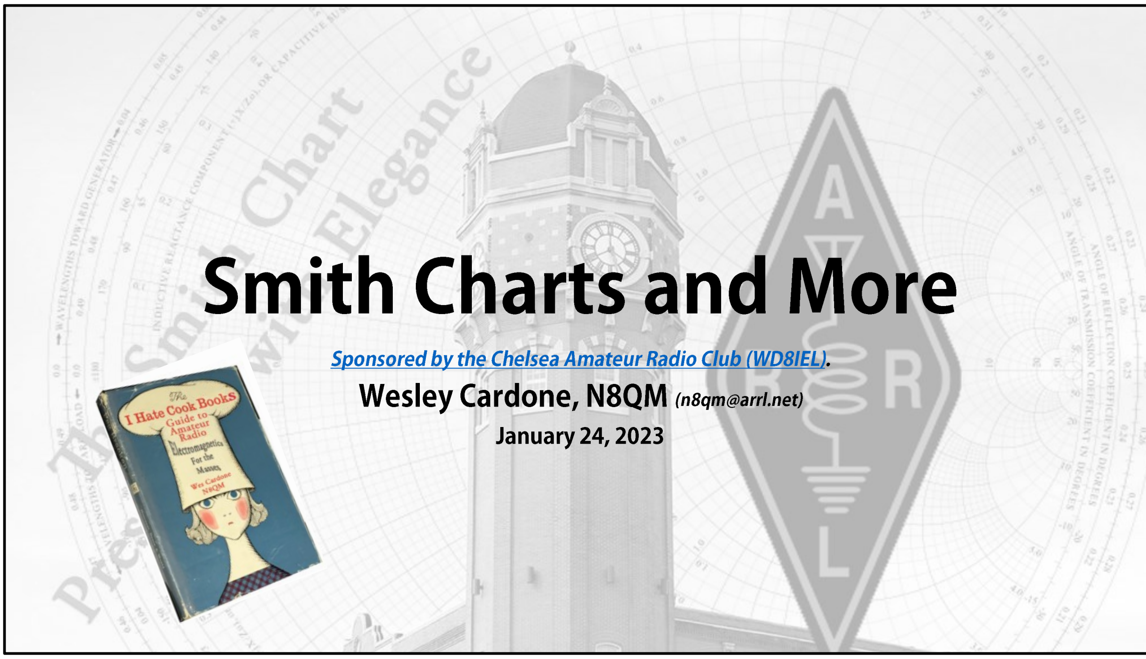
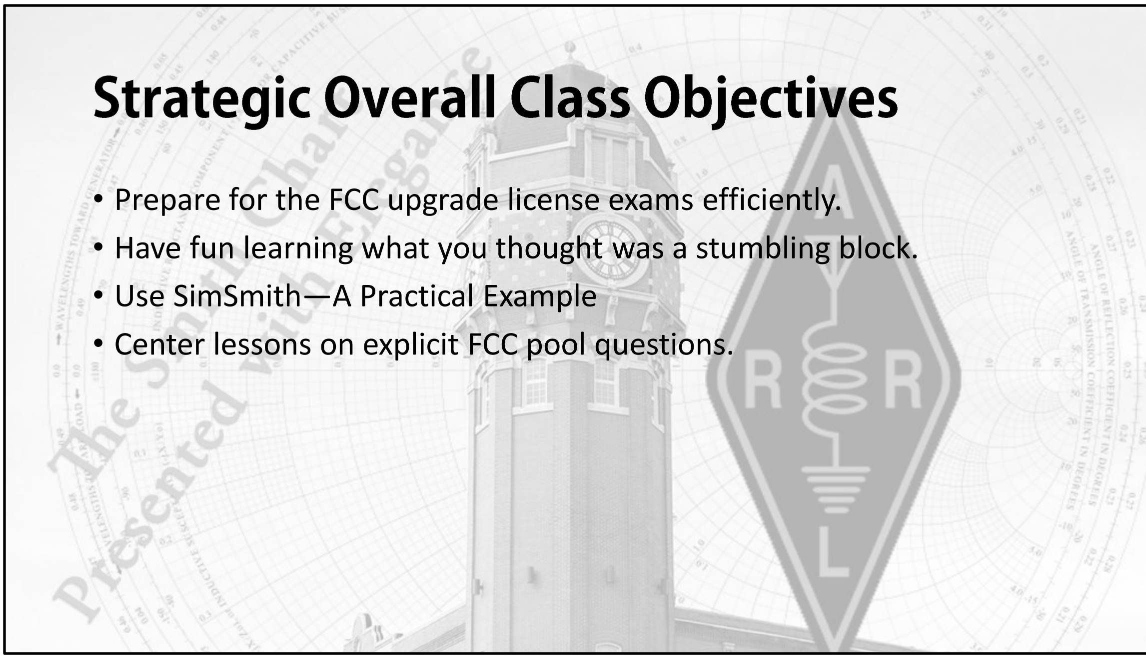


