

# Radio Design 401, Episode 3 – RFI Noise in Buildings

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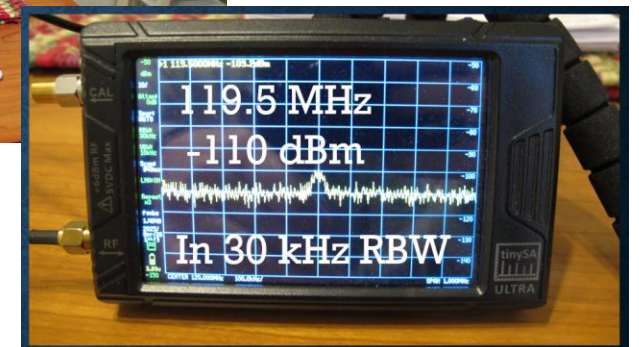
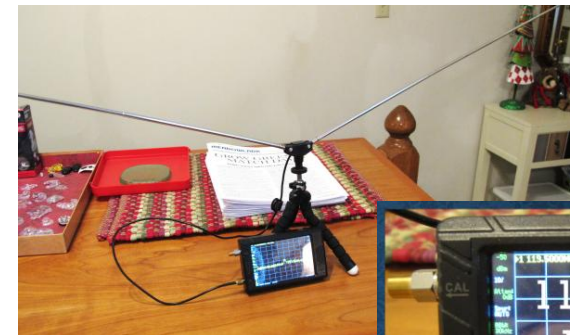
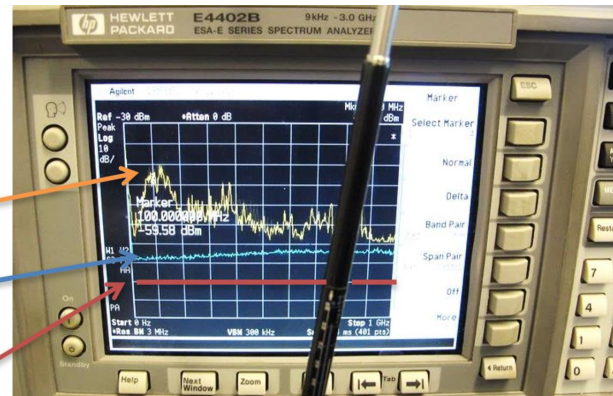
This episode examines radio frequency interference in commercial and residential buildings. We concentrate on RFI at VHF and UHF frequencies, but the theory is general and many examples are shown in detail. At the end, we consider the full set of issues that limit a radio receiver's ability to receive weak signal, including Thermal noise, RFI, and intermodulation, and discuss the value of Q-enhanced front-end amplifiers / filters to help address these issues.



*In-building RFI*

*Analyzer noise floor*

*Thermal noise floor*





# Radio Design 401

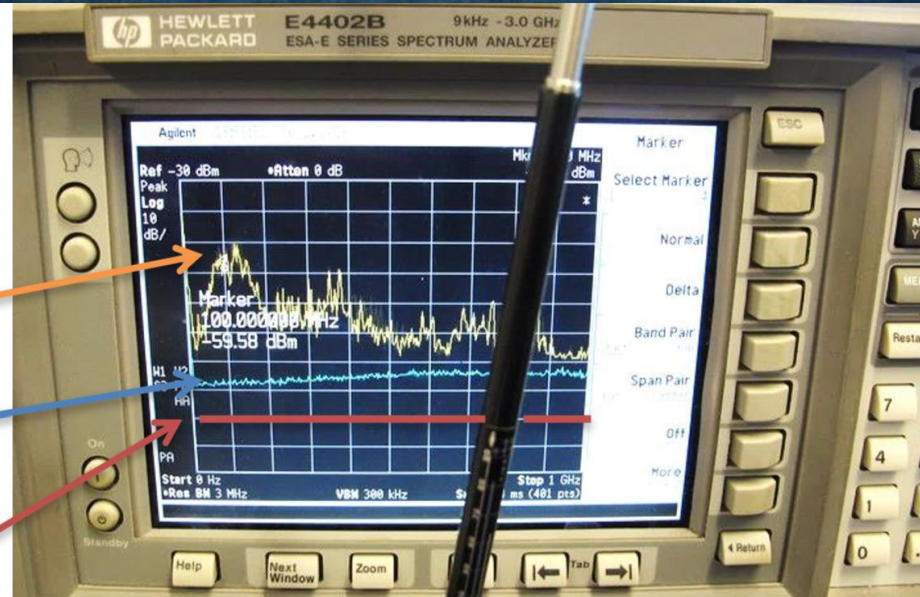
## Episode 3



*In-building RFI*

*Analyzer noise floor*

*Thermal noise floor*



# RFI Noise in Buildings



# An Excellent Video from ARRL


youtube.com/watch?v=y0dmgeORIFQ

finding and fixing rfi arrlhq

## Finding and Fixing RFI

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W1VLF@arrl.org

ARRL  
the national association for  
amateur radio®

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7,537 views Apr 27, 2021

RFI (Radio Frequency Interference) has been a problem for Ham radio operators and SWL's (Shortwave listeners) since the radio hobby began. Both from natural sources (QRN) and manmade sources (QRM). Things have changed in the last 20 years with the advent of widespread solar power, LED lightning, grow lights, digital computing devices etc. The technology boom has enhanced our daily lives, but at what price? Learn all about finding and fixing RFI in today's world.

For help with RFI issues, ARRL members can utilize the Technical Information Service:  
<http://www.arrl.org/technical-informa...>

This presentation is part of ARRL's Learning Network webinar series. To learn more and view the upcoming schedule:  
<http://www.arrl.org/arrl-learning-net...>

For more great amateur radio content, join the ARRL today!  
<https://www.arrl.org/join-arrl-renew-...>

## Let's Thank The Major Players Who helped make this presentation possible

90 % of cases

1. Power line noise
2. LED lighting and grow lights, dimmers
3. Solar power PV Photovoltaic systems
4. SMPS switching power supplies, phone chargers
5. Plasma TVs, computers, routers, modems
6. HVAC, appliances, EMC motors
7. AFCI arc fault circuit interrupters
8. Dog fence.. Invisible fence 7.5 kHz ... 10.8 kHz
9. Unknown sources

LEARNING NETWORK

8:06 / 1:00:16 • Major Pla...

### Finding and Fixing RFI

ARRLHQ  
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## EMI Suppression Components



Common mode chokes    Inline EMI Filter    Snap on Ferrite

LEARNING NETWORK

29:17 / 1:00:16 • Inline Fil...

