HAMWAN
PACKET RADIO FOR THE 21ST CENTURY

Bryan Fields, W9CR
w9cr@flscg.org

WHO AM I?
HOW DID I GET HERE?

- Bryan Fields, W9CR

- Originally from Chicago/North West Indiana

  - Ran the first Wireless ISP in North West Indiana (2000)

  - Background in microwave network design

  - Carrier IP/Optical network Engineer

  - Relocated to St Petersburg, Florida in 2005

- **Sr. Consulting Engineer in IP/Optical Networks – Nokia**

- AMPRnet Technical Advisory Committee member

HamWAN

- HamWAN is high performance multi-megabit networking over Amateur Radio

  - Network technology – Standards for an Internet connected wireless network
    - How to interconnect with ham users
    - How to route to the internet
    - Not all IP networks are HamWAN – Mesh/BBHN will never be capable of this.

  - An organization – HamWAN is a members organization
    - It's responsible for standards and certifying affiliate networks
    - Founded in 2013 by a group of hams in Seattle, WA
    - Puget Sound Data Ring (PSDR) is the largest network of HamWAN coverage in the the US (and now Canada!)
    - Other networks can certify to be part of the HamWAN standard

HamWAN

- HamWAN is a linked network of cell sites

  - Sites have access radios for users and backbone radios to move data to other sites

    - Eliminates contention between access and backbone, a major problem in Broadband-Hamnet

    - All sites are routed allowing a secure and stable network with deterministic performance

- HamWAN over the air clients must be Mikrotik NV2 protocol

  - A single proprietary standard, but a necessary evil. All run at 5.9 GHz in the exclusive part 97 space

  - Clients are intended to be nomadic, you can move a client radio from one site to another with out a reconfiguration.

- HamWAN must be connected to the internet

  - Does not need to use AMPERNET IP space, however it's free and a great resource.

  - IPv6 is encouraged and deployed in Tampa Bay HamWAN

WHY?

- **We need a backup to commercial Internet services.**

  - The system cannot go down due to your cable modem going offline.

- **Protect our microwave bands!**

- Most of the good microwave bands are shared with Part 15.

  - That's good, as most Part 15 wireless gear can be "tuned" into the Part 97 only parts of the bands. Cheap radios!

  - That's bad, as everywhere has Part 15 radio, raising the noise floor for us, and making most of the band downright unusable. If the front end does not have a tight filter this makes the adjacent part 97 only channels harder to use. Good filters cost money, no cheap radios have them.

- Part 15 operators (WISP's, MSO's and your neighbors) have trashed most of the Part 15 bands, and want more space. They are blissfully ignorant of how RF works**.**

  - ***"Hey these hams have space!"*** – They now are trying to take the exclusive bands from us.

    - 5850-5925 is next, it's even got a designator "U-NII-4". The FCC is eying even 70cm and 23cm for commercial use.

    - 10 GHz – Mimosa networks NPRM-11715. Backed by the WISPA industry association and a "former" ham. They want to take over all but 20 MHz of this band for commercial use at up to +55dBW (yes dBW, 316 kW) EIRP. I commented on this, **did you?**

    - 3.3-3.5 GHz is next; there is a small allocation at 3.65-3.70 GHz* for WISP use. UK hams have lost most of the 23 & 9 cm bands

PRACTICAL APPLICATIONS

- General Internet access for Hams*

- Examples of some services that can run over IP networks

  - Repeater linking

    - All work over the Internet, but when your ISP goes down during an emergency, what good is the network?

    - Allstar link. My node is 40821.

    - ADSB Receiver linking – KJ4SHL has one by TPA

    - NXDN/P25/etc. is all IP based (multicast)

    - Wi-Fi based video cameras on site relay back to EOC!

   - Remote Radio control/WebSDR scanner/WebCams

  - http://www.foto-webcam.eu
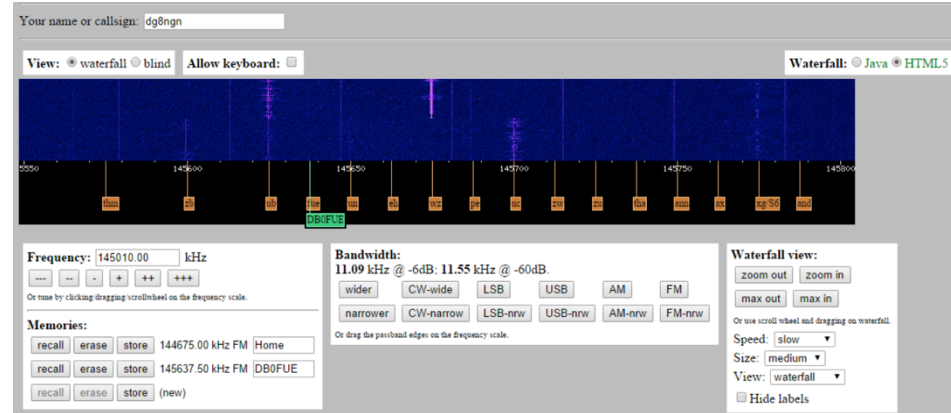
INTRODUCTION TO NETWORKING
THE INTERNET IN A NUTSHELL

- IP Networking is basis of the Internet

  - Many smaller networks interconnected form the Internet

  - Anything that works over the Internet can be made to work over any IP network

  - Every device on the Internet needs a <u>unique IP Address</u>

  - Amateur radio has 44.0.0.0 to 44.255.255.255 "44/8" (16M IP's)

    - This is managed by a non-profit and known as AMPRNET

    - IPv4 Space is hard to get in quantity now ($$$), lucky we have this resource with almost unlimited IP resources

    - IPv6 is encouraged!

  - All networks must know where to find destination IP stations

    - This is done via routing protocols, BGP between different networks externally and OSPF internally
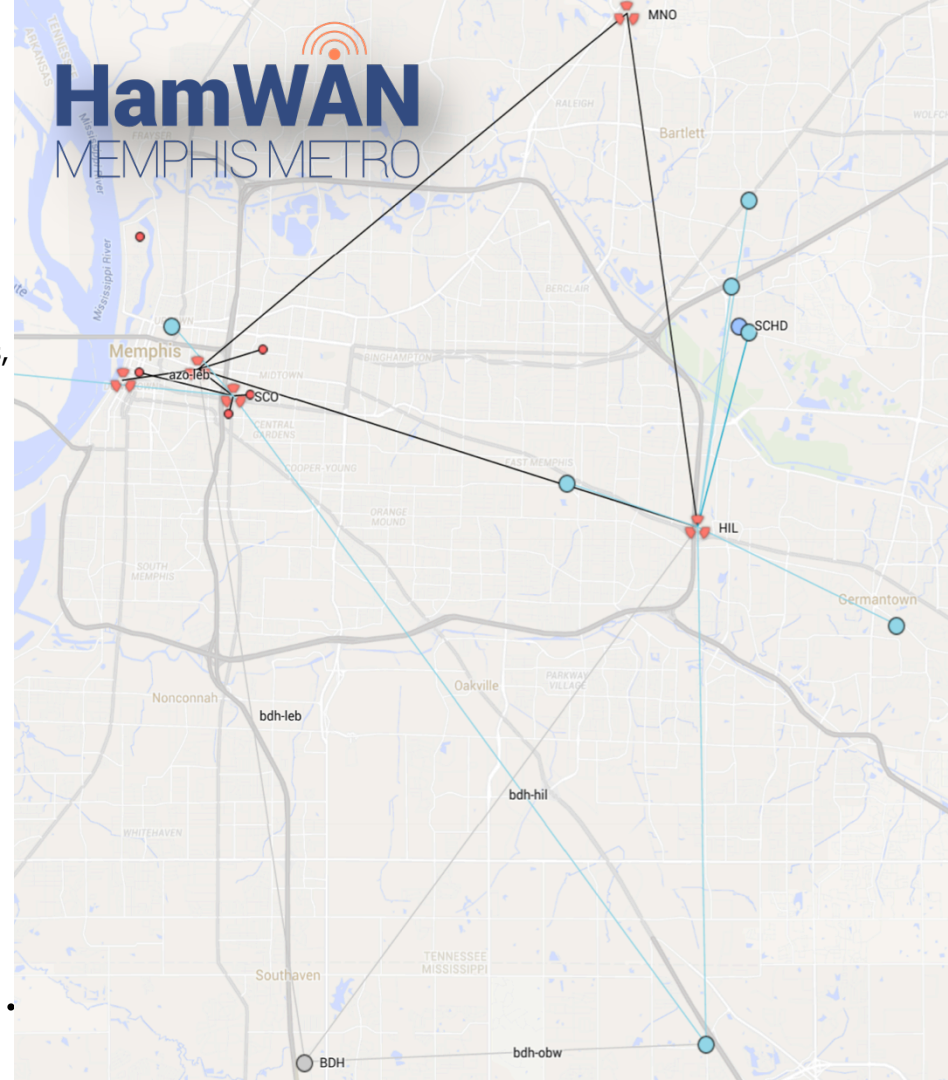
HAMWAN DEPLOYMENTS

