

Noise and receivers

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Noise and receivers

- ▶ The importance of noise
- ▶ Definition of noise
- ▶ Thermal noise
- ▶ ‘Measuring’ noise
- ▶ Other noise distributions
- ▶ Noise and amplifiers
- ▶ Signal and Noise
- ▶ Noise and receivers
- ▶ Receiver specifications

Noise and receivers

- ▶ Receiver noise sources
- ▶ Expected ambient noise
- ▶ Combining noise sources

The importance of noise

- ▶ Noise is one of the two factors in Signal/Noise ratio, a most important indicator of readability of signals
- ▶ We often focus on the S part of S/N ...
 - high power transmitters
 - antenna gain
- ▶ ... ignoring the N part!

What is noise

- ▶ Noise is any unwanted energy that degrades a desired signal

Thermal noise

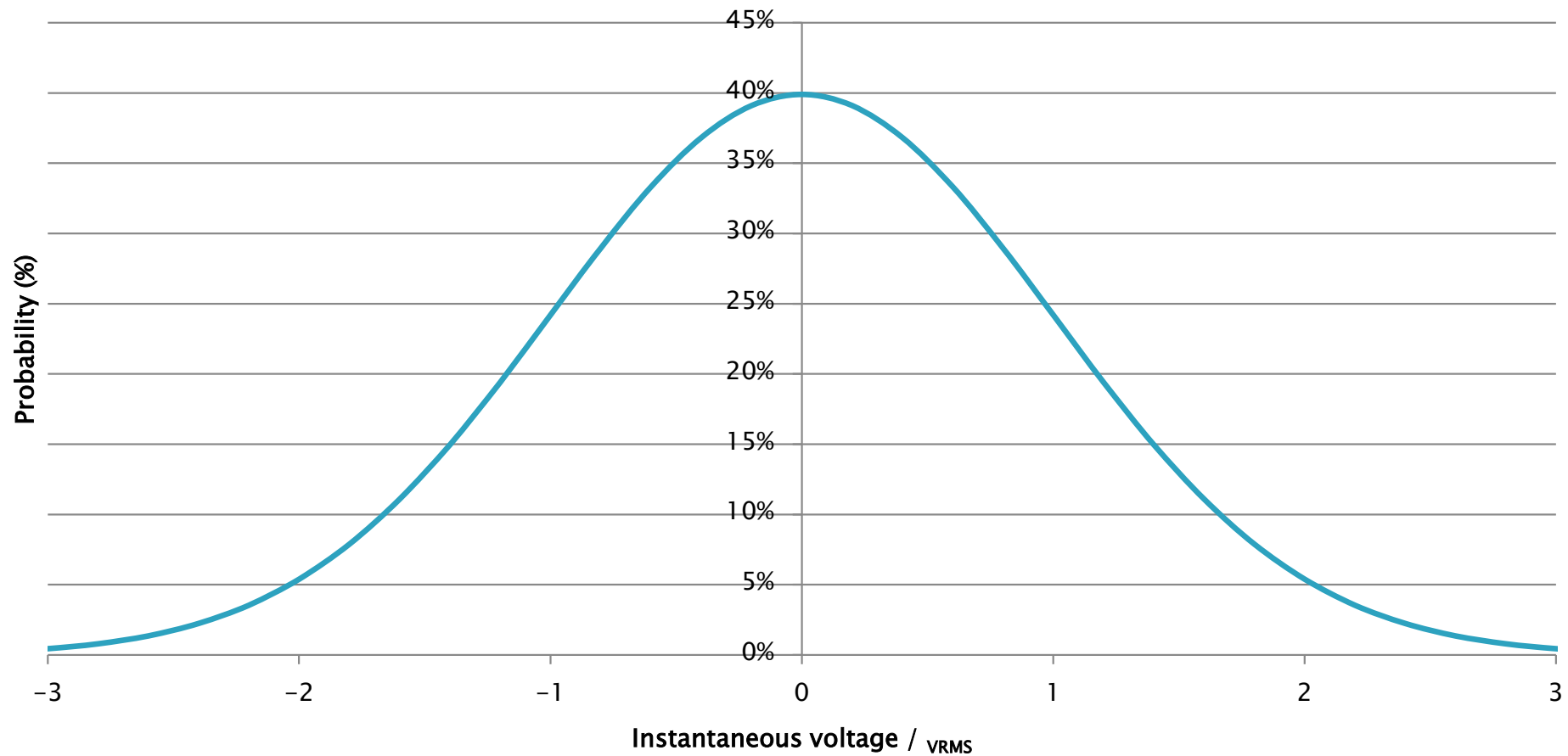
- ▶ Thermal noise (Johnson Noise, Nyquist Noise) is:
 - electronic noise created by the thermal agitation of electrons inside a conductor
 - created by virtue of the absolute temperature of the conductor, and independent of any externally applied current
- ▶ Thermal noise power per unit bandwidth is approximately independent of frequency (white noise)
- ▶ Power available from a resistance is:
 - $P_N = k_B T B W$ where
 - B is bandwidth (Hz)
 - T is the absolute temperature of the resistance (K)
 - k_B is Boltzmann's constant (1.38×10^{-23} J/K)
- ▶ Noise Power Density available can be calculated as:
 - $NPD = k_B T W / \text{Hz}$

