Spectrum Management in Florida

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Introduction

Background

What happened?

- Amateur radio repeaters
- Need for frequency coordination
- The FRC and FASMA

Technical basis

Models and data

- Death of “standard spacing”
- Technical standards
- Part 90 Standards
- Core concepts

Finding the right balance

- Hams are not pros
- Modelling and interference
- PL!

FASMA Process

Showing what’s in progress

- Database
- Ticketing
- Deployment plan

Coordination modelling

- Examples in google earth

Background

Amateur Radio Repeaters

Layer 8 problems

Florida Amateur Spectrum Management Association
Successor to the Florida Repeater Council

- FASMA is the coordinator and is the successor to the Florida Repeater Council
  - The FRC suffered from serious corruption and the board was not acting in good faith.
  - The Membership voted the board out and elected the interim board at a meeting on July 6
  - The FRC was transferred to FASMA once it was 501(c)3
  - FASMA is committed to openness and records availability, and an online system will make that happen. Ideally the database will be posted in an automated form for those who wish to use it.
  - Our email systems need to be tracked and manage all interactions with members in a forthright and honest manner.
  - There is no bigotry or favoritism.

- Prior coordination was done by one person for the entire state!
  - It's now being done by a committee which is impartial from the board.
  - **We need HELP on this!**

- Mostly for repeater coordination, but we also do spectrum management for other users. These other users are able to be full members of FASMA and have a say in it's management.

Amateur radio repeater coordination background

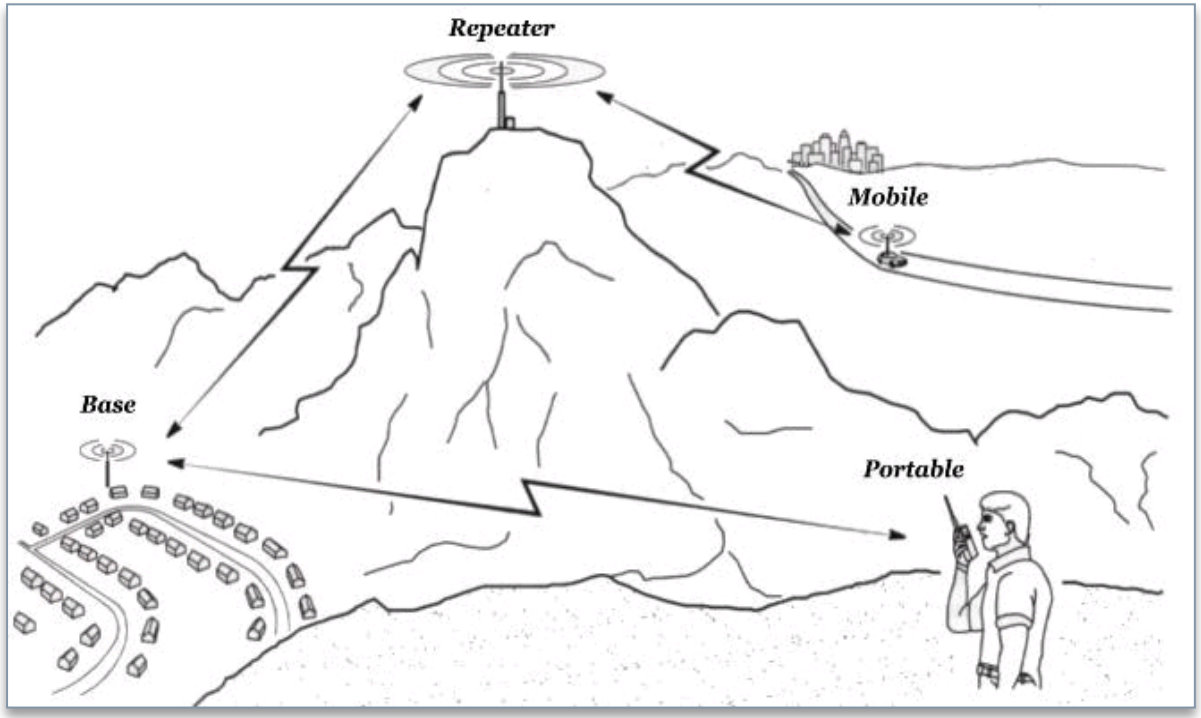
- The FCC sets standards, but amateurs self comply
  - VHF and UHF frequencies (50-1300 MHz) are used for local communications
  - Typically with a “repeater” station to boost range, but repeaters are not the only users
  - The FCC sets no standards as to what portion of spectrum is to be used for repeaters or other users

- Amateurs must self-regulate

  - FCC has clearly said it will not get recognize a frequency coordinator
  - ARRL has stayed out…

Typical Repeater use

- Line of sight comm's
- The repeater enables hidden users to talk so long as they both can see the repeater.
- Different bands are optimized for different uses
- 50 MHz is great in a car/truck with a big (6') antenna. Not good in a portable (HT)
- 440 and 900 MHz is great in a HT, but doesn't have the distance of 144 MHz
- Higher bands have more channels (2m has 72 pairs)
- Lower bands go further, and 2m is popular



Frequency Planning

Commercial Standards

Applied to amateur radio

Frequency Planning Concepts

- In Part 90 commercial radio it's very important licensees have reliable coverage.
  - FCC station codes
    - FB – Fixed base, FB2 – Basic repeater 32km radius (may have co-channel), FB6/FB8 – Central High coverage, protected repeater up to 120km.
    - MO – mobile users, assumed to be at 1.83m AGL (6 feet, remember this!)
  - Planning is based on normal every day propagation.
- In amateur radio coordination we seek to have the most fun and least interference
  - A ham repeater is analogous to FB6/8 under part 90
  - The FCC has the benefit of assuming high-quality radios are used meeting part 90.
- All coordination is based on signal levels as decibel microvolts per meter, dBu
  - 0 dBu = 1 microvolt per meter, -3 dBu = .5 uV/m, +30 = 100 uV/m
  - An absolute value, independent of the receiver or antenna gain used.