### Finding and Fixing RFI

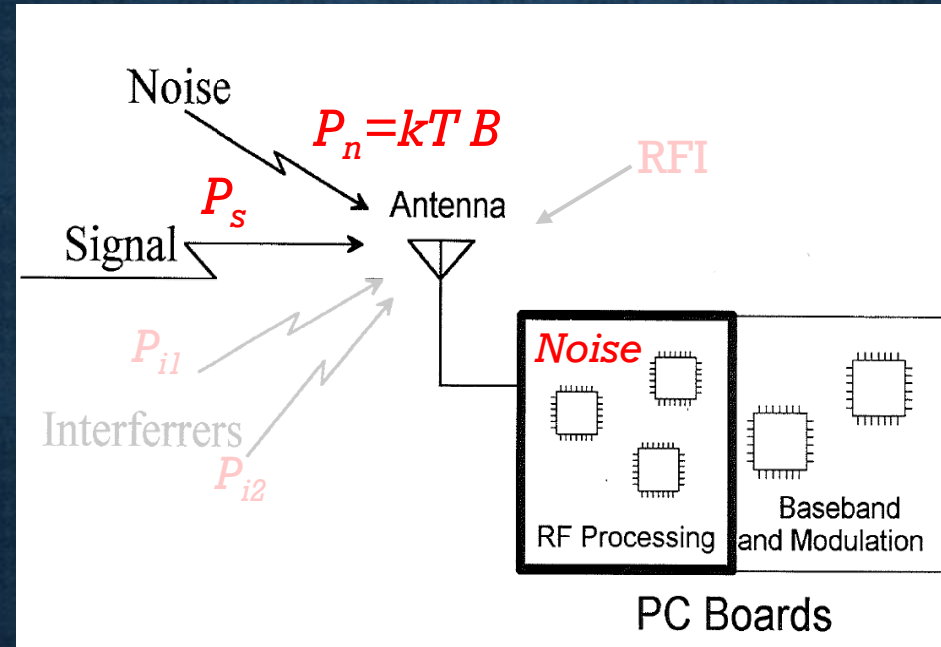
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# Receiver Sensitivity Without RFI

From  
Episode 2



$$P_{s\_min} = -174 \text{ dBm} + 10 \log(B) + S/N_{min} + NF_{rcvr}$$

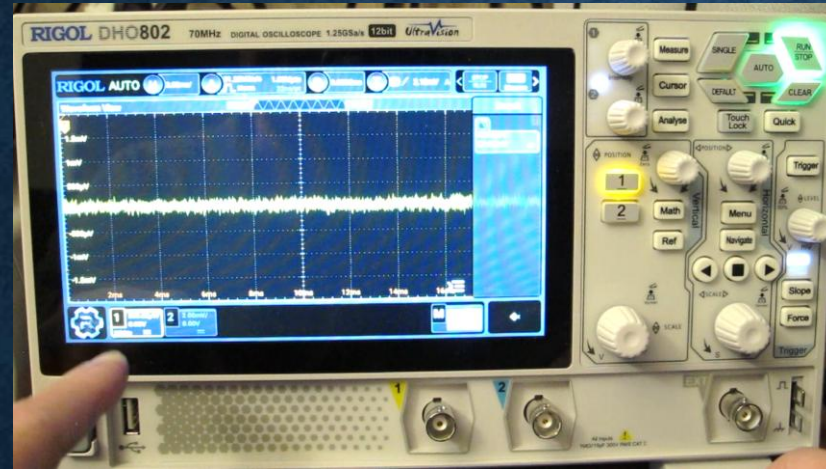
Caveats: Assumes  $T \approx 290K$  no RFI, and High Dynamic Range receiver  
(no receiver intermod issues)



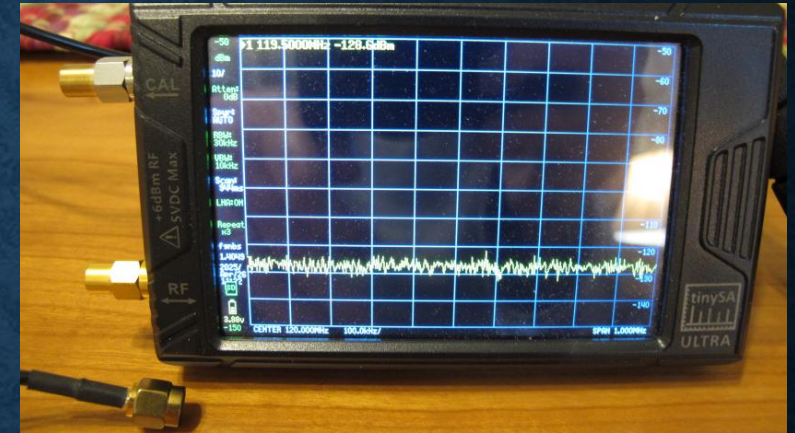
# Noise vs RFI

## Time Domain

Additive White  
Gaussian Noise  
(AWGN)



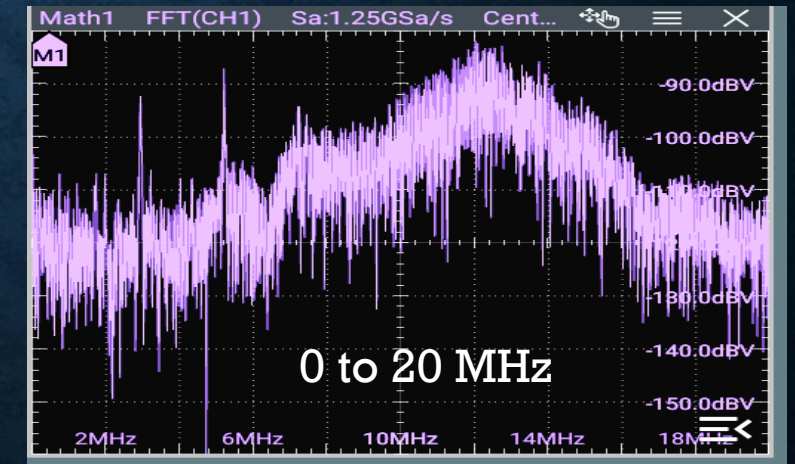
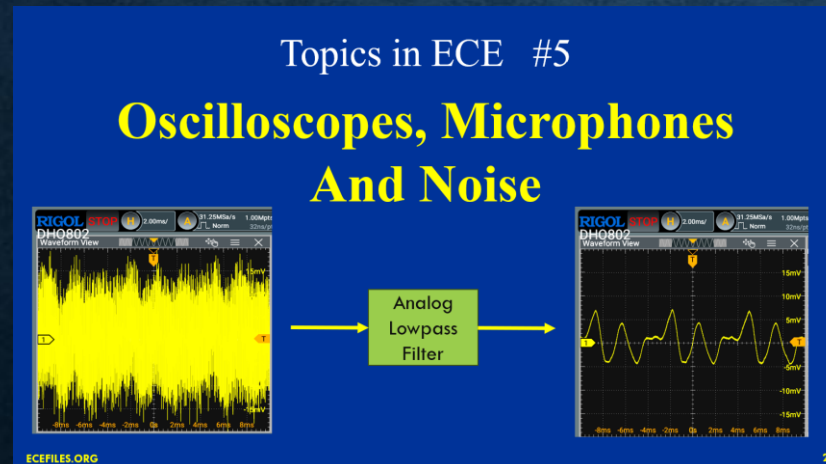
## Frequency Domain