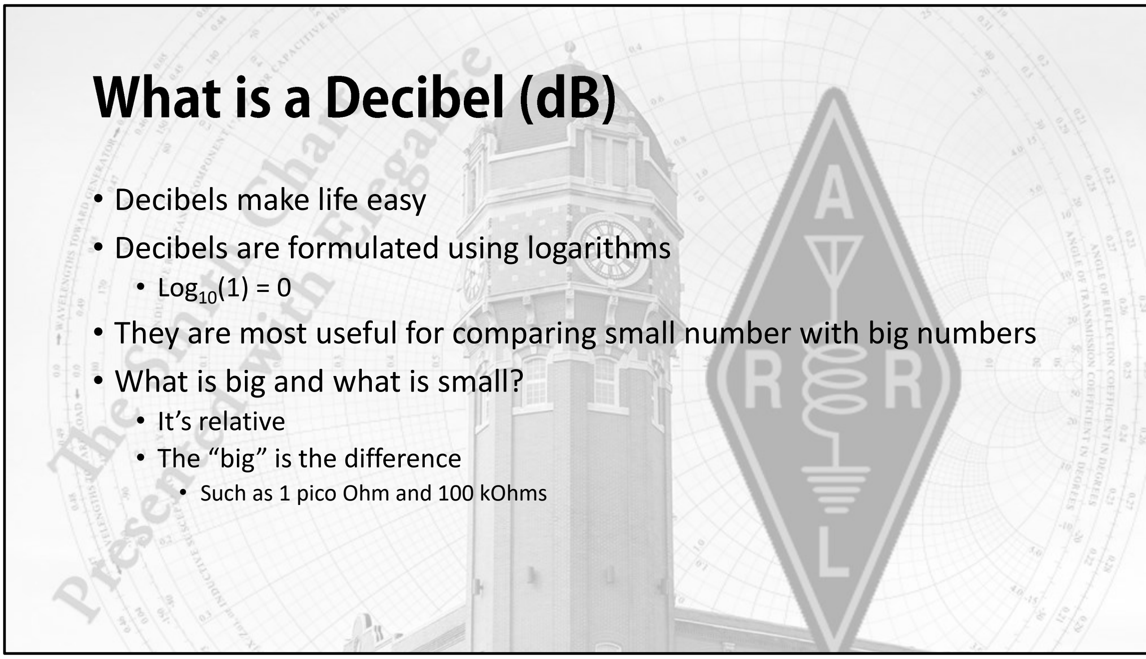
This is the Smith Charts 'n More training (otherwise known as the I Hate Cookbooks Guide to Amateur Radio Electromagnetics) sponsored by the Chelsea Amateur Radio Club.



This class is aimed at addressing the electromagnetics of the FCC pool questions for upgrading an amateur radio license to both General and Extra classes. The study protocol is predicated upon you already knowing much of electromagnetics, but you just didn't know that you knew. With the knowledge gained in this series of classes you will be able to put Smith Charts to work for you.

Tonight··· Reviewing from Last Week

- dB
- dBm
- noise



When first introduced to decibels it is natural to think that they are the enemy and that you will need to figure out how to co-exist with them because you know that you can't get rid of them. But believe it or not, decibels are your friend. They make life in the engineering disciplines easy. In amateur radio we routinely use them to quantify ratios. What is the ratio of two numbers that are equal? The ratio is unity or 1. We will be looking at that more a little later. For now, understand that decibels are extremely useful when we compare two or more numbers that have values that are decades apart. That is for example, a 1 Ohm resistor together with a 1 meg Ohm resistor. But now, let's look at little closer to the logarithms that are used to make decibels.

