Gloucester County Amateur Radio Club

W2MMD

Troubleshooting & Repair
W2MMD 147.180/442.100 Repeaters

Version 1 - January 29, 2022
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Special thanks to K2ZA, KB2AYU, KT2Y

Goals

- Provide basic information to assist members new to these topics, and ensure that members of the repeater committee are speaking the same language
- Form the basics of a high-level plan to address the performance issues and restore the repeater(s) to good working order
- Create documentation for those working on the system in the future
- Utilize the experience as a learning opportunity for the membership

Current Inventory

The club owns and maintains a total of 3 repeaters:

W2MMD-R, 147.180, Pitman, NJ
Location: Pitman Water Tower, Laurel Ave., Pitman, NJ
Repeater: Yaesu DR-2X (equipped with optional voice module)
Duplexer: ???
Primary Feedline: ???
Antenna: Commander Technologies 220-2N

W2MMD-R, 442.100, Pitman, NJ
Location: Pitman Water Tower, Laurel Ave., Pitman, NJ
Repeater: Yaesu DR-1X
Duplexer: ???
Primary Feedline: ???
Antenna: ???

W2MMD-R, 224.660, Sewell, Washington Township, NJ
Location: Washington Twp. Water Tower @ Washington Twp. High School
Repeater: Bridgecom
Duplexer: ???
Primary Feedline: ???
Antenna: ???

Basics & Terminology

This may be old hat for some, but let's define a few things so we are all speaking the same language.

A repeater is a system. Many factors influence the performance of a repeater, including, but not limited to:

- Receiver
- Transmitter
- Duplexer
- Antenna
- Feedline
- Nearby Emitters (both intentional and unintentional, more on that later)
- Condition of the repeater site

Basics & Terminology (continued)

Receiver Sensitivity[1]

Receiver sensitivity is a measure of the minimum signal strength that a receiver can detect. It tells us the weakest signal that a receiver will be able to identify and process. Receiver sensitivity is expressed in dBm. Since it represents how faint an input signal can be to be successfully received by the receiver, the lower the power level of the signal, the better.

Receiver Selectivity[2]

A measure of the performance of a radio receiver to respond only to the radio signal it is tuned to (such as a radio station) and reject other signals nearby in frequency, such as another broadcast on an adjacent channel.

Selectivity is usually measured as a ratio in decibels (dB), comparing the signal strength received against that of a similar signal on another frequency.

Receiver Desensitization (better known as "**densense**")[3]

Receiver desensitization, commonly called "receiver desense", is caused when high RF signal levels enter a receivers antenna input.

When desense occurs, the usual symptom is as though the desired signal was reduced; the signal becomes noisy or even fades out completely.

The frequency of the desensitizing signal can be considerably different than the frequency the receiver is tuned to. The interfering signal can be wideband noise and/or spurious emissions from the associated transmitter or other nearby transmitters.

The susceptibility of a specific receiver to off-frequency signals is dependent upon the receiver design and any external filtering added to the receiver.

Transmitter Noise[4]

Every transmitter emits signals other than those on the desired frequency. The frequencies and amplitudes of these undesired signals varies greatly and is dependent mainly upon the transmitter design and the modulation used. The amount of transmitter noise can be reduced by external filters and/or physical isolation between the transmitter and any receivers.

[1] – Credit: https://www.everythingrf.com/community/what-is-receiver-sensitivity
[2] – Credit: https://en.wikipedia.org/wiki/Selectivity_(radio)
[3] – Credit: DUPLEXERS, An Introductory Tutorial Copyright 1996-2005 Jack Daniel Company
[4] – Credit: Anritsu, Passive Intermodulation (PIM), https://www.anritsu.com/en-us/test-measurement/technologies/pim

Basics & Terminology (continued)

PIM ("**Passive Intermodulation**" or sometimes just "**intermod**")[1]

PIM is a form of intermodulation distortion that occurs in components normally thought of as linear, such as cables, connectors and antennas.

Intermodulated signals are generated late in the signal path, they cannot be filtered out and may cause more harm than the stronger, but filtered, IM products from active components.

An Excerpt From:

Intermod & Bandpass Cavities[2]

By Peter Policani, K7PP

I remember breaking into the two way radio business in the early sixties and finding a great amount of concern over intermodulation and site degradation and desense. These are all ingredients for the disruption of a receivers ability to hear a signal. On community sites, it's intermodulation that rears it's head all to often.