- Puget Sound Data Ring in Seattle area

- Has about a dozen sites ➔

  - 20 active users, with another 25-30 nodes for other hams registered

  - **Certified** HamWAN

  - First cross border HamWAN network, a site in Victoria, BC came online a couple months ago. Over a 80 mile path for backhaul

  - Provides linking to a number of repeater sites and an EoC

  - All sites are on UPS protected power

8
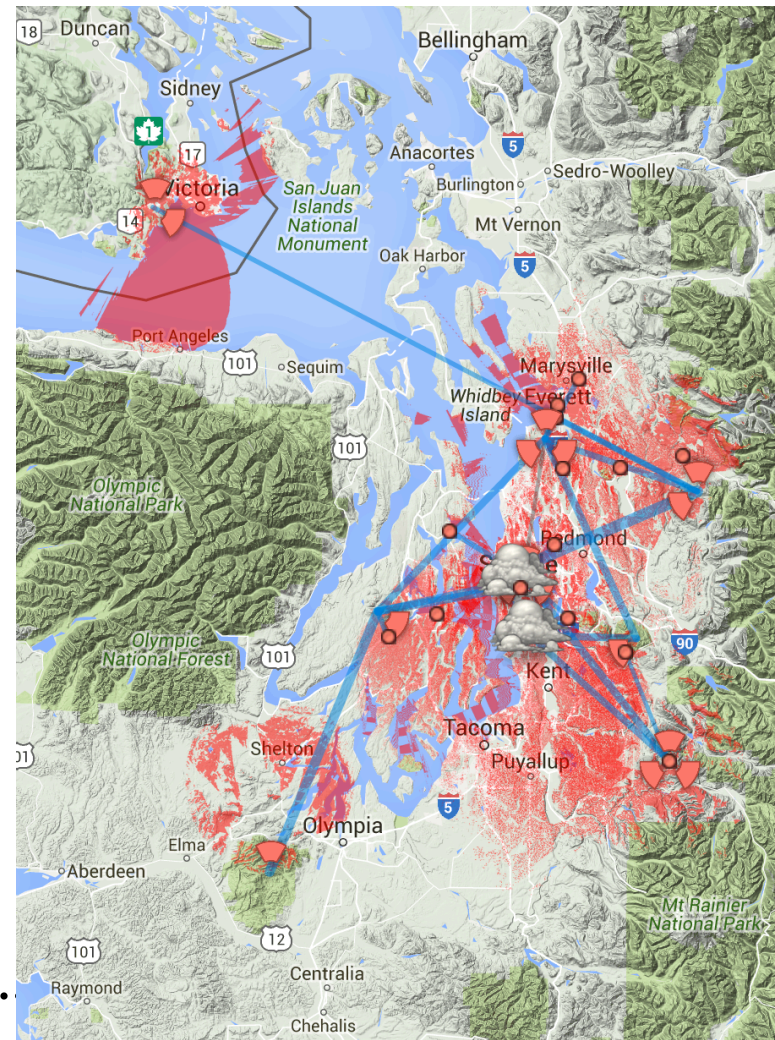
HAMWAN DEPLOYMENTS
MEMPHIS METRO

- ## Second certified **HamWAN** network
  - Set out to cover the 10 county Memphis Metro region
  - Partnering with amateur radio clubs, technology and maker groups, and response agencies

- ## Cell sites:
  - Midtown (SCO)
  - East Mem (HIL)
  - Methodist North (MNO)

- ## Points of presence:
  - First Tenneessee (FTN)
  - LeBonheur (LEB)
  - Millington (MIL)
  - AutoZone (AZO)

9

HAMWAN DEPLOYMENTS
## MEMPHIS METRO

- Network Services – Running today with redundancy + resiliency:

  - Flight tracker (on flightradar24.com)

  - IP Cameras (for weather, traffic, site equipment)

  - Weather stations (on weather underground)

  - VoIP and Video Conferencing

  - Monitoring and logging

  - Streaming of scanners and receivers

- Provide network connectivity for other club's D-Star and Allstar repeaters

# WHAT OTHER GROUPS ARE DOING
EUROPEAN HAMNET

- European HamNET -
http://hamnetdb.net

  - Covers most of central Europe including: Germany, The Netherlands, Switzerland, Belgium, North Italy, Czech Republic

  - About 4k nodes/users. It's by far the largest deployment

  - Unfortunately it uses the IP-IP legacy 44net IP transport, but is moving away from that to BGP. This means everything must go via UCSD gateway to reach the internet.

  - Jann, DG8NGN has done an amazing job!
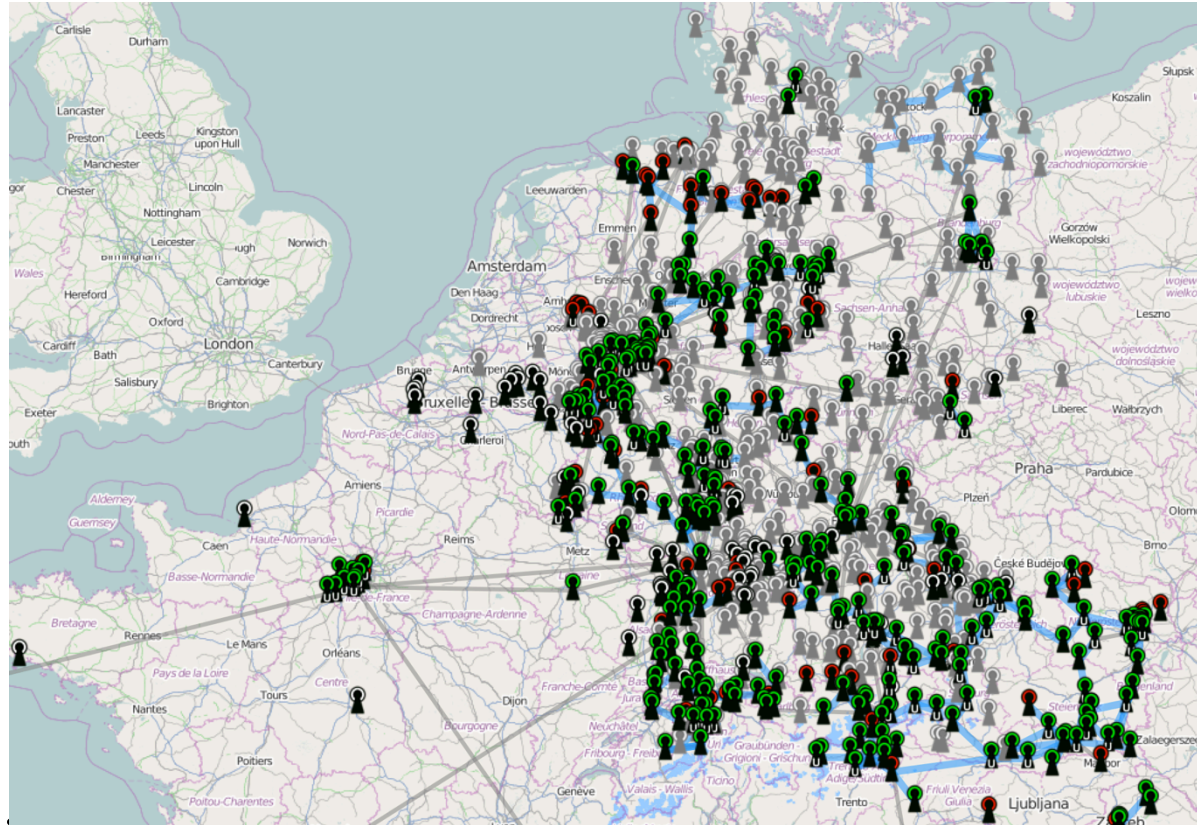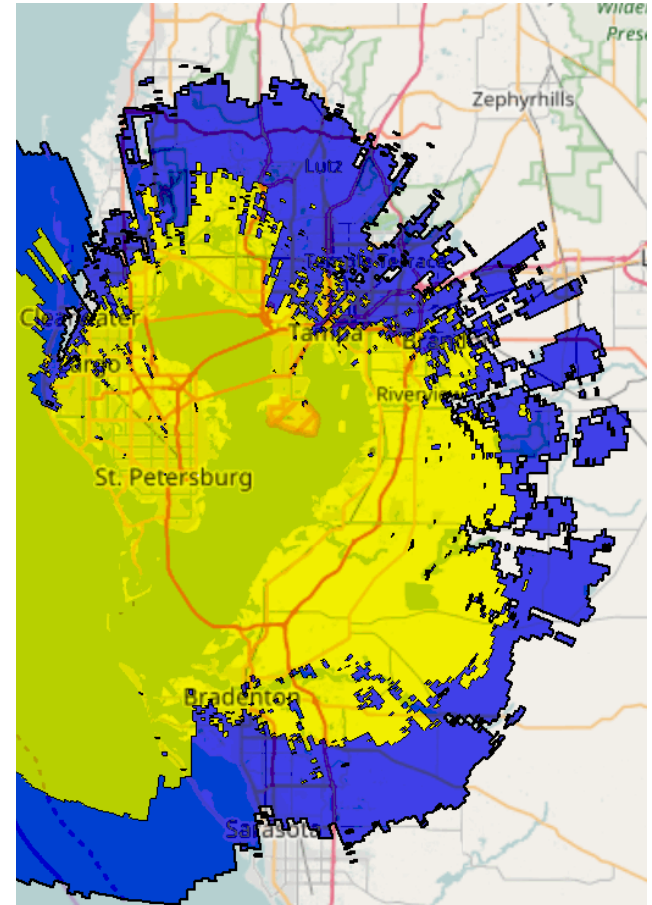
HAMWAN DEPLOYMENTS
TAMPA BAY

