re-discover radio

FlexRadio Systems®
Software Defined Radios

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6m BBQ
Noise in a Digital World

September 30, 2017

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About me


N5AC

TAPR DCC Noise in a Digital World

Agenda

- Knowing Noise
- dB, dBm, mW, W, Oh my…
- Noise Figure, Sensitivity and Gain
- Calculating gain and loss at 6m
- FLEX-6000 Family Line-Up
- Q&A

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Knowing Noise

Do you know…?

- Why does the noise floor in my panadapter drop when I change panadapter bandwidth?
- Is my radio out of calibration if my receiver noise measurement doesn't match my panadapter noise floor?
- I can see a signal in my panadapter, but I can't hear it… my radio must be broken, right?

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Knowing Noise

Do you know…?

- You're selecting a radio … do you care about sensitivity, noise figure, preamp gain, something else?
- Is there a relationship between any of these numbers?
- Your buddy is boasting about his rig's sensitivity (which is 3dB better than yours). Is this important? Should you be ashamed and trade rigs?

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Knowing Noise

Do you know…?

- I looked up the ADC in my direct sampling receiver, it says 16-bits with an ENOB of 12.3 bits and 74dB SNR. I know there are 6dB per bit of dynamic range. 12.3 x 6 = 74. Heck, even if I could use all 16-bits, 16 x 6 = 96dB. A radio manufacturer says his radio has 105dB of 3rd order dynamic range.

He's lying, right?

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Knowing Noise Sources

They're everywhere

- Thermal noise
- Gaussian noise
- Flicker Noise
- Quantization Noise
- Phase Noise
- Additive Noise
- Powerline Noise
- Splatter
- Power Supply Noise
- Atmospheric Noise
- Reciprocal Mixing
- EMI

Noise can be complicated and even those that know it well will have to think and figure on some questions

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Noise and Bandwidth

What is the *Noise Floor*?

- We often hear “Noise Floor,” we know how to point at it, but what is it?

Noise Behavior

Better get a bucket…

What your ADC sees:

Think of noise as trough of water

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Noise Behavior

Better get a bucket…

What Happens if I split the trough into two troughs?

Water level drops by a factor of two (3dB)

(note: *all computations in the water domain*)

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Noise Behavior

Find the diamond…

There's a diamond at the bottom of the trough

I'll give you as many bins as you want,
in many sizes (all factors of 2)

How can you find the diamond?

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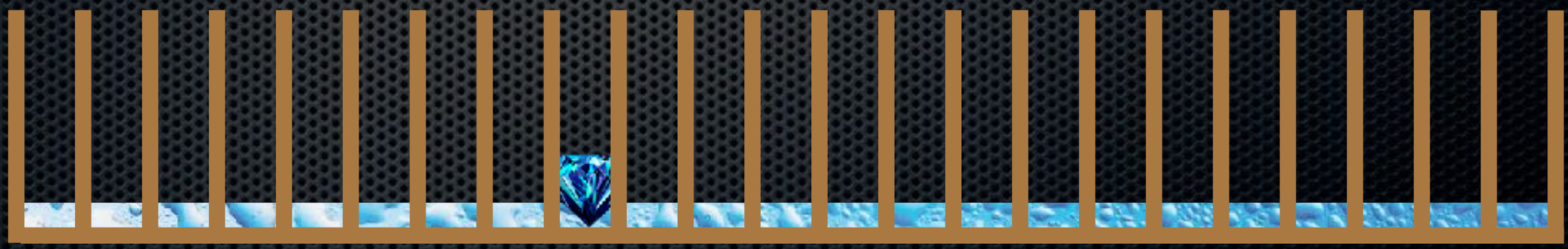
Noise Behavior

Find the diamond…

What if you split the water into 1024 buckets, each 1/1024 the size of the original trough?

Congratulations, you've just created the first water trough FFT!

a.k.a. the WTFFT



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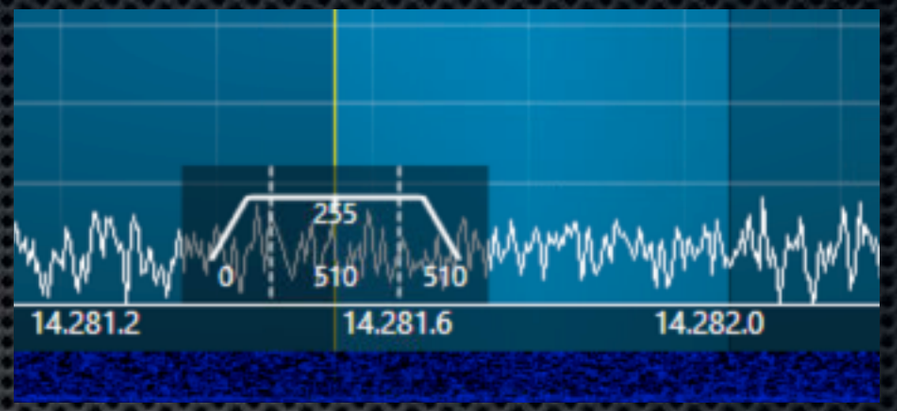
Noise Behavior

OK, what about a RADIO?



- In a receiver (on an FFT bin), we filter
- Bandwidth limited to receiver bandwidth
- Noise is reduced in dB by:

$$10\log_{10}\left(\frac{BW_{initial}}{BW_{final}}\right)$$

Think of an FFT as a series of receiver S-Meters stacked next to each other

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Noise Behavior

OK fine, but how does this work in a RADIO?

- So for our 1024-bin WTFFT, we reduced the water in each bin by:

$$10\log_{10}\left(\frac{1024}{1}\right)=30.1dB$$

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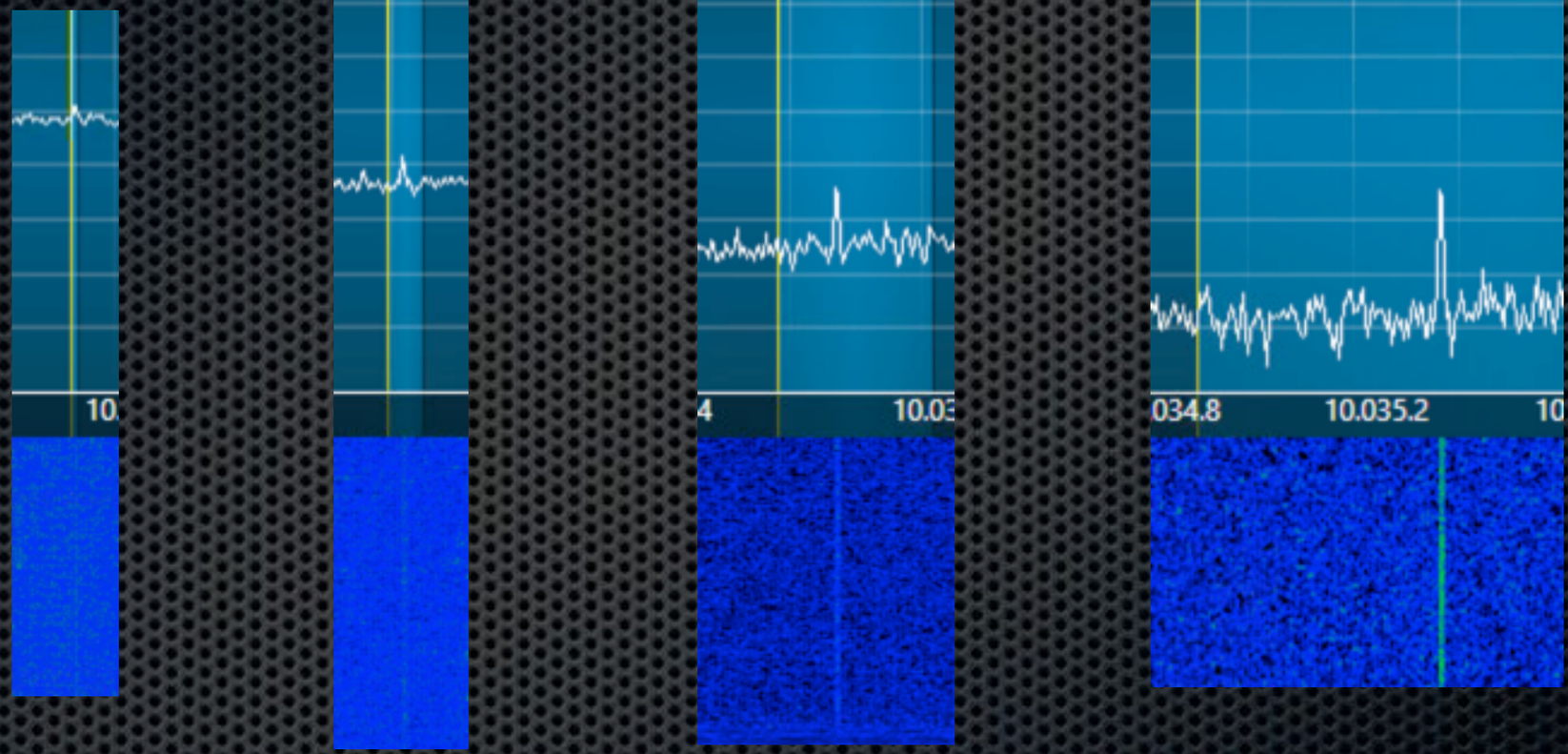
Noise Behavior

Why doesn't my signal go down too?

- If your signal is contained entirely in a single bin, you lose none of it by filtering
- If your noise is evenly distributed, you reduce it as shown in the previous slide
- If you split the signal (evenly) across two bins, it will reduce by 3dB in any one bin
- For the pedantic: yes we're ignoring window leakage, scalloping, etc.

Noise Behavior

WSJT / FT8



Noise drops as we narrow bandwidth, exposing the signal

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Noise Behavior

Does this ever NOT work?

- YES, when not evenly distributed (not AWGN)
- For example: Frequency dependent noise source
- Special tools…

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Noise Behavior

Review

- QUESTION: Why does the noise floor in my panadapter drop when I change panadapter bandwidth?
- ANSWER: We reduce the noise by 3dB each time we reduce the bandwidth by half

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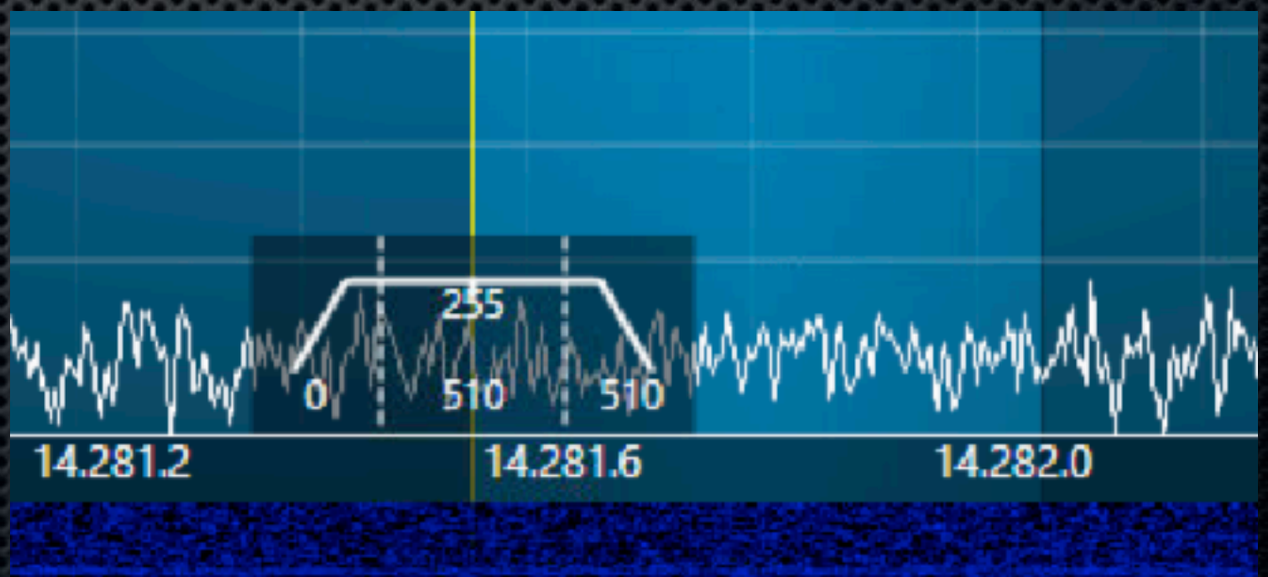
Noise Behavior

Review

- QUESTION: Is my radio out of calibration if my receiver noise measurement doesn't match my panadapter noise floor?
- ANSWER: NO, look at the difference in receiver bandwidth and panadapter FFT bin size



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Noise Behavior

Review

- QUESTION: I can see a signal in my panadapter, but I can't hear it… my radio must be broken, right??
- ANSWER: NO, a good FFT is generally a better instrument than your ear/brain when the bin size is small (<~50Hz).

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Noise Behavior

Review

- QUESTION: Assuming your signal strength in your 500Hz receiver (noise only) says -100dBm and your panadapter shows -120dBm, what is your FFT bin size?
- ANSWER: 5Hz

$$10\log_{10}\left(\frac{500}{x}\right)=20dB$$

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Noise Floor

Terminology

- “Noise Floor” is used haphazardly
- Vendors, ARRL, etc. use 500Hz bandwidth
- Noise Floor down as bandwidth is decreased
- WSJT, CW, etc take advantage of this
- “12dB below the noise floor,” they mean the 500Hz noise floor. If their detector (filtered receiver) is only 10Hz wide, they are hearing 5dB *above* the actual noise floor for the receiver.

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Noise and Bandwidth

What is the *Noise Floor*?

- “That’s pretty — what’s the noise floor of that receiver, there?”

Knowing Noise

Do you know…?

- I looked up the ADC in my direct sampling receiver, it says 16-bits with an ENOB of 12.3 bits and 74dB SNR. I know there are 6dB per bit of dynamic range. 12.3 x 6 = 74. Heck, even if I could use all 16-bits, 16 x 6 = 96dB. My radio manufacturer says it has 105dB of 3rd order dynamic range.

He's lying, right?

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Knowing Noise

Do you know…?