So, let's deal with intermodulation first. I will attempt to dispense with all of the technical bull and hopefully offer you an explanation of concepts. You might find it a little more useful.

If you mix two signals together, you will come up with a combination. You will see the two originals, the sum of the two and the difference. That's not all. If you have a very efficient mixer, you might also see the difference frequency mixed with the sum frequency and its sum and difference mixed with one of the two originals. In other words, depending on the quality of your mixing device and the strength of the signals that are present you have the ability to generate thousands of new frequencies.

A receiver operating anywhere near these mixes can hear them as if they were a valid signal. The fact is, they are a valid signal. Mixes can take place in any device that acts as a diode. You may hear it referred to as a non linear device. A transmitter final, a receiver front end, a water contaminated connector can all present a place to mix. Supply two or more signals, a non linear device and a way to a radiating element and you have a transmitter.

[1] – Credit: Anritsu, Passive Intermodulation (PIM), https://www.anritsu.com/en-us/test-measurement/technologies/pim

[2] - http://www.repeater-builder.com/k7pp/art003.html

An Excerpt From:

Some Thoughts on Repeater Performance and the Isolation Between Receiver and Transmitter[1]

By Mike Morris, WA6ILQ

In many cases fixing a transmitter problem is easier than fixing a receiver problem. Good receiver performance depends on being able to hear the users... and the receiver performance is divided into two major areas: sensitivity and selectivity. Sensitivity is obvious - how weak a signal can you hear clearly, but selectivity is a more difficult parameter to measure. A good analogy to selectivity is this: imagine trying to focus on only the person sitting next to you whispering during a LOUD rock concert - the more surrounding noise you can tune out the better you can hear the signal you are trying to hear.

To continue the rock concert analogy, it's not how well the receiver works on the bench, it's how well it works in real life, at the site. You may have good ears, but when the noise surrounds you just how well can you hear the person next to you? And if you can't accurately measure the before and after performance, you can't really tell if you've made any improvements, and if so, quantify how much. You need to be able to measure the Effective Sensitivity of the receiver, and the measurement methodology must be repeatable.

Receiver performance in a duplex environment (doesn't matter if it's repeating or not) depends on isolation between the repeater receiver and not just the repeater transmitter but all other emitters within earshot. I used the term "emitters" instead of "transmitters" deliberately - you have to consider every RF source that might affect the receiver. Most folks think that you need some magic amount of isolation for good performance, and buy a duplexer with more than that magic number, and end up disappointed. In fact any more than "enough" (plus a reasonable amount of headroom) does nothing but drain your wallet.

In reality you have to isolate your receiver from all of the other RF sources at the site that your receiver can hear - the local oscillators, the transmitters in the building (and the next one over, and the one down the road), the RF-noisy tower strobe light blinker, even that intermod-creating rusty tower bolt or the internal hidden crack in the antenna. Isolation starts at the receiver antenna jack(s) of the equipment and includes everything - the best duplexer in the world won't help if the jumper cable between it and the receiver was made from thirty year old Radio Shack CB coax with 75% shield. Actually, all it takes is one nickel-plated connector, or even one good quality connector that was improperly installed.

[1] - http://www.repeater-builder.com/antenna/thoughts-on-isolation.html

Performance Expectations

Comparison of published specifications – DR-2X vs. popular repeater combinations

Specification	GE Mastr II	Motorola Micor	Motorola MTR-2000	Yaesu DR-2X
Receiver Sensitivity (12 dB SINAD)	0.175 µV (w/ preamp opt.)	< 0.175 µV (w/ preamp opt.)	0.35 µV	0.2 µV
Selectivity (Adjacent Channel)	-100 dB (30 kHz)	-95 dB (w/ preamp) (30 kHz)	-80 dB (25/30 kHz)	-60 dB (@ 35 kHz)
Intermodulation	-95 dB	-80 dB	-85 dB	> 65 dB Typ.
Transmitter Spurious Emissions	85 dB (40 to 110W)	> 85 dB	-85 dB	> 65 dB Typ.