- Deployed Tampa Hub April 2016

  - IPv6 Enabled!

- Core building site has been secured

  - Florida is not blessed with mountain tops or terrain

  - Fiber had to be fusion spliced for this

  - 5.9 GHz Sectors are in place

  - Started in January 2016 after MOU with site manager

- Proposed coverage based on 30 dBi client

- Also support three analog repeaters

  - 224.280, 443.525, 927.050

  - Organized under Florida Simulcast Group, Inc. a 501(c)3 non-profit
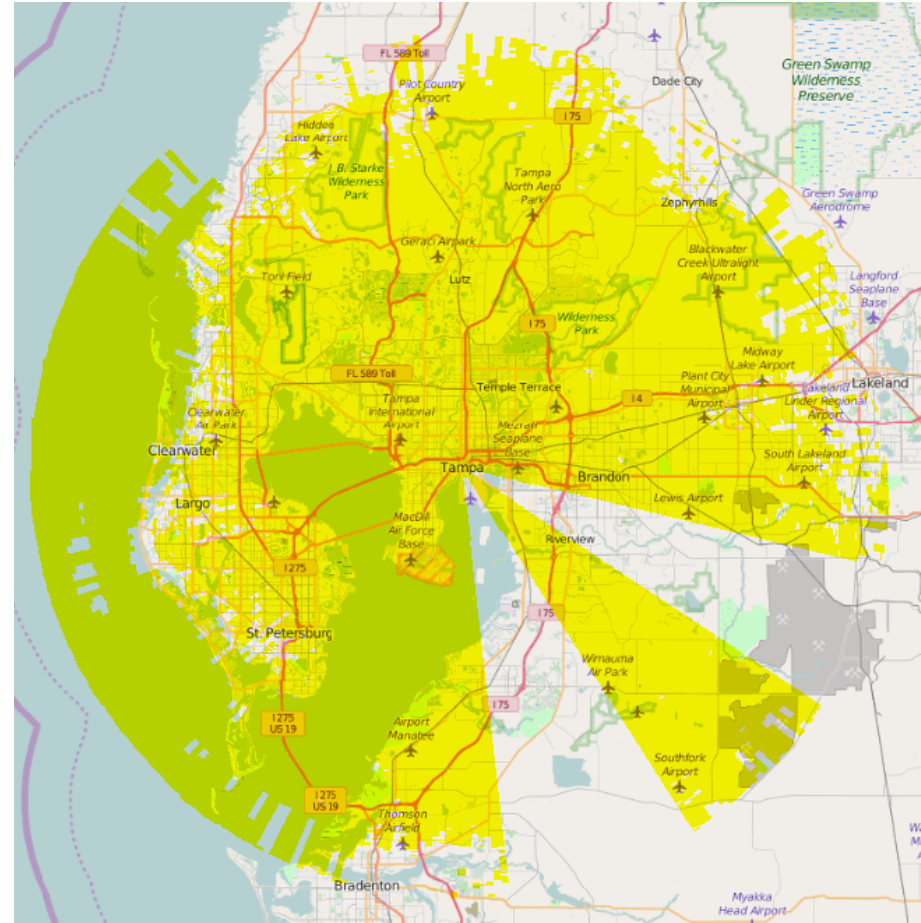
HAMWAN DEPLOYMENTS
St Petersburg

- Deployed December 2016

- Links back to Tampa at 3.4 GHz

  - 140 Mbit/s Link -65 dBm Signal with 24 dBi Dish

- Proposed coverage based on 30 dBi client

- Tested to link up in Sarasota at -85 dBm

  - 90' up on a building at 30 Miles

- Supports a couple repeaters

  - KA9RIX has his hub linked on it from Madeira beach.

- North county coverage could be better

HAMWAN DEPLOYMENTS
St Petersburg

| PING	DOWNLOAD	UPLOAD
8 ms	42.35 Mbps	34.84 Mbps

HAMWAN DEPLOYMENTS
St Petersburg - Tampa

- Combined coverage of Network is excellent

- We fill in several nulls from Tampa

- Looking to the future

  - Expansion to Sarasota

    - This is planned for 2017 at 280' in downtown

    - Will enable a full ring redundant backbone

    - Sarasota to Tampa shot is a bit long at 42 miles.