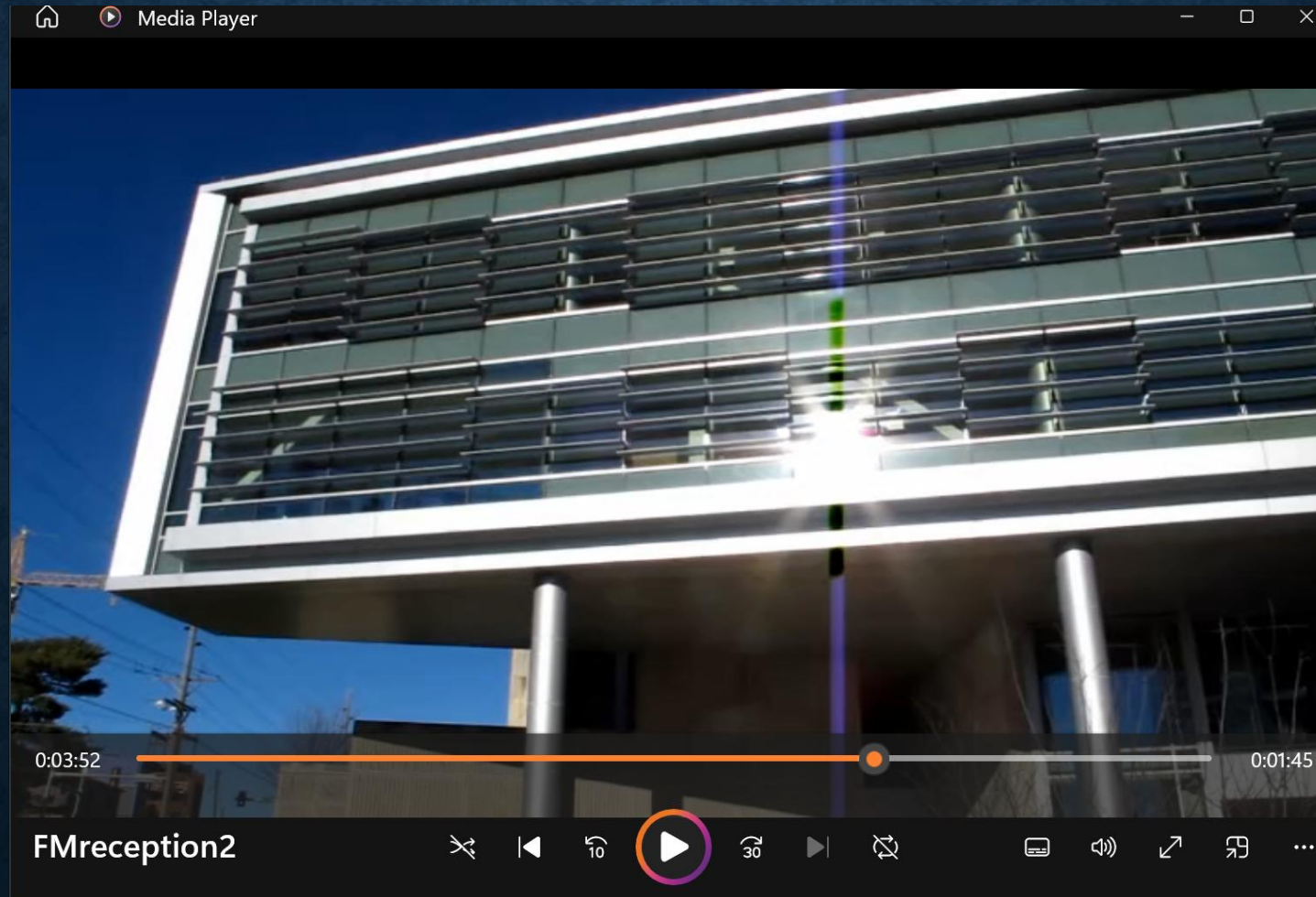
Topics in ECE #5

## Oscilloscopes, Microphones And Noise

Radio Frequency  
Interference  
(RFI) “Noise”



# Radio Reception in Buildings

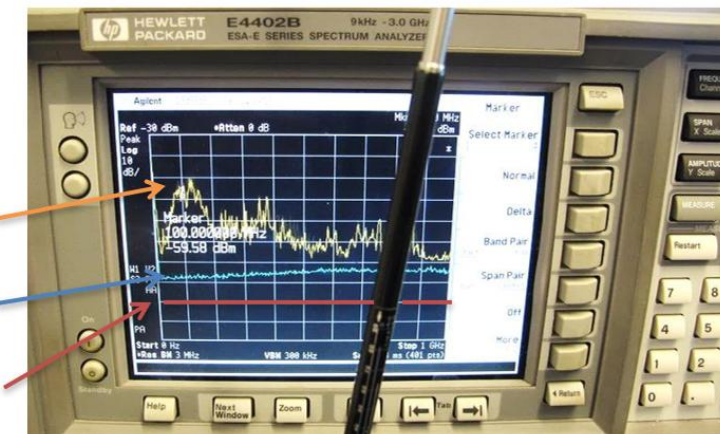




# RFI and Attenuation in Buildings

See: "Wireless communication problems in energy-efficient building construction,"  
IEEE International Symposium on Electromagnetic Compatibility (EMC), 2016