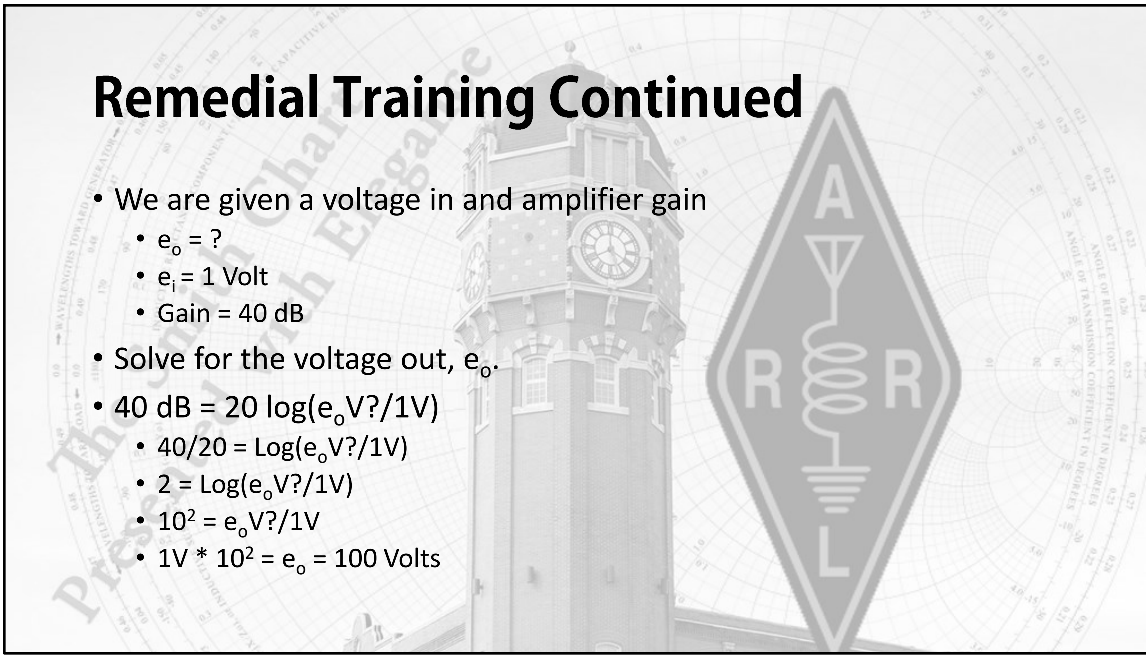
Decibel Rules

- A log function
  - $X\ dB = 20 \log(e_o/e_i)$
  - We know the values of
    - The voltage out (e_o)
    - The voltage in (e_i)
- An Anti-Log function
  - $e_o = e_i\ 10^{X/20}$
  - $e_i = e_o\ /10^{X/20}$

Remedial Training

- Deep-dive into the nature of logarithms
- We are given a voltage in and out from an amplifier
  - e_o = 100 Volts
  - e_i = 1 Volt
- The gain is the voltage out divided by the voltage in (e_o/e_i)
- dB gain dB = 20 log(100/1)
- - Log(100) = 2
- - 20 Log(100) = 40 dB

If someone has an interest in this we can continue with this and the next couple of slides. This brief remedial training centers on the use of logarithms as the basis of working with decibels. We will use an example of an amplifier that is given 1 Volt in and produces 100 Volts out. What is the gain of that amplifier? The gain is a ratio of voltage out over the voltage in which is 100 in this case. Decibels are ratios as in this case. We apply a logarithm to that ratio. We will use log-base ten but any log base will work equally. The log of 100 is 2. Because this is a voltage ratio, to find the decibels we multiply by 20 instead of 10. If this were a power or Wattage ratio we would use 10. Multiplying 2 by 20 produces a positive 40 dB. But we have all seen negative decibel values. In another slide we will explore those.

