Creating A Calibrated Noise Monitoring Antenna & Using To Measure Baseline @ EOC Construction Site

Gordon Gibby KX4Z

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Industry uses dBuV/m (E-Field)

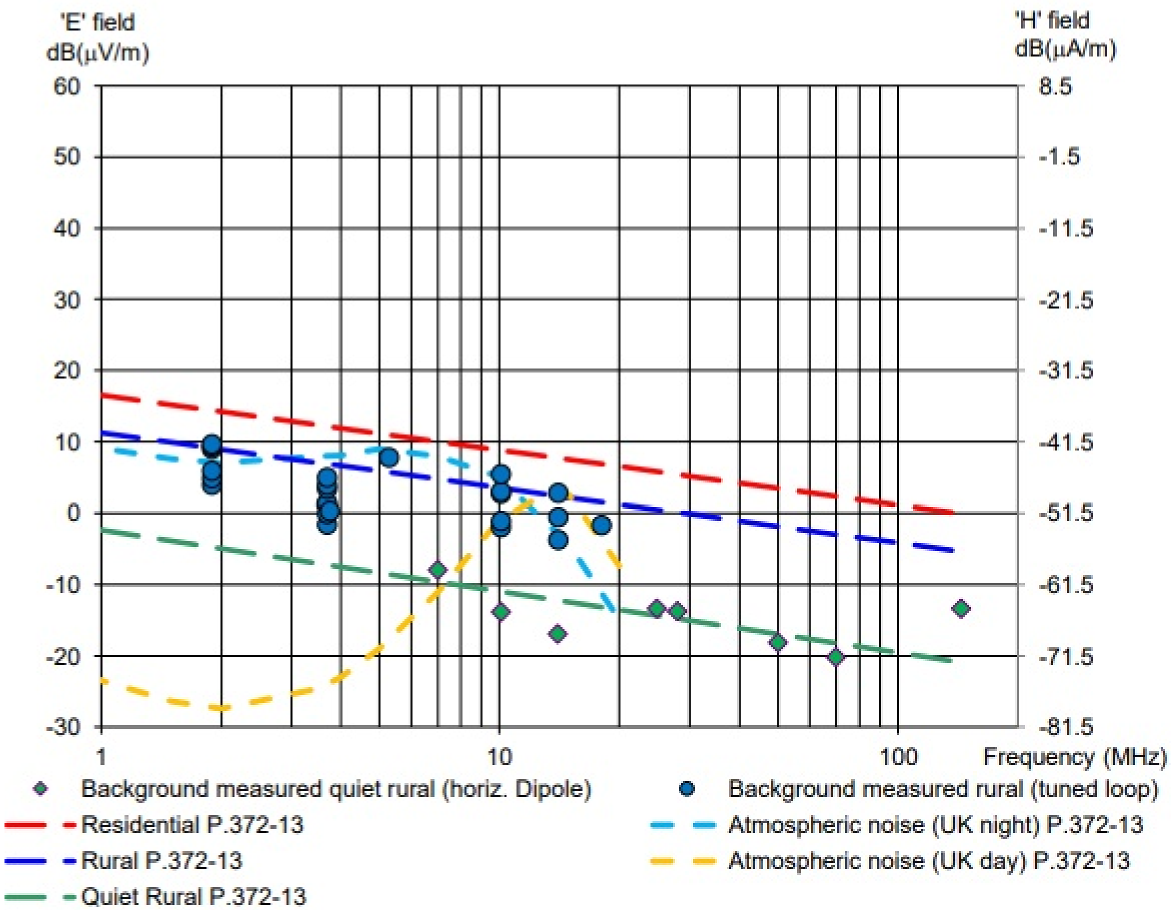
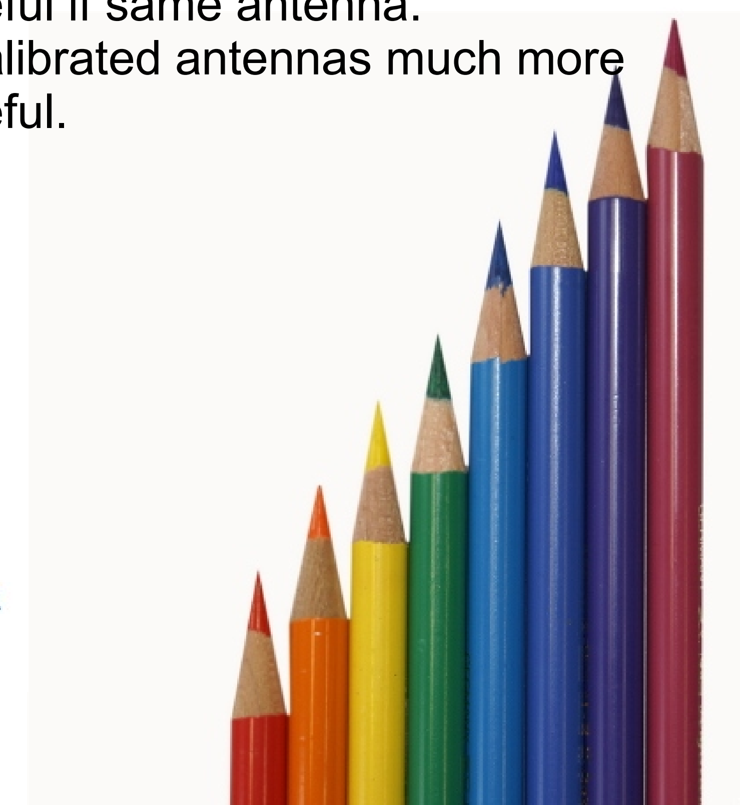


Figure 1 ITU/R P.372-13 expected receiver noise levels together with levels measured by RSGB EMCC 2014 to 2017.

REF: https://rsgb.org/main/files/2017/12/221216-Noise-leaflet-issue-2.pdf, page 3

Reporting the E-Field makes the measurements independent of the type of antenna or gain.