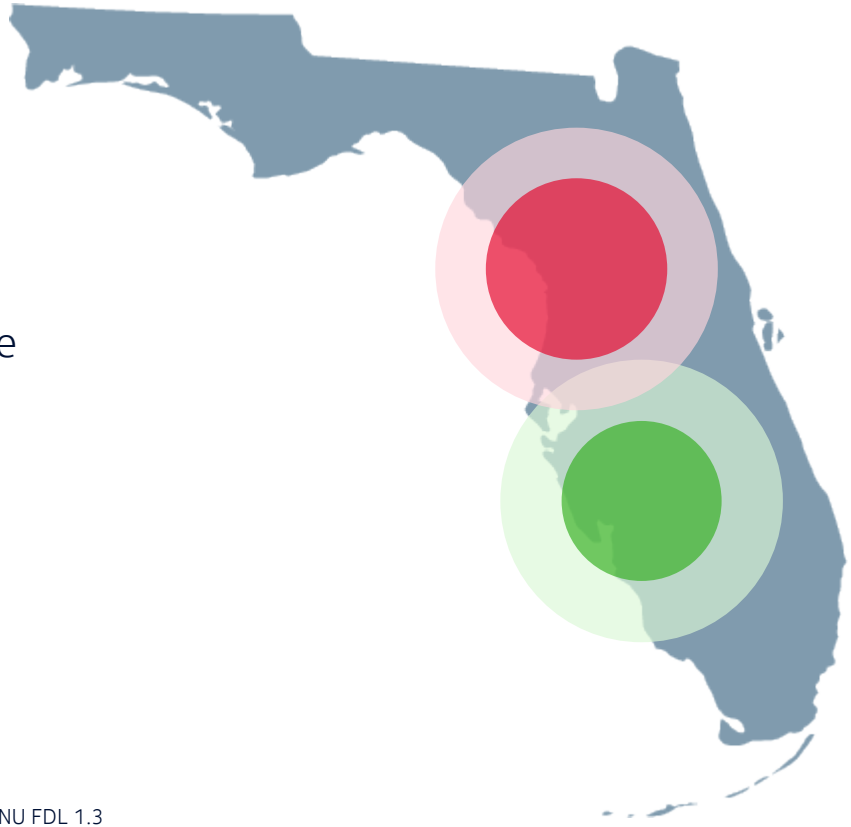
Frequency Planning Concepts continued
Interference defined

- Harmful interference is interference which degrades another spectrum user's communications.
  - Not all interference is harmful
- In amateur radio we're use to working "in the noise", But not for repeaters
  - Ducting and tropo can enhance propagation, we can't avoid this
  - We must define a normal service area for the repeater
  - Height, ERP, antenna, all effect this area.
- How best to define a normal service area for our FB8's?
  - The FCC uses the concept of service contours, interference contours, and professional engineering
  - Research into this has been ongoing from empirical data in the 1950's
    - FCC REPORT NO. R-6406 (1964), FCC DA-02-1319 (2002), LMCC research
- TIA/EIA Standard TSB-88 compiles all this with scientific rigor

Frequency Planning Concepts continued

Service contours and the capture effect

- Service contour has a given signal strength and will over ride any interfering signal in the area.
- Using CTCSS/PL made this easy in 1970.
  - All repeaters need to use RX and TX tone!
- The issue in this was one of determining the signal levels needed.
- 16K0F3E (wideband) needs about 6-9 dB for this to work, but the FCC never considered digital for it.
- Mostly based on TV modeling



Frequency planning concepts continued
TSB-88

- TSB-88 is the major rethinking of the service contour
  - Model each mode, taking into account signal bandwidth, adjacent signals, receiver filters, etc.
  - CPC – Channel performance Criteria
  - It defines a voice CPC using delivered audio quality or DAQ for a given system
    - DAQ is 1-4, 3.4 is what most systems use.
  - We can model all the interferers in the desired coverage area and ensure our CPC DAQ is >3.4 in the service area.
  - Adjacent channel users are considered as they may be wideband users overlapping a narrow band channel.

DAQ Delivered Audio Quality	Faded Subjective Performance Description	Static SINAD equivalent intelligibility[1,2]
1	Unusable, Speech present but unreadable	<8 dB
2	Understandable with considerable effort. Frequent repetition due to Noise/Distortion	12 ± 4 dB
3	Speech understandable with slight effort. Occasional repetition necessary due to Noise/Distortion	17 ± 5 dB
3.4	Speech understandable with repetition only rarely needed. Some Noise/Distortion	20 ± 5 dB[3]
4	Speech easily understood. Occasional Noise/Distortion	25 ± 5 dB
4.5	Speech easily understood. Infrequent Noise/Distortion	30 ± 5 dB
5	Speech easily understood.	>33 dB

[1)] The VCPC is set to the midpoint of the range.
[2)] Measurement of SINAD values in fading is not recommended for analog system performance assessment.
[3)] The 20 dBS equivalency necessitates a DAQ of approximately 3.4. This value can then be used for linear interpolation of the existing criteria. Non public safety CPC specifications would normally request a DAQ of 3, while Federal Government agencies commonly use a DAQ of 3.4 at the boundary of a protected service area. Note that regulatory limitations could preclude providing a high probability of achieving this level of CPC for portable in-building coverage. In addition, higher infrastructure costs could be needed with potential lessened frequency reuse.

