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

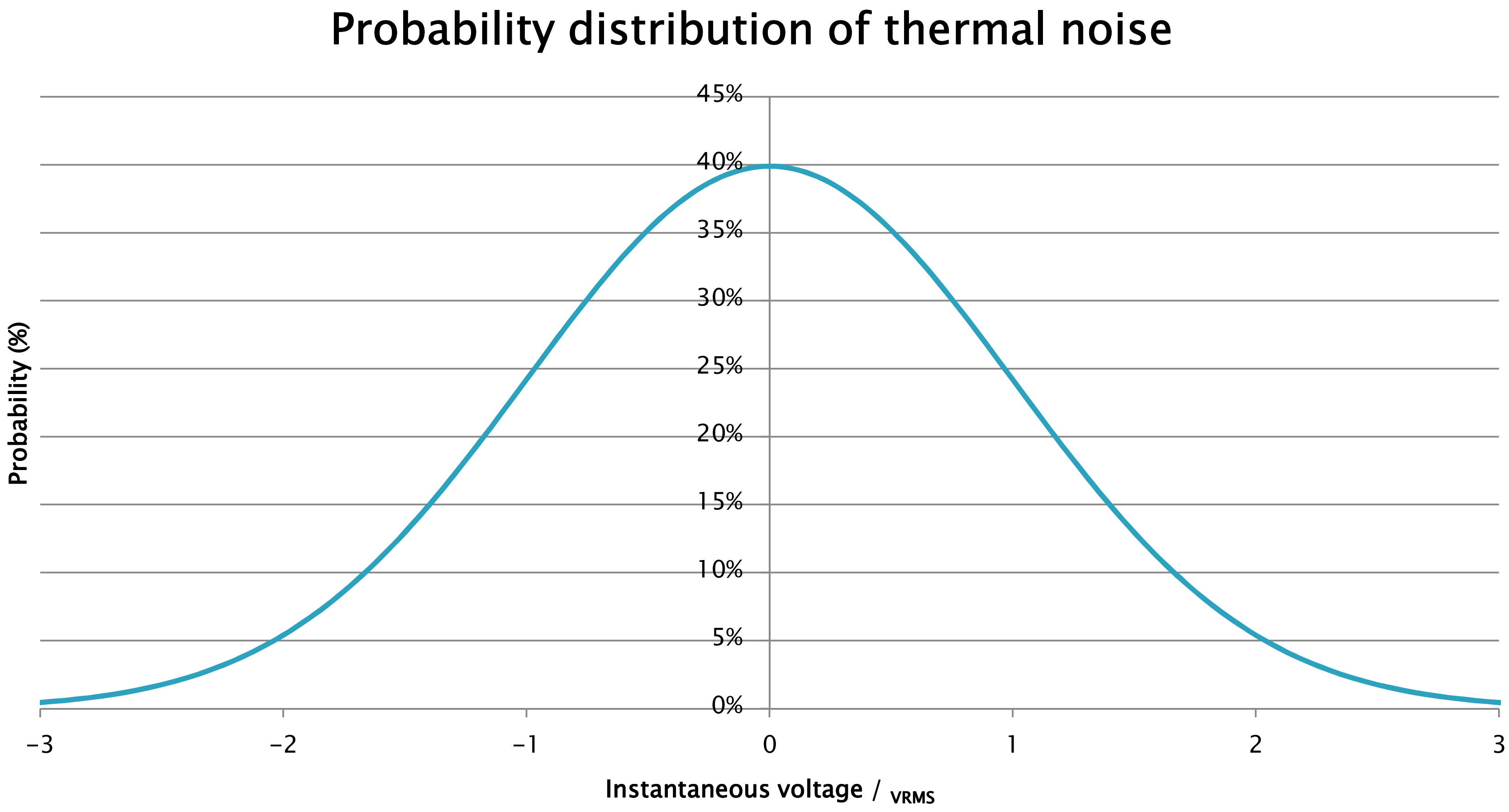
Thermal noise

- 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 (1.38e−23 J/K)
- Noise Power Density available can be calculated as:
  - NPD= $k_B T\ W/Hz$

Thermal noise (2)

- Noise voltage generated in a resistance is:
  - $V_N = \sqrt{4k_BTBR}$ 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}=mean (0); and
    - $V_{RMS}=\sqrt{variance}$

Thermal noise (3)