- "S-Units" quite unreliable.
- Spectrum analyzer dBm only useful if same antenna.
- Calibrated antennas much more useful.



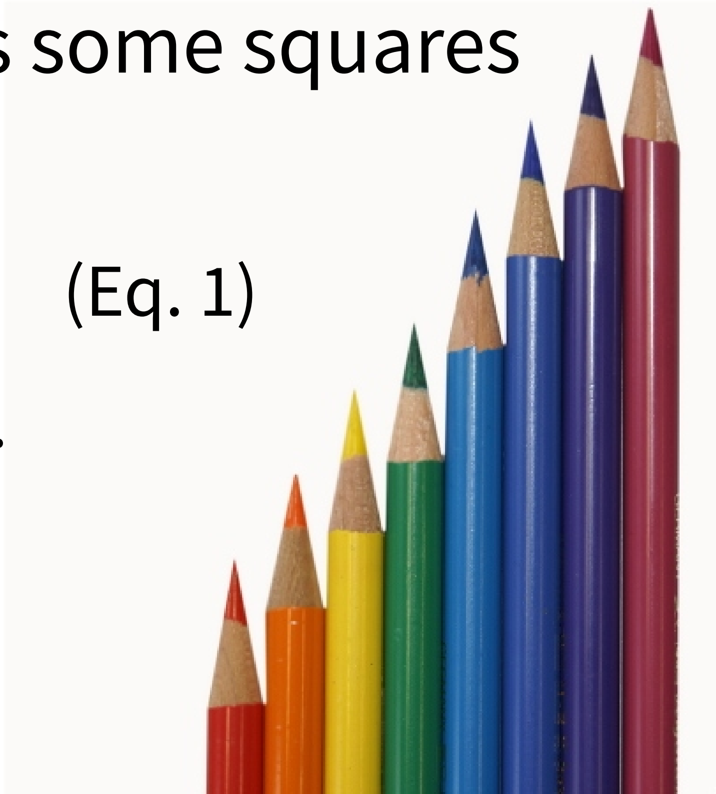
Commercial Calibrated EMC Antenna

- Industry uses Vertical monopole, high impedance amp
- **$3000 used**.
- Calibrated with Antenna Factor, allows conversion from Spectrum Analyzer dBm directly to dBuV/m

- Standards usually refer to a VERTICAL monopole….
- But our EOC / inter-county communications are generally NVIS type comms, so I have used HORIZONTAL measurements to be more applicable to the real situation.

Conversion

- Assumption of 50 ohm environment
- Spectrum analyzer reports POWER in dBm
- Converting to a voltage involves some squares & math
- E dBμV/m =107dB + dBm + AF (dB) (Eq. 1)
- Universally agreed upon conversion.



My Procedure to Calibrate New Antenna

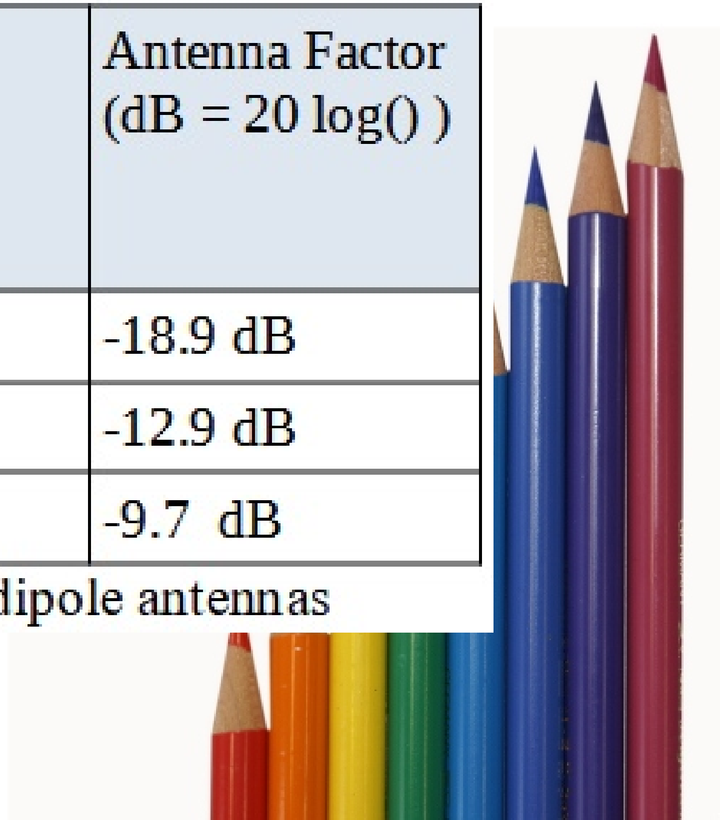
- Measure likely isotropic noise with antenna whose AF can be known, calculate dBuV/m
- Measure with antenna to be calibrated, get dBm on analyzer
  - *Issue: not exactly in the same "field": full size stretched tree to tree; test antenna out on porch roof….*
- Reverse the math to figure out AF for test antenna.

Antenna Factor for Full Size Dipole

Electromagnetic Theory allows obtaining the AF for a full sized dipole   Noise (excluding point source nearby) has advantage of generally isotropic in azimuthal directions. .