- Overall, receiver sensitivity is not bad on the Yaesu DR-2X.
- Selectivity of the Yaesu is pretty poor compared to others. Why?
  - DR-2X is fully frequency agile without a tuned front end. No pre-selector on the receiver.
  - The MTR-2000 is also frequency agile, but it is equipped a varactor-tuned front-end. For further hardening, an external preselector was available.
  - The GE Mastr II and Motorola Micor are stand-out performers because they are crystal controlled, single frequency units with fully tuned exciters, front-ends, and helical resonators.
- The poor selectivity of the DR-2X will have an impact on it's effective sensitivity.
- Transmitter spurious emissions also suffer on the DR-2X. Why might this concern us?
  - More "noise" for the receiver to deal with
  - More chances for mix products resulting in even more "noise" for the receiver to deal with
  - "Bad Neighbor" – perhaps less of an issue at our location

Performance Expectations (continued)

There are several reports of performance problems with the Yaesu DR line, especially at "high-profile" sites.

- The Valley Wide REACT Team in Boise, Idaho[1]
  - Attempted to use DR-1X units at their mountaintop site
  - VHF mobile coverage dropped by 30 miles compared to prior equipment
  - Improved performance some with OCI Bandpass Filters and Front End Preamp/Helical Filter from GE Mastr II units
  - Ultimately mountaintop site was too much. Yaesu repeaters were moved to valley sites, and the mountaintop sites went back to "commercial grade" equipment.

- Dan Gunter, KK4ICE has documented[2] the VHF desense issues in the DR line, complete with test data, and found that the DR requires approximately 20db more isolation when compared to a GE Mastr II.

In summary, the DR line is made from two Yaesu "amateur grade" mobiles placed in a common chassis. The units are fully frequency agile with no retuning required (i.e. no tuning of coils with a diddle stick). This flexibility provides easily deployment for amateurs, but comes at a cost in performance.

So are we doomed?

Quite possibly, no. Although the DR-2X is less than stellar, given our lower profile repeater site it may perform quite adequately if the remainder of the system is in good working order.

[1] - http://www.vwreact.org/2019/11/16/noise-noise-and-more-noise-adventures-in-repeater-filtering/
[2] - http://www.repeater-builder.com/yvs/fusion-vs-mastr2/fusion-vs-ge-mastr2.html

Notes on Our Repeater Site

- The 2m and 70 cm repeaters are located at the top of a water tower on Laurel Avenue in Pitman
  - The water tower is approximately 135' tall, and the base of the antennas are approximately 140' above ground level (275' above sea level).
  - This is approximately 207' above average terrain.

- While not a "high profile" site (mountain top, 500' tower..), it is a good site capable of serving the majority of the club membership.
- The vast majority of RF equipment on the tower is cellular. There appears to be very little land mobile equipment in place.
  - This is a very good thing for us – less signals, less "noise."
- We do not (yet) know what transmitters (if any) may be nearby on other structures. A site survey will help us determine this.

- Good sites are very hard to come by and can be very expensive.
- Non "commercial-grade" hardware (e.g. the DR-2X) is not permitted at many commercial sites for all the performance reasons discussed on the past few slides.

Plan of Attack

We can (and may need to) ask for “professional” assistance. Before doing so we should evaluate what we can, and eliminate any obvious problems. There is no sense in wasting professional time on simple issues.

1. Convene Repeater Committee
2. Conduct Physical Site Inspection
3. Conduct Site Spectrum Evaluation
4. Baseline Performance Analysis
5. Repair any defects found
6. Repeat Performance Analysis and compare to baseline
7. Decide next steps based on outcome of above

Physical Site Inspection

Evaluate Antennas

- Caution against using “antenna analyzers” – Any RF coming down that feedline looks like reflected power (Tnx N2CX)

Evaluate Feed Line & All Jumpers

- Absolutely no foil on braid coax (e.g. LMR) anywhere in the system. *No exceptions!*
- Avoid any coax containing dissimilar metals in contact (e.g. 9913)
- Avoid “Type” or “Like” coax (e.g. “RG-214 TYPE”)
- Good choices for jumpers include Superflex Heliax, and double silver plated shield coax (e.g. RG-214, RG-393, RG-400)
- Avoid RG-142 because it has a copper-clad, silver plated steel center conductor that has been known to fracture when repeatedly flexed
- Connectors should be of the silver plated variety. Avoid nickel or chrome plated
- Avoid adapters unless absolutely necessary. If unavoidable, the adapter should be silver plated.

