Amateur Radio Backup Communications Improvement
Proposals & Documentation

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EXECUTIVE SUMMARY

The current amateur radio backup communications for the Alachua County EOC, Red Cross and shelters relies on the functioning of repeater stations on high towers for connection.   These repeaters allow low power walkie-talkies with small antennas at near ground level to communicate via direct line of sight, because the repeater antenna is hundreds of feet above the trees, thus most of the path between the communications volunteer and the repeater is actually in “free space” with very low signal loss.

This could be a problem, because an emergency of such significance as to remove ordinary communications systems (cell phones, telephones, trunked radio systems) would likely also disable the amateur radio repeaters!   This could be due to high winds, loss of power or other weather-related impacts. The distances between the low-lying EOC and Alachua County shelters are

Further, the EOC appears to have few means of long-distance communications abilities, should normal telecommunications fail.   The antenna situation for the shortwave amateur radio station is poor.

After objective documentation of the communications issues, we have developed proposals that include:

1. Repositioning VHF amateur radio antenna(s) at the EOC to gain significantly greater direct communications abilities.
2. Creating two inexpensive HF amateur radio antennas at the EOC that will make long distance communications far easier, and will also ready the EOC for possible future NCSHARES. communications, which are available at no cost, using the existing equipment, and without requiring amateur radio licenses; many governmental units nationwide are taking advantage of this opportunity.
3. Positioning external VHF antennas at chosen shelters so that direct communications with the EOC can be maintained even after repeater failure; a side benefit being weather radio antenna installation

Finally, as more and more digital communications techniques become seasoned and tested, we are adding hands-on training opportunities for our volunteers that include modern digital techniques, antenna construction and placement, and other topics that will enable them to add expertise and gain higher FCC licensure status.

VHF ANTENNAS FOR ALACHUA COUNTY EMERGENCY OPERATIONS CENTER COMMUNICATIONS TO ALACHUA COUNTY SHELTERS

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Executive Summary:

The ARES group was asked to develop backup amateur radio communications plans to reach the Alachua County Shelters in the event of emergencies that include telecommunications failures. Testing at the Alachua County Emergency Operations Center (EOC) revealed that the existing VHF antennas there are positioned at a low height, and with the low altitude of the EOC (approximately 120 ft MSL) and the elevation of Gainesville (up to 190 feet MSL), the existing antennas have a very limited range to the west, without the use of repeaters. In a telecommunications failure, the repeaters may not continue to function, due to failure of power, antenna, tower, or equipment. Therefore I conducted studies to determine what changes to the EOC antenna, and what type of Shelter antennas, would be necessary to obtain direct (simplex) communications between the EOC and Shelters. Free online tower coverage software quickly revealed that due to terrain, the main problems would be at the Newberry and High Springs shelters.

Ground elevation in the city of Gainesville is as high as 190 feet MSL. Unfortunately, the EOC is at a significantly lower altitude, 132 feet MSL. Worse, the Newberry shelter is at 86 feet MSL and the High Springs shelter at 65 feet MSL. High terrain can dramatically impede communications between lower VHF stations. There is the further adverse impact of "radio horizon" due to the curvature of the earth. An unpredictable amount of "diffraction" can lessen the impact of these adverse conditions; indeed, without diffraction, a communications link between these distant sites would require enormous towers.

Further observation and actual testing using acceptable proxies for the EOC and shelter locations demonstrates that the EOC should position one or more amateur VHF/UHF antennas (preferably antennas with gain over a dipole) ***as high as possible*** on the existing EOC tower. Without this, direct communications to shelters beyond the "Gainesville Ridge" will be dramatically impeded by terrain impact of the radio wave.

Shelter antennas at the Newberry and High Springs shelters should be collinear vertical antennas with significant gain over a dipole, and positioned at the top of 50-foot metal towers. Towers should be positioned such that <150 feet of low loss (LMR400 or RG8) coaxial cable can be utilized to reach the intended communications position.