Frequency (MHz)	Wavelength (meters)	Antenna Factor (linear) for isotropic background noise signal = 9.72 / (λ)	Antenna Factor (dB = 20 log())
3.50	85.7 m	0.113	-18.9 dB
7.0	42.9 m	0.228	-12.9 dB
10.1	29.7 m	0.327	-9.7 dB

Table 2: Computations of Antenna Factor for full-size dipole antennas

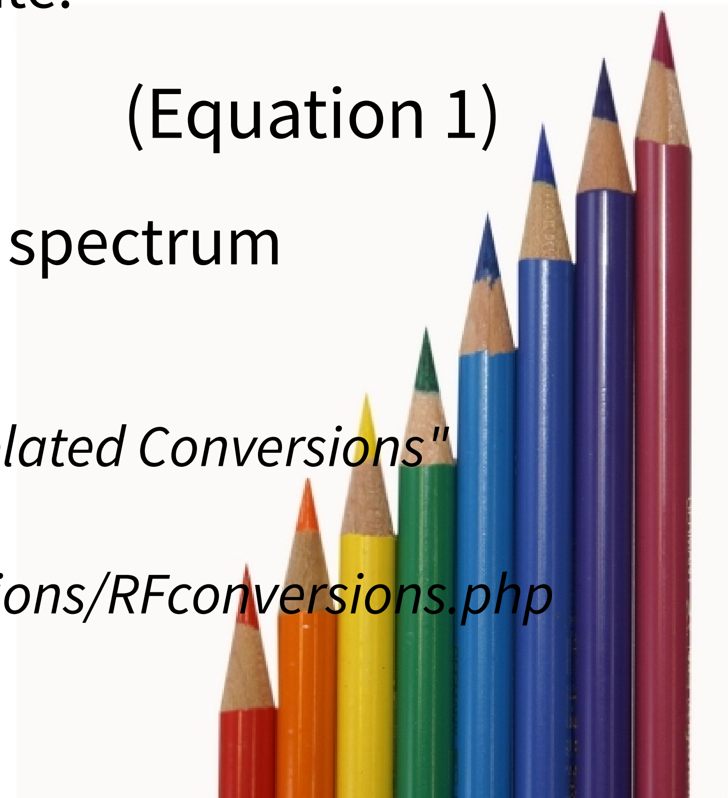


Conversion to dBuV/m

Spectrum analyzer power measurements were then converted to E-field signal strength ($\mathrm{dB\mu V/m}$) using Equation 1, which is derived from Ohm's Law in a 50 ohm system using the definitions of decibel for power and voltage as appropriate.

$$E\ \mathrm{dB\mu V/m} = 107\mathrm{dB} + \mathrm{dBm} + AF\ (\mathrm{dB}) \qquad \text{(Equation 1)}$$

where dBm is the power measured by the spectrum analyzer.



REF: A. H. Systems, Inc. "Useful Formulas for RF Related Conversions" [Online]. Available: https://www.ahsystems.com/EMC-formulas-equations/RFconversions.php Accessed 2/10/2024.

Noise = Noise

- Whether measured by a full sized antenna or by a small 2-foot portable measurement antenna…the E-field of isotropic background noise is the same.
- Allows for an equality equation that gives us the Antenna Factor for the small 2-foot antenna.

Resulting Calibration Curve
Simple 2-foot Antenna

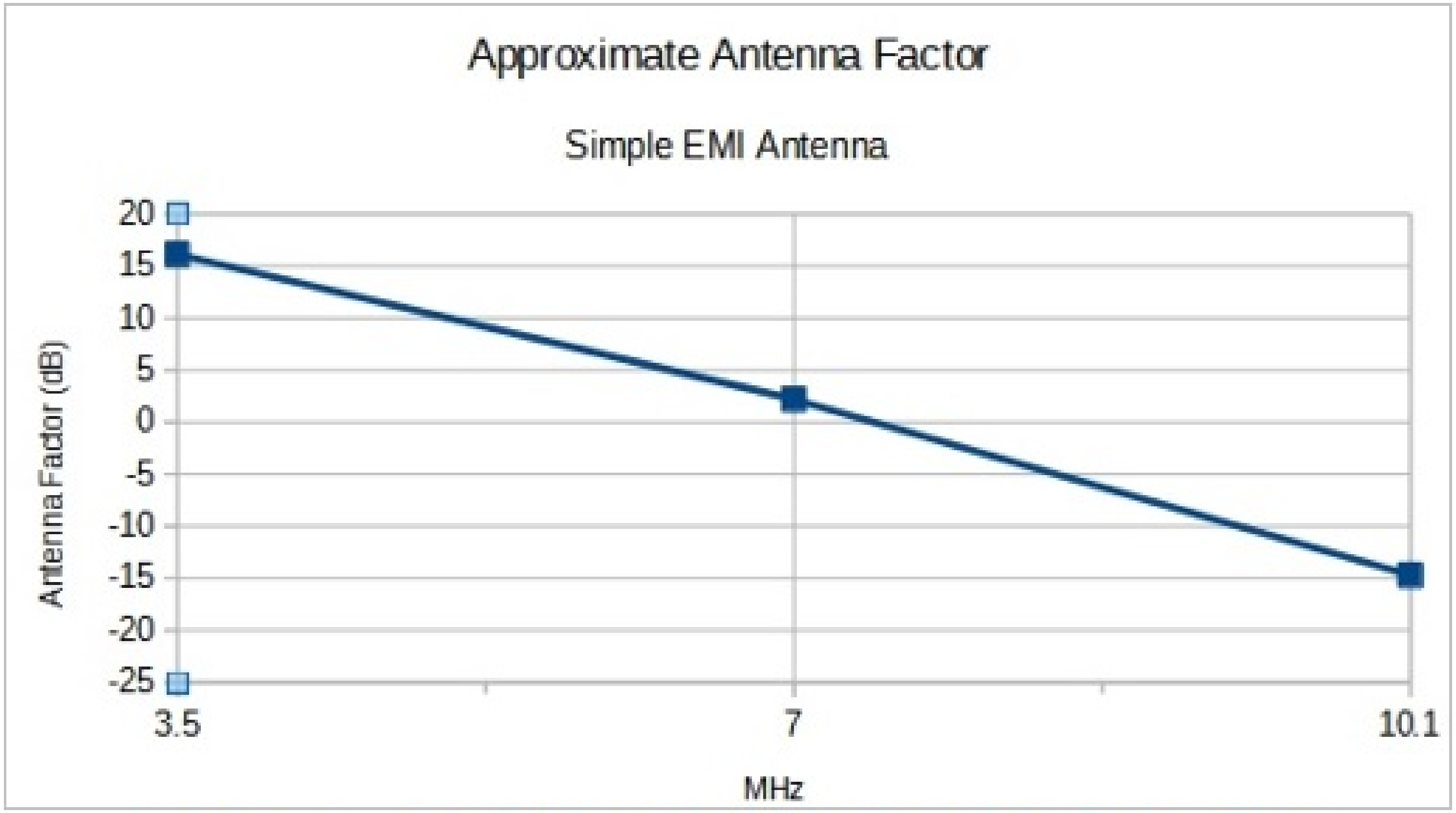
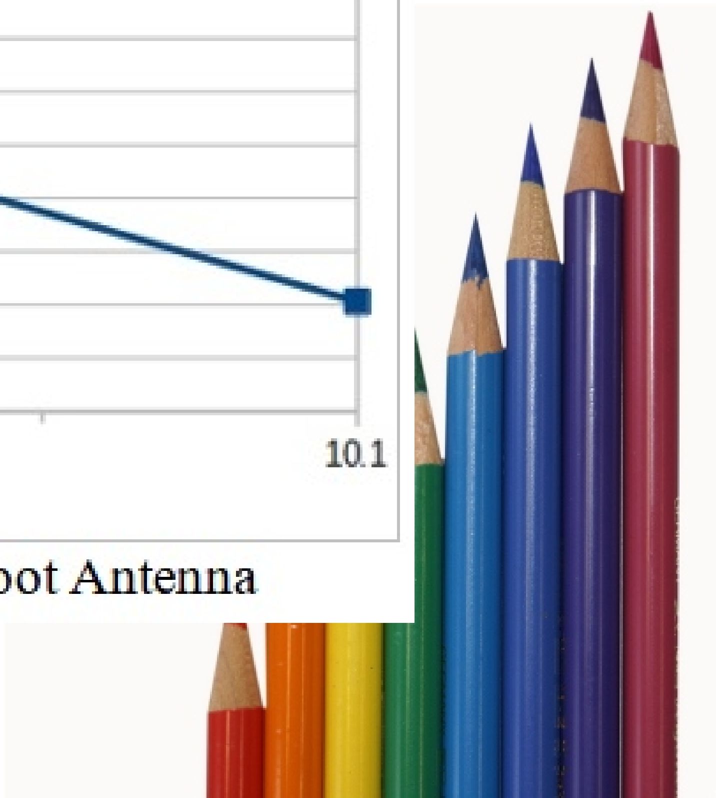