- 12.4 bits ENOB is spec'd at the *full bandwidth of the converter*
- We know how to convert — lets say we're going from 100MHz to 48kHz

$$10\log_{10}\left(\frac{100{,}000{,}000}{48{,}000}\right)=33dB$$

33dB+74dB = 107dB = 17.8-bits

Actual bits toggling = 16 * 6 + 33 / 6 = 21.5-bits

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Knowing Noise

Do you know…?

NO, He's not lying

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Noise Figure, Sensitivity & Gain

Oh My!

- You bought a 6m radio with a stated noise figure of 5dB

Where is the noise floor?

A. -128dBm B. -135dBm C. -142dBm
D. Insufficient Information

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Noise Figure, Sensitivity & Gain

Oh My!

TRICK QUESTION!

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Noise Figure, Sensitivity & Gain

Oh My!

- You bought a 6m radio with a stated noise figure of 5dB

Where is the noise floor?

A. -128dBm B. -135dBm C. -142dBm

D. Insufficient Information

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Noise Figure, Sensitivity & Gain

What you need to know

- Golden Rule: **0dB NF = -174dBm in 1Hz**
- To calculate the noise floor in ANY bandwidth given the NF and bandwidth:

-174dBm + NF + (dB bandwidth difference from 1Hz)

For example, a receiver with a 5dB NF and a bandwidth of 500Hz has a noise floor of:

-174dBm + 5dB + (10 + 10 +10 - 3) = -142dBm

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Noise Figure, Sensitivity & Gain

What you need to know

What's the golden rule?

0dB NF = -174dBm in 1Hz

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Noise Figure, Sensitivity & Gain

Cascaded Noise Figure

- Cascaded NF tells us the final NF and Gain given a series of preamplifiers / attenuators heading into a receiver

$$NF_C = 10\log\left(nf_N + \frac{nf_{N-1}}{G_{N-1}} + \ldots\right)$$

Noise Figure, Sensitivity & Gain

Cascaded Noise Figure

- Example: 10dB NF receiver with a 5dB NF preamp with 10dB gain:

Select number of cascaded amplifiers:

2

Noise(dB)	Gain(dB)
5	10
10	0

Calculate

6.1dB

Result:

Total Noise Figure: 6.088 dB
Total Gain: 10.00 dB

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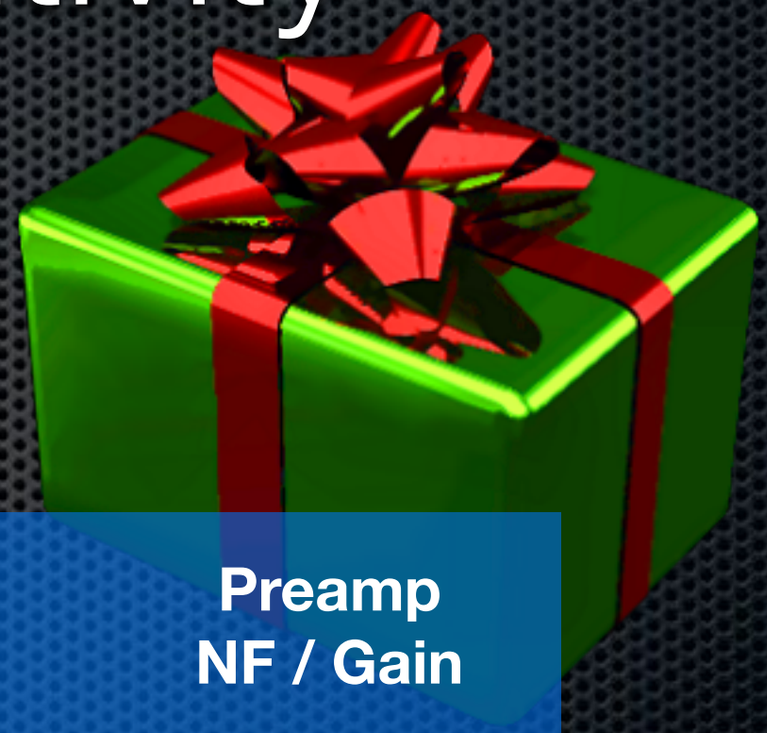
Noise Figure & Sensitivity

What's Important?



	Sensitivity Noise Floor in 500Hz	NF	Preamp NF / Gain
Radio 1	-136dBm	13dB	5dB / 10dB
Radio 2	-123dBm	24dB	2dB / 30dB
Radio 3	-139dBm	8dB	7dB / 20dB

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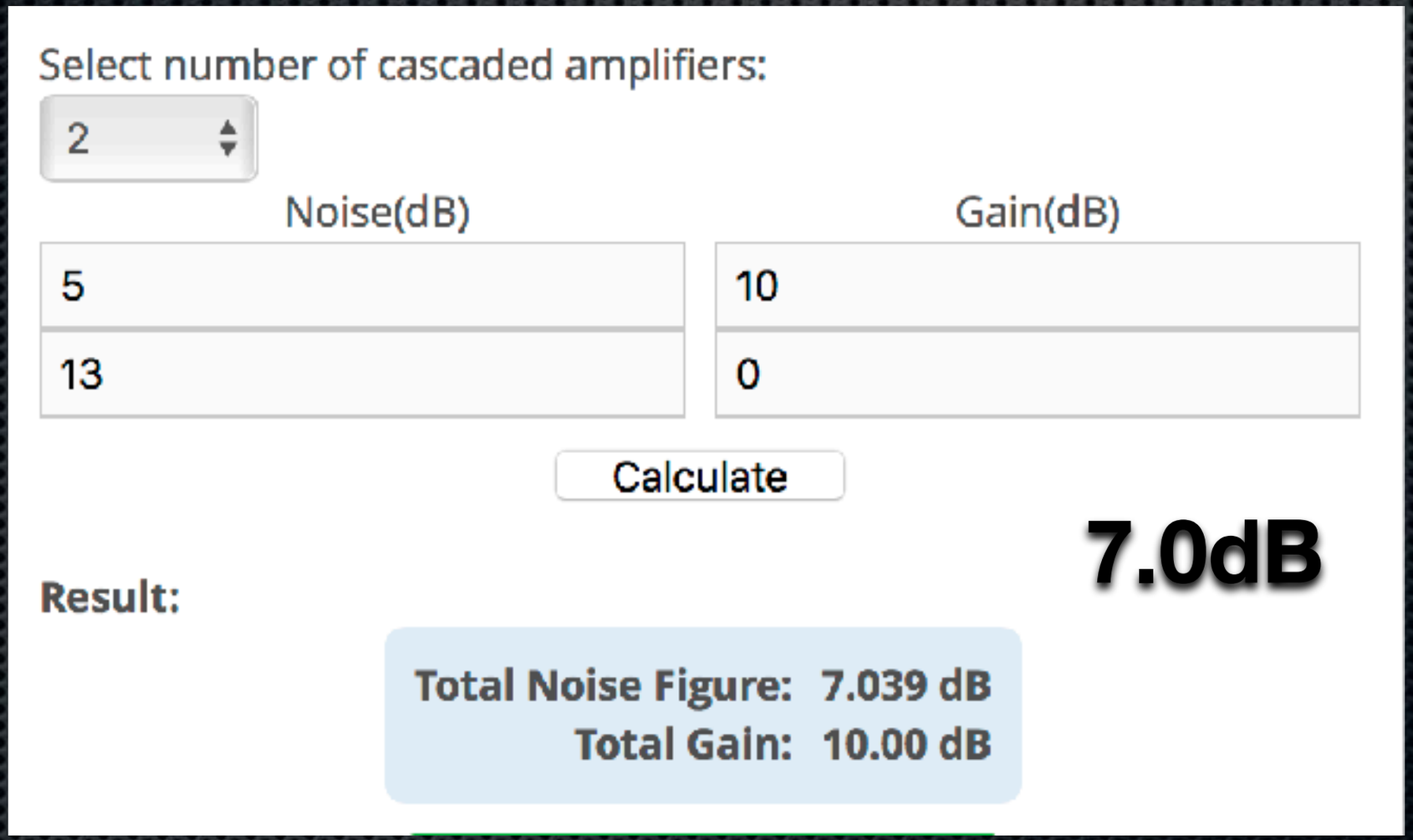
Noise Figure & Sensitivity

What's Important?