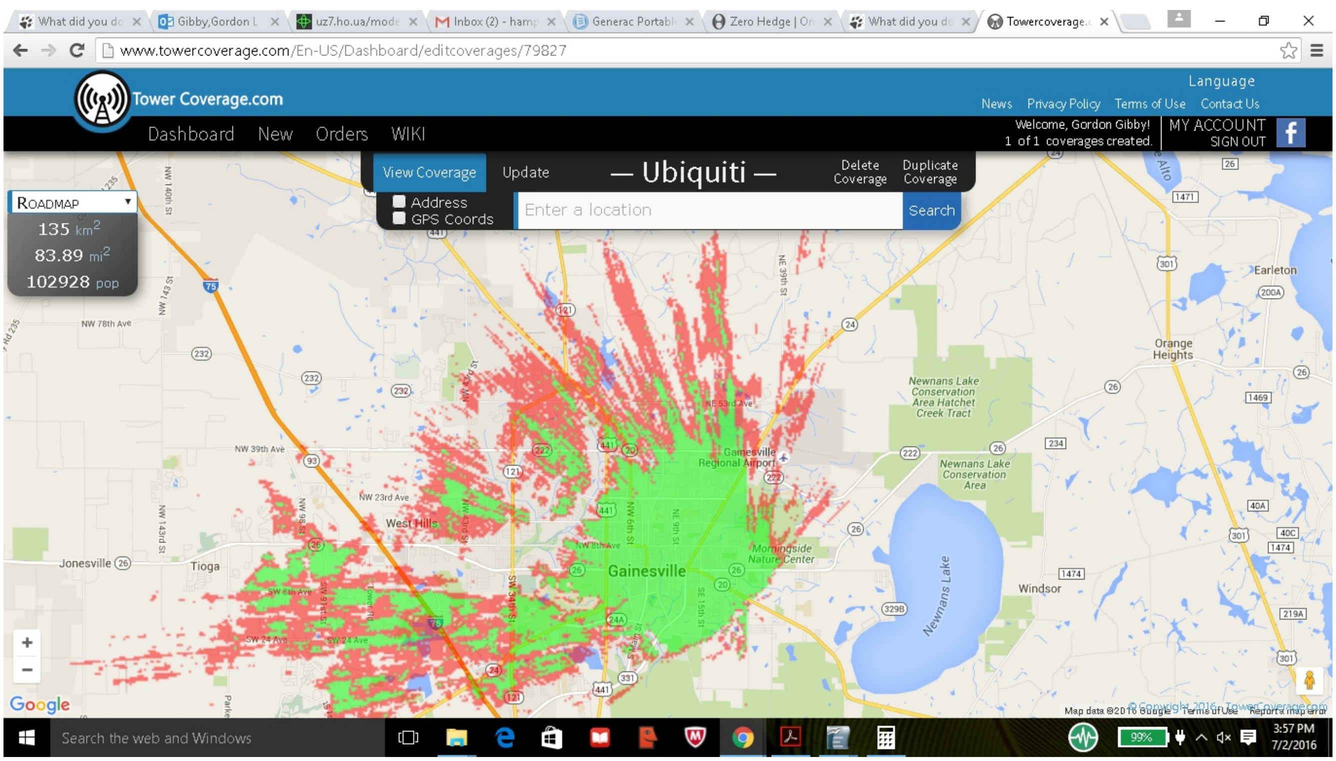
Shelter antennas at other shelters have not been specifically studied, but based on simulations should pose much less of a problem as long as the antenna is positioned at 20 feet or higher (e.g., on the side of a building near the peak of the roof), not substantially shaded by nearby larger/higher structures, and are connected by <150 feet of low loss (LMR400 or RG8) coaxial cable to the intended communications position.

Simple weather antennas can be mounted at the same time, generally much less sensitive to height,and a coaxial cable routed to the desired point of weather monitoring.