Figure 1: Antenna Factor for Simple 2-foot Antenna



AF values at 7MHz/10MHz Suspect

- During calibration, 2-foot antenna placed on porch roof limited by 10-foot coax.
- May have been in higher noise field than comparison 100-foot dipole stretched in back yard.
- Would result in inappropriately negative AF calibration results…..
- 3.5 MHz value may be reliable, and this **by itself** allows useful measurement of noise environment due to harmonics of 60Hz power systems…

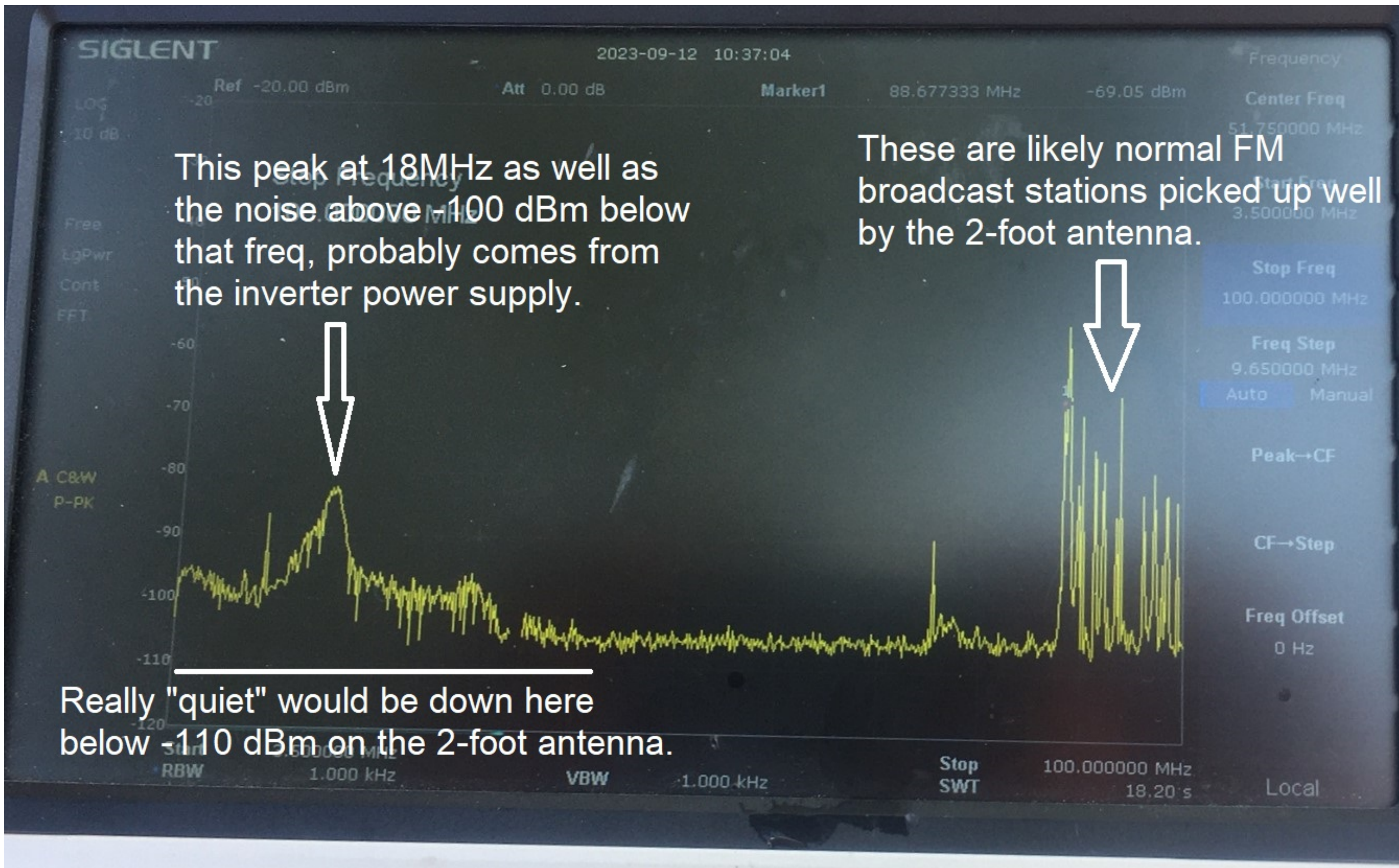
Utilization for EOC Measurement