7.0dB

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Noise Figure & Sensitivity

What's Important?

Select number of cascaded amplifiers:

2

Noise(dB)	Gain(dB)
2	30
24	0

Calculate

Result:

2.6dB

Total Noise Figure: 2.637 dB
Total Gain: 30.00 dB

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Noise Figure & Sensitivity

What's Important?

Select number of cascaded amplifiers:

2

Noise(dB)	Gain(dB)
7	20
8	0

Calculate

Result:

7.0dB

Total Noise Figure: 7.046 dB
Total Gain: 20.00 dB

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Noise Figure & Sensitivity

What's Important?

	Sensitivity Noise Floor in 500Hz	NF	Preamp NF / Gain	System NF
Radio 1	-136dBm	13dB	5dB / 10dB	7dB
Radio 2	-123dBm	24dB	2dB / 30dB	2.6dB
io 3	-139dBm	8dB	7dB / 20dB	7dB

The radio with the "worst sensitivity" has the best NF

Go Figure!

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Noise Figure, Sensitivity & Gain

What you need to know

What's the golden rule?

0dB NF = -174dBm in 1Hz

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Noise Figure, Sensitivity & Gain

QUIZ TIME!

You have figured out your radio with the preamp has a 6dB NF. You run coax from your radio to the tower and up the tower to your 6m antenna. You're using 180' of LMR-200 from the rig to the antenna.

What is your system Noise Figure?

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Noise Figure, Sensitivity & Gain

QUIZ TIME!

Coaxial Cable Data

Product:	LMR-200
Frequency (MHz):	50
Run Length (Feet):	180

« Reset | Calculate »

PRODUCT PERFORMANCE PARAMETERS

Attenuation:	2.3 db/100ft	7.5 db/100mtr
Average Power:	0.79 KW	
Cable Vg:	83 %	
Nominal Td:	1.22 nSec/ft	4.02 nSec/mtr
Capacitance:	24.5 pF/ft	80.3 pF/mtr
Typical Connector Loss:	0.01 dB/pair	

CABLE ASSEMBLY PERFORMANCE

Cable Run Attenuation:	4.1 dB
Total Cable Assembly Loss:	4.5 dB
Cable Run Efficiency:	38.8 %
Cable Run Time Delay:	220.34 nSec

180’ LMR-200 @ 50MHz

4.5dB LOSS

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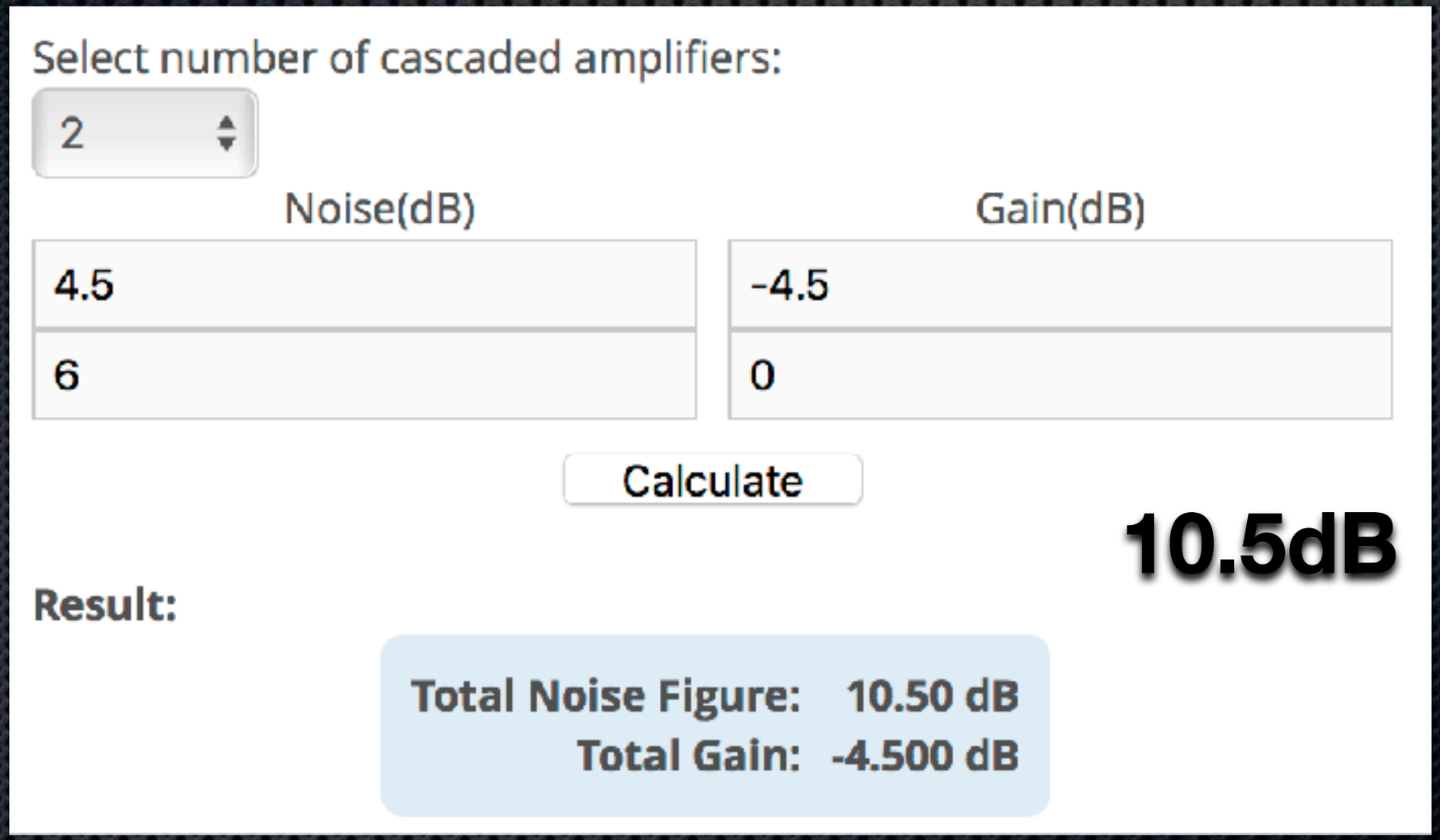
Noise Figure, Sensitivity & Gain

What you need to know



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Noise Figure, Sensitivity & Gain

QUIZ TIME!