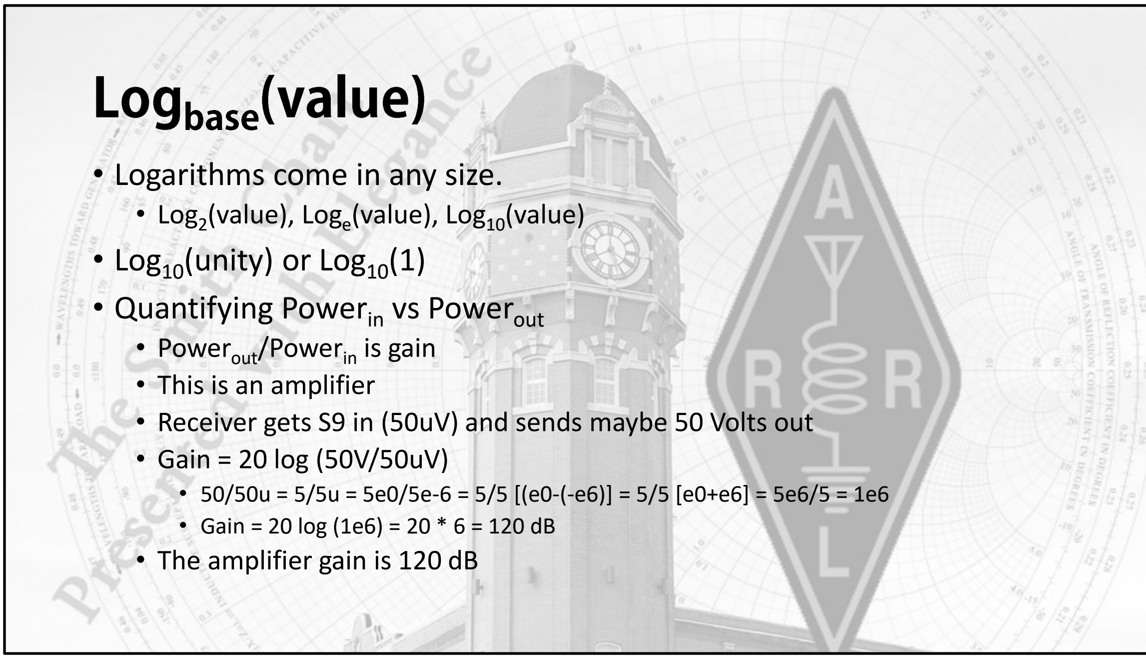


But suppose that we were given a voltage in (one Volt), a gain, but no Voltage out? We apply a little algebra and do the same things arriving at an output voltage of 100 Volts.