- Alachua County, Florida is moving their EOC and Fire-Rescue Headquarters to a huge old WWII building
- Building will be renovated.
- Previous EOC beset with mega-dB RFI HASH presumably from backup power systems
- Desire to avoid repeat.

Monitoring Setups

MUST have quiet power supply!

(Embarrassing record of mea culpa.)



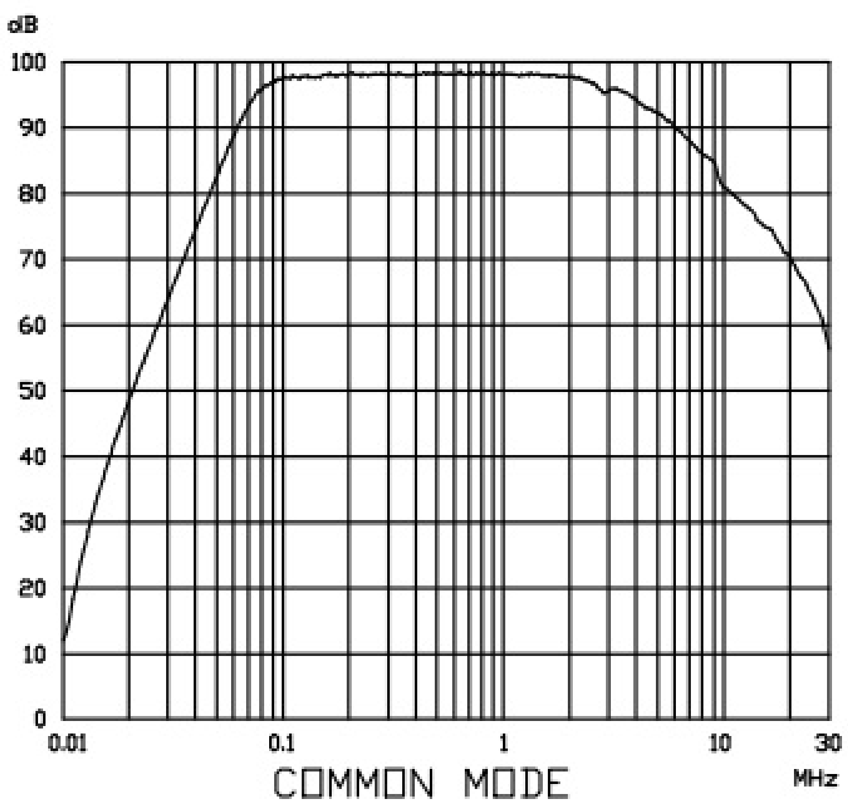
Sleuthing

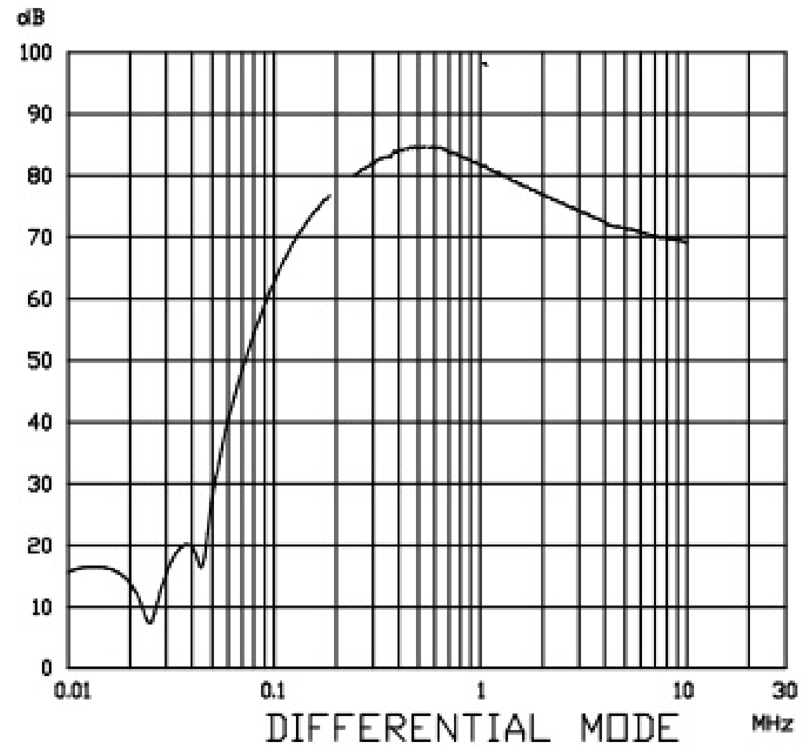
- Discovered when comparing measurements back home, powered by diesel generator (free wheeling alternating controlled only by mechanical governor) versus the filtered inverter
- Utility power is also usually quiet.