You have figured out your radio with the preamp has a 6dB NF. …

What is your system Noise Figure?

10.5dB!!!

What now?

MAST MOUNTED PREAMP

or BETTER COAX

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Noise Figure, Sensitivity & Gain

QUIZ TIME!

KP-2-6M $199

<1dBNF 15-20dBg

Noise Figure, Sensitivity & Gain

QUIZ TIME!

You realize your coax is killing you. You add a mast mounted preamp with 0.8dB NF and 10-20dB of gain (adjustable). What's your NF now?

Select number of cascaded amplifiers:

3

Noise(dB)	Gain(dB)
0.8	10
4.5	-4.5
6	0

Calculate

3.5dB

Result:

Total Noise Figure: 3.472 dB
Total Gain: 5.500 dB

Select number of cascaded amplifiers:

3

Noise(dB)	Gain(dB)
0.8	20
4.5	-4.5
6	0

Calculate

1.2dB

Result:

Total Noise Figure: 1.154 dB
Total Gain: 15.50 dB

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Noise Figure, Sensitivity & Gain

I've got it!!

I totally understand: You should add preamps to lower your NF so you can hear weak signals!

NO… only lower the noise floor to ~6-10dB below your atmospheric noise. Lower just reduces your dynamic range

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Noise Figure, Sensitivity & Gain

QUIZ TIME!

How do you decide where to set the gain??

As you move from 10-20dB, you lower your noise floor by **3.5-1.2 = 2.3dB**, but at the same time, your overload is lowered by **10dB.** The overall affect on DR is 2.3-10=**-7.7dB**

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Noise Figure, Sensitivity & Gain

QUIZ TIME!

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Noise Figure, Sensitivity & Gain

HF Atmospheric Noise

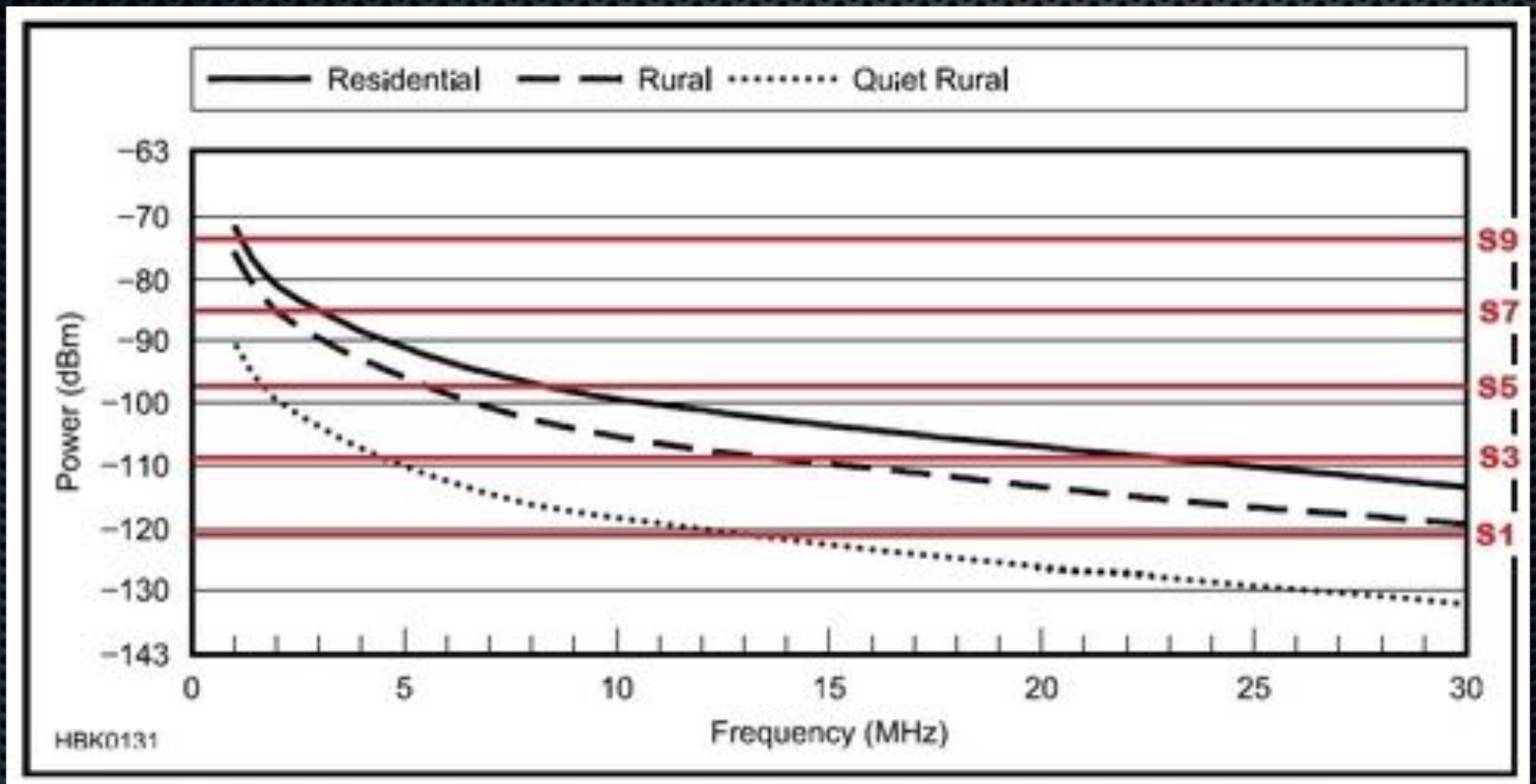

Fig 19.37 — Typical noise levels versus frequency for various environments. (Man-made noise in a 500-Hz bandwidth, from Rec. ITU-R P.372.7, *Radio Noise*)

Noise Figure, Sensitivity & Gain

Review

- QUESTION: Your buddy is boasting about his rig's sensitivity (which is 3dB better than yours). Is this important? Should you be ashamed and trade rigs?
- ANSWER: No, there are many other factors to consider including preamps, ergonomics, RMDR, DR, etc.

TAPR DCC Noise in a Digital World

Agenda

The Blank Look — We can teach it!