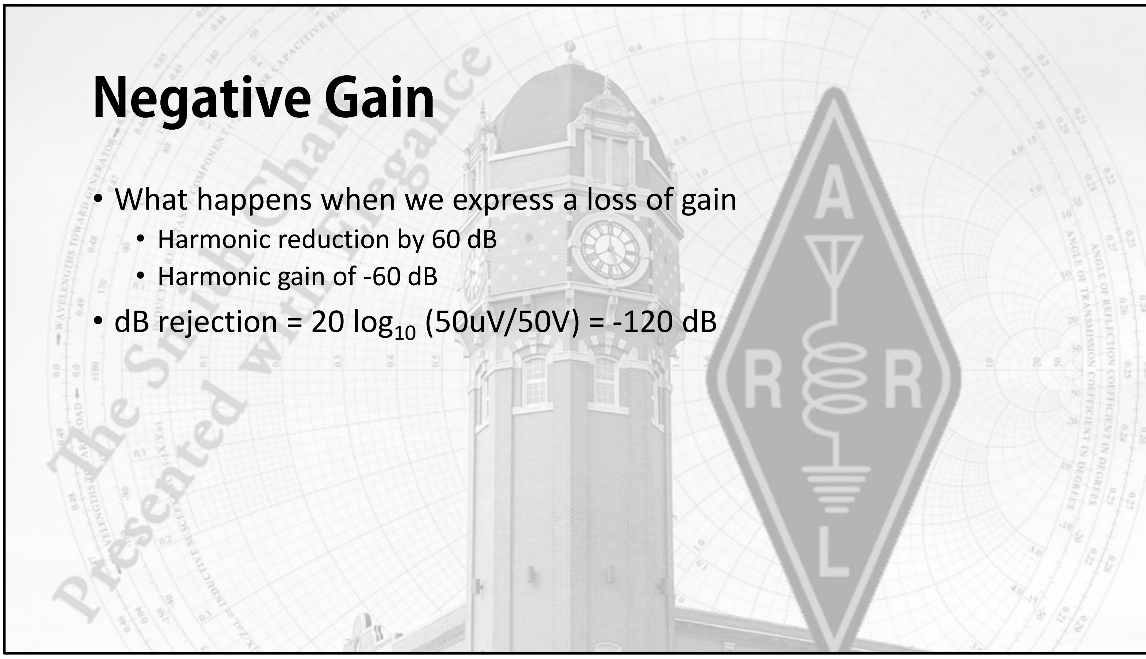
Remedial Training Continued 2

- What is the gain/loss with reversed values such as with a resistor?
  - e_o = 1 Volt
  - e_i = 100 Volts
- Again, gain is the voltage out divided by the voltage in (e_o/e_i)
  - Gain is 1/100 = 0.01
- dB gain   dB = 20 log(1/100)
- \-   Log(0.01) = -2
- \-   20 Log(0.01) = -40 dB
- Gain is -40 dB (which is a loss)

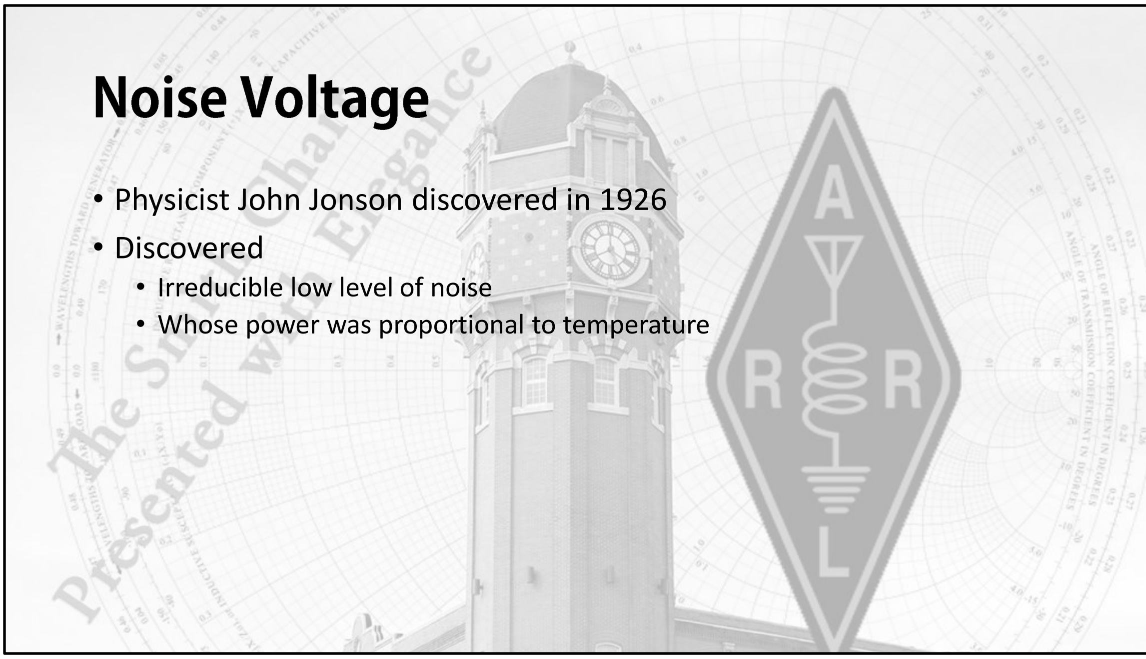
We've been looking at amplifier gain. What about the case where the output voltage is less than the input voltage such as with a resistor. Again, good old friendly algebra allows us to solve this. It's the same function but just moved around.