EOC-SHELTER COMMUNICATIONS LINK EVALUATION

Tower Coverage Simulation To Identify Geographic Difficulties

When I began this analysis, in concert with other ARES members, none of us had significant understanding of the Alachua County terrain geography Therefore, my first effort to evaluate the tower coverage of the EOC VHF antenna involved using free online tower-coverage computers. Unfortunately, I was unable to find one that could correctly model 144 MHz communications, but I did find models for 2.4 GHz signals that suggested that even with very high antennas on the EOC tower, we would still have a coverage problem to the west. [1] The following image is for a highly direction antenna attempting to cover to the northwest, mounted 75 feet above ground level at the EOC....and it doesn't get much past 13th street, where a 180-190 foot ridge is located.



Extensive modeling of omnidirectional antennas suggested that the EOC coverage to the east would be adequate and that west and northwest were significant problems – even with an antenna at 75 feet AGL.

1 Www.towercoverage.com

Power Budget Computations

Next, I turned to a traditional communications power budget computation to evaluate the best possible link outcome. Simplex (direct) communications links such as the EOC to Shelter link are typically first evaluated using a "free space" communications link budget, as follows:

First, the output power of the transmitter is converted into deciBels above a 1 milliwatt standard If we assume a moderate 50 watts of VHF output power, this is 46 dBm.

Any loss due to the transmission line cable is then subtracted, and any gain due to the transmitter antenna is added.

> *A first cut assumption is that transmitter gain will be similar to transsmission line loss, leading to no over all effect.*

The "free space loss" is a mathematically calculable loss that takes into account both the spreading out and thinnning out of the transmitted energy as the wave gets spread out farther and farther from the transmitter, and also the reduced energy capture of smaller receiver antennas at higher frequencies. Internet calculators make it easy to obtain the free space loss.[2] The receiver antenna gain (it doesn't have to be a small antenna!) then adds to the signals strength, receiver transmission line loss subtracts, and the final result is the amount of signal in dBm reaching the receiver.

> *Free space loss at 144 MHz for 23 miles (from the EOC to High Springs) = -107 dBm.*
> *Power receiving receiver = 46 dBm – 107 dBm = -61 dBm*

Receiver sensitivity to just discern a signal is often around -110 dBm (in the fractions of a microvolt) but to get accurate reception one probably wants to see -105 dBm. Since we have -61 dBm available, we have comfortable free space loss cushion.

> *-61 dBm - (-105 dBm) = 44 dBm Quite a Cushion!*

The problem, however, is that for almost all of the EOC's communications links, ***signals will have to go through foliage and possibly even impact terrain***, since the EOC's altitutde (132 feet) isn't nearly as high as the terrain to the west (as high as 190 ft MSL). With an antenna near the top of the available tower, at 90 feet, the signal starts at 220 feet MSL which is below the tops of trees in middle of Gainesville.

Foliage and residential signal loss can be horrendous, reaching 10-20 dB per MILE. With a 10 dB loss, only 10% of the power makes it past one mile; 1% past 2 miles, 0.1% past 3 miles – virtually NONE of the power makes it past five miles.

Thus, it becomes very important for long distance VHF communications links where one or more stations is low enough that foliage will be encountered, to use the highest possible antennas.

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2 http://www.qsl.net/pa2ohh/jsffield.htm

Optical Horizon

Because of the curvature of the earth, beyond a certain distance, even high objects simply cannot be seen. Tall masts of sailing vessels appear to shorten and then disappear as the ship sails away from land. This phenomenon causes the Coast Guard and boaters to want the highest possible antennas. The optical horizon can be estimated as:

1.22 x square root of the observer height

This limitation occurs on BOTH sides of a communications link. It is desirable that neither stations's signal should impact terrain! The following is a table of the observer height above ground (in feet) and the distance to the horizon (in miles):

Height (feet)	Horizon (miles)
20	5.5
30	6.7
50	8.7
70	10.2

EOC – Newberry Shelter is 19 miles.
EOC – High Springs Shelter is 23 miles. Even if there were no intervening high terrain, the optical horizon would predict that antennas of >70 feet at both ends would be required for signals to reach from the EOC to the High Springs shelter!