Frequency planning concepts continued
TSB-88 Planning of new sites

- We must first define our service area.
  - This can be based on a model of a known location, or
  - A service area is defined and locations are picked that will provide the required signal level
  - This area is broken up into tiles and each tile is considered
- Once this is done, a frequency search happens and we can identify a frequency
  - Interference is modeled per tile for adjacent and co-channel users.
  - The idea here is the service area will provide a 3.4 DAQ or better even with adjacent channel or co-channel users.
  - We then do the same in reverse to our co-channel users
- This is much more complex than a simple FCC contour.
  - But we have tons of data for every possible interference modulation!

Frequency Planning
Amateur Standards

Amateur Radio Repeaters

- Amateur Radio repeaters are used for communications at local scale
- A repeater listens on one frequency and retransmits on another (known as a “split”)
- Typically a repeater is located high up (100-1000’)
- Have excellent antennas 6-12 dB gain typical.
- Have high power output (50-150W) compared to handheld (1-5W) or mobile/base radio (30-50w)
- Designed for continuous duty operation
- Not easily moved to different frequency
  - Filters needed for transmit and receive simultaneously
    - Need high isolation (85-100 dB) between TX and RX to keep RX working
    - Not easy to “tune”
  - Some require custom cut crystal oscillators (common with older surplus repeaters)
    - These are very expensive

- **Bottom line, it’s hard to change frequency.**

Amateur Radio Repeaters
Need for coordination

- Two repeaters in the same area on the same (or close channel) will interfere
  - Thus the need for coordination of frequencies
  - It's hard to change frequency
  - Coordinator only looks at the output frequency typically
  - The signal takes up space +- the channel (carrier), this is known as bandwidth
  - Emission designators
    - An emission designator is a code that gives info on a signal's bandwidth and the nature of the signal on the frequency.
    - Typical codes 4K00F1D - NXDN, 7K60FXE- DMR, 8K10F1E- P25, **11K2F3E - NFM, 16K0F3E - WFM,**
    - The first part of this code is the bandwidth (4 char) and the second is the type of data carried (3char). We are only worried about the first part for frequency planning. This is the occupied bandwidth of the signal (99.5%, -26dBc), and in the example above is 4.00, 7.60, 8.10 11.2, 16.0, and 20.0 KHz. More info is here https://www.apcointl.org/spectrum-management/resources/licensing-links/emission-designators.html
  - Channel size
    - Coordinators allocate channel size in wide and narrow channels. The tendency is to move to digital methods that occupy less bandwidth than analog FM. This does come at the expense of audio quality

Amateur Radio Repeaters
Standard Splits and bandwidths

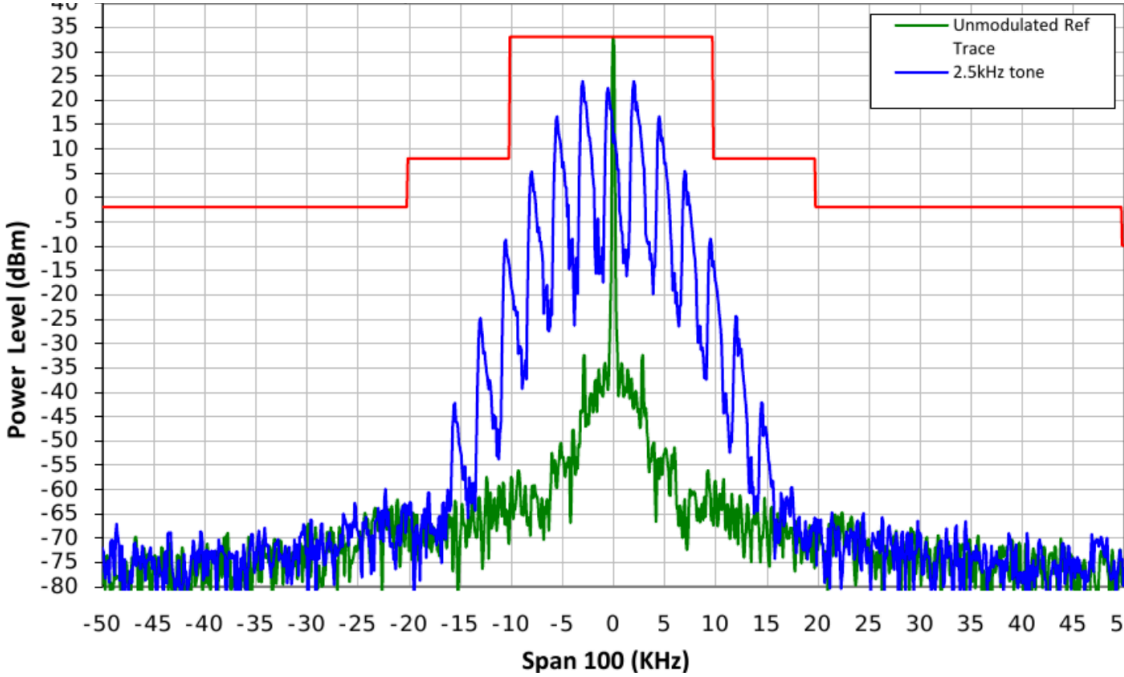
- Typically each band has a standard split and channels used
- 10m (28.0-29.7 MHz) = 100kHz – 20 KHz – Wide only
  6m (50MHz) = 500kHz - 20 KHz – Wide only
  2m (146MHz) = 600kHz – 20 & 15 KHz Wide, 10 & 7.5 Narrow
  1.3m (220MHz) = 1.6MHz – 20 KHz Wide only
  70cm (440MHz) = 5MHz – 25 KHz Wide, 12.5 KHz Narrow
  33cm (900MHz) = 25MHz – 12.5 KHz Narrow, but 25 KHz is permitted
  23cm (1200MHz) = 12MHz – 25 KHz