- The problem is two-fold:
  - *Energy efficient exterior glass attenuates signals entering (or leaving) the building*
  - *Interior lights produce high levels of RFI*
- Glass was measured and found to attenuate by up to 30 dB
- RFI from interior lighting is up to 60 dB or more above thermal noise floor
- *Wireless communication links (especially at VHF) can be strongly impacted*



# Outdoor vs Indoor Spectrums

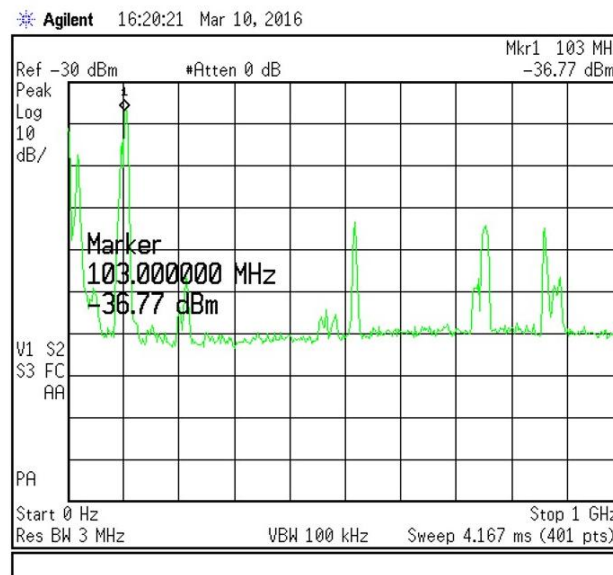
See: "Wireless communication problems in energy-efficient building construction,"  
IEEE International Symposium on Electromagnetic Compatibility (EMC), 2016

25 - 29 July 2016 ■ Ottawa, Canada

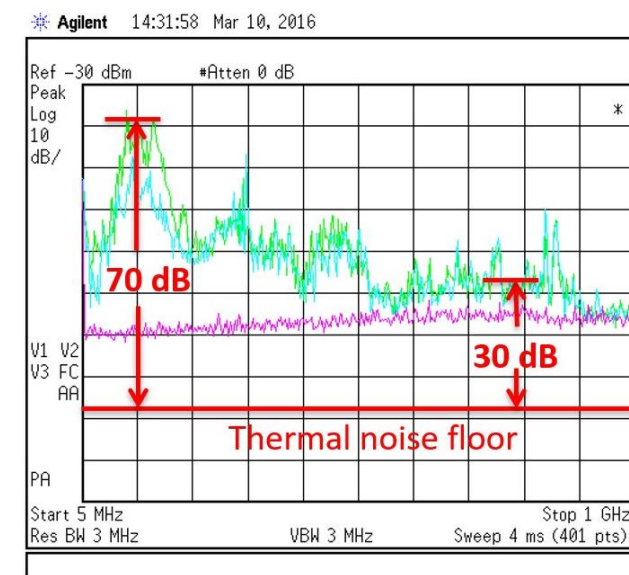
## 0 to 1 GHz Spectrums

- RFI is most concentrated from about 50 MHz to 500 MHz
- Still quite strong at 800 MHz and above
- **Indoor** RFI is above noise floor by 30 dB in lower cell-bands
- Cellphone tests indicated 20 to 30 dB attenuation as well
- Combined hit is 50+ dB
- Worse in VHF band ( up to 90 dB total ! )