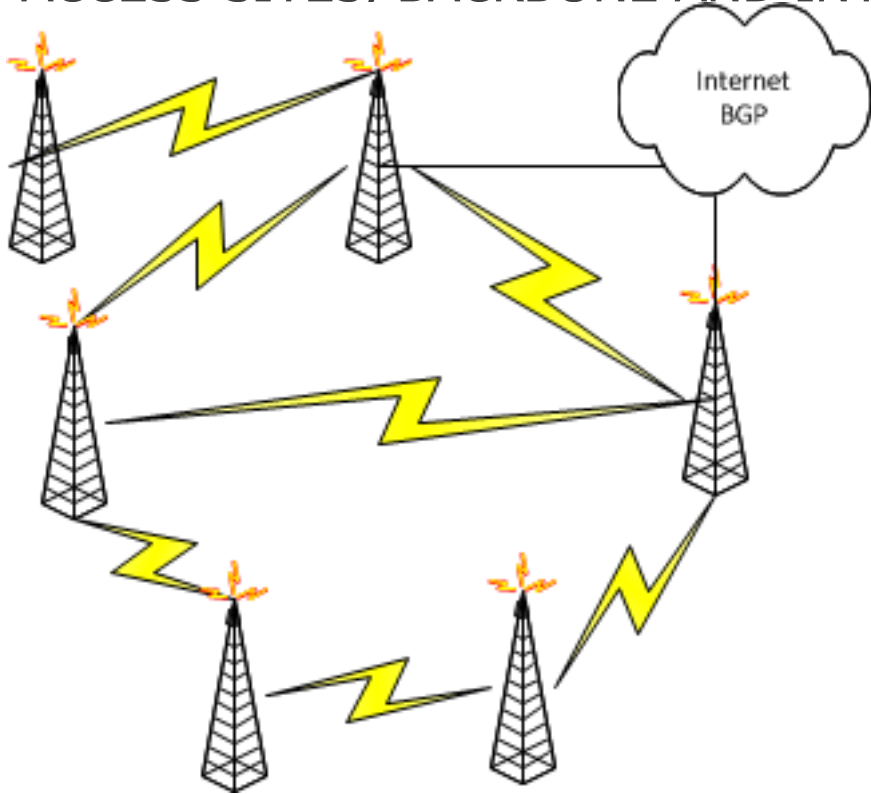 - Can we pickup a site on the East side of the Bay?
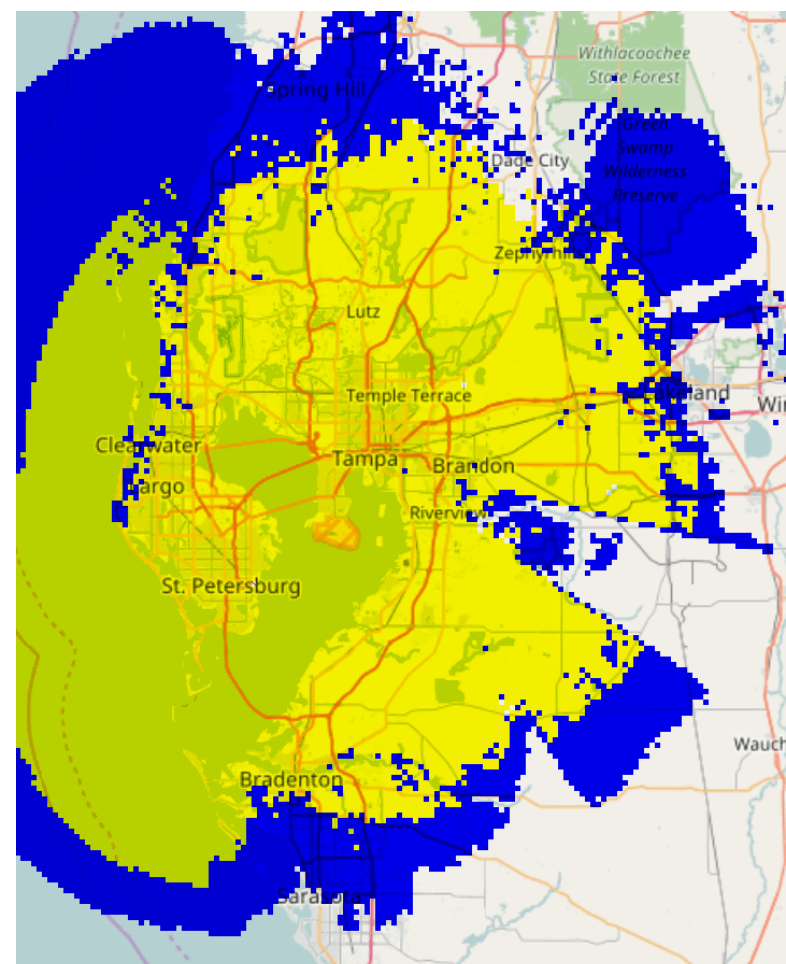
NETWORK ARCHITECTURE
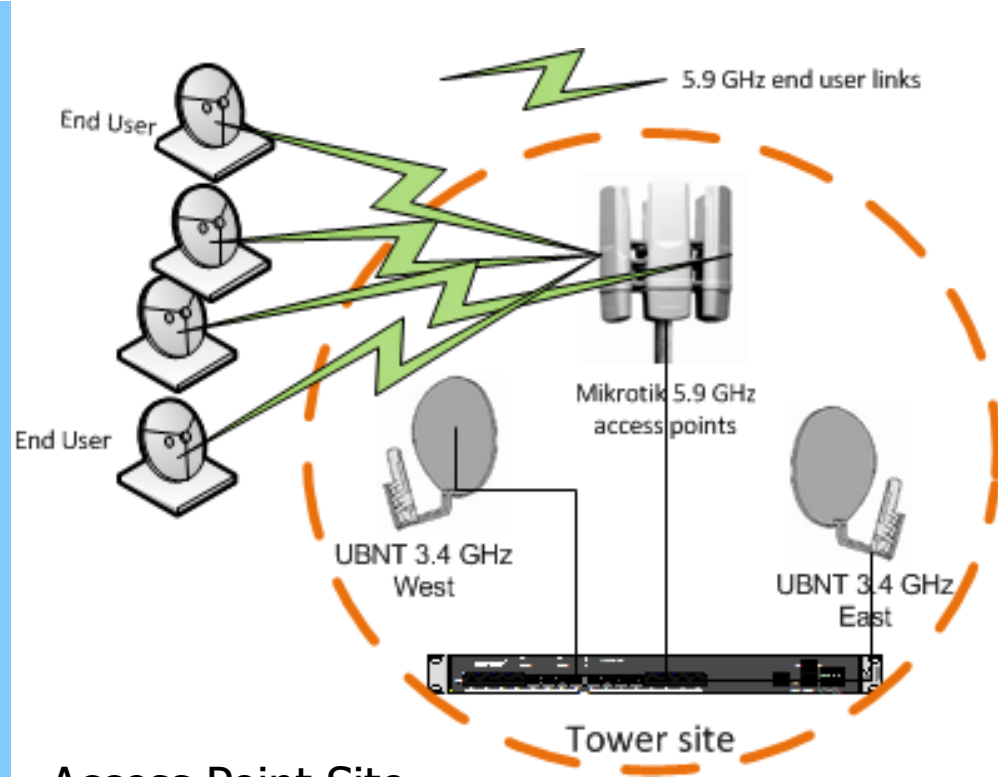## ACCESS SITES, BACKBONE AND INTERCONNECT

- Major parts of the network

- An access site is basically a rooftop user facing access points (AP's) are on.

  - **AP's** are in the 5.9 GHz band. Provide end user access, must be Mikrotik to be HamWAN

  - **Backbone** links at 9cm, or unlicensed bands, anything that is IP transport will work

  - **Router** – All radios (AP's and backbone) are connected to a router (JNPR EX 4200)

  - An access site is ideally co-located with a conventional/digital repeater for linking voice over the network

  - As with any site this should be on generator or emergency back up power.

NETWORK ARCHITECTURE
ACCESS SITES, BACKBONE AND INTERCONNECT

Internet BGP

Network Overview

End User

End User

5.9 GHz end user links

Mikrotik 5.9 GHz access points

UBNT 3.4 GHz West

UBNT 3.4 GHz East

Tower site

Access Point Site

NETWORK ARCHITECTURE
ACCESS SITES, BACKBONE AND INTERCONNECT

- Network Backbone & Interconnect

  - The backbone consists of the interconnect between all sites.

    - These can be almost any radio or frequency band, so long as they support the bandwidth needs of the sites flowing over it.

  - In TB HamWAN we use the 9cm band for many good reasons

    - No chance of interference between ISM/U-NII users and hams, the only users of this band are hams and the government.

    - Slightly lower path attenuation and larger Fresnel zones means easier links.

    - Keeps our backbone out of the 5cm Band where we have our AP's

    - One disadvantage is antennas tend to be about 40% larger than an equivalent gain antenna on 5cm

  - Interconnect Routers

    - These are the connection of the RF backbone into the internet.

    - These sites require only back bone radio and a higher performance border router.

WHAT DOES THIS LOOK LIKE?
RADIOS, ROUTERS, ETC.

- Two major vendors of product

  - MikroTik

    - Linux based with a bunch of propriety stuff, good support for SBC/router boards and Wi-Fi cards.

    - Great for "roll your own"

    - I tend to favor this for ham radio, with the exception of the UBNT gear for PtP 9cm band links

  - Ubiquiti - UBNT

    - Has their own OS (2 actually). Both Linux based with add-ons same as MikroTik.

    - Makes some good all in one radios, not known for their routing.

    - No longer ham friendly as they will not give out the code to unlock the 5.9 GHz band or support this anymore.