Diffraction can ameliorate these otherwise bleak predictions. The tops of trees and other elevated obstacles cause bending of the signals, as does the variation in densities in the atmosphere. These effects can be very difficult to predict, so once the link budget calculations were considered, I moved on to observational and experimental testing.

Real World Testing

First, consider the following table of ground elevations (measured against Mean Sea Level (MSL)) of points that need to connect, as well as testing levels, and elevations of some helpful colleagues who assisted me in multiple tests:

Location	**Ground Elevation (feet MSL)**	**Comment**
EOC	132	

Red Cross	190	Example of Gainesville ridge
Newberry Shelter	86	
High Springs Shelter	68	
KX4Z (Jonesville)	100	
Windsor Baptist Church	103	
East Newman's Lake ham	Approx 120	
Oak's Mall Ham	Approx 140	
High Springs Ham	74	

The antenna heights of the colleagues are known; some have more than one antenna available for testing. If we assume an EOC antenna at 90 feet AGL (above ground level), then we arrive at the following MSL altitudes:

Location	**Ground Elevation (feet MSL)**	**Antenna Height MSL**
EOC	132	132+75 = 207 MSL
Red Cross	190	Existing antenna 210 MSL
Newberry Shelter	86	
High Springs Shelter	68	
KX4Z (Jonesville)	100	Existing Antenna 145 MSL
Windsor Baptist Church	103	Test antennas up to 148 MSL
East Newman's Lake ham	Approx 120	Existing antenna 210 MSL
Oak's Mall Ham	Approx 140	Existing antenna 190 MSL
High Springs Ham	74	Highest existing antenna 140 MSL

It is apparent that we can use some proxies for EOC and shelter antennas:

EOC Antenna approximated by East Newnan's Lake ham
High Springs Shelter approximated by 35 and 70 foot antennas at High Springs Ham

Furthermore, I set up a test antenna at 25feet AGL (with roughly dipole gain) , 38 feet AGL and 52 feet AGL in Newberry, Florida, at a location in the vicinity of, and at roughly the same altitude as the Newberry Shelter.

Using these locations, testing with roughly 75 watts output demonstrated:

- **EOC to High Springs.** The EOC proxy for a 90 foot EOC antenna was able to communicate with the High Springs proxy using a 70 foot AGL antenna (equivalent to a 70 foot antenna at the High Spring shelter) with acceptable but not strong signal.
- **EOC to Newberry.** The EOC proxy for a 90 foot EOC antenna could be weakly heard by the 52 foot antenna at the Newberry Florida antenna, but my signal could not be reliably read by the EOC proxy. The likely reason for this is that I used relatively high loss (RG8X 100 feet) coax cable.
- OaksMall Area: All stations– EOC proxy, High Springs Proxy, and my Newberry test station -- could be easily copied by the Oaks Mall area colleague with an antenna at 190 foot MSL – because signals going to him took a much higher angle, and were less impacted by the curvature of the earth and thus had much less foliage loss. The Oaks Mall Colleague ended up relaying most of the communications between Newberry and EOC Proxy. This demonstrates that shelters located at higher elevations will only require modest antennas for direct communications. For example, the Red Cross ground is at the same elevation as the Oaks Mall elevated antenna!

Testing also demonstrated another important finding: communications did not "fall off a cliff" when lower antenna were utilized, but instead became progressively more and more degraded as antenna heights declined. For example, the Newberry test station with a lower, 25 foot AGL antenna could still make communications with the High Springs proxy – they were just weaker and more difficult. This supports the diffraction and foliage impact theories discussed above.