### Outside building

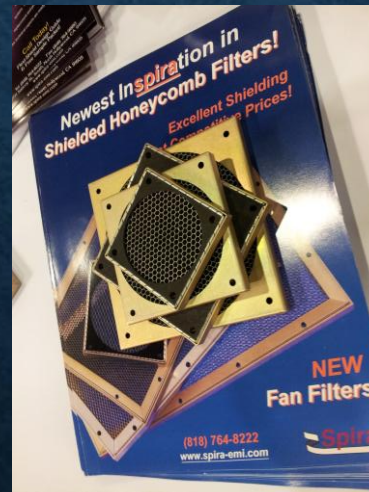


### Inside building



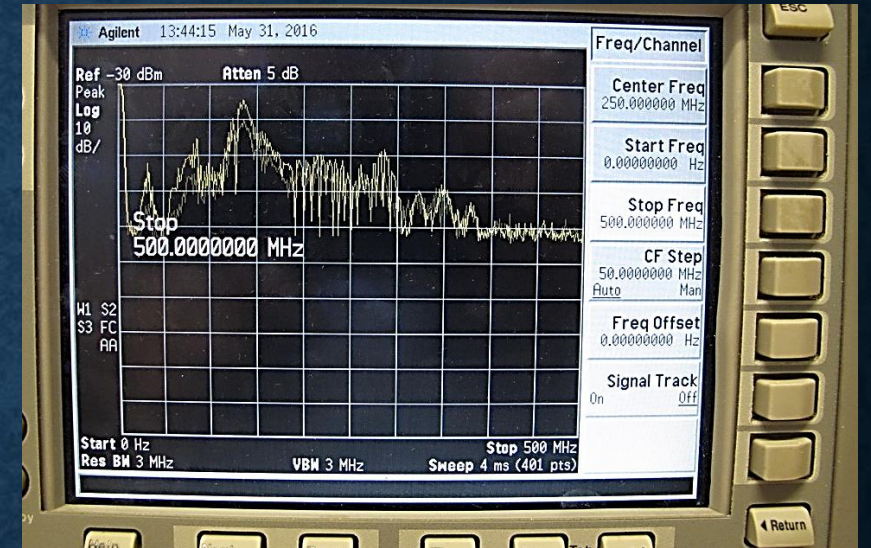


# IEEE EMC Conference 2016 Ottawa Canada



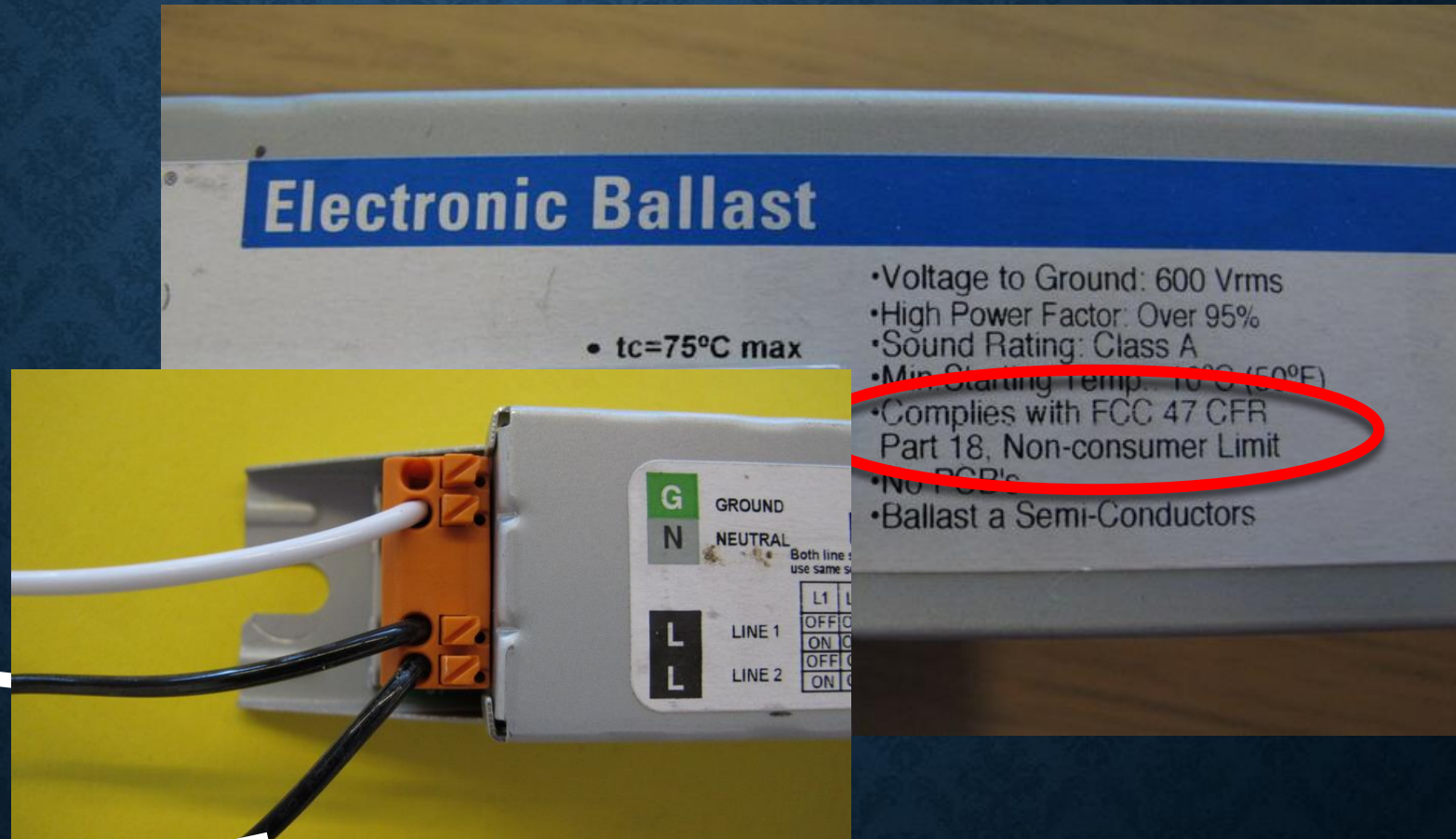


# Tracking Down the “Noise”





# Building Wiring is Antenna



# Time Domain Observations





# Theories and Solutions

At 100 MHz and above, these capacitors are inductors, not capacitors, and common-mode choke is an AC coupling cap !

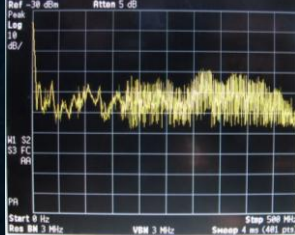
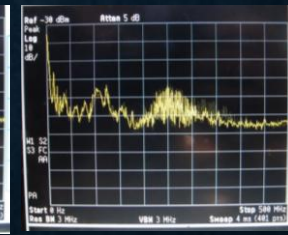
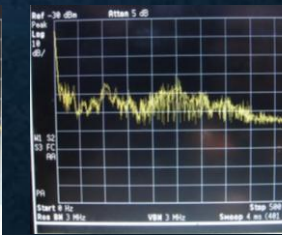
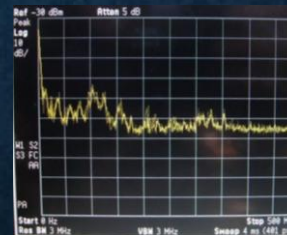
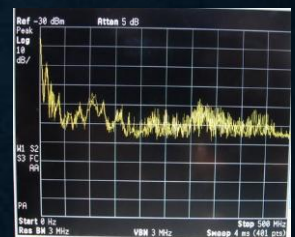
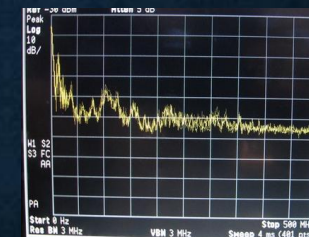
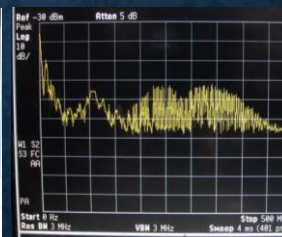
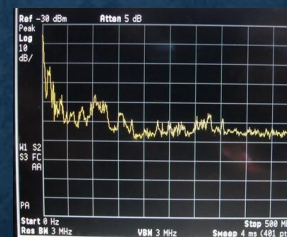
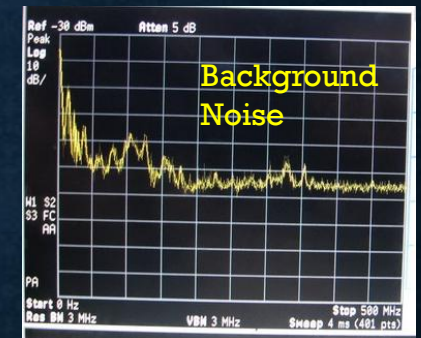
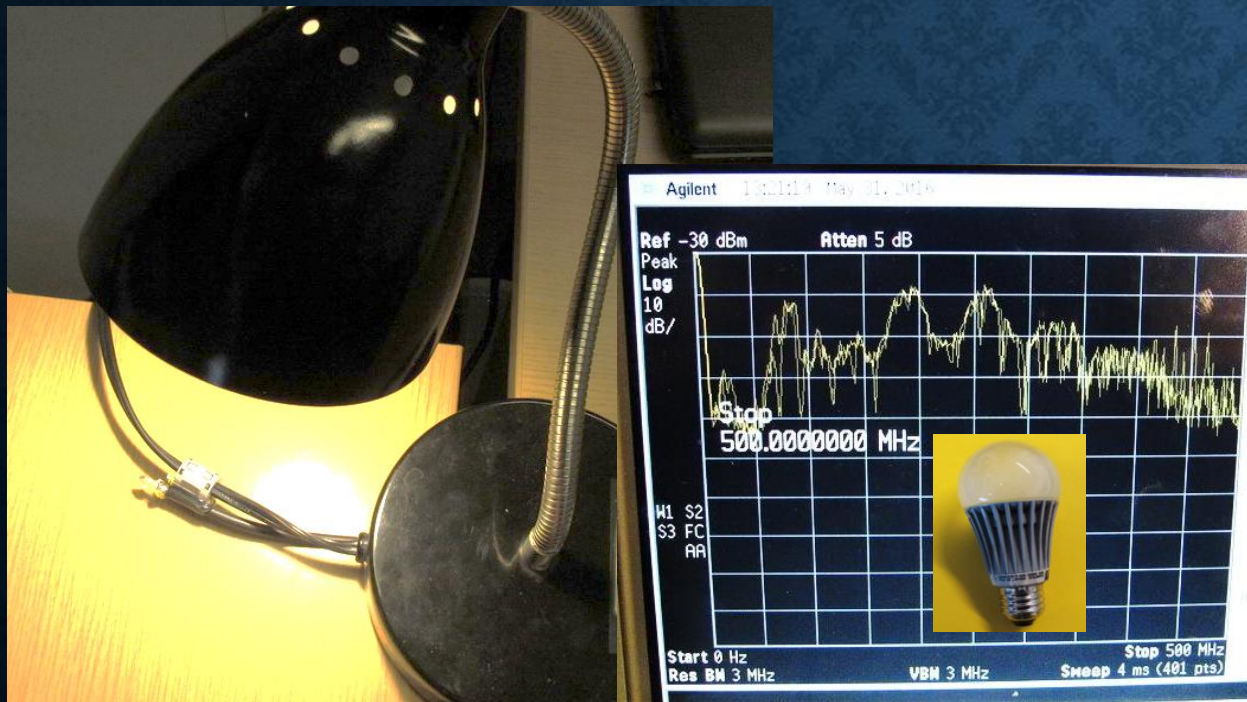