  - Other vendors

    - DBII - cool mini-pci radio cards, good support with MikroTik

BASE STATION

- Sector Antennas

  - UBNT 19dBi Sectors and Shields

  - 5.9 GHz

- Back bone links

  - 9cm (3.4GHz) Band

  - 24 dBi Dish antennas

  - MiMo, uses H and V pol simultaneously

- HamWAN has a site BoM on the wiki

  - Typical 3 sector site ~2k USD in hardware

30 DBI CLIENT
MIKROTIK 5.9GHZ

- **MikroTik RB912 MiMO 1.3W Station**

  - About $70

  - Typically with shielded box

- 2' Dual Polarity UBNT Dish

  - 30 dBi Gain – Radio mounts to dish

- 30+ ft. mounting height recommended

- ~$200

- Highest performance

- What all coverage maps are modeled to

24 DBI CLIENT
MIKROTIK 5.9GHZ

- MikroTik Mikrotik DynaDish 5

  - About $150 on Amazon, $180 on prime

  - Includes radio, dish, and POE

- No connections needed, radio in part of antenna.

  - Simple to install

- 30+ ft. mounting height recommended

- Moderate performance

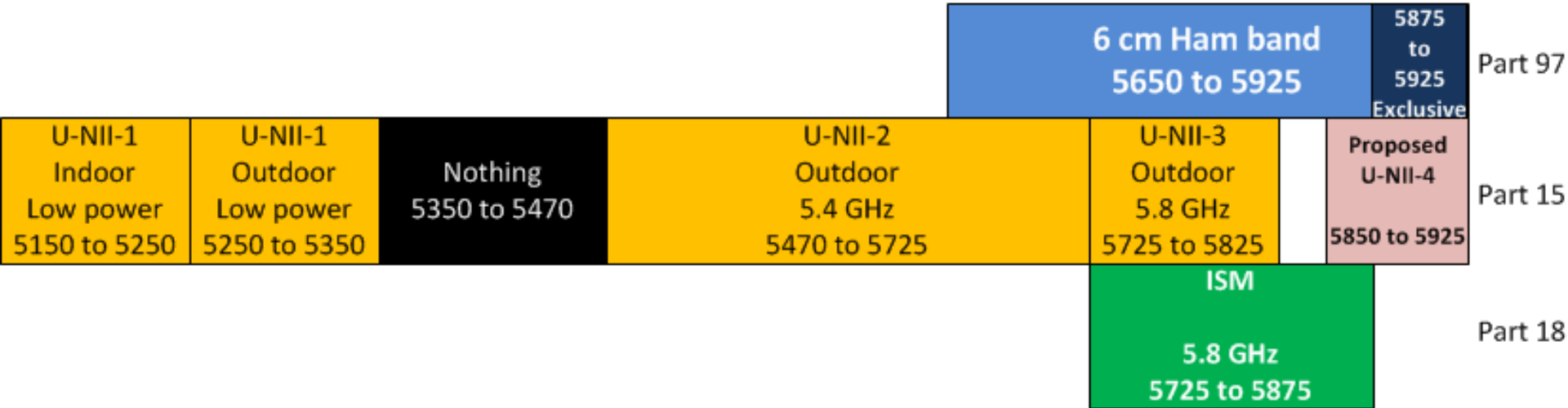- Signal will be -5 dB from coverage maps.
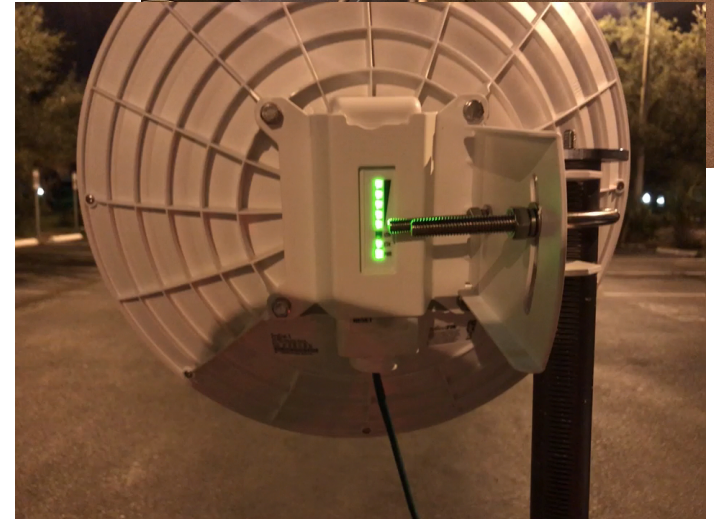
TYPICAL INSTALL
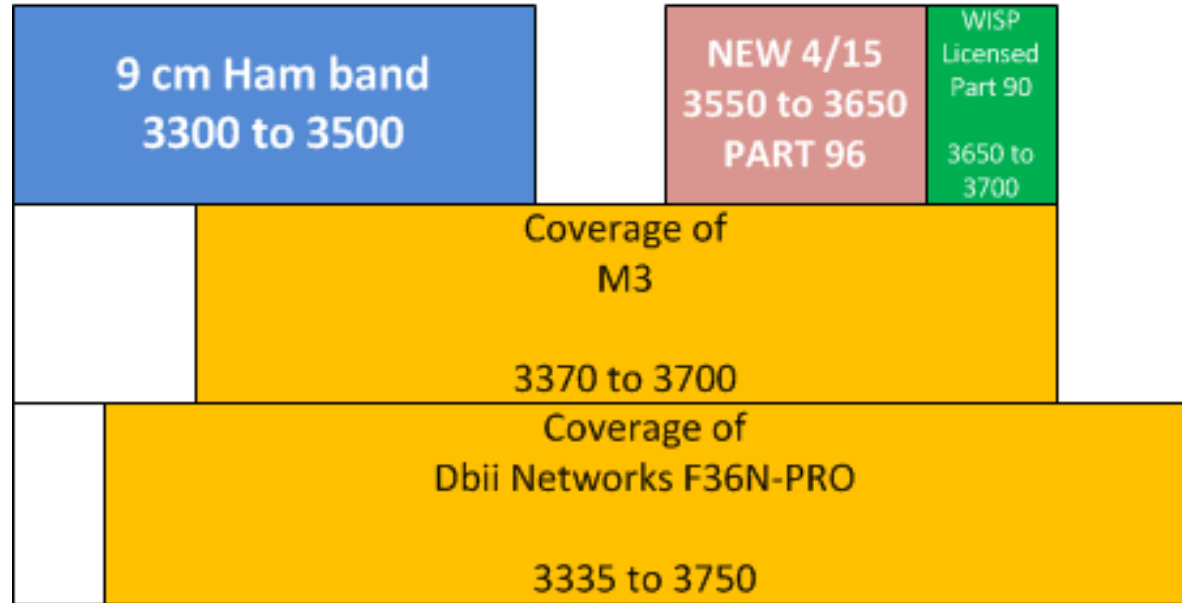
MICROWAVE BAND OVERVIEW

- 5 GHz Bands

- Lots of overlap for Hams, only a 50 MHZ sliver of our band is truly "free"

- Most commercial operators don't "play nice"

				6 cm Ham band 5650 to 5925		5875 to 5925 Exclusive
						Part 97
U-NII-1 Indoor Low power 5150 to 5250	U-NII-1 Outdoor Low power 5250 to 5350	Nothing 5350 to 5470	U-NII-2 Outdoor 5.4 GHz 5470 to 5725	U-NII-3 Outdoor 5.8 GHz 5725 to 5825	Proposed U-NII-4 5850 to 5925	Part 15
				ISM 5.8 GHz 5725 to 5875		Part 18

MICROWAVE BAND OVER VIEW
CONTINUED

- 3 GHz Band – 9 cm

- No Other users... Yet.

- OFCOM (UK FCC) has eliminated most of the 9cm band from UK hams for broadband

- Part 96 new allocation at 3550 to 3650.

- **Ideal for inter-site links**

9 cm Ham band
3300 to 3500

NEW 4/15
3550 to 3650
PART 96

WISP
Licensed
Part 90

3650 to
3700

Coverage of
M3

3370 to 3700

Coverage of
Dbii Networks F36N-PRO

3335 to 3750

PROPAGATION AND PATH ANALYSIS
WILL IT WORK ALL THE TIME? AT ALL?

- Microwave is basically "Line-of-Sight"

  - There are some links that don't need it, but at much reduced capacity.

    - Radio will modulate down (FM to SSB to CW) in the event of signal loss/fade, but capacity (mbit/s) goes down

    - This may be fine for temporary/field ops, but not for a production network

- We need to ensure availability of the backbone at all times.