‘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
    - $\frac{S}{N} = 10\log\left(10^{\frac{\frac{P_{S+N}}{P_N}dB}{10}} - 1\right)$ 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
  - $NF = 10log\left(\frac{\left(\frac{S}{N}\right)_{in}}{\left(\frac{S}{N}\right)_{out}}\right)$ dB
  - $NF = \left(\frac{S}{N}\right)_{in} dB - \left(\frac{S}{N}\right)_{out} dB$

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

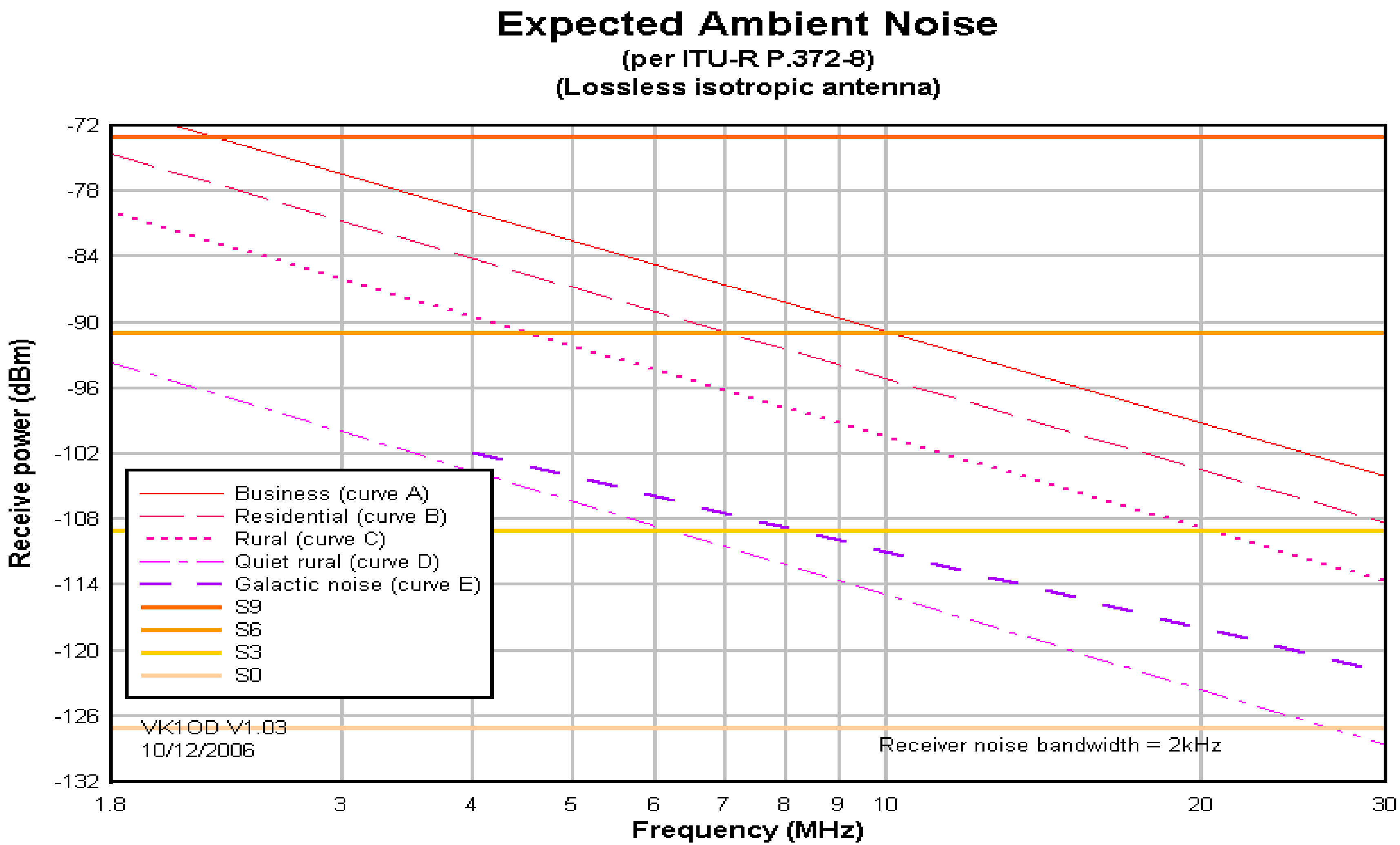
Receiver specs – examples

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

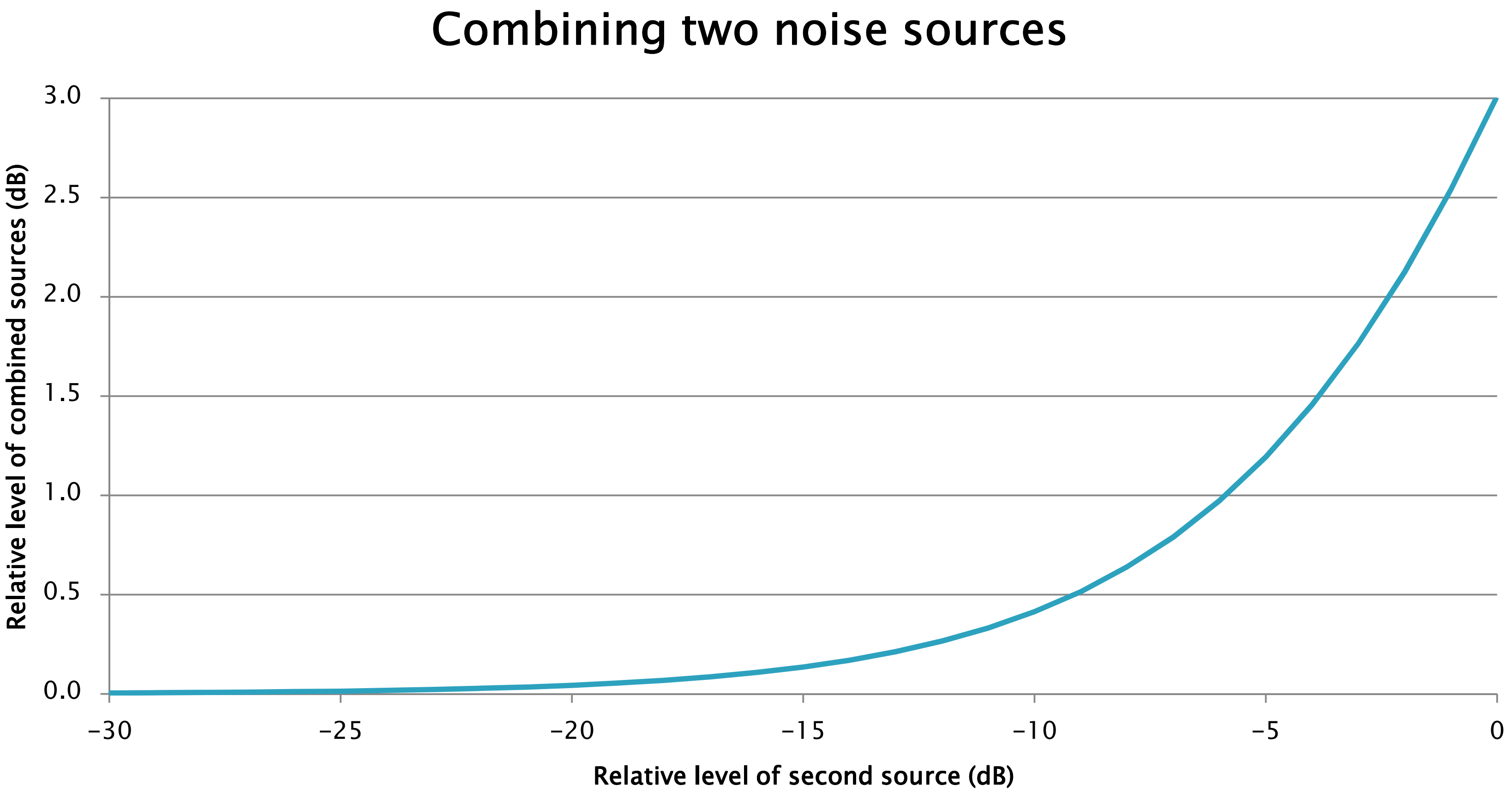
Receivers – noise sources

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

Expected ambient noise



Combining 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 10dB higher
- We can afford antenna system gain to be as low as −24dBi

Links / tools

- Receiver sensitivity metric converter
  - http://www.vk1od.net/calc/RxSensitivityCalc.htm
- Expected ambient noise level
  - http://vk1od.net/measurement/noise/FSAmbientNoise.htm
- Convert Vpk-Vpp-Vrms-dBV-dBu-mW-dBm
  - http://vk1od.net/calc/voltcnv.htm

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Slides available on-line

- http://vk1od.net/presentations.htm