Products need better diff-mode and common-mode filtering.  
(Tradeoffs with cost, but still ...)



# Regular Bulbs (2015)

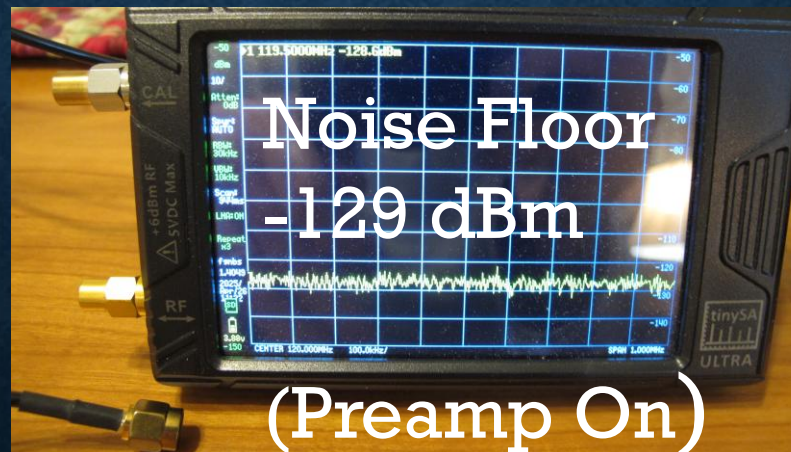
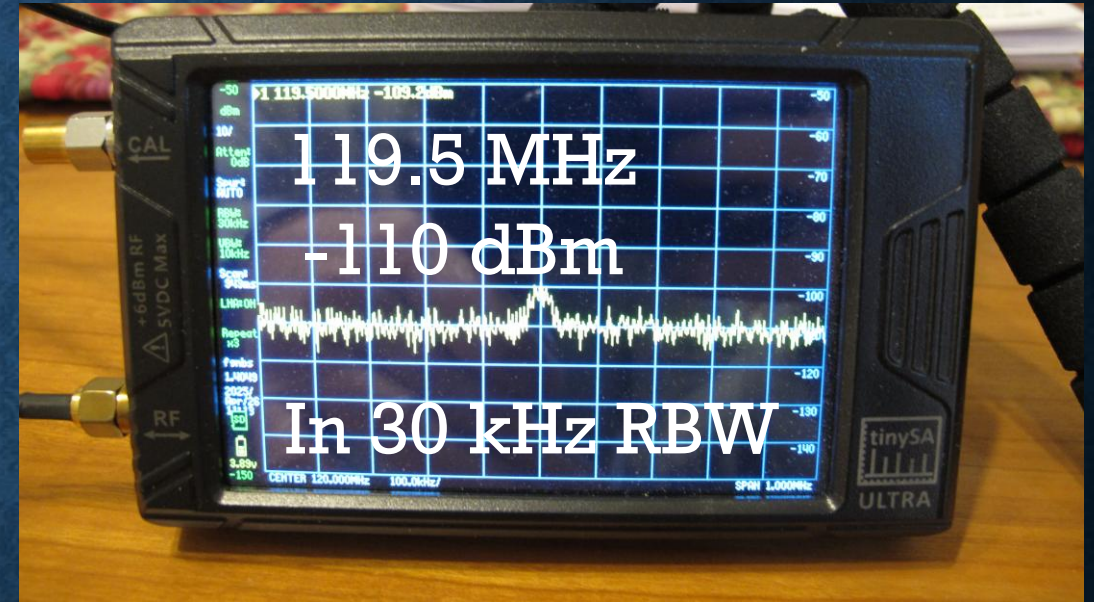
Some 60W A19-base LED bulbs may be similar or worse in conducted emissions ! (2015 Vintage bulbs shown)