Thermal noise (2)

- ▶ Noise voltage generated in a resistance is:
 - $V_N = \sqrt{4k_B T B R}$ V where
 - R is resistance (Ω)
- ▶ Thermal noise is created by a random process
- ▶ Statistical equivalent
 - instantaneous voltage is Gaussian, ie it behaves like a Normally distributed independent random variable with a mean and variance:
 - $V_{DC} = \text{mean (0)}$; and
 - $V_{RMS} = \sqrt{\text{variance}}$

Thermal noise (3)

Probability distribution of thermal noise



‘Measuring’ noise

- ▶ Successive ‘measurements’ don’t capture exactly the same phenomena
- ▶ Noise is sampled rather than measured
- ▶ Additional element of uncertainty due to the sampling process

‘Measuring’ noise (2)

- ▶ Measurement instruments / techniques:
 - bandwidth
 - integration period
 - true power (RMS voltage)
 - averaging detector
 - quasi peak detector

Other noise distributions

- ▶ Pink noise
- ▶ Band limited

Noise and amplifiers

- ▶ practical / imperfect amplifiers
- ▶ noise equivalences – power, voltage, temperature, resistance
- ▶ cascading stages – gain, noise power, equivalent input noise
- ▶ system equivalent noise
- ▶ source noise

Signal and Noise

- ▶ Signal to Noise (S/N)
 - conceptual, often not directly measured
- ▶ $(S+N)/N$
 - quite measurable
 - can be converted to S/N , $S/N = (S+N)/N - 1$
- ▶ SINAD
 - $(S+N+D)/(N+D)$
 - similar to $(S+N)/N$, but recognises Distortion component
- ▶ Noise Factor / Noise Figure
 - the degradation of S/N by a system component

Signal and Noise (2)

- ▶ S/N ratio – ALWAYS a power ratio
 - can be expressed in dB
 - $\frac{S}{N} = 10 \log \left(\frac{P_{S+N}}{P_N} - 1 \right)$ dB
 - $\frac{S}{N} = 10 \log \left(10^{\frac{\frac{P_{S+N}}{P_N} \text{ dB}}{10}} - 1 \right)$ dB
- ▶ (S+N)/N ratio – ALWAYS a power ratio
 - can be expressed in dB
 - $10 \log \left(\frac{P_{S+N}}{P_N} \right)$ dB
 - $20 \log \left(\frac{V_{S+N}}{V_N} \right)$ dB
- ▶ SINAD ratio – ALWAYS a power ratio
 - can be expressed in dB
 - the ratio of the total power level (Signal + Noise + Distortion) to unwanted power (Noise + Distortion)