Logarithms come in all sorts of shapes as defined by a base. All that we are going to concern ourselves with tonight is those that are of base 10. The only other one you will see in amateur radio is base e which is a natural log. We are not going to look at natural logs tonight but we are just going to note that they exist and that their usefulness relates to many naturally occurring processes such as the growth of a colony of field mice. In looking at logs of base 10, we are not going to concern ourselves with how to solve for them. Our handy-dandy calculators will do that. The special aspect of logs that are of interest tonight is the logarithm of unity. Consider an amplifier having 50uV coming in and sending out 50 Volts. What is its gain? We could say its gain is 1 million. But it would be better understood for follow on work if we called it 120 dB. We have the ratio of 50 volts to 50 micro Volts. Divided that comes out to 1 million or 1e6. Take the log of that and multiply it by 20 for the 120 dB gain. But we also use the decibel to describe negative gain or loss such as harmonic reduction.



We can use the earlier numbers again for convenience. Suppose our harmonic content was 50 Volts and our suppression network was able to reduce that to 5 micro Volts. I think we have punished ourselves enough on logarithms.


Noise Voltage
• Physicist John Jonson discovered in 1926
• Discovered
• Irreducible low level of noise
• Whose power was proportional to temperature
A
R R
L

Noise Figure Voltage--V_{ns}

- Is defined at terrestrial temperatures (290°K or 62°F)
- Noise
  - exists in the environment
  - Is very small but detected by radio receivers
  - Principle contributors: the ground, atmosphere, and the sun.
  - Dependent on temperature.
- $V_{noise-source} = \sqrt{4kTB}$
  - k = Boltzmann's constant of $1.380\ 649\ ^{Joules}/_{°K}$
  - T = temperature °K
  - B = bandwidth (Hz)

Noise just simply exists in the environment dating to the creation of the earth. It was there when T. Rex roamed the earth. This environmental noise has a very great dependence on temperature. In the depths of outer space there would be a very low noise figure if it were measurable. Because of thermal agitation of charged particles, virtually everything around us radiates very weak radio waves. This becomes a component of a "floor" for communications sensitivity. The signal being detected must be above this noise floor. While there are additional sources of noise that collectively define a particular receiver;s "noise floor," this "noise figure" is a component of that. For standardization purposes, this environmental noise figure is specified at 290°K which is roughly room temperature (62°F).

Noise Figure Power--N_{sa}

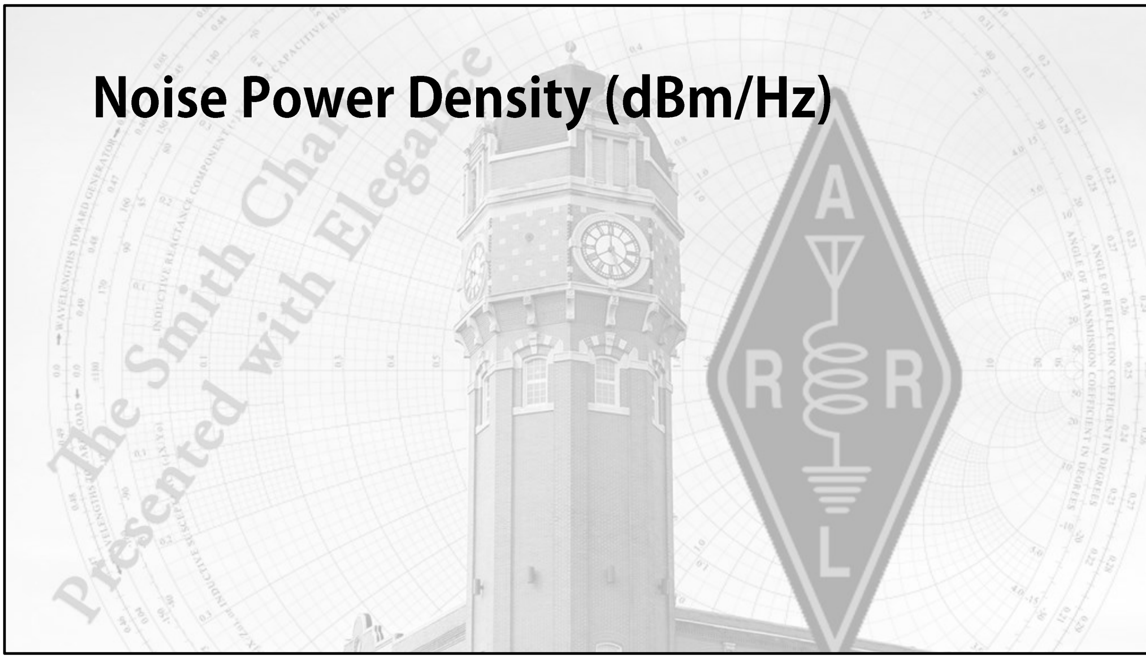
- Is a measure of how much a device degrades the signal-to-noise ratio (SNR).
- Voltage noise source: $V_{ns} = \sqrt{4kTB}$
  - k = Boltzmann's constant of 1.380 649 ${}^{Joules}/_{^\circ K}$
  - T = temperature °K
  - B = bandwidth (Hz)
- Power: $N_{sa} = {}^{V_{na}^2}/_{R_s} = {}^{kTB}/_{R_s}$
- When T=290°K, $N_{sa} = {}^{4kTB}/_{R_s}$
- SNR at an output will always be smaller than at its input since circuits always add noise to a system.

