$C/N \& E_b/N_o$

Modified from: Signal-to-Noise, Carrier-to-Noise, Eb/No on Signal Quality Ratios by Wolfgang Damm, Noisecom, https://www.google.com/un?aart&rct-j@gn-@scrvs.ksource-web&cd+1&cad-rja&uact-v&xed-loah.UKEwi6cton2_LohkUkAMKHV1uchQDGggMAA&url+http%3A%2F%2Fwww.noisecom.com%2F-%2Fmedia%2FNoisecom%2FWebinars%2FSN%2520CN%2520EbNo.ashx&usg-AFQjCNEOfVqyY7EAwN1 5/Hwift-Y9fhorisok2Rsig23-44wvGcGv-W9florTzYgGOA.

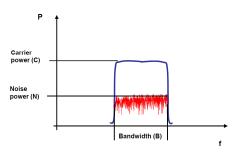
Carrier to Noise Ratio (C/N)

What is it?

C/N is the ratio of the relative power level to the noise level in the bandwidth of a system.

Why:

Allows to analyze if a carrier can still be recognized as such, or if it is obliterated by ambient and system noise. C/N Provides a value for the quality of a communication channel.



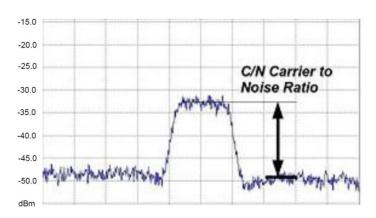
 \boldsymbol{C} and \boldsymbol{N} may be measured in watts or in volts squared

How:

The quality of the system is usually determined through BER plots against C/N.

Modified from: Signal-to-Noise, Carrier-to-Noise, Eb/No on Signal Quality Ratios by Wolfgang Damm, Noisecom,
https://www.google.com/un?a=t&rrti@q=&err=s&source=web&cd=1&cad=rja&uact=&&ved=0ahUKEwi6cthop=LahlukMikHVLLQCOgg@hMAAd=urhstpx%334%2F%2Fwww.noisecom.com%2F~%2Fmedia%2FNoisecom%2FWebinars%2FSN%2520CN%2520EbNo.ashx&usg=AFQ|CNEOfVqyY7EAwN1
5OHwTCv9DndssQ&sig2=44wxCgu-W9l6oT2v1gG00A

C/N Example



Example: Spectrum of a QPSK signal interfered by ambient white noise. The horizontal axis shows the frequency in Hertz, and the vertical axis the power in dBm In this example, the C/N is (-32.5 dBm) – (-48 dBm) = 15.5

Modified from: Signal-to-Noise, Carrier-to-Noise, Eb/No on Signal Quality Ratios by Wolfgang Damm, Noisecom, https://www.google.com/un?a=t&rct-igkq=&escrs&source=web&cd=1&caderja&uact=&&ved-doah.UKEwi6cfbne_LAhlik&MeHVLsCOOggeffMAAGuriehttpiX33X02FK2Fwww.noisecom.com%2F~%2Fmedia%2FNoisecom%2FWebinars%2F3N%2520CN%2520ENo.ashx&usg=AFQ|CNEOfVqyY7EAwN1 50HwtTcV9DndssQ&sig2=44wxGou-W9l6oTZv1gGooA

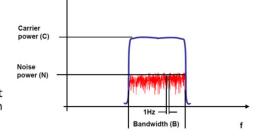
Carrier to Noise Spectral Density Ratio (C/No)

What is it?

C/No is the ratio of the power level to the noise power spectral density (normalized noise level relative to 1 Hz) in a system.

Why:

Similar as C/N but C/No does not factor the actual noise bandwidth in. This simplifies analysis of systems where variation of the (utilized) BW may apply.



How:

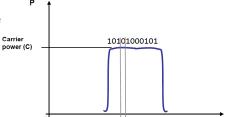
As C/N, C/No is usually determined through BER plots.

Modified from: Signal-to-Noise, Carrier-to-Noise, Et/No on Signal Quality Ratios by Wolfgang Damm, Noisecom, https://www.google.com/ur/?a=t&rct-igkq=&er-rs&source=web&cd=t&cad=rja&uact=&eed=abUKEwi6cfbpe_LAbulk&McWHU.CDCOgg@McMaculertbp%33/8/2F%2Fwww.noisecom.com%2F~%2Fmedia%2FNoisecom%2FWebinars%2F3N%2520CN%2520EbNo.ashx&usg=AFQ|CNEOfVqyY7EAwN1 5OHw/TcV9DndsxQ&sig2=44wCGu-W9|6oTzV1gG00A

Energy per Bit (Eb)

What is E_b?