Had to repeat entire measurement...

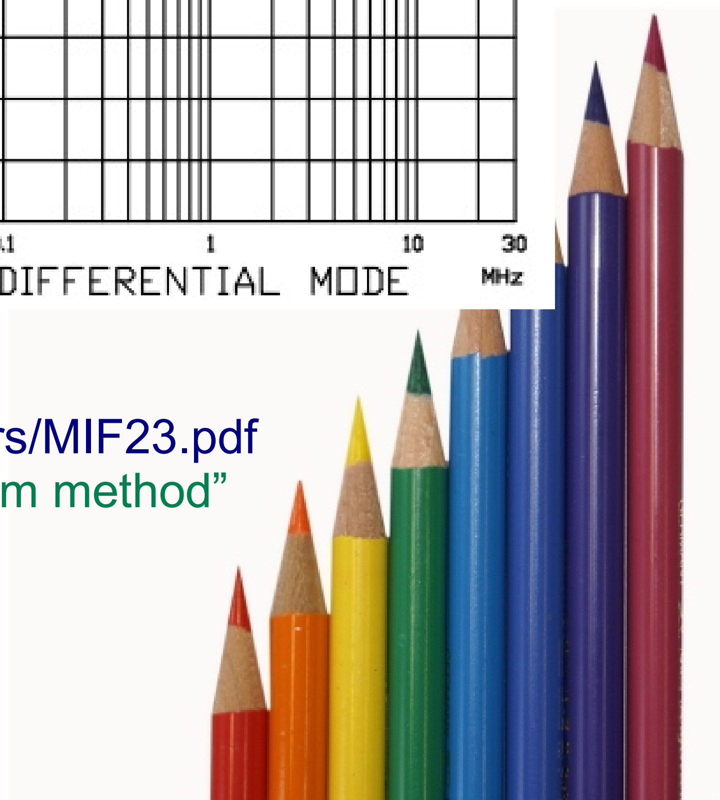
- Back to the site
- Utilized diesel generator
- PLUS MIF23 filter
- PLUS 100ft extension cord (laying on ground)
- Compared to utility where possible
- FAR quieter measurements discovered.

MIF23 Filter





REFERENCE:
https://cdn.automationdirect.com/static/manuals/emifilters/MIF23.pdf
“Filter Insertion Loss Characteristics, CISPR 17 – 50 Ohm method”

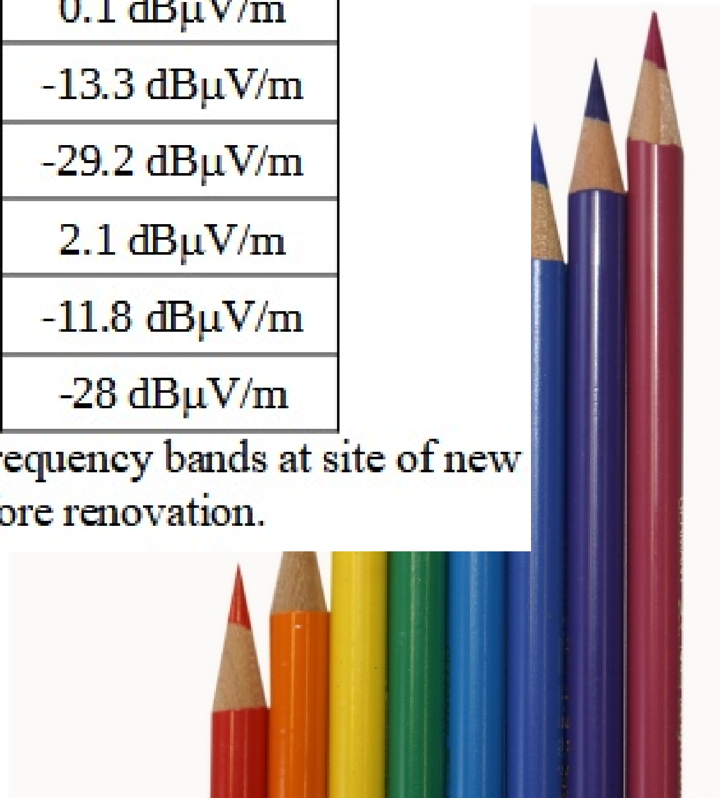


Measurement Locations
Left = 1   Right = 2

Final Result
Baseline Measurement

Location	Frequency (MHz)	dBm noise power measured	AF for 2-foot antenna at that freq.	Calculated dBμV/m (baseline noise)
1	3.5	-123 dBm	16.1 dB	0.1 dBμV/m
1	7.0	-122.5 dBm	2.2 dB	-13.3 dBμV/m
1	10.1	-122 dBm	-14.2 dB	-29.2 dBμV/m
2	3.5	-121 dBm	16.1 dB	2.1 dBμV/m
2	7.0	-121 dBm	2.2 dB	-11.8 dBμV/m
2	10.1	-120.8 dBm	-14.2 dB	-28 dBμV/m

Table 2: Measurements of baseline RFI noise at important NVIS frequency bands at site of new Alachua County EOC/Fire Rescue Headquarters, before renovation.



Spectrum Analyzer measurements comparison with existing EOC

Power measurements (same antenna) @ 10kHz BW at new EOC site:

3.5MHz -123 dBm
7 MHz -121 – 122.5 dBm

Old EOC roof is 40-50 dB more noisy.
Old EOC Parking Lot is still as much as 30dB more noisy...