# Residential “Noise” Levels

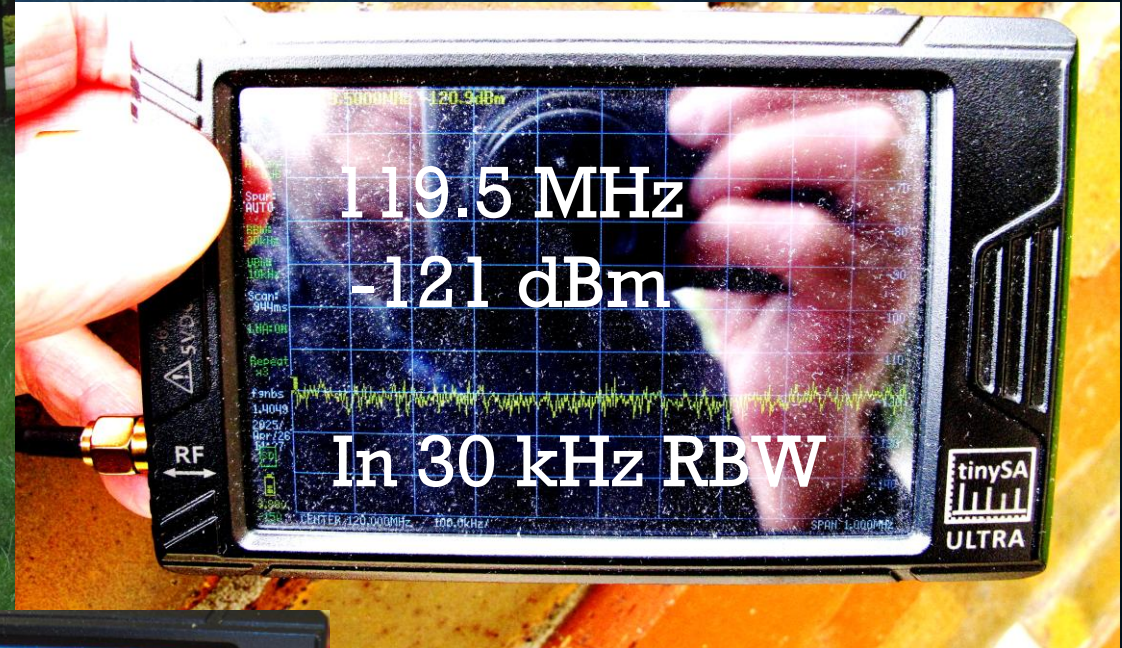
Indoors



TinySA-Ultra Noise Figure is about 3 dB with Preamp ON

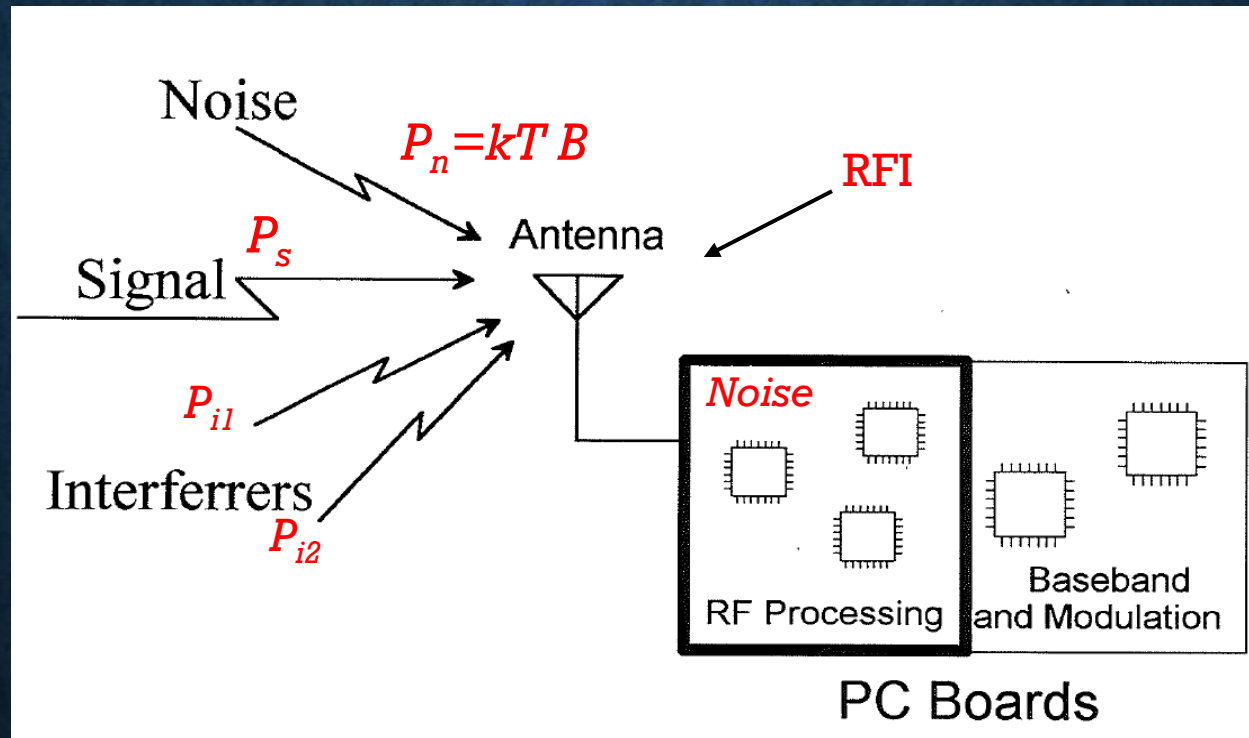


# Residential “Noise” Levels





# Limits to Receiver Sensitivity

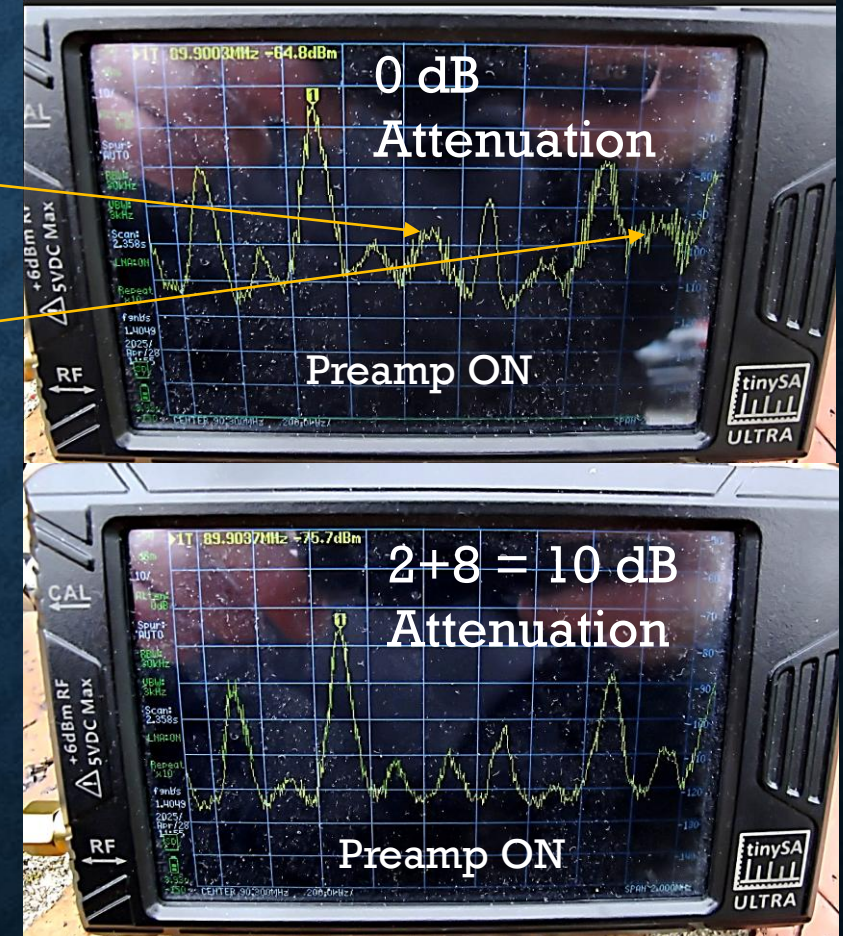
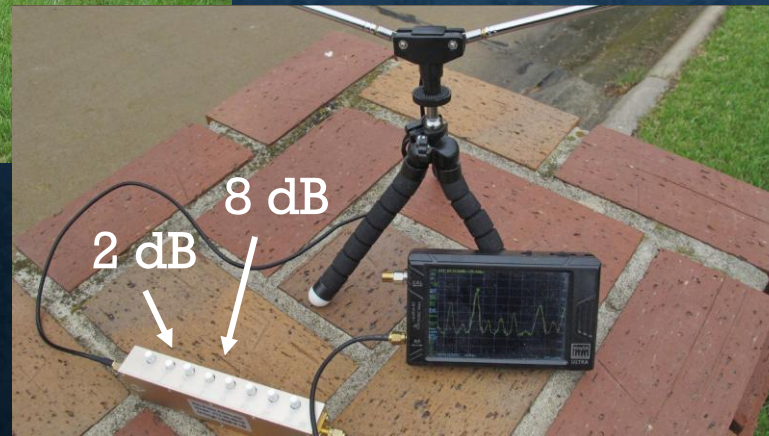




# Residential Reception Noise + RFI + Intermodods



Intermod  
Corrupted  
Stations

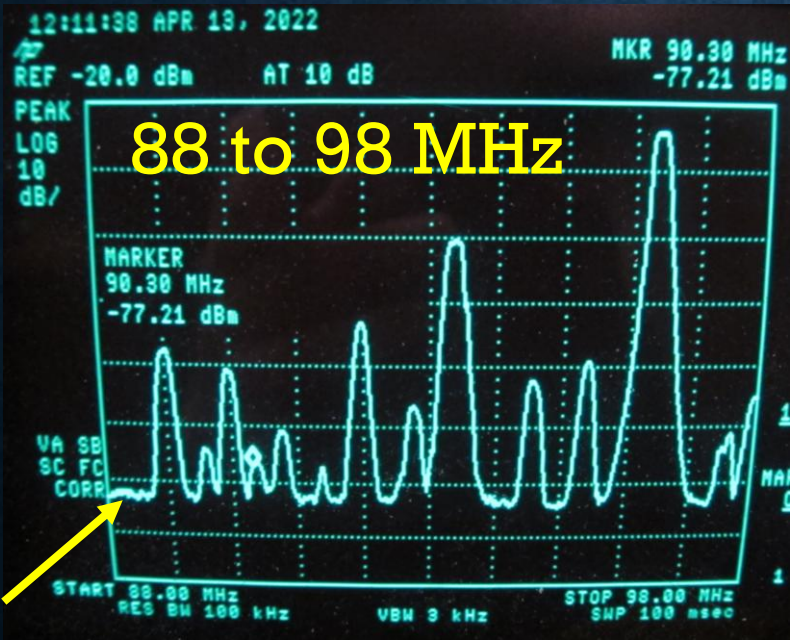




# From Radio Design 401 - Episode 1

*RD101 Radio Out-performed all 3 Commercial Ones !*

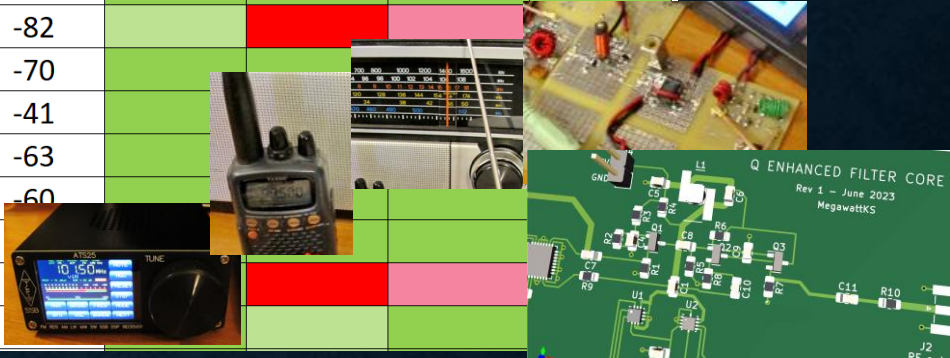
*(when using 200 kHz bandwidth Q-enhanced Front-End filter)*



88.1 MHz

Station	dBm	ATS 25	VR-120	SW-60	RD-101*
88.1	-96				
88.9	-58				
89.5	-75				
89.9	-61				
90.3	-77				
90.5	-85				
90.7	-71				
91.3	-80				
91.9	-55				
92.5	-82				
92.7	-70				
93.3	-41				
94.5	-63				
95.3	-60				
96.3					
97.5					
97.9					

With Q-enhanced filter front-end added





# Possible Future Videos

- ***Receiver Performance*** *(Including the math)*
  - *Compression, Intermodulation, 3<sup>rd</sup> Order Intercept Point, and SFDR*
  - *Noise Figure Tradeoffs with Intermod Performance (including CTB ?)*
  - *Noise analysis and simulation in circuits*
- ***Design of Q-enhanced Front-ends*** *(Follow-up to Episode 1)*
  - *Effects of positive feedback on gain, selectivity, input Z, ...*
  - *Core CB amplifier design ( $Q_o$  of inductors, feedback topology, biasing for desired gain...)*
  - *Self-tuning hardware and software ?*

*Thanks For  
Watching !*