Energy per information bit (i.e. the energy per bit net of FEC overhead bits). Carrier power divided by actual carrier power (c) information bits.



 $E_b = C/R$

where

C is the carrier power, and

R is the actual information bit rate.

Simplified depiction of \mathbf{E}_b . Bits in modulation schemes are not as shown directly linked to a certain frequency.

Why?

Using the Eb rather than overall carrier power (C) allows comparing different modulation schemes easily.

Unit of Eb is:

Joules [J], Watts/Hz [W/Hz] or Watts * s [Ws]. All three units express the very same metric..

Modified from: Signal-to-Noise, Carrier-to-Noise, Eb/No on Signal Quality Ratios by Wolfgang Damm, Noisecom, https://www.google.com/url?sa-t&rctvj&q=&sercvs&source=web&cd=1&cad=rja&uactvs&wed=UahUKEwi6-clDn*_LADUkMMKHY1ctOcQ/rgg/MAA&UMS-thtySiAM2F9k2Fwww.noisecom.com%2F%2Fmedia%2FNoisecom%2FWebinars%2FSN%2520CN%2520ENO.ashu&usg=AFQjCNEDfVqYYFAwN1

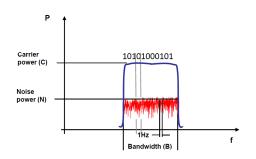
Energy per Bit to Noise Spectrum Density (E_b/N_o)

What is it?

 E_b/N_{\circ} is the ratio of the Energy per Bit divided by the noise power density.

Why:

Allows comparing bit error rate (BER) performance (effectiveness) of different digital modulation schemes. Both factors are normalized, so actual bandwidth is no longer of concern.



How:

Modulation schemes are compared through BER plots against $E_{\rm b}/N_{\rm o.}$

E_{b /} N₀ is a dimensionless ratio.

Modified from: Signal-to-Noise, Carrier-to-Noise, Et/No on Signal Quality Ratios by Wolfgang Damm, Noisecom, https://www.google.com/un7sa=t&rct=igkq=&scr=s&source=web&cd=1&cad=rja&uact=s&ved=0ahUKEwi6cfbpe_LAbult&McWHU.CDC0fggfMAAuriehttp%.3A3N2F%2Fwww.noisecom.com%2F~%2Fmedia%2FNoisecom%2FWebinars%2FSN%2520CN%2520EbNo.ashx&usg=AFQjCNEOfVqyY7EAwN1 sOHwiTcV9OndxsQ&sig2=44wCGu-W9l6oT2v1g60oA

Correlation: C/N, C/No and $E_{b/}N_{o}$

C/N, C/No and Eb/No are correlated

$$C/N = C/(N_o * B) = (E_b/N_o) * (R/B)$$

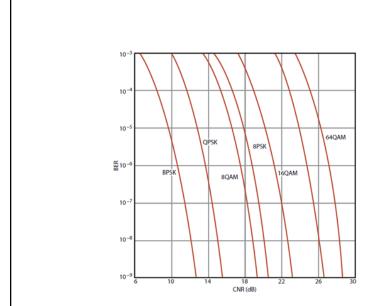
$$E_b / N_o = (C / N) * (B / R)$$

$$N_o = (N * E_b * R) / B * C$$

- B channel bandwidth in Hertz;
- C total carrier power
- N total noise power in the bandwidth.

 $C/N_{dB} = 10 \log (Eb/No) + 10 \log (R/B)$

Modified from: Signal-to-Noise, Carrier-to-Noise, Et/No on Signal Quality Ratios by Wolfgang Damm, Noisecom,
https://www.google.com/unl?a=t&crt=i8qn=&serr=8,source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwi6ctnip=_LAhulkaMMHYJucbQOFggfMAA&uri=http%3A%2F%2Fwww.noisecom.com%2F~%2Fmedia%2FNoisecom%2FWebinars%2FSN%2520CN%2520ENo.ashv&usg=AFQjCNEOfVqyY7EAwN1
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From: http://electronic design.com/communications/understanding-modern-digital-modulation-techniques