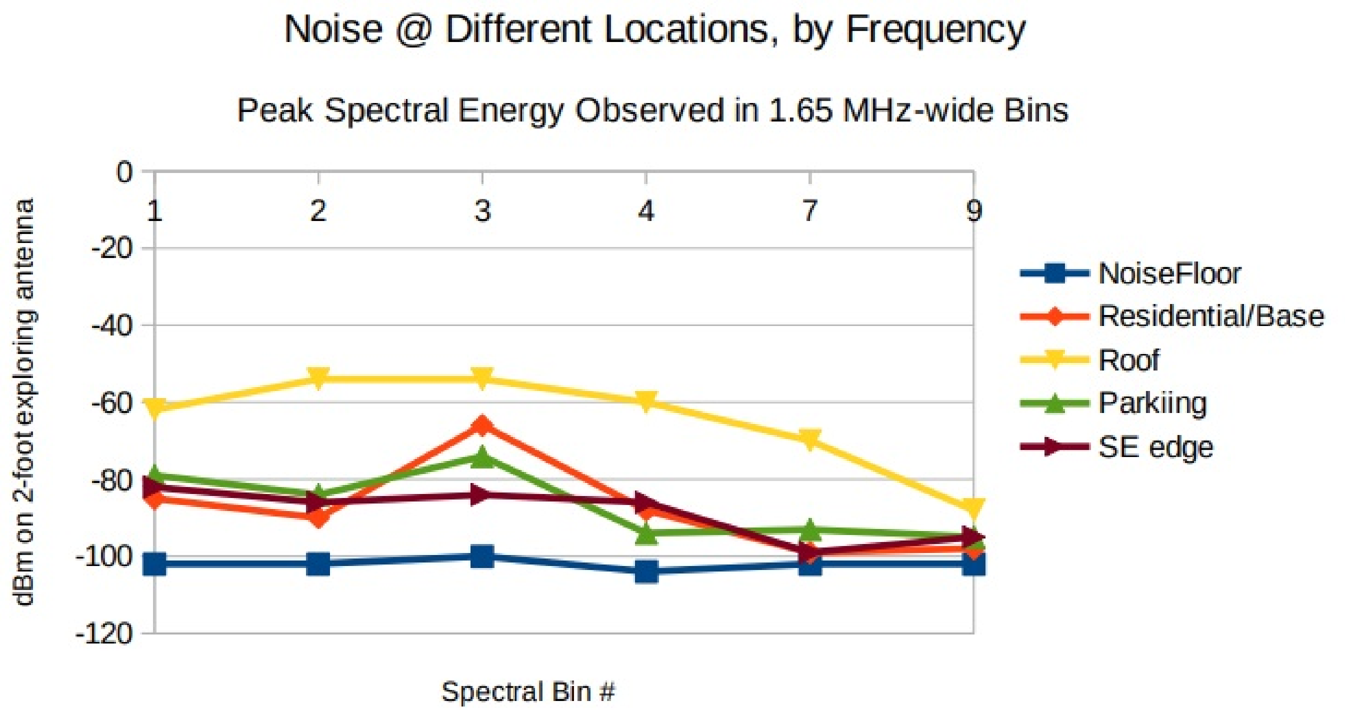


Figure 1. Graph of largest signal in each of 6 selected frequency segments, measured at different locations, using 2-foot dipole, 6dB external attenuator, appropriately taken into account. 100 kHz bandwidth for all measurements.

To correct to 10kHz bandwidth, subtract 10dB for power measurements.

Plotted on RSGB Data dBuV/m

3.5 MHz data seem reasonable, but 7 is at low end of RSGB measurements and 10 MHz much lower.

Suggests AF calibration may be suspect for 10 MHz...so the dBuV/m measurements may need further refinement, but the spectrum analyzer dBm measurements with same antenna, versus older EOC are still quite relevant.   .

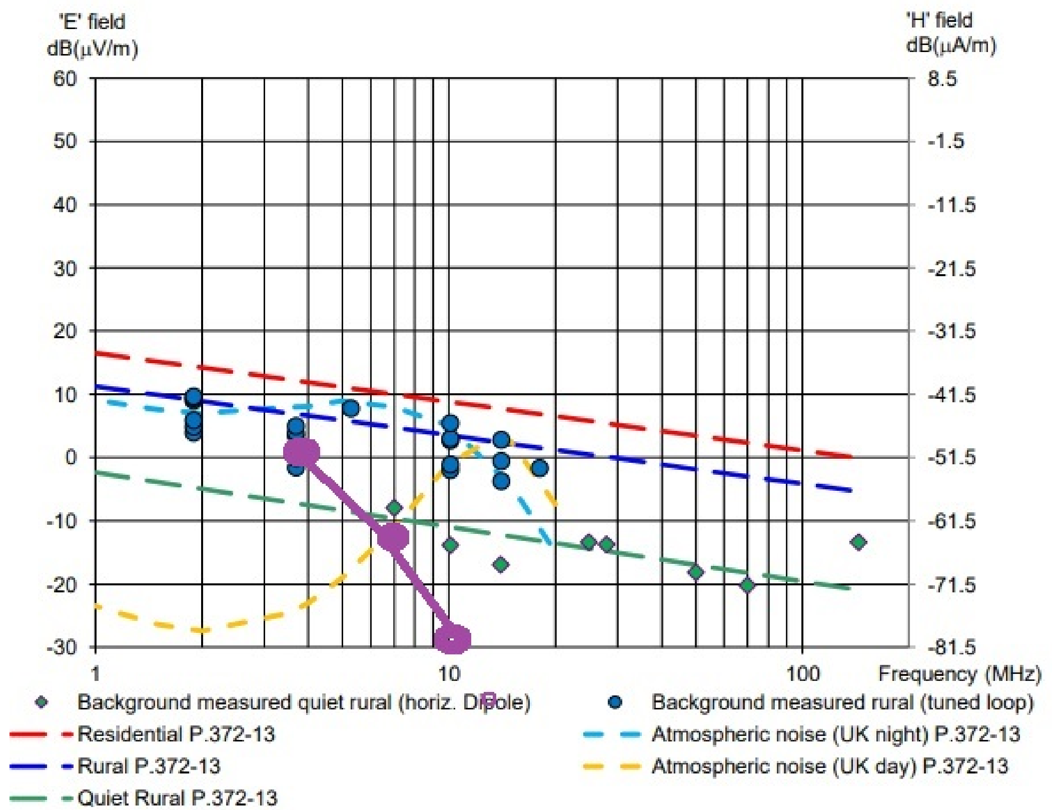


Figure 1 ITU/R P.372-13 expected receiver noise levels together with levels measured by RSGB EMCC 2014 to 2017.