  - Note, we are working to define this better, as the prior coordinators didn't have it worked out
  - In each band the channels have a size: Wide band channels 25, 20, 15 KHz are common, and Narrow channels are 12.5, 10 and 7.5 KHz.
  - A single wideband channel occupies the space of 2 narrow band channels . This allows more users in the same spectrum, and presents issues with adjacent channels interference.

Adjacent channels
Legacy of bad decisions

- 2 meters presents a number of issues
  - Two main channel sizes, 20KHz below 146, 15 KHz above 146
  - Offsets all over the place
  - Narrow band 10 and 7.5 KHz, are difficult to make use of
  - 15khz channels are smaller than the wideband signal, and need to be protected from adjacent users
- Typical ham grade transceivers are effected by strong adjacent channel systems.

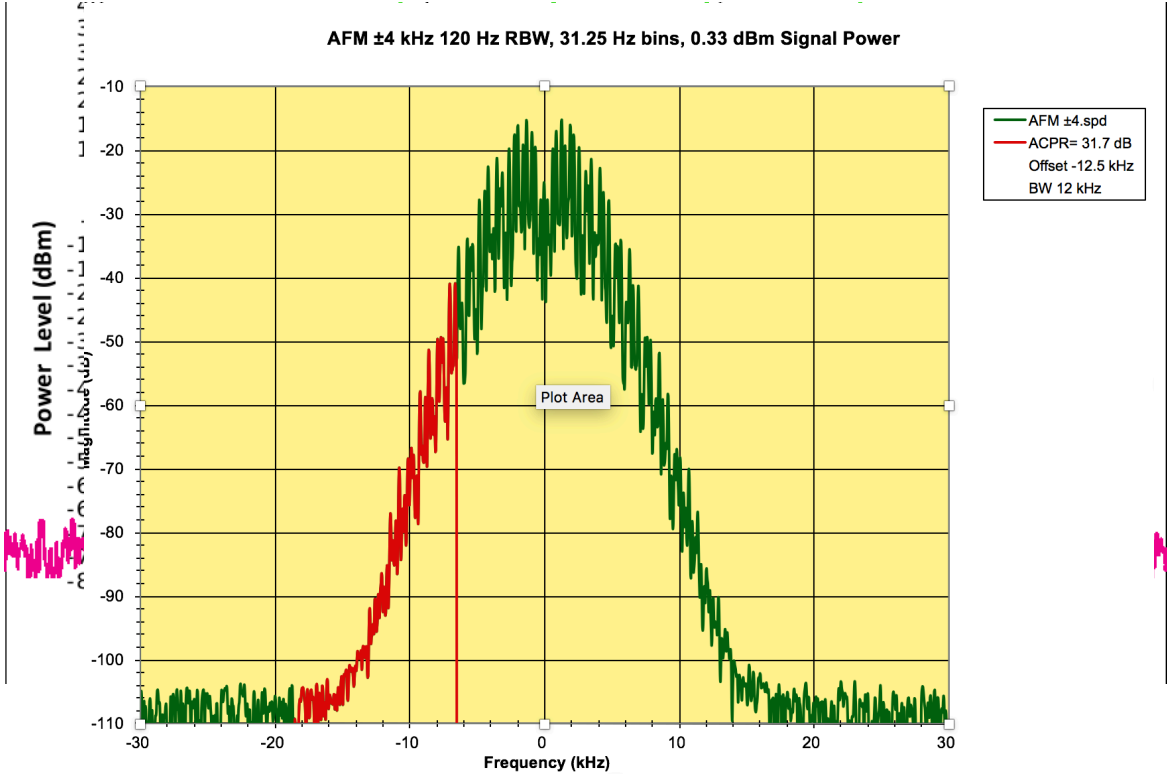
- Example mask of a 16K0F3E signal



15 KHz channels

The FCC does it, so it's got to be ok, right?