Knowing Noise

dB, dBm, mW, W, Oh my…

Noise Figure, Sensitivity and Gain

FLEX-6000 Family Line-Up

Q&A

FlexRadio Systems®
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FlexRadio Product Overview

FlexRadio Systems
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Maestro

A XVTR ANT1
TX
Po 25 50 75 100
S 1 3 5 7 9+20+40
USB 4.7 NB NR ANF QSK RIT DIV
14.303.600

MENU

B XVTR ANT1
TX
Po 25 50 75 100
S 1 3 5 7 9+20+40
USB 4.7 NB NR ANF QSK RIT DIV
14.262.500

-100 -105 -110 -115 -120 -125 -130
14.235 14.250 14.265 14.280 14.295 14.310 14.325 14.340 14.355 LIVE
-5s -10s -15s -20s
DISPLAY

A
AF AGCT SQL
LOW SHIFT HIGH WIDTH
SOLO
BW SELECT

B
AF AGCT SQL
LOW SHIFT HIGH WIDTH
SOLO
BW SELECT

MOX TUNE ATU
BYPASS
F1 F2 F3
F4 F5 F6

MIC SPEED PWR
TX MENU

RX TX A·B RX TX
RIT XIT A>>B RIT XIT

A STEP B

A LOCK B

A MENU/CLR
B MENU/CLR

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Maestro

Take your radio anywhere…

- Local or remote
- In front of the rig or across the world
- Production stalled for months due to supplier problem
- Problem now resolved and production resuming

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PowerGenius XL™

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Power Genius XL

- 1500W, 37lbs
- 220V *or* 110V (reduced power)
- TRUE SO2R
- Works with any transceiver (CAT, CI-V, BCD, Ethernet)

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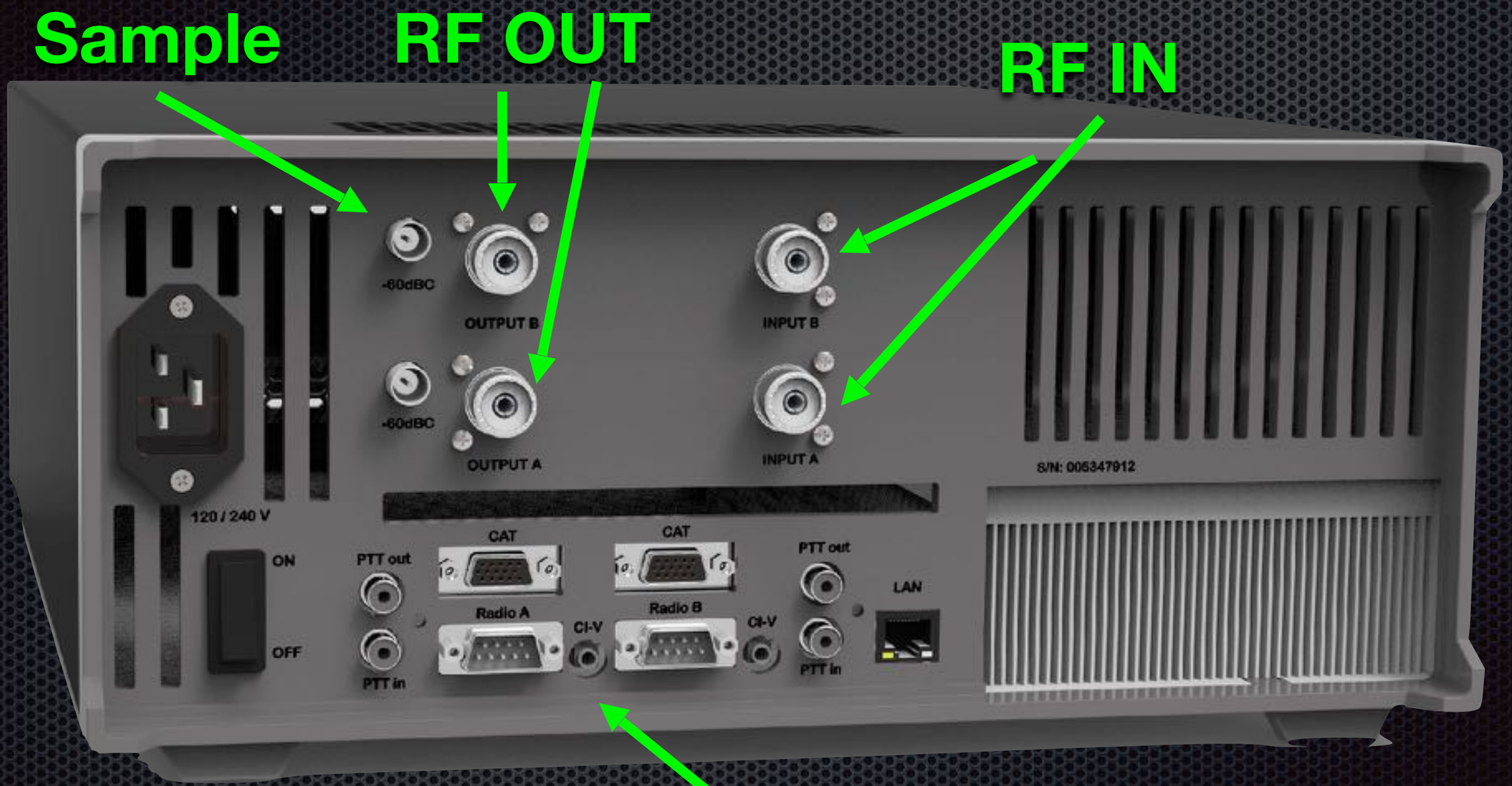
PowerGenius XL



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Introducing... **FLEX-6600**

FlexRadio Systems®
Software Defined Radios

FLEX-6400 / FLEX-6600

Reimagined

- Both models:
  - Run SmartSDR just like all FLEX-6000s
  - Improved receiver
  - TWO VFO Controls
  - MARS/SHARES/CAP Option
  - 116db RMDR
  - Full Duplex
- FLEX-6600
  - Enhanced preselector
  - Two XVTR Ports / SO2R

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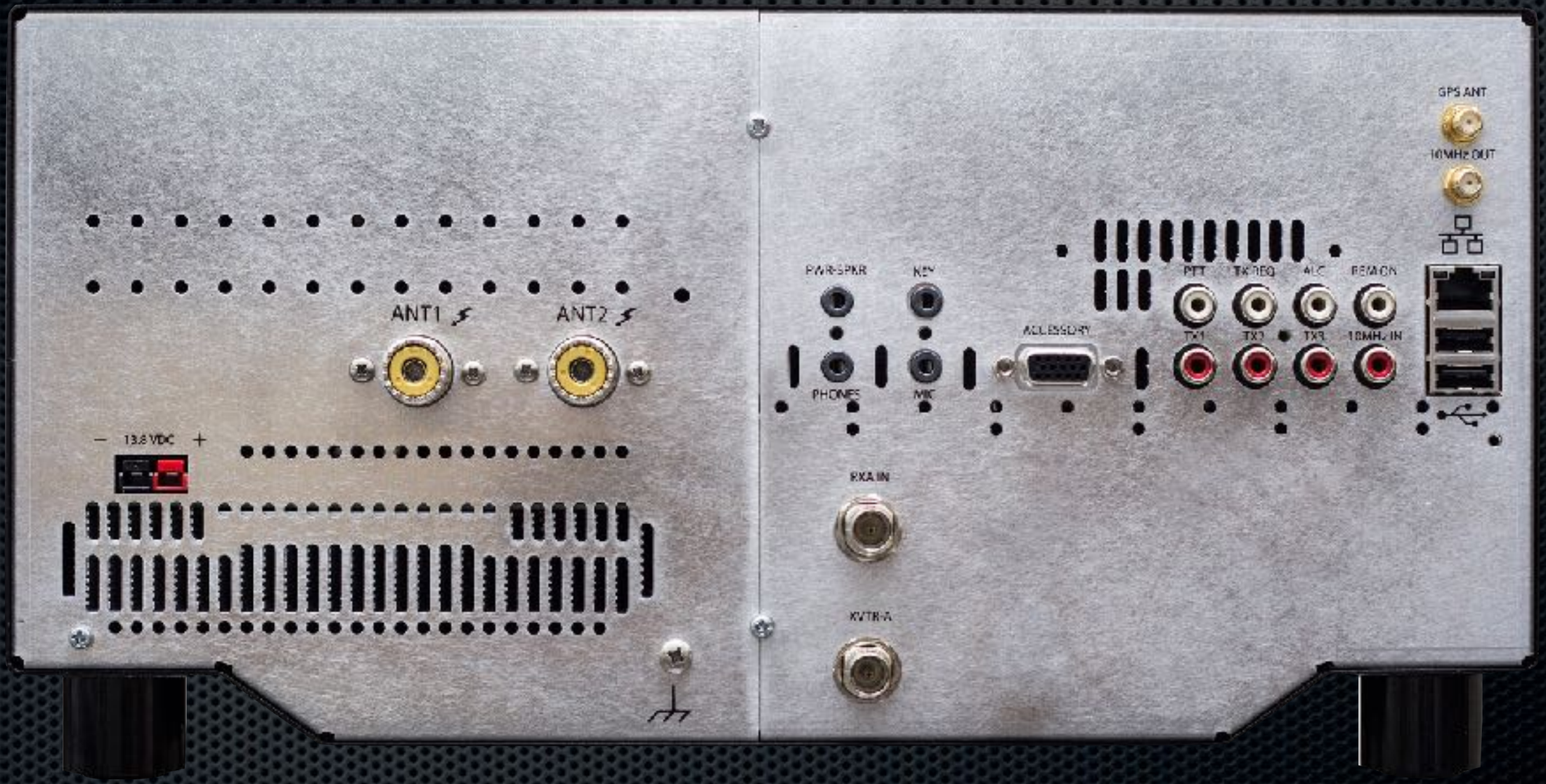
FLEX-6400