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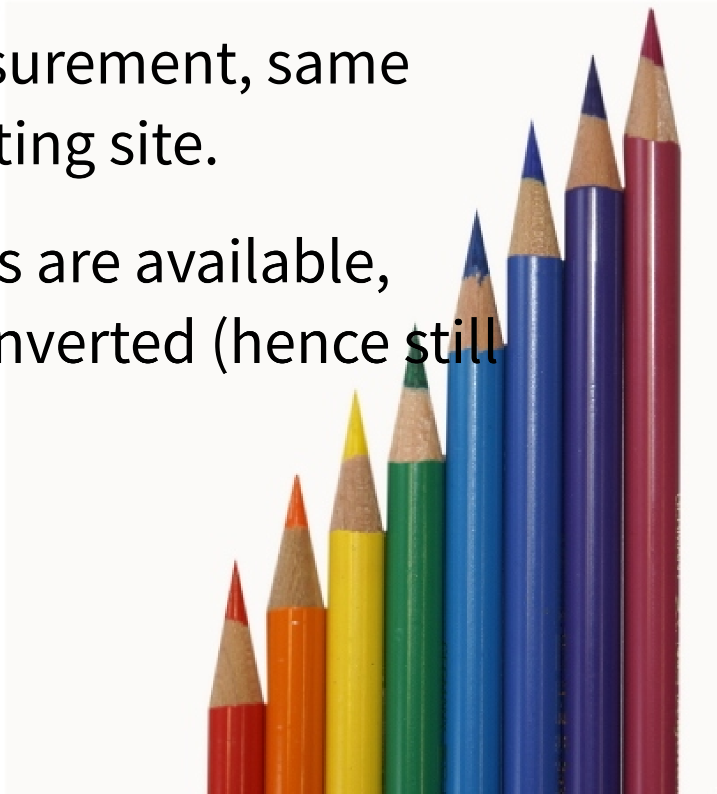
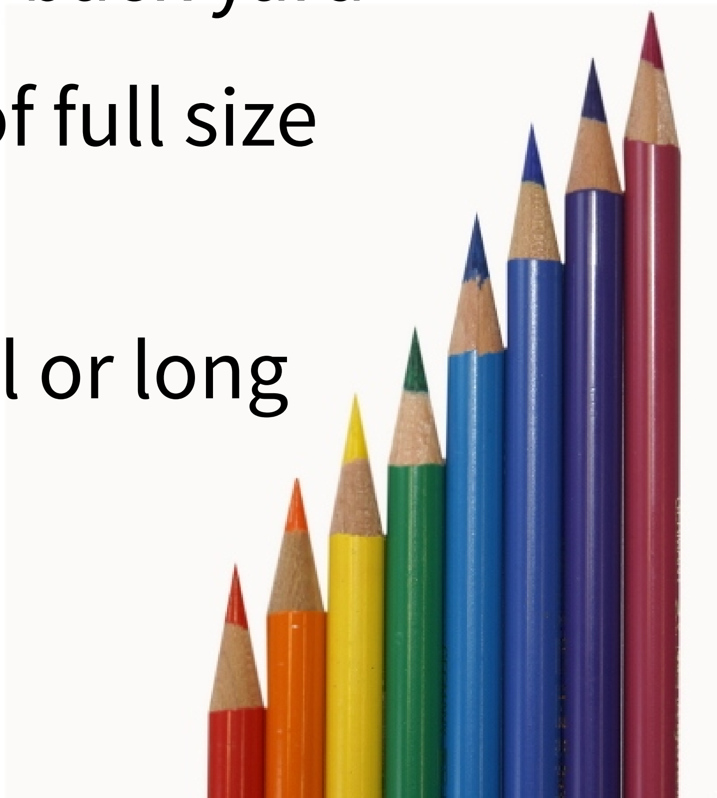
Conclusions

- Making accurate noise measurements is **tricky**, requires attention to inadvertent corruption due to power system noise in measurement setup
- AF calibration for 7/10 MHz of simple antenna appear suspect.
- New EOC site (when comparing dBm measurement, same antenna) is FAR quieter than built-out existing site.
- When more accurate 7MH/10MHz AF values are available, retained dBm measurements can be re-converted (hence still useful)



Next: Improvement Steps

- Improve AF for simple 2-foot antenna by creating individual full size dipoles for 3.5, 7 and 10 MHz – out in large 5-acre back yard
- Place 2-foot antenna at center of full size dipoles for each comparison
- Power either from filtered diesel or long extension cords.
- Solar panel system off.



HOW TO APPLY THIS STUDY
TO AN ALREADY EXISTING RADIO STATION

It is easy to determine your local radio noise at an existing station, if it has a reasonably "full size" HF antenna. Since noise comes from generally all directions ("isotropic"), the "gain" of any full-sized antenna with respect to isotropic noise is basically 0dB. Using a calibrated spectrum analyzer (rather than an S-meter), make measurements of the received energy at a "vacant" spot in a ham band (in dB-milliwatt, "dBm") and use the following formula to calculate the E-field of noise at each frequency:

E-field noise in dBμV/m = 107dB + dBm reading on spectrum analyzer +20log(9.72/ λ)

where λ = wavelength of that frequency in meters = 300/(frequency in MHz).

After calculating the E-field noise for your location in dBμV/m, simply compare to the chart on page 3 of this Radio Society of Great Britain handout: https://rsgb.org/main/files/2018/01/180116-Noise-leaflet-issue-2.3.pdf