Having introduced a noise voltage source, we may now introduce a power noise when a system impedance (R_s) is known.

Noise Factor

- Is a measure of a receiver’s ratio of SNR (signal-to-noise ratio) at its input to the ratio of the SNR at its output.
- Defined at a named frequency
- Defines the ratio of total noise Power per Hz available at the output port when the noise temperature of the input is at 290^{o}K to that portion of engendered at the input.

Noise Power Density (dBm/Hz)

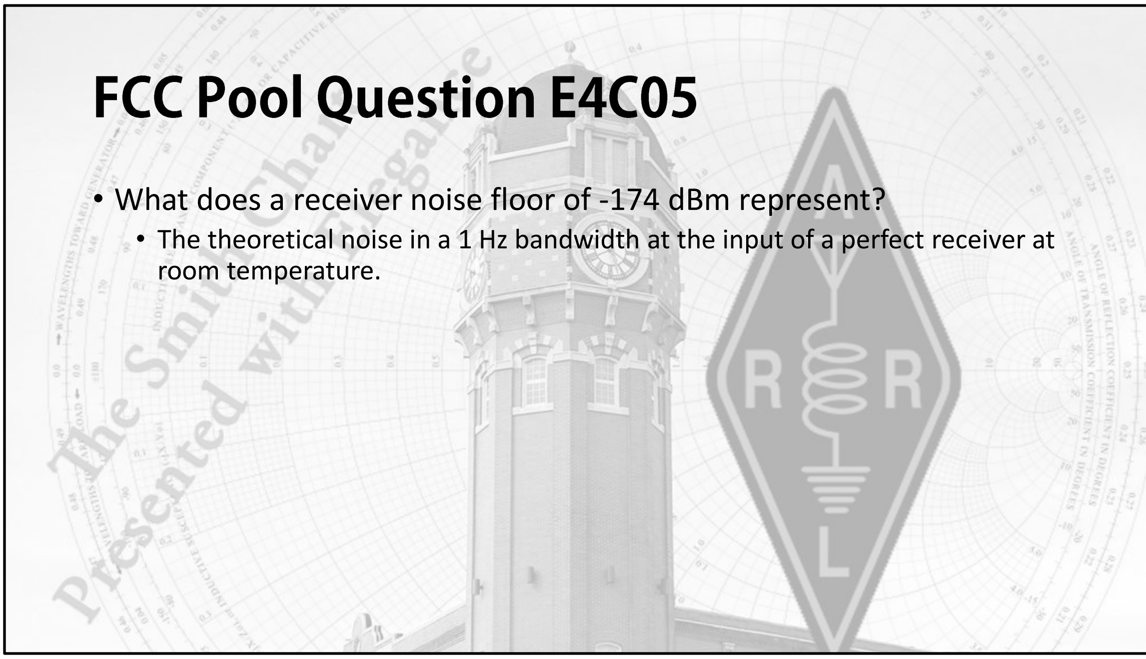


Noise Floor

- [Microsoft Word - 2012 rev 2.00 Amateur Extra syllabus (zebrahamradio.com)]
- A noise floor will increase as a receiver's bandwidth is increased.