Further observational results of interest:

1. Antennas high enough to allow avoidance of terrain ("free space") had a dramatic impact: the EOC proxy could communicate at only 5 watts output power and cause a full quieting effect when transmitting to the 200+ AGL High Springs Repeater antenna – covering the full distance from EOC to High Springs. This corroborates the free space theoretical results discussed above – the reason simplex signals become weak at these distances from EOC to Shelters is because of foliage and terrain impact.
2. Direction digital VHF communications are easily possible from a 20 foot AGL antenna at the (high elevation) Red Cross to the 145 foot MSL KX4Z Jonesville antenna – despite the low 100 foot elevation of the KX4Z station west of significant hills. The reason is the commanding ground height of the Red Cross location

The majority of the stations involved in these tests (only a porton of the results of which are repeated here) were operating:

  - 50-70 watts output power
  - 75-100 feet of relatively low loss coax cable
  - Antennas without significant gain

Because communications installations can be expected to degrade with the passage of time, to achieve these parameters several years after installation, I would recommend that all installations use:

- collinear or other antennas of modest to high gain
- Low loss coaxial cable with limited lengths, < 150 feet in Newberry / High Springs, and < 200 feet everywhere.
- VHF equipment capable of up to 75 watts output power.

CONCLUSIONS

1. The EOC should mount one or more VHF amateur antennas as high as possible on their tower for maximum communications potential.
2. Newberry and High Springs shelters should strategically position fifty foot towers with relatively high-gain collinear antennas on top, such that communications positions can be reached with < 150 feet of low-loss LMR400/RG8 coaxial cable.
3. Closer and higher shelters (above 140 feet MSL) should strive for as close as possible to 190 foot MSL antenna elevation or higher, placing antennas as high as possible on existing buildings, and using <200 foot lengths of lowloss LMR400/RG8 coaxial cable to reach communications positions.
4. Shelters at or below 140 feet MSL should be considered on a case-by-case basis with testing at the shelter.

IMPROVED HIGH FREQUENCY ANTENNAS FOR THE ALACHUA COUNTY EMERGENCY OPERATIONS CENTER

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Executive Summary:

The current high frequency (HF, "shortwave") antennas at the Alachua County Emergency Operations Center) have been shown in testing to be dramatically suboptimal in performance.

For back-up amateur radio communications detailed in the EMComm plan, and for possible future NCSHARES communications efficiency, much better & inexpensive antennas can be easily installed. Two rugged & very inexpensive antennas are proposed: (1) a horizontal copperweld-wire antenna supported by existing reinforced concrete lightpoles on the south side of the EOC, designed more for statewide to regional communications on frequencies from 3-14 MHz; and (2) a vertical copperweld-wire antenna supported by a standoff from the existing tower structure at the northwest corner of the EOC and extending to ground level within the fenced-in protection area, designed for regional to national communications on frequencies from 7 to 21 MHz. The horizontal antenna will make much better use of an existing EOC automated antenna tuner (by moving it much closer to the antenna) and greatly reduce feedline losses compared to the current HF vertical antenna installation. The vertical antenna will be usable over a wide range of frequencies with a simple manual tuner and by older vacuum tube transmitters even without a tuner.

A separate proposal for VHF/UHF antennas will be provided at a future date.

INTRODUCTION

The amateur radio goal for backup communications in the event of disaster, is to be able to have communications with Tallahassee emergency personnel on amateur radio "nets" that will convene at 7.242 MHz during the day, and 3.950 MHz at night. Additionally, amateurs may need to communicate with the HWN Hurricane Watch Net which meets at 14.325 MHz during tropical weather events, in order to provide ground reports to the National Hurricane Center via amateur radio. Additionally a growing number of emergency communications groups are developing capabilities to send e-mail via the WINLINK high frequency network, which includes radio message servers throughout the world, allowing communications even in the event of nation- or world-wide loss of Internet and normal telecommunications, and has a proven record in multiple emergencies, including Katrina. There are five WINLINK high frequency amateur radio radio message servers located in Florida, four in Georgia, and one in South Carolina. There are more than 45 such radio servers in the continental USA.