  - This means shorter links typically are better (15 miles at most) even though 30 miles will work.

  - The atmosphere is not a perfect medium it can delay/bend/distort signals during certain weather. Over water is fun!

  - Need what's called "fade margin", extra signal above the minimum.
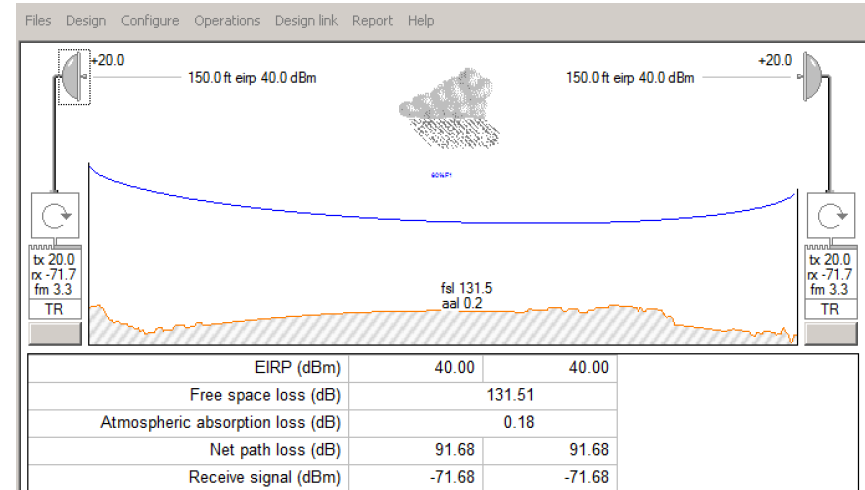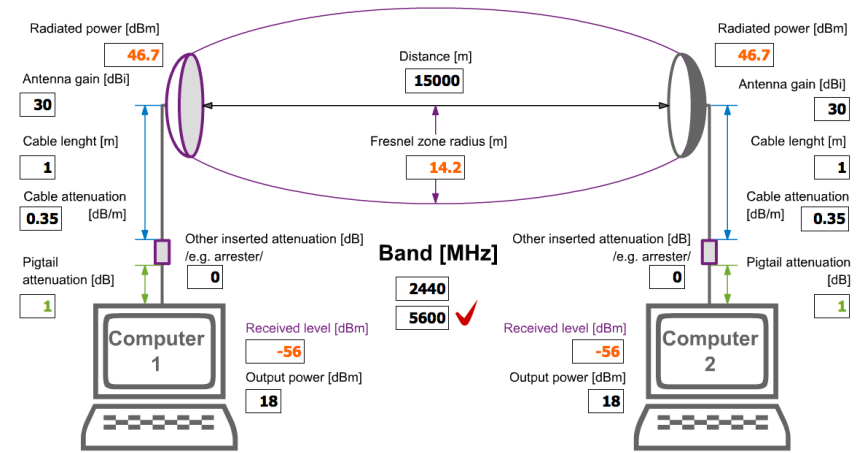
CALCULATING PATHLOSS

- Free (beer) software online

- Radio Mobile

- WiFi Calc

- Non-Free Software

- Pathloss 5.0

    - Industry standard for microwave path prediction

    - Awesome program, I own it.

    - Models reflection/diffraction/multipath/rain

    - About $7k

MODULATIONS AND PROTOCOLS
QAM VS. CHANNEL SIZE VS. THROUGHPUT VS. SIGNAL RATE VS. AIRTIME

- How much throughput can my link support? It's a 300 mbit/s radio!

- Not as much as the box says. Many things influence this

  - QAM – Quadrature Amplitude Modulation level AKA MCS index

  - Channel size – Bigger channels with higher mod level means more throughput

  - Airtime – The amount of time the radio spends transmitting

  - Network Protocol – Wi-Fi vs. proprietary

  - Distance – Long distance links can affect performance

  - MiMo – Multiple input Multiple output.

ROUTERS
ROUGHT-ERS NOT ROOT-ERS

• Routers are the repeater controllers of the network.

• Routers know what the entire network looks like at any given time.

• They know this through the use of Routing Protocols.

- TB HamWAN uses IS-IS

• These are what provide the resiliency to our network.

- If a link dies in the back bone, they will "route" around it. Users would never know!

- TB HamWAN has standeridside on the Juniper EX4200

  - Cheap ($300 on eBay) and many donated ones from members

  - 10g performance and mature OS

  - Easy to manage

LEGAL ISSUES

IT'S MORE FUN TO POINT OUT POTENTIAL PART 97 VIOLATIONS THAN DO SOMETHING!

- Part 97 puts some restrictions on our communications as hams

  - Legally the control operator is responsible for every packet of data his node X-mits

    - Inbound traffic from the internet (ping/traceroute/etc.) can cause transmissions of packets.

  - No encryption

    - Wi-Fi has link level crypto as an option, obviously this is not legal

    - This presents some interesting issues regarding the use of our network for welfare type traffic which may be under HIPPA. Many times this uses session level encryption (SSL). Is this legal?

    - How to ID a link? HamWAN solves this via the modem name

    - All stations must ID. SSID would be one callsign. Encoded ICMP/Locally administered MAC's encoded with callsign work too

  - Only licensed amateur radio operators can connect.

    - This proposed network should be for Amateur Radio use only. No public Wi-Fi, etc. EOC internet access during an emergency or other temporary use should be fine IMO.

INTERNET INTERCONNECT
TAMPA ONLY FOR NOW

- Edge sites should are where the network connects to the public Internet
  - These sites can be at a data center or even via a VPN
  - The routers will announce the IP address used on the network to the internet
  - This design allows multiple internet connections at different parts of the network
- A "normal" cable modem/DSL connection will not work for this
  - These are designed to serve up a single IP address for end user use.
- BGP – Border Gateway Protocol is the routing protocol used for this.
  - It's policy based rather than cost based.

IDEAL SITE LOCATIONS
HEIGHT IS MIGHT (NOT ALWAYS)

- Centrally located so many hams can see it from their homes/other sites

- Lower sites (150') are fine.

  - Easy access (outside of normal 9-5 hours)

  - Should be able to be on the back up power

    - All tall buildings have backup generators for elevators, at most a UPS would be needed for a few minutes

    - A good ground must be available

- Ability to make changes and install multiple antennas

- Everything installed must be to commercial standards. (R56)

CONCLUSION
WHO'S IN?

- We need interest, even if you're not a networking person

- Every region in the US needs a HamWAN network

- TB HamWAN is designed for growth!

 - Get a client online for under $200!

- We can interlink entire states

 - Think of the public service aspects of this, multi-megabit file transfers and other applications linking EOC's

- Typically a small group of dedicated hams involved.

 - We can actually bring younger hams into the project and have them learn.

  - Lots of interest from High School/college networking classes

ADDITIONAL RESOURCES

- Florida Simulcast Group – http://flscg.org
  - Small group of techie hams in the St Petersburg/Tampa region
  - Florida Non-Profit, 501(c)3 federal charitable status.