MDS—Minimum Discernable Signal

- Site noise floor
- Receiver
  - Noise Figure
    - Ratio in dB of the noise generated within the receiver itself compared to the theoretical minimum noise.
  - Sensitivity
  - selectivity



-174 dBm is mostly universally representative of the environment. You will see this number a lot since it is theoretical.

FCC Pool Question E4C06

- A CW receiver with the AGC off has an equivalent input noise power density of -174 dBm/Hz. What would be the level of an unmodulated carrier input to this receiver that would yield an audio output SNR of 0 dB in a 400 Hz noise bandwidth?
  - Answer: -148 dBm
- Discussion
  - The level with a 400 Hz receiver bandwidth is the dB difference between a 1 Hz bandwidth and the 400 Hz bandwidth.
    - dB = 10 log(400/1) = 26 dB

FCC Pool Question E4C07

- What does the MDS of a receiver represent
  - The minimum discernable signal

FCC Pool Question E5A02

- What is resonance in an LC or RLC circuit
  - The highest frequency that will pass current
  - The lowest frequency that will pass current
  - The frequency at which the capacitive reactance equals the inductive reactance.
  - The frequency at which the reactive impedance equals the resistive impedance.
- This is a critical element of antenna analysis
  - The antenna is resonant when the reactance is neutral
    - The capacitive reactance equals the inductive reactance.

FCC Pool Question E5A03

- What is the magnitude of the impedance of a series RLC circuit at resonance?
  - High, as compared to the circuit resistance
  - Approximately equal to capacitive reactance
  - Approximately equal to the inductive reactance
  - ~~Approximately~~ equal to the circuit resistance
- Why?
- At resonance reactance
  - Is neutral
  - Capacitive and Inductive reactances cancel each other
  - Therefore, there is no travel along the vertical axis and
  - There is only resistive impedance

FCC Pool Question E5A04

- What is the magnitude of the impedance of a parallel RLC circuit at resonance?
  - ~~Approximately~~ equal to the circuit resistance
  - Approximately equal to the inductive reactance
  - Low compared to the circuit resistance
  - High compared to the circuit resistance
- No matter whether series of parallel, at resonance, reactance is neutral, capacitive and inductive canceling each other.
- Only a resistive component is left.

FCC Pool Question E5B12

- What is admittance
  - The inverse of impedance
  - The term for the gain of a field effect transistor
  - The turns ratio of a transformer
  - The inverse of Q factor
- Hints to use if you don’t remember while taking the test
  - You are going to have to remember that admittance has something to do with or is related to impedances.
  - Therefore
    - A field effector transistor answer is out of the question leaving 1, 3 & 4.
    - A transformer is disqualified leaving only 1 & 4.
    - You will likely recall that admittance is the inverse of something making the last elimination tough. You will have to remember that Q is not an impedance thing.

FCC Pool Question E5C01

- Which of the following represents capacitive reactance in rectangular notation
  - -jX
  - +jX
  - Delta
  - Omega
- Rule out 3 & 4, those are gibberish answers leaving only 1 & 2.
- Nos 1 & 2 are both viable answers as far as relevance is concerned.
- Is easy to forget which is which
- Recall that +X (northern hemisphere) is inductive
- Therefore, -X is capacitive reactance.

FCC Pool Question E5C03

- What coordinate system is often used to display the resistive, inductive, and/or capacitive reactance components of impedance?
  - Maidenhead grid
  - Faraday grid
  - Elliptical coordinates
  - Rectangular coordinates
- A Maidenhead grid is for a global grid square locator map eliminating No 1 and Faraday grid is just plain gibberish eliminating No 2.
- Elliptical coordinates are unheard of so eliminate No 3…
- …leaving No 4.

FCC Pool Question E5C06

- What does the impedance 50 – j25 represent?
  - 50 Ohms resistance in series with 25 Ohms inductive reactance
  - 50 Ohms resistance in series with 25 Ohms capacitive reactance
  - 25 Ohms resistance in series with 50 Ohms inductive reactance
  - 25 Ohms resistance in series with 50 Ohms capacitive reactance
- There are no non-sense answers here to eliminate
- You should immediately recognize the R +/- jX convention cluing you in to eliminating Nos 3 & 4 leaving only 1 & 2.
- You need to remember that minus (-) reactance is capacitive leaving you with No 2.

Questions