sensitivity in any particular case it is necessary to quantify the signal presented to the demodulator.

The demodulator must detect this signal in the presence of noise and output an acceptable BER.

Carrier to Noise Ratio

As the desired signal is a modulated carrier waveform (RF or IF), the Carrier to Noise Ratio (C/N or CNR) is referred to as the SNR of particular interest.

The C/N is obtained by applying both the date rate (R) and system bandwidth (B_T) to the signal.

$$C/N = (E_b/N_o) \times (R/B_T)$$

For QPSK

B/W(B_T)	= Data Rate (R)
R/B_T	= 1

[For BPSK

B/W(B_T)	= 2 x Data Rate (R)
R/B_T	= 0.5]

So (E_b/N_o) x (R/B_T) can be calculated for each of the BER requirements.

Eg for BER 1 x 10^{-3}

E_b/N_o	= 4.78 (linear)
Modulation format	= QPSK
So R/B_T	= 1.0
Therefore (E_b/N_o) x (R/B_T)	= 4.78 x 1.0
	= 4.78 (linear)
	= 6.8 dB

For BER 1 x 10^{-6}

E_b/N_o	= 11.22 (linear)
Modulation format	= QPSK
So R/B_T	= 1.0
Therefore (E_b/N_o) x (R/B_T)	= 11.22 x 1.0
	= 11.22 (linear)
	= 10.5 dB

Maximum (theoretical) receiver sensitivity can now be calculated:

For BER 1 x 10^{-3}:

Signal Type (Data Rate kb/s)	**Sensitivity (Floor sensitivity + C/N)**	**Resultant Sensitivity dBm**
1 (32)	-124 + 6.8	-117.2

2 (64)	-121 + 6.8	-114.2
3 (1024)	-108.9 + 6.8	-102.1
4 (2048)	-105.9 + 6.8	-99.1

For BER 1 x 10^{-6}:

Signal Type (Data Rate kb/s)	**Sensitivity (Floor sensitivity + C/N)**	**Resultant Sensitivity DBMS**
1 (32)	-124 + 10.5	-113.5
2 (64)	-121 + 10.5	-110.5
3 (1024)	-108.9 + 10.5	-98.4
4 (2048)	-105.9 + 10.5	-95.4

This sensitivity is expressed without the benefit of coding gain.

Coding Gain

Digital modulation schemes have the ability to carry extra bits, used as additional 'qualifiers' to the data being carried.

These extra (or code) bits may be applied in a number of different ways – or coding methods.

Each different coding method (block ie RS, BCH etc or convolutional ie Viterbi, tree etc.) is optimum at detecting or correcting different impairment types found in typical propagation conditions, eg Gaussian distributed noise, multipath distortion, contiguous bit errors etc. Codes may also be concatenated in order to cascade their effectiveness.

In the mobile radio environment both block codes and convolutional codes are used. A new class of code process has been adopted for higher BER classes in Wideband CDMA – Turbo Coding

This may be taken as an improvement to receiver sensitivity.

The combination of Reed Solomon and Viterbi coding gives an improvement of 6 to 7 dB. Turbo coding used on the 1 x 10^{-6} traffic adds a further 1.5 to 3 dB.

The receiver sensitivity figures will improve to:

Data Rate	**10^{-3} BER**	**10^{-6} BER**
32 kbs	-123.5/-124.5 dBm	-121/-123.5 dBm
64 kbs	-120.2/-121.2 dBm	-118/-120.5 dBm
1024 kbs	-108.1/-109.1 dBm	-105.9/-108.4 dBm
2048 kbs	-105.1/-106/1 dBm	-102.9/-105.4 dBm

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