- Example of wideband FM at full modulation with strong adjacent channels.
- This overlap is is known as Adjacent Channel Power Ratio or ACPR
- This is the worst case, and a typical receiver wouldn't be able to handle this.
- What we can do is determine the relative ratio needed between the center and adjacent channels where we have a DAQ of 3.4.
- TSB-88 provides this for all known modulations (except Dstar ☹)



Applying TSB-88 to amateur radio
Putting it all together

- Contour based methods
- Keeping the FCC example receiver of a dipole at 1.83m off the ground
  - We'd like a service area of 20 dB SINAD, DAQ of 3.4
  - For FM this means we need to be >6 DB over the interference
  - Assuming our radio needs a -110 dBm input signal and a half wave antenna, this is:
  - e = P +77.2dB + 20 log(Fmhz) - g(dBi) , or e = -110 +77.2 dB + 20 Log(146)-2.15 = 8.33 dBu
  - 16 dB for noise and variance of receiver performance in amateur radio, 24 dB
  - Reliability from a 50% number of dBu to 90% is 12dB at VHF, 14 dB at UHF, so 36.33 dBu
  - The value used by the FCC is 37 for VHF, which matches closely
- 18 dB between our intended signal and any co-channel interferes, meaning any co-channel signals must be under 19 dBu inside that 37 dBu service area.
- ACPR for wideband FM is +5 dB, meaning at the overlap area, an adjacent channel must be less than 42dBu on the adjacent frequency.

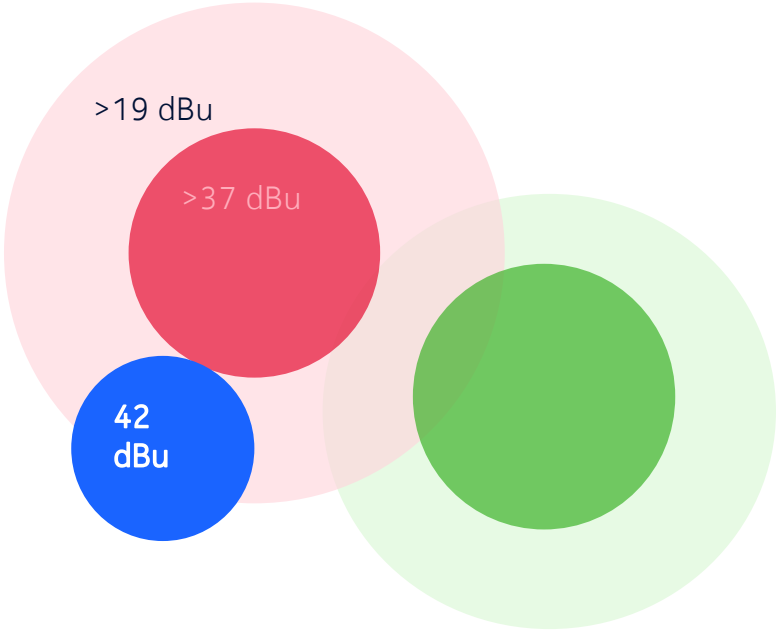
Coordination basics

- A coordinator's job is to find the best pair for a repeater in a given area
- Sometimes there will be no pairs open
- RF prediction is software is used for this.
  - This is used to determine a "service contour" and an interference contour
  - The service contour is a predicted signal level (uV/m) in dBu (0 dBu = 1uV/m). This is predicted for 50% of the time at 50% of locations 2m off the ground.
  - The interference contour is a lower value but at 50/10
  - Optionally there is an adjacent channel contour as well. This is an issue as some bands use a 15 KHz channel for 20 KHz channel, 16K0F3E emissions. Only 2m band has this now.
  - Different bands have different standards for contour levels
  - A coordinator must ensure a interference (or adjacent) contour of a repeater doesn't overlap (much) the service contour of another co-channel repeater.
  - As FM has a "capture effect" a weak signal from a distant repeater may be heard in the service contour of another, but when the primary keys up, it will capture the users radio.
  - This is why CTCSS/DCS is used to not pass distant signals in the receiver.
  - http://wiki.radioreference.com/index.php/Signal_Contour

Visualizing service contours

- Service contour is the dark red
- Interference is the light red/green and is used to ensure red doesn't interfere with the green co-channel user
- Can't have the light green overlap dark red or vice versa. (note it does a bit here!)
- The blue would be an adjacent system, it's circle can't overlap the dark red or blead over will occur.

- This is assuming 2/220 values here in this example.
- Users in the red area in CSQ may hear green if the red repeater is not keyed up. Once red keys up it's signal will override greens interference and lock them out.



Coordination Standard Contour Levels

Per Amateur band

Band	Service Contour	Interference Contour	Adjacent Channel Deratings, if applicable
29 MHz 50-54 MHz	31 dBµ F(50,50)	13 dBµ F(50,10)	There is no adjacent channel protection on 20 KHz users. There are no narrowband channels on these bands.
144-148 219-225 MHz	37 dBµ F(50,50)	19 dBµ F(50,10)	42 dBµ F(50,10) 15 kHz adjacent channel wide band to wide band 44 dBµ F(50,10) 7.5 kHz adjacent channel narrow band to narrow/wide band. 20 KHz channels need no adjacent channel protection wide to wide 10 KHz channels shall not need adjacent channel unless the intended mode is >8 KHz. If so a 25 dBµ F(50,10) value is to be used for this.
440-450 MHz	39 dBµ F(50,50)	21 dBµ F(50,10)	There is no adjacent channel protection on 25 or 12.5 KHz users. It's still advisable to be cognizant of this.
900 MHz	40 dBµ F(50,50)	22 dBµ F(50,10)	There is no adjacent channel protection on 25 or 12.5 KHz users. It's still advisable to be cognizant of this.

Modeling coverage
Free Software to the rescue

- The standards need a model that can accurately simulate the real world signal levels.
- Standard is based on Longley Rice Irregular Terrain Model
  - https://en.wikipedia.org/wiki/Longley%E2%80%93Rice_model

- Divides a system into radials, and takes into account elevation, terrain, clutter , ERP, gain, receiver height and climate conditions. Can model for a percentage of confidence in each mode.