Rear View



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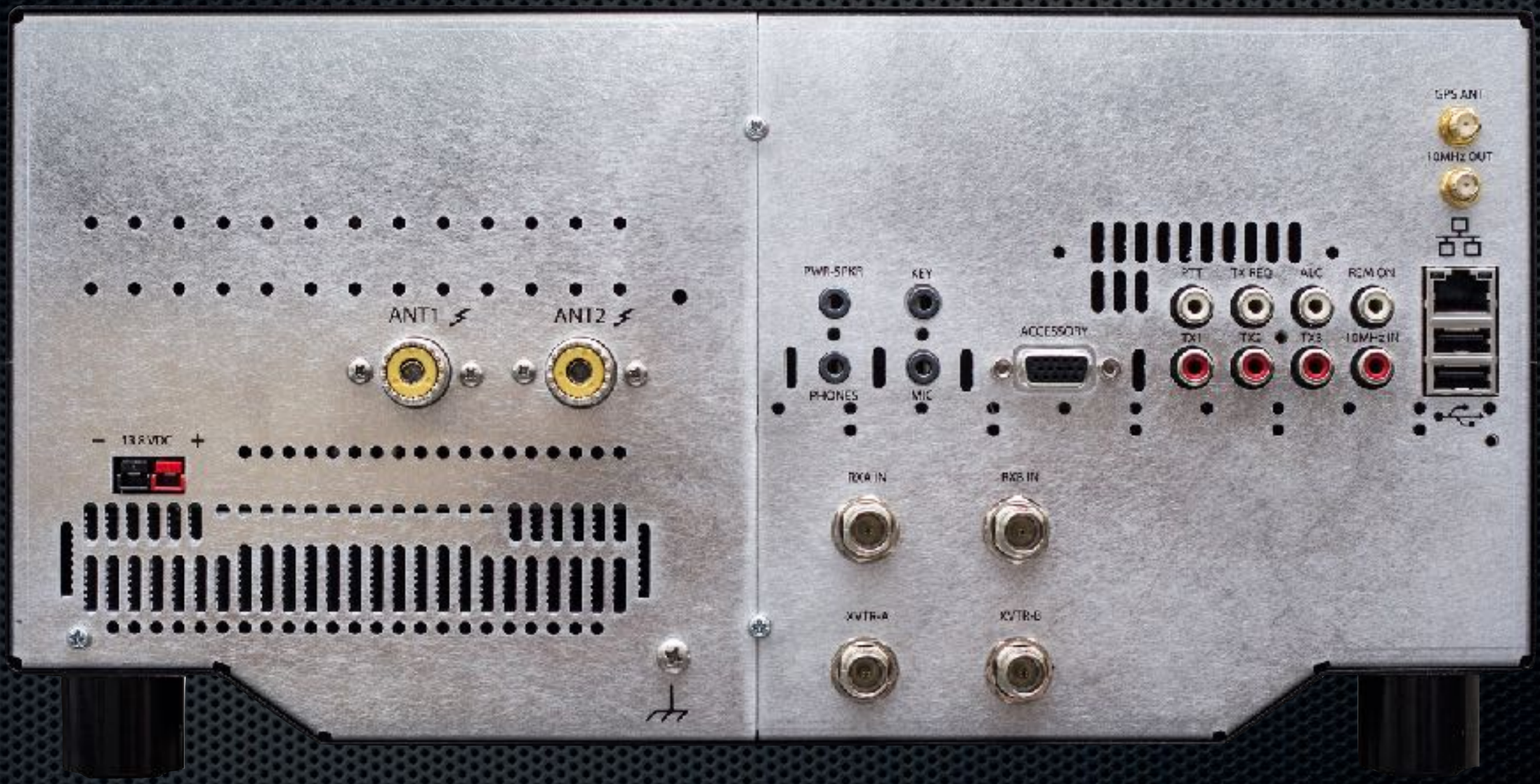
FLEX-6600

Rear View



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FLEX-6400M & FLEX-6600M

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FLEX-6400M & FLEX-6600M

Features

- All the capabilities of a FLEX-6400/6600
- Best screen available: 1920x1200 IPS CAP Touch
- Support for external HDMI display
- PLUS front panel with touch screen and controls
- Builds on excellent Maestro design
- Includes SmartLink for remote operation
- Can be used with Maestro, iPad, DogparkSDR, etc.