Signal and Noise (3)

- ▶ Noise Figure is a measure of the degradation of S/N ratio – ALWAYS a power ratio expressed in dB

- $NF = 10 \log \left(\frac{\left(\frac{S}{N}\right)_{in}}{\left(\frac{S}{N}\right)_{out}} \right) \text{ dB}$

- $NF = \left(\frac{S}{N}\right)_{in} \text{ dB} - \left(\frac{S}{N}\right)_{out} \text{ dB}$

Noise and receivers

▶ Noise Figure

- good measure, bandwidth independent
- measurement possible, Y factor method, usually with known broadband noise source (diode noise source, resistors at known temperature, cold sky, Sun, other Celestial objects)

▶ Sensitivity

- bandwidth dependent
- states signal level for given S/N , $(S+N)/N$, SINAD
- measured with Standard Signal Generator and audio output power measuring instrument (could be automated SINAD meter)

Noise and receivers (2)

- ▶ Equivalent Noise Temperature
 - good measure, bandwidth independent
 - not usually directly measured
 - can be calculated from Noise Figure
 - not usually expressed in dB
 - mainly used for very low noise systems
- ▶ Noise Floor
 - bandwidth dependent
 - equivalent system noise referred to input terminals
 - can be measured directly, but usually calculated from an indirect measurement
 - often expressed as dBm, need to know bandwidth

Noise and receivers (3)

- ▶ Minimum Discernable Signal (MDS)
 - bandwidth dependent
 - ARRL preference, and fundamental to some other ARRL used terms
 - misleading term (it is possible to copy CW well below MDS)
 - meaning and measurement is as per Noise Floor

Receiver specs – examples

- ▶ Elecraft K3: "Sensitivity: -136 dBm or better (typical), 500Hz b/w."
 - is preamp ON/OFF?
 - what is the S/N?
 - is the 500Hz b/w effective noise bandwidth?

Receiver specs – examples

- ▶ Kuhne TR 1296 H-144: “RX gain min 20 dB, Noise figure @ 18 °C typ 1.2 dB”
 - what is worst case NF?
 - otherwise, complete and meaningful