In addition to these communications possibilities, the equipment owned by the Alachua County EOC can easily be licensed to participate in the NCSHARES federal emergency communications system, which enables County employees to have nationwide communications abilities without amateur radio licenses. The State of Florida EOC has such a license, and has brought up one SHARES Winlink radio message server within this system located in Tallahassee, and has plans to position another in Orlando. There is an additional SHARES Winlink server just west of Gainesville, in Jonesville (operated by the author of this report).

Thus functioning HF antennas at the Alachua County EOC would allow backup emergency radio communications via a multitude of opportunities, including direct (simplex) radio communications on up to seven amateur bands capable of local, regional, national and world-wide communications; amateur radio email via WINLINK, and NCSHARES email via WINLINK.

In a previous report[3] I documented the inadequacy of the current HF & VHF antennas at the Alachua County Emergency Operations Center, by several objective measurements. I then began to work to plan improvements. I first conducted an 8-hour live testing sequence (including both daylight and nighttime conditions) in order to better understand actual antenna requirements (specifically antenna heights & optimal frequencies) needed for various distances during day and night, and documented the results. [4]

High frequency (HF) radio communications typically make use of ionospheric "skip" to reach long distances without any complicated infrastructure, repeaters, or towers. A simple antenna can often reach tens, hundreds, or thousands of miles directly on these frequencies. However, the ionization state of the upper atmosphere changes through the day and night as a result of solar radiation, and thus typically one uses lower frequencies (towards 7 or 3.5 MHz) at night, and higher frequencies (14-28 MHz) during the daytime. These choices are compromises chosen based on the D- and F-layer ionization states at any given time. Radioisonoside results can help inexperienced users select optimal frequencies, and software programs have been devised to give predictions for any given link distance at any time as well.

3 EOCReport, May 14, 2016, Gordon L. Gibby. Included as APPENDIX ONE: EOCReport

4 Real-Life Propagation Study to Evaluate Proposed Antenna Installations at Alachua County EOC and Red Cross, May 23, 2016, Gordon L. Gibby Included as APPENDIX TWO

Discussions with EOC management had indicated a desire to put up a horizontal antenna on the south side of the building, which I agree will be the most-useful-- and thus primary---HF antenna. Ideally this antenna would serve all amateur and SHARES frequencies from 3 MHz through 14 MHz and beyond. Horizontal antennas at modest heights above ground (e.g., 25 feet) are considered optimal for NVIS (near vertical incidence skywave) communications both state- and region-wide. This antenna is therefore the **first priority** for amateur radio emergency communications at the EOC. The design proposed is one that I personally have used with great success as a WINLINK RMS server antenna over many different amateur bands.

However, the existing availability of a tall tower suggests that a second amateur radio antenna of vertical polarization should also be constructed. Because of the space limitations, this antenna cannot be quite as long as the horizontal antenna, but it should ideally serve the amateur and SHARES frequencies from 10MHz through 21MHz – the prime frequencies for day-time emergency HF communications during the time period that the absorbing ionospheric D-layer makes NVIS 3.5MHz and 7MHz communications difficult. In order to take advantage of the vertical tower, I proposed five possible antennas to colleagues with SWR-simulations calculated by EZNEC. [5] Of these proposed antennas, #4, a non-resonant fan dipole consisting of a 52-foot and 40-foot dipole connected at the center seemed optimal. I then constructed a full-size prototype of that antenna (using a tree as support) and made measurements that indicated the antenna was a true success. [6]

The remainder of this report gives the construction and materials details for these proposed antennas.