- Open source, originally written in ~~Latin~~ FORTRAN
  - SPLAT! – Free Software, scriptable on Unix
  - Radio Mobile – Non-Free windows freeware, clunky to use, but works well
  - Pathloss 5 – about $7k, mostly for microwave work.

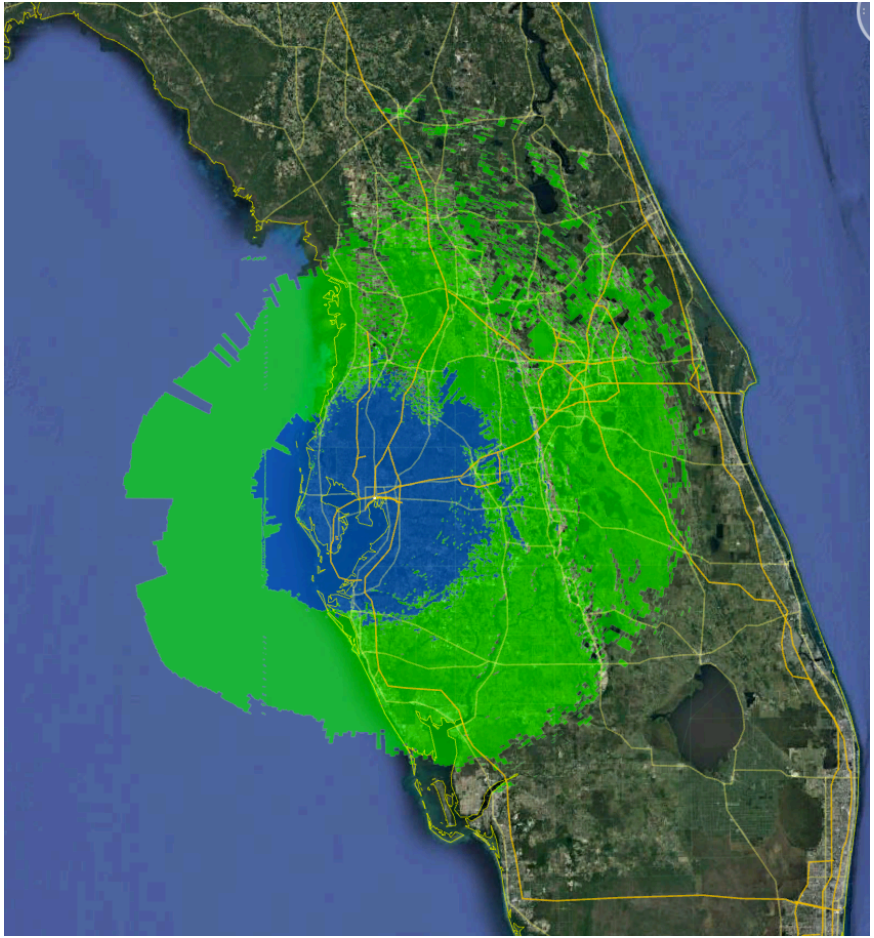
- All these pull SRTM – a digital elevation model of earth. High quality (1 arc second, 30m) is FREE.
  - Entire US dataset is large! 10's of gb's. Florida is about 5gb alone

Modeling example

- 224.2800 MHz 16K0F3E emission about 450 W ERP at 500’

- 37 dBu Service contour
- 19 dBu Interference contour
- No adjacent channel (20KHz channel and it’s 220)
- Note the mid Florida ridge taken into account
- Exportable as a Keyhole map (KML) for easy display in Google Earth

- Hardest part is getting the proper data, modeling takes 15-30 min.



FASMA

Our Process

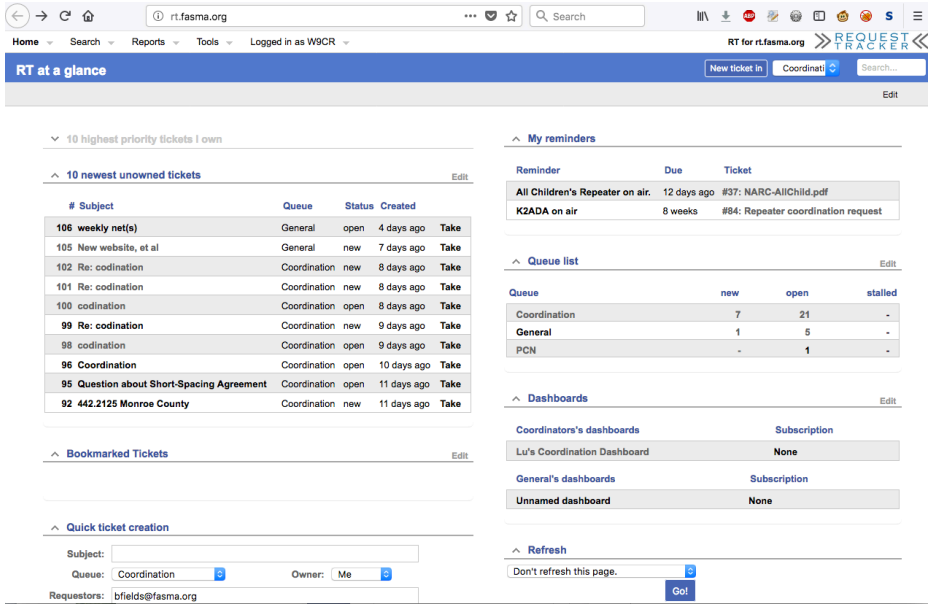
OSS/BSS
Website

- http://fasma.org
  - Designed to replace florida-repeaters.org
- Wordpress + CiviCRM for member management
  - Every login is identified by CALLSIGN
  - Must be approved by admin
  - CALLSIGNS can be verified online, and may change, need a script to automate.
  - An org can be a member, and we will assign an admin to this.
  - Members must be paid at signup

- Most of this progressing well.