Receiver specs – examples

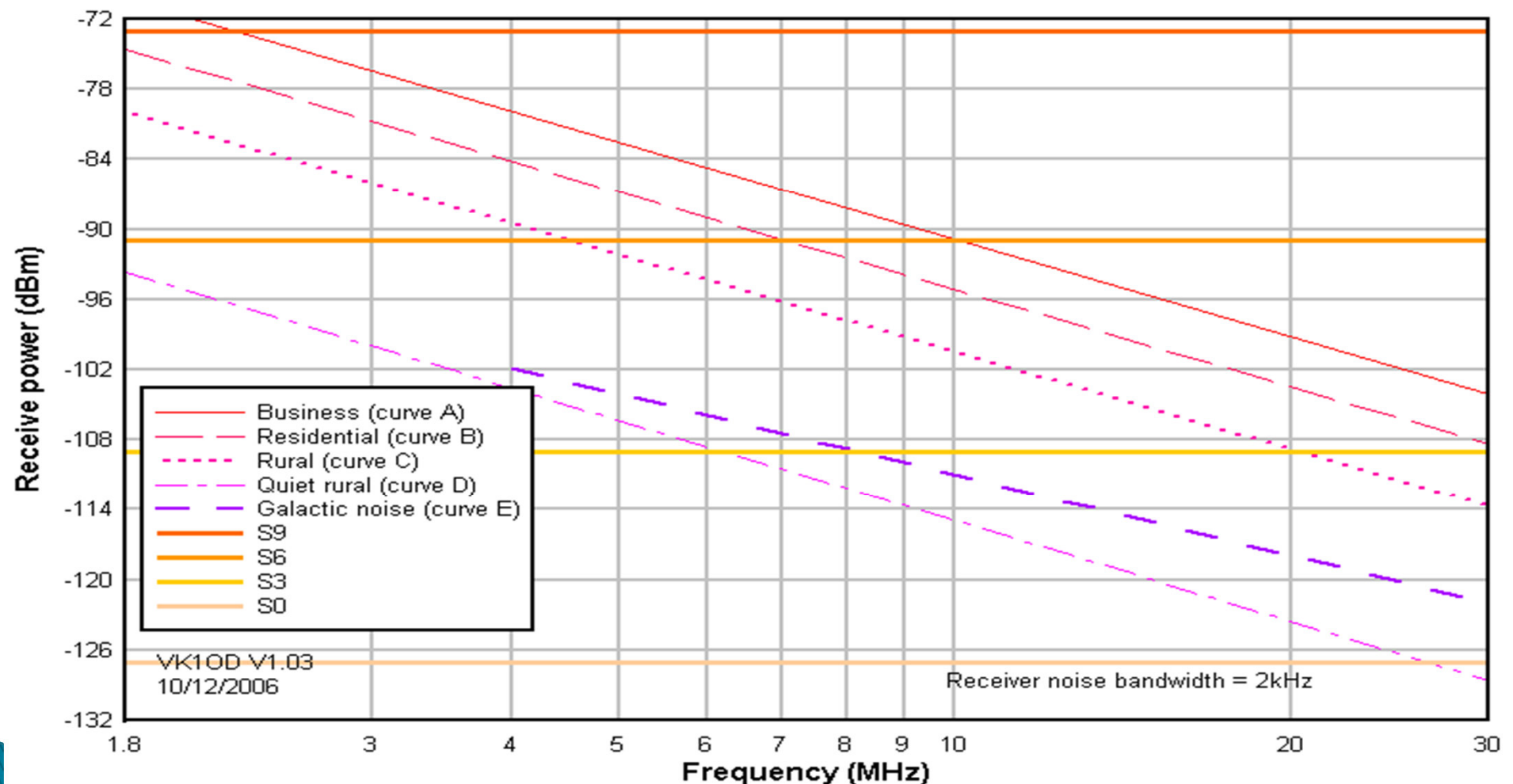
- ▶ Icom 7800: “Sensitivity (typical) (BW: 2.4 kHz at 10dB S/N) SSB 1.8–29.999 MHz 0.16 μ V (Preamp 1 ON)”
 - what is worst case?
 - is bandwidth effective noise bandwidth?
 - otherwise, complete and meaningful

Receivers – noise sources

- ▶ internal
- ▶ external (ambient)
 - man made noise (QRM)
 - galactic noise (Q??)
 - atmospheric noise (QRN)