 - My YouTube channel - https://www.youtube.com/user/gulfcoastequity/videos

- HamWAN - http://www.hamwan.org

 - #hamwan and #44net on irc.freenode.net.
  - Me, W9CR is DarkHelmet, stop by and say hi

- 44net email list - http://www.ampr.org/pubs.html

- Memphis Metro HamWAN – http://memhamwan.org/

- My wiki, mostly radio and hacking stuff – http://wiki.w9cr.net/

THANK YOU
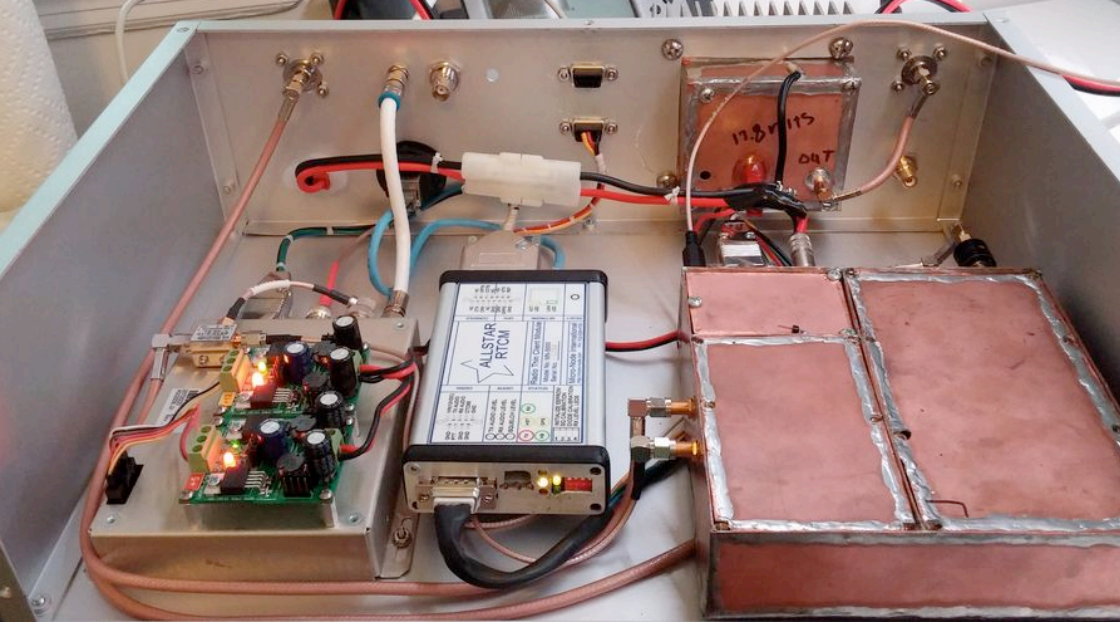
Backup slides

UBNT NANOSTATION M3 9CM BAND
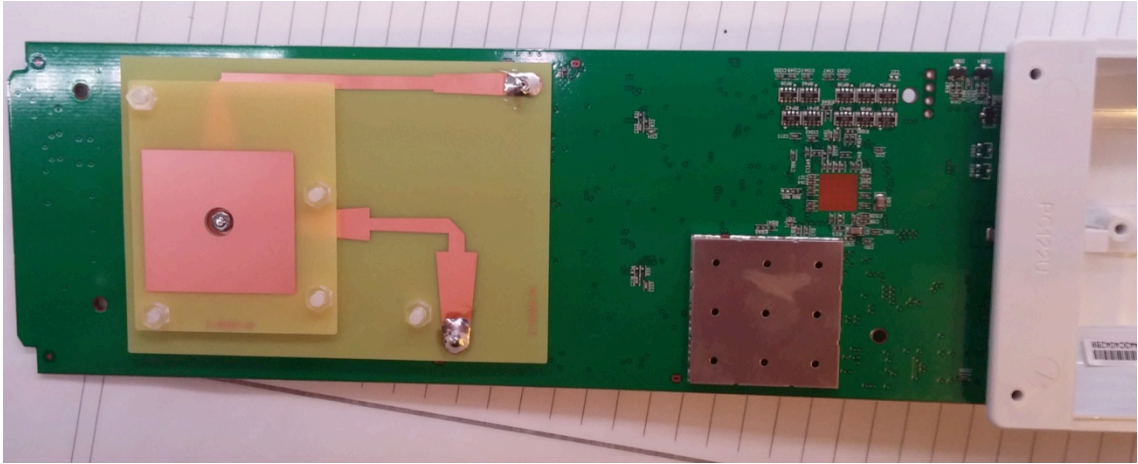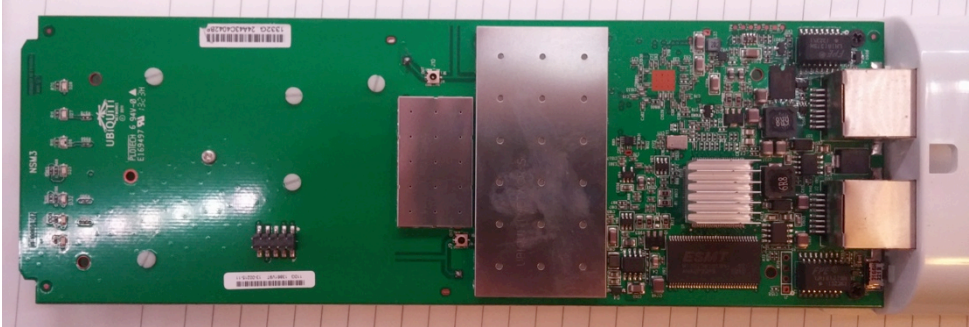
UBNT XR3 9CM CARDS – MIKROTIK ROUTER HOST

REF 30.0 dBm   10 dB/   "5100"   ATTEN 40 dB

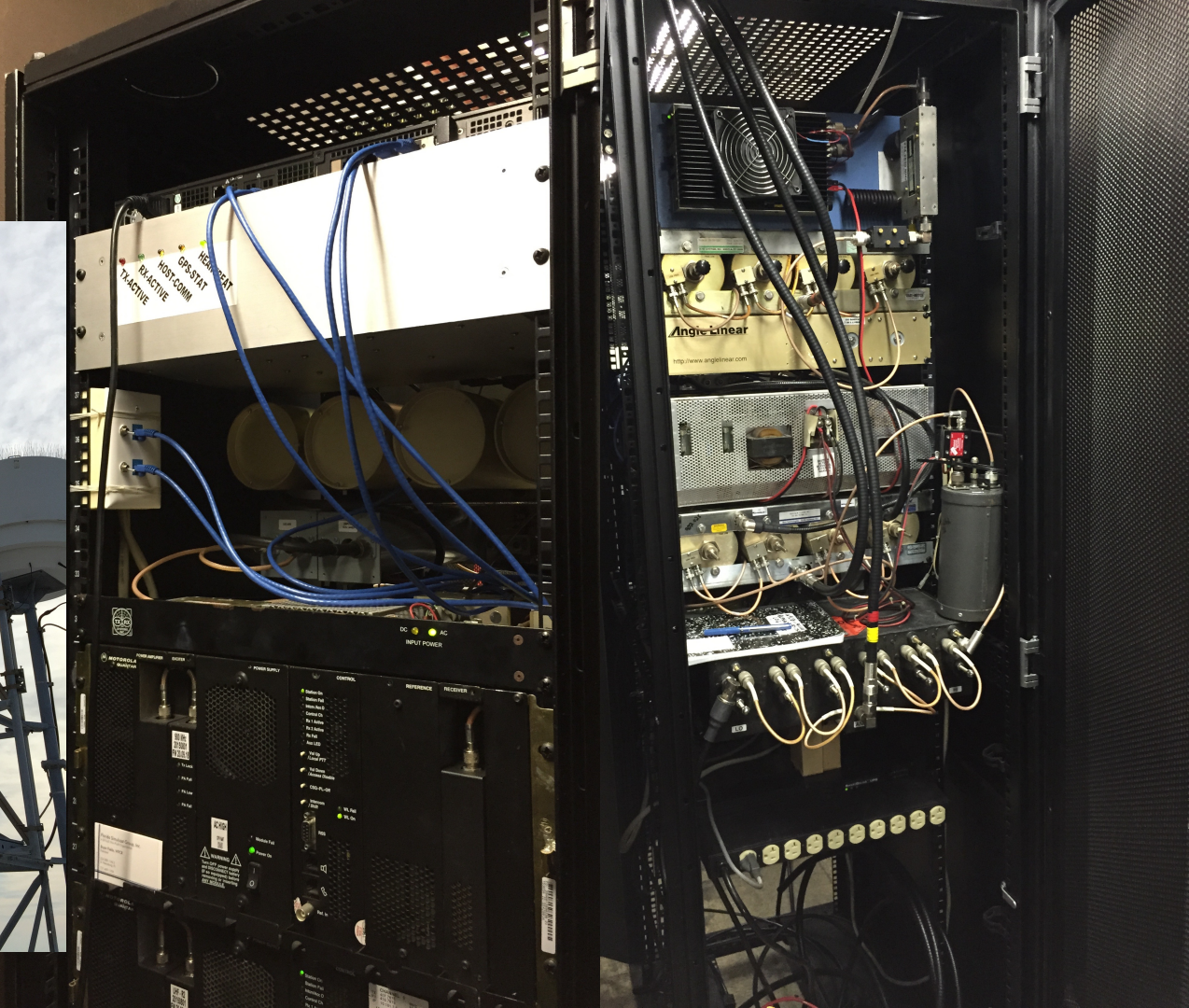START 3.100 GHz   RES BW 3 MHz   VBW 3 MHz   SWP 22.5 msec   STOP 4.000 GHz
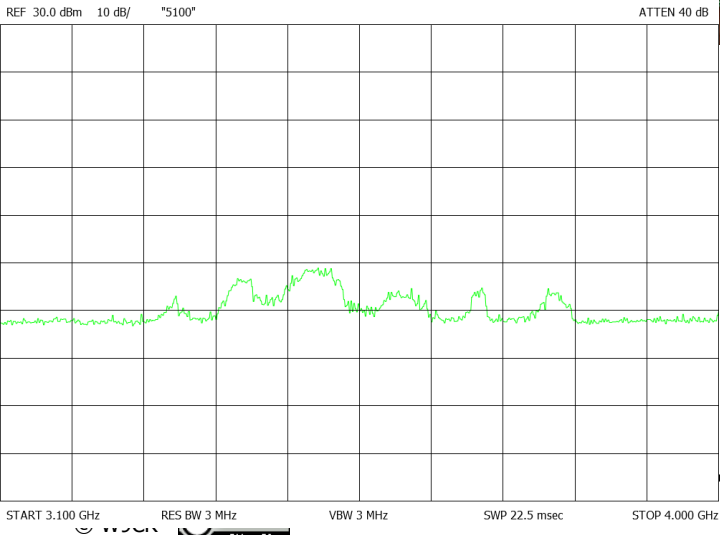
224.28 W9CR REPEATER
ALLSTAR IP RTCM INTERFACE