OSS/BSS
Ticketing

- http://rt.fasma.org
  - Based on Request Tracker,
  - 3 queues – general, coordination, and PCN
  - Members have priority in the system
  - When a new request comes in, coordinator will get an email and starts working on it.
  - Supports sub tickets for border state coordinators and capture all emails from requestor.
  - Complete history is available, including all attachments



coord@fasma.org
Important to keep subject the same or tracking will break

OSS/BSS
Coordination DB

- http://db.fasma.org
  - Under active development
  - Will be open source
  - Revision controlled data storage with audit trail
  - PoC's have the right to make changes to various parts
    - Admin/Org, Tech, Trustee
  - Will have these interfaces to the users:
    - Search for frequency
    - Submit application or change existing
    - Record searching, compare
    - PoC update to records
    - Modeling via SPLAT! on the server

OSS/BSS – Examples

Coordination application

- User logs in using the auth from the website
  - If not there, the user is prompted to create a password
  - The owner is defined if an org or other valid login
- The bare minimum is the required fields
  - Metric is stored in the db, but US units are displayed too
- Validation of the data is done before submittal (is it in the state, 160 km from a state line, etc.)
- The data is now entered in the DB as Pending
  - A ticket is popped in the coordination queue – email to the requestor and notice to queue members
  - Flagged based if user is a member
- A coordinator grabs the request
  - RT provides SLA and notice to the requestor that it's being worked.

OSS/BSS – Examples

Coordination application Continued

- Coordinator now works application and models the system
  - Coordinator updates the database with contour data and works with the requestor via ticketing for any more information needed
  - If 160km from state line a sub-ticket is created to the neighbor state with a link to either close the ticket as non-interfering or explain what the issue is on this sub ticket. RT automatically closes this ticket as complete if no response in 7 days
  - Coordinator work this issue if exist, and then completes the coordination, changing status to provisional.
  - This sends an email to the PoC's they have 30 days to get it online
  - At 30 days a verification ticket is created and email sent to the user asking them to confirm it's online. Typically a coordinator will check this too.
- Coordinator will now respond to this ticket and update the status to coordinated (or registered if not a user). This needs to be checked in the member database at this point, and then formal coordination notice email sent to the PoC's.

OSS/BSS – Examples for version 2.0

Search for frequency

- User drops a pin on a map or enters lat/lon, selects band and then channel width
- The database provides a search based on
  - Output frequency vs. list of valid channels displaying any unused channels as part of the list
  - Distance of interference contour from location
  - Distance of adjacent contour from location
  - Distance of service contour from location
  - Distance from location
  - Records should be displayed sorted on distance
- This now gives the user a list of frequencies to evaluate in a modeling program or submit on their application for a new coordination
- Eventually results will be able to be displayed on a map with the contours displayed for each system as an overlay.

Itinerant Policy
Backyard repeaters

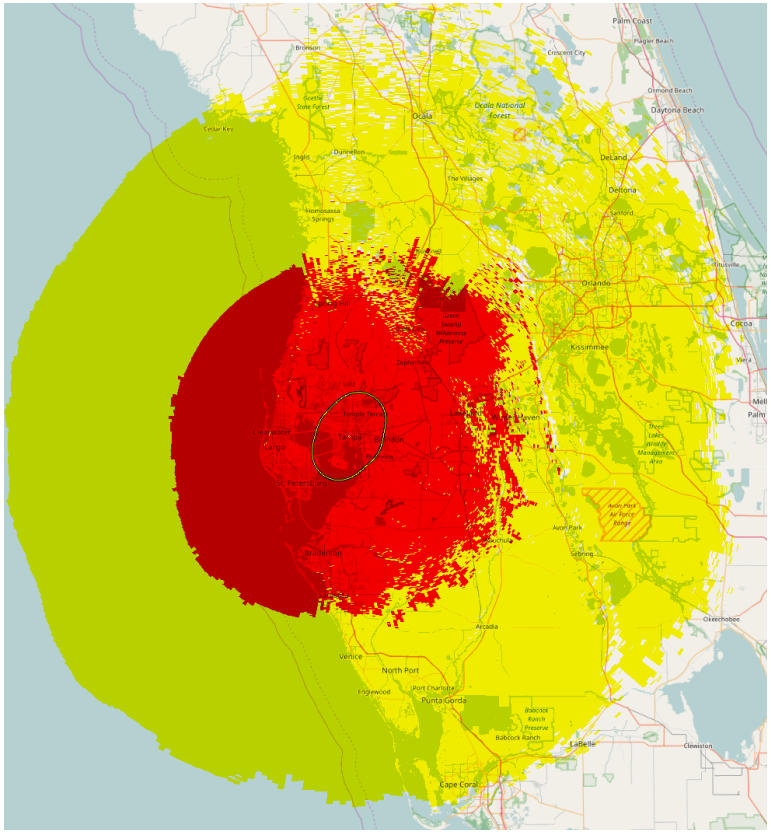
- The FRC was asked to do backyard repeaters for >15 years
- http://fasma.org/proposed-itinerant-repeater-policy/
- FASMA has put together the following:
  - 70cm band
  - Under 50’
  - 20km service contour
  - TPO <40W
  - 6dBd max antenna gain
  - Height above Average terrain must not exceed 60 feet out 25 miles.
  - CTCSSS/DPL/etc required
  - You have to work with your neighbors
- All frequencies are adjacent, no need to retune