5 EOCAntennaOptions, Gordon L. Gibby

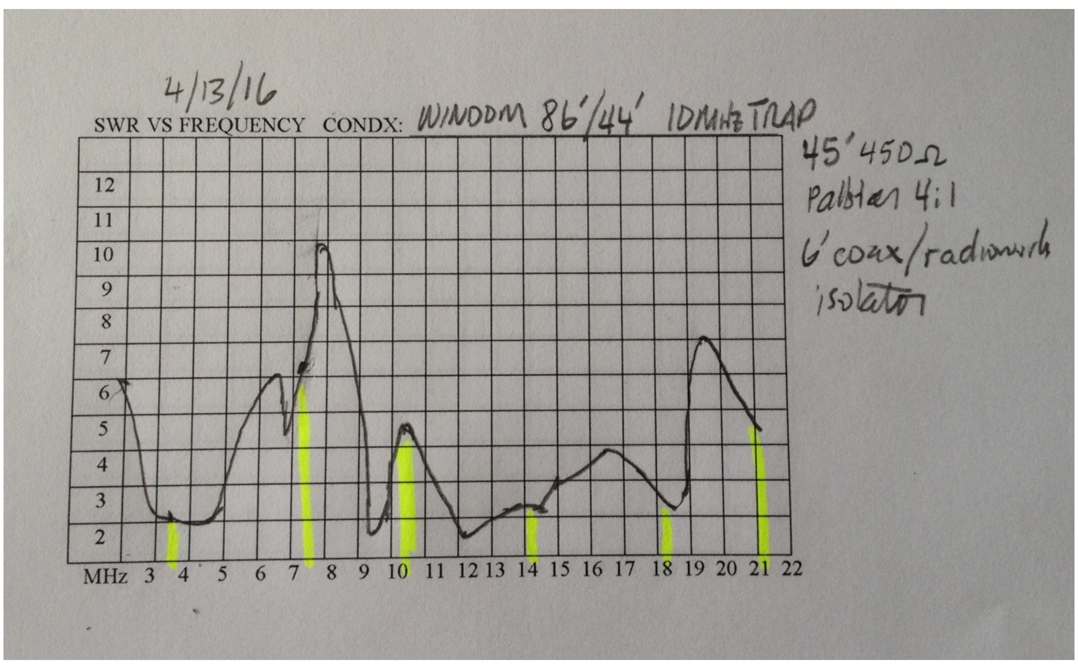
6 Test of tower mounted antenna proposal for Alachua County, June 22, 2016, Gordon L. Gibby. Included as APPENDIX THREE.

HORIZONTAL ANTENNA

GOAL: The horizontal antenna should cover amateur radio bands at 3.5 MHz, 7 MH, 10 MHz, and 14 Mhz—and potentially also the 18MHz, 21 MHz, 24 MHz and 28MHz bands. Useful for state-wide, regional and nationwide communications both day and night.

These frequency bands are harmonically related, which poses a problem for typical centerfed dipole antennas, because the feedpoint impedance rises dramatically from the fundamental frequency (half-wavelength, approximately 70 ohms) to the 2nd harmonic (full wavelength, thousands of ohms). Odd multiples of the fundamental frequency are relatively easily accommodated whereas even multiples pose a problem. There are several possible solutions to the harmonically-related frequencies matching problem, but I propose an off-center-fed single wire dipole of approximately 130 feet, fed 44 feet from one end. These type antennas are sometimes referred to as “Windom” style antennas. This design will make optimal usage of the Yaesu remote-mounted automated antenna tuner which is already owned by the EOC and interfaced with the EOC amateur band transceiver. Typically such automated tuners are able to handle SWRs up to approximately 10:1 This is not a perfect way to measure their performance, as a 10:1 SWR can be constructed of an infinite number of different impedances, but it conveys some level of performance.

I have previously used an antenna of this type for several weeks and have actual measurements of the SWR across a wide range of frequencies as shown in the following photo (using an optional 10 MHz trap to enable usage on the 10 MHz band):



Observed SWR results from a Windom antenna similar to the one proposed.


Homemade coaxial cable traps under test to determine their center frequency..

This antenna in my experience was very easy to match on multiple amateur radio bands using a commercial auto-tuner similar to the one owned by the Alachua County EOC.   However, a “trap” was necessary to make the 10 MHz amateur band tune easily.   That is a matter of preference and of secondary importance.   The addition of the trap adds a small degree of added complexity to the antenna (and thus increased storm vulnerability).   If the 10 MHz band is considered important, I will construct and donate one to the EOC. Below is a photo of a testing setup for two homemade traps (The Windom requires only one).