Perform Desense Check (see later slide)

Physical Site Inspection (continued)

Evaluate Duplexers

- Note Make & Model
- Inspect interconnect cables (see above)
- Measure and record interconnect cable lengths
- Sketch interconnect cable diagram noting presence and orientation of all connectors, adapters, tees, etc.
  - Duplexers vary, but some (e.g. Motorola T1504) have stringent interconnect cable requirements affected by things as easily overlooked as the orientation of the tee connector.
- Understand that duplexer was tuned into a 50 ohm load, and any mismatch with the antenna results in degradation in performance
  - Never use a duplexer as an antenna tuner
- Any retune is best done with a proper VNA

Inspect Jumpers Inside DR-2X Chassis

- Several complaints of inadequate coax (RG-58 type) inside repeater chassis
  - "..had the lid off my DR-2X and was disappointed to find cheap looking RG-58 jumpers between the radio chassis and back panel. I'll be swapping those out for RG-142 and silver plated crimp connectors." (https://forums.radioreference.com/threads/yaesu-system-fusion-repeater-program-same-but-new.382998/post-3072424)
- If ours matches complaint, consider replacing
- This is not a silver bullet solution to our problems but eliminates a point of possible desense.

Checking Desense

1. Connect your spectrum analyzer to the receive port of your duplexer.
   - Be careful, start with high attenuation on the spectrum analyzer.
2. Tune the analyzer to your RECEIVE frequency.
3. Use an external key line to key your repeater transmitter.
4. Step the sensitivity of your analyzer down to the point where you start to see the noise floor rising. Then un-key your transmitter.

If the noise floor drops considerably, then there is your problem.

Mistuned duplexer, perhaps PIM in the antenna or transmission line.

(Tony Dinkle, WB6MIE, regular contributor to the repeater-builder mailing list)

Site Spectrum Evaluation

- Evaluate noise floor and signals present at site
  - Record signals and strength
  - Spectrum Analyzer
  - SDR better than nothing
  - Could be value in both
- Evaluate signals present
  - Identify potential mix products

Baseline Performance Analysis

At various locations:

1. Take receive signal strength measurements.
2. Identify level or quieting achieved at a given transmit power level.

We can do this with a mobile transceiver and an SDR.

Repeatability of these tests is an absolute must.

- Need to keep careful log of antenna, radio, and locations used so anyone can repeat the test in the future.
- If using SDR, must carefully document the settings in the SDR software so future measurements are on a level playing field (ie: AGC, rf gain, etc.). Record results in db.

Transmit testing, consider taking 2 separate measurements.

1. Step out of the vehicle and using an HT with a "stock" antenna.
2. Mobile transceiver with a mobile antenna.

- Avoid Baofeng or similar HTs because they are too inconsistent.
- This is a fairly subjective test so a 1-5 signal report (or similar) is probably sufficient.

The coverage prediction done years ago shows the repeater should have coverage of approximately a 12 mile radius.

Consider 4 measurements at 5 miles out, and 4 more at 10 miles out.
Additionally measure from the clubhouse since it is very easily repeated.

Aim for fairly distributed sample, covering various terrain and makeup, and in areas where a lot of the membership resides.

5 mile: Deptford, Washington Twp/Turnersville, Clayton, Mullica Hill.
10 miles: Westville/Brooklawn border, Williamstown/Sicklerville border, Franklin Township/Elmer, and Swedesboro.

Future Considerations / Dreams

- Satellite receivers
  - Increases receive “diversity”
  - Improves reception in dead spots
  - Improves “picket-fencing”
  - Requires a “voter”
  - Unsure of compatibility with DR and fusion.
  - Needs research

- “Internet” Access
  - Remote management, monitoring, and power control
  - Could enable Echolink and/or Wires-X on site
  - Connectivity Options
    - AREDN
    - Point-to-point link to clubhouse site
    - Leverage Comcast public Wifi service
      - Possibly in conjunction with a VPN tunnel to clubhouse site

Valuable References

Measuring FM Receiver Sensitivity - Jeff DePolo, WN3A

http://www.repeater-builder.com/tech-info/receiver-sensitivity.html

Some Thoughts on Repeater Performance and the Isolation Between Receiver and Transmitter - Mike Morris, WA6ILQ

http://www.repeater-builder.com/antenna/thoughts-on-isolation.html

Measuring Effective Sensitivity - Chris Boone, WB5ITT

http://www.repeater-builder.com/tech-info/effective-sens.html

Yaesu Fusion vs. G.E. Mastr II - Selectivity Causes Huge Differences In Desensing - Dan Gunter, KK4ICE

http://www.repeater-builder.com/yvs/fusion-vs-mastr2/fusion-vs-ge-mastr2.html

Repeater-Builder Technical Information Page

http://www.repeater-builder.com

The Repeater-Builder mailing list on groups.io

https://groups.io/g/repeater-builder/