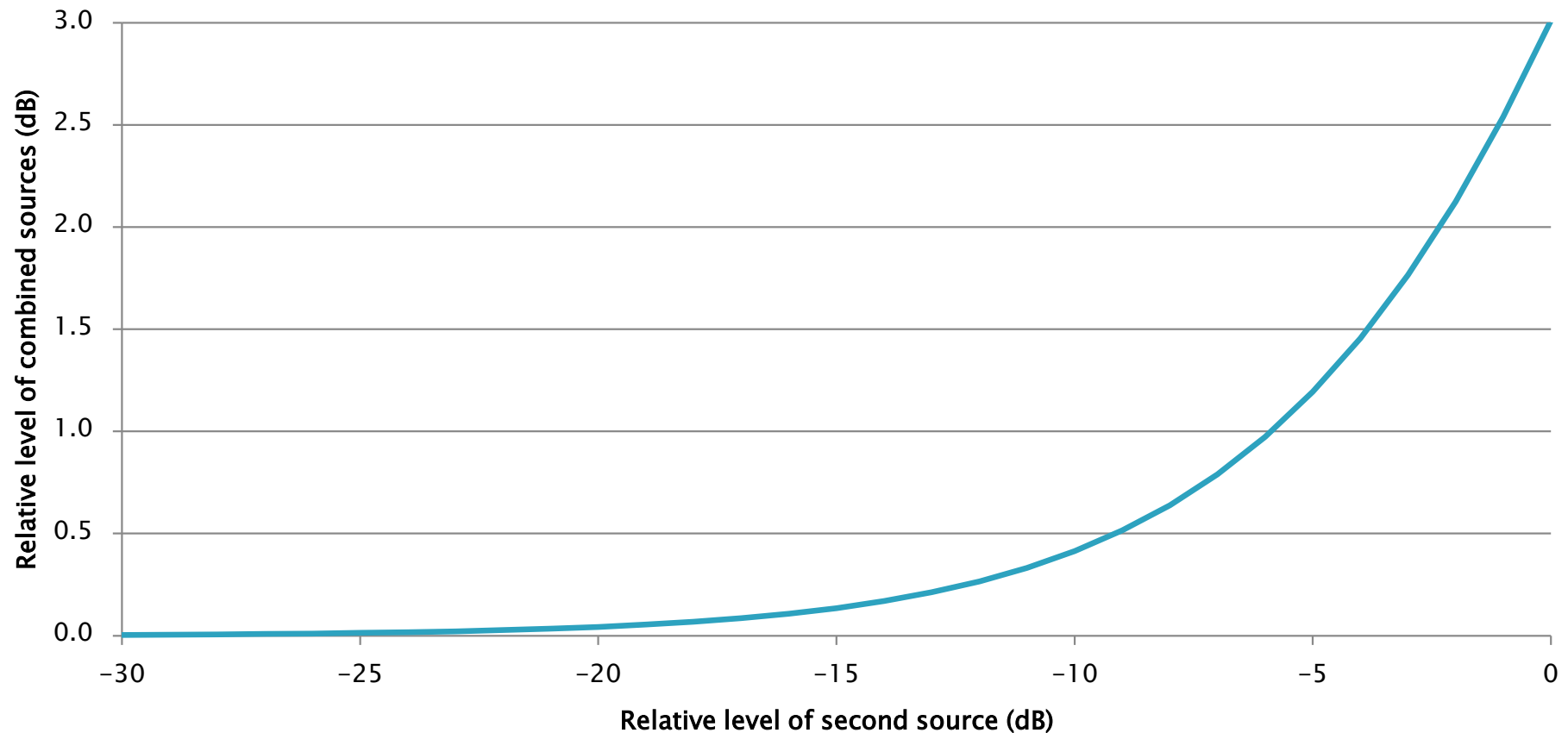
Expected ambient noise

Expected Ambient Noise (per ITU-R P.372-8) (Lossless isotropic antenna)



Combining noise sources

Combining two noise sources



Combining noise sources – Ex

- ▶ Receiver noise floor (preamp OFF) in 2kHz
 - -125dBm
- ▶ 40m residential, assume ambient noise is per ITU-R P.372-8
 - -91dBm with lossless 0dBi antenna
- ▶ Ambient noise is 34dB above receiver noise
- ▶ For less than 1dB S/N degradation due to receiver noise
 - we want external noise fed to the receiver to be at least 6dB higher
- ▶ We can afford antenna system gain to be as low as -28dBi

Links / tools

- ▶ Receiver sensitivity metric converter
 - <http://owenduffy.net/calc/RxSensitivityCalc.htm>
- ▶ Expected ambient noise level
 - <http://owenduffy.net/measurement/noise/FSAmbientNoise.htm>
- ▶ Convert Vpk-Vpp-Vrms-dBV-dBu-mW-dBm
 - <http://owenduffy.net/calc/voltcnv.htm>
- ▶ Signal to Noise ratio degradation by receiver internal noise
 - <http://owenduffy.net/calc/snd.htm>

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Slides available on-line

- ▶ <http://owenduffy.net/presentations.htm>