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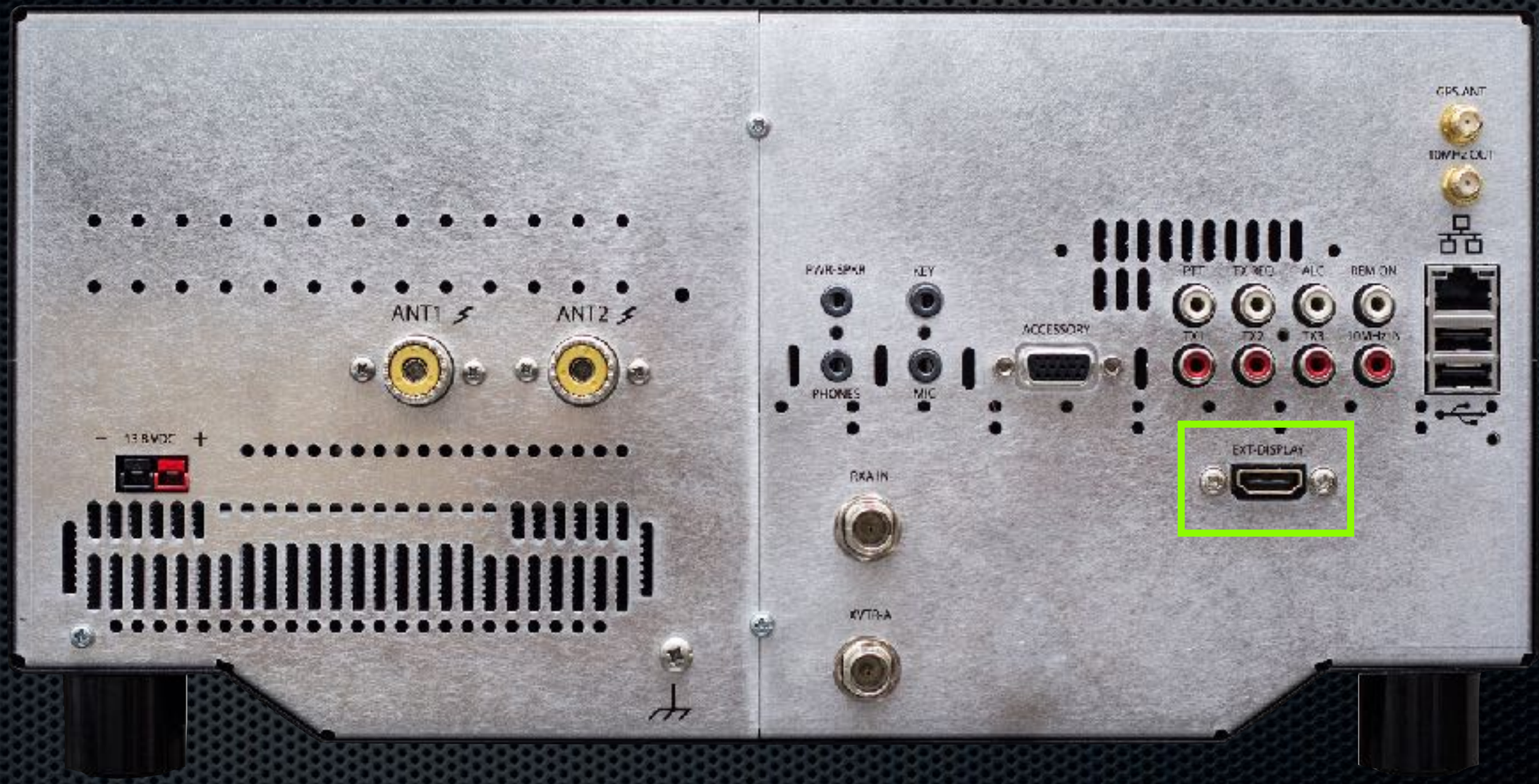
FLEX-6400M

Rear View



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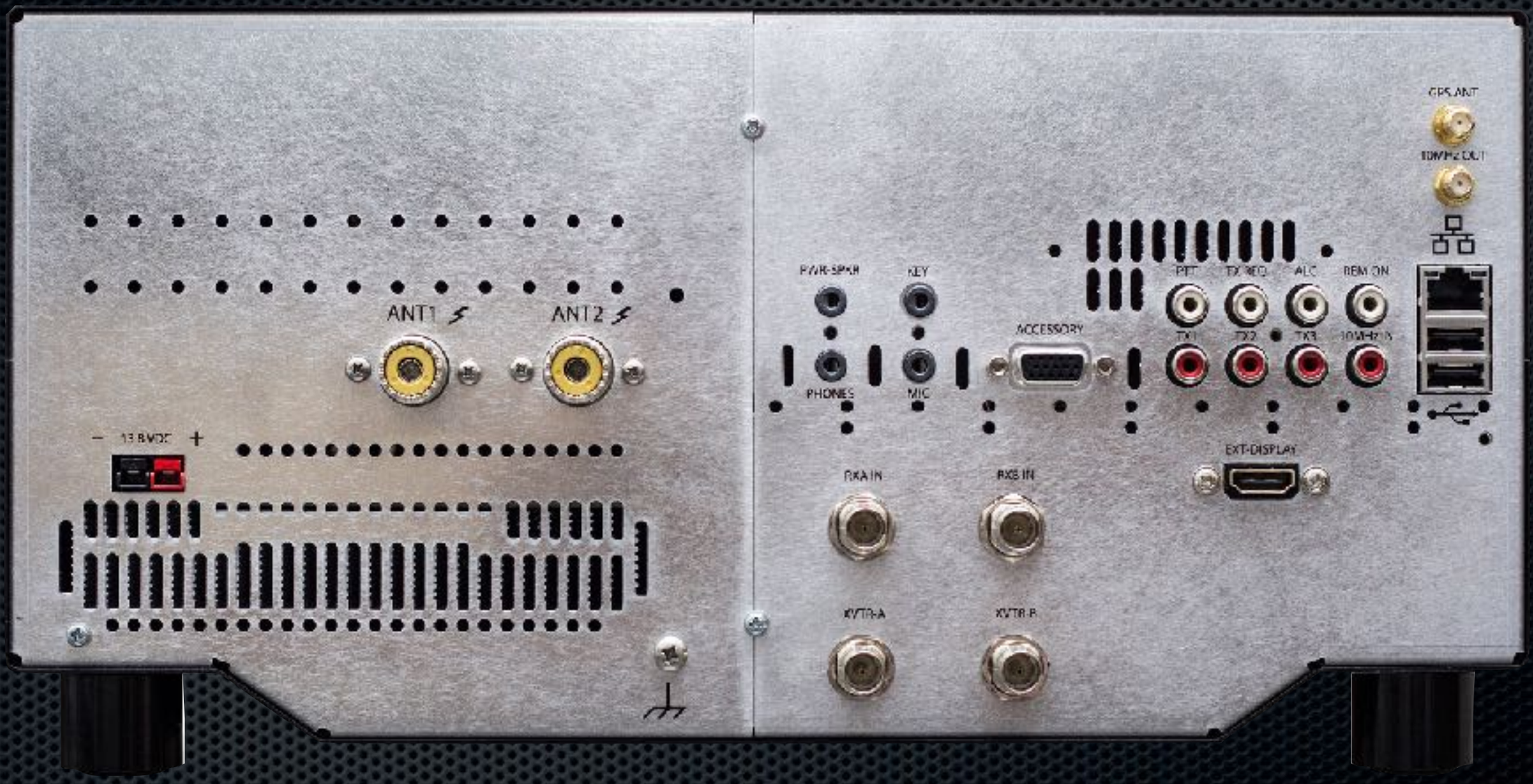
FLEX-6600M

Rear View



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FLEX-6000 Lineup

	6400	6400M	6600	6600M	6700
RX/Pan	2/2	2/2	4/4	4/4	8/8
Pan Width	7MHz	7MHz	14MHz	14MHz	14MHz
SCU	1	1	2	2	2
SO2R			✅	✅	✅
RX Presel	✅	✅	✅✅	✅✅	✅
XVTR	1 / 2	1 / 2	2 / 4	2 / 4	1
ATU	OPT	OPT	✅	✅	✅
GPSDO	OPT	OPT	OPT	OPT	OPT
MARS	OPT	OPT	OPT	OPT	✅
Displ/Knob		✅		✅	
	$1,999	$2,999	$3,999	$4,999	$7,499

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QUESTIONS?