Wideband		Narrowband	
Pair	***Output***	***Pair***	***Output***
1	441.8250	1A	441.8250
		1B	441.8375
2	441.8500	2A	441.8500
		2B	441.8625
3	441.8750	3A	441.8750
		3B	441.8875
4	441.8000	4A	441.9000
		4B	441.9125
*5	441.9250	*5A	441.9250
		*5B	441.9375
		6	441.9500
		7	441.9625
		8	441.9750
		9	441.9875

Channel 5A/B 36 Hour max use Truly Itinerant repeater only Hamfest/etc.

Frequency Planning
Coordination Examples

Coordination Example 1



- 443.525 MHz 16K0F3E emission about 700 W ERP at 147m
- 39 dBu Service contour
- 21 dBu Interference contour
- No adjacent channel (20K bandwidth)
- A smaller coverage repeater in palm beach would likely work on this frequency.

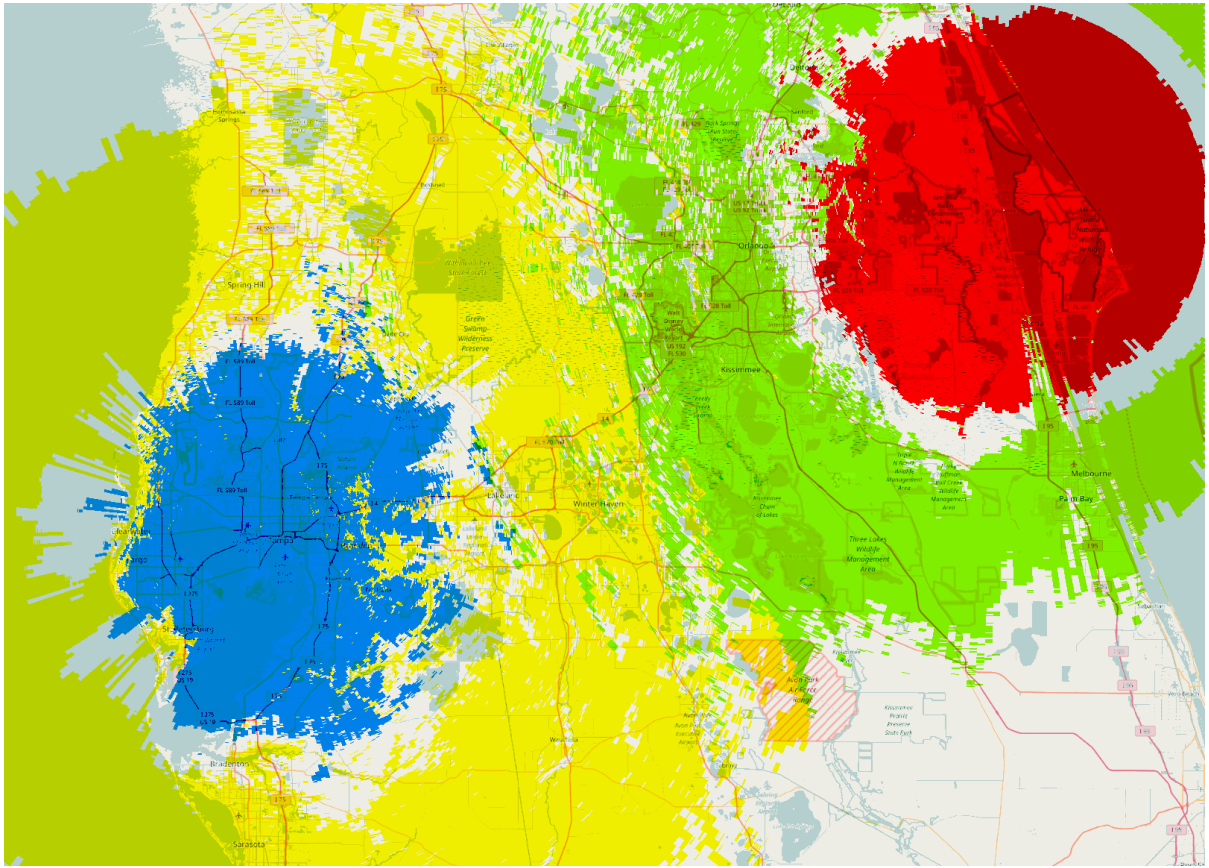
- Coordinator will best fit the contours as a radius in KM
  I = 153 KM, S = 72KM

Coordination Example 2

- Two Co-Channel repeaters
- Tampa, S = 41 Km, I = 92 Km
- Titusville, S = 43Km, I = 97 Km
- 39 dBu Service contour
- 21 dBu Interference contour

- Very little chance of interference here
- Ridge in the middle of the state helps

- Based on the contours alone it's easy to see a repeater in Ocala would work if it's of similar coverage.



Questions?

Thank you!