TAMPA SITE
SECTORS AT 500'

PATHLOSS 5.0 PROFILE
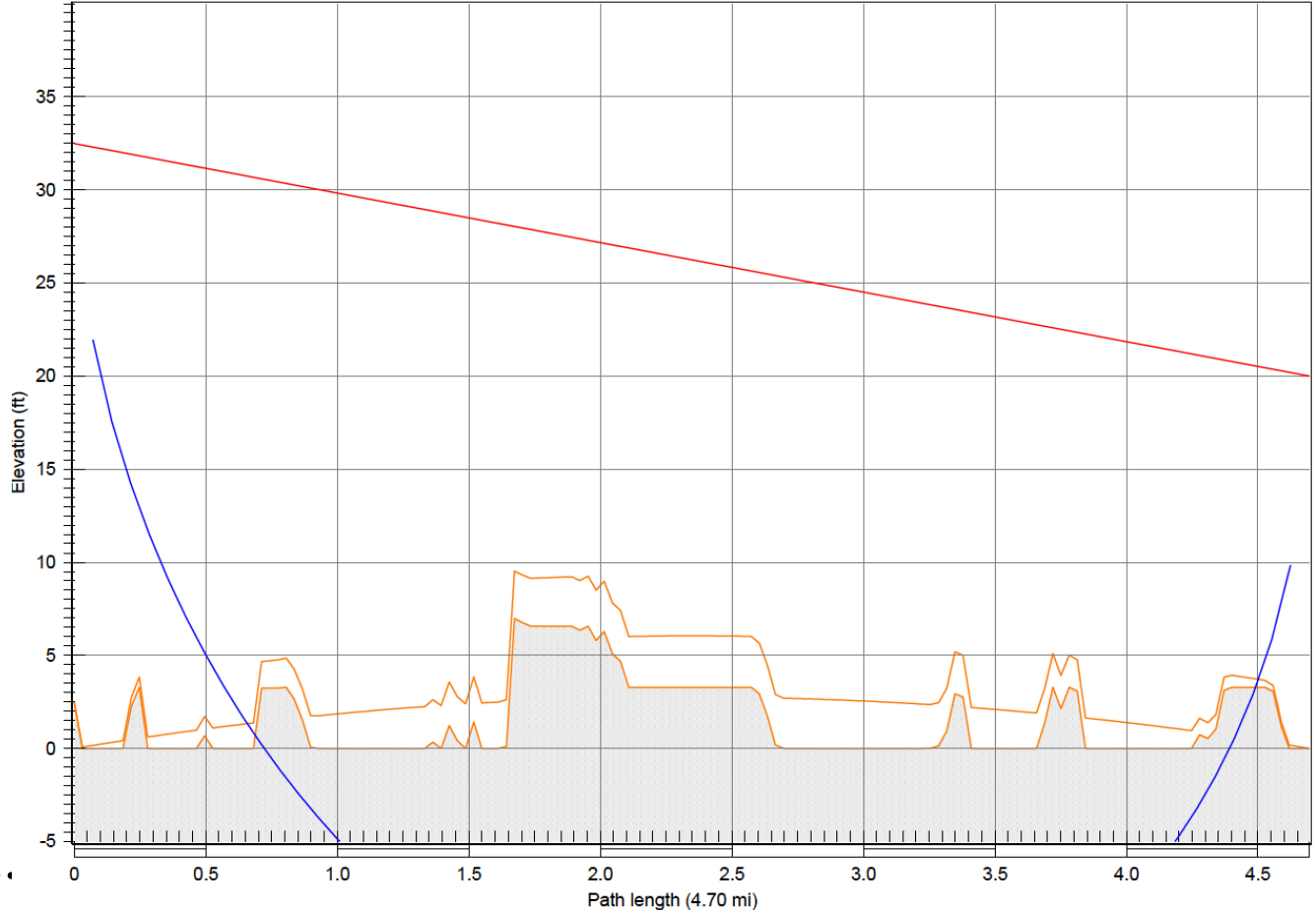
ST PETE

rocket M3

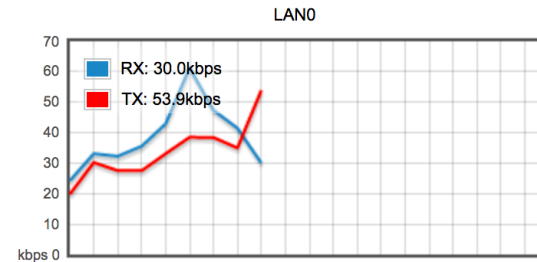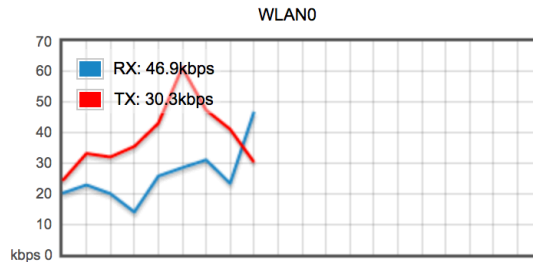airOS™

| MAIN | WIRELESS | NETWORK | ADVANCED | SERVICES | SYSTEM |

Tools: Logout

Status

Device Model:	Rocket M3
Device Name:	KJ4SHL St. Pete
Network Mode:	Bridge
Wireless Mode:	Station WDS
SSID:	KJ4SHL-Tampa_StPete
Security:	none
Version:	v6.0 (XM)
Uptime:	57 days 14:10:07
Date:	2017-02-25 10:10:35
Channel/Frequency:	94 / 3470 MHz
Channel Width:	20 MHz
Frequency Band:	3460 - 3480 MHz
Distance:	16.3 miles (26.3 km)
TX/RX Chains:	2X2
TX Power:	25 dBm
Antenna:	RD-3G-26 - 26 dBi
WLAN0 MAC:	68:72:51:0A:E6:D0
LAN0 MAC:	68:72:51:0B:E6:D0
LAN0:	100Mbps-Full

CPU:	4 %
Memory:	34 %
AP MAC:	68:72:51:0A:E6:E3
Signal Strength:	-63 dBm
Chain0 / Chain1:	-65 / -67 dBm
Noise Floor:	-95 dBm
Transmit CCQ:	96.4 %
TX/RX Rate:	130 Mbps / 130 Mbps
airMAX:	Enabled
airMAX Priority:	Base
airMAX Quality:	90 %
airMAX Capacity:	90 %

Monitor

Throughput | AP Information | Interfaces | ARP Table | Bridge Table | Routes | Log

WLAN0

RX: 46.9kbps
TX: 30.3kbps

LAN0

RX: 30.0kbps
TX: 53.9kbps

ST PETE

ST PETE