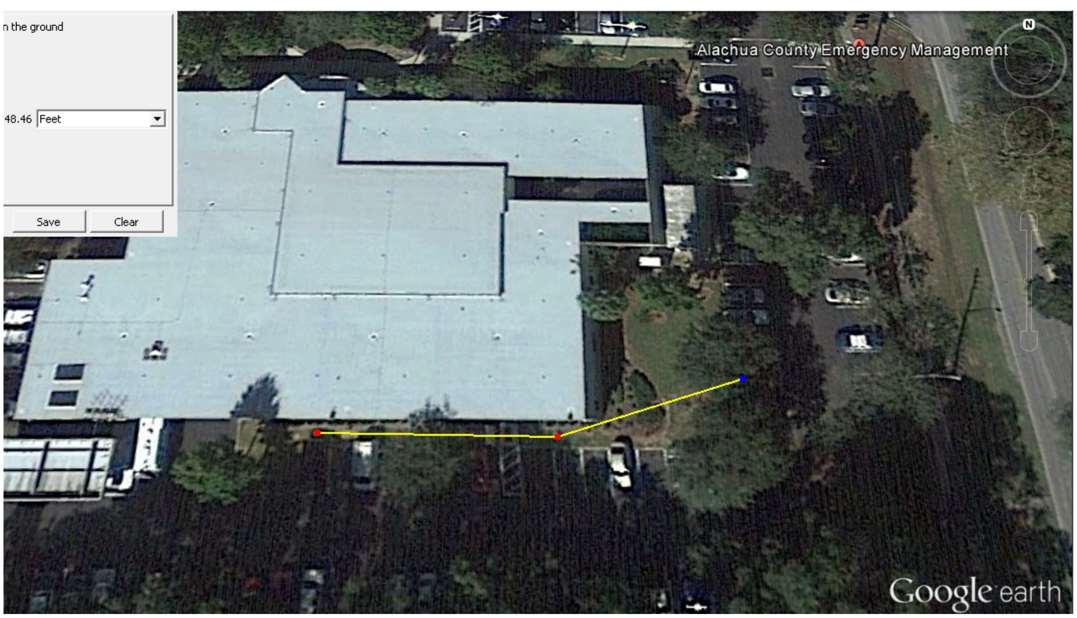
Starting from the transceiver, the components of this antenna system are:

> *Transceiver--> long 50 ohm transmission line operated at 1:1 SWR → building mounted auto antenna tuner → 20-40 foot 450-ohm ladder line → off center fed dipole*

LOCATION & CONSTRUCTION: This antenna can be mounted without significant tension requirements other than to prevent unsightly drooping, using three 25-foot reinforced concrete light poles located on the south and southeast edges of the EOC.   A photo below shows the general location.

Central light pole for horizontal antenna at the southeast corner of the EOC building.

The off-center feedpoint insulator of the antenna can be at or near the light pole at the southeast corner of the EOC building shown in the photograph.   A pole to hold the west end of the antenna is located approximately 84 feet west of that along the south border of the EOC building.   The east pole will have to be selected from three poles variously located beyond modest trees in the bend of the parking lot area southeast of the EOC building.   An approximate path of the antenna is shown as a yellow line in a Google Earth screen shot below:



Possible path of EOC Horizontal antenna

The 84-foot section of the off-center fed antenna should be installed at the (clear path) west end, allowing the feed point to be near the center light pole and simplifying transmission line support. The 44 foot remaining segment can be supported by light nylon rope from any of the remaining three lightpoles, passing through branches of trees. If the tree should be damaged by high winds and the nylon rope separates, the 44-foot section can actually be tied off to any remaining ground structure and the antenna will actually very likely continue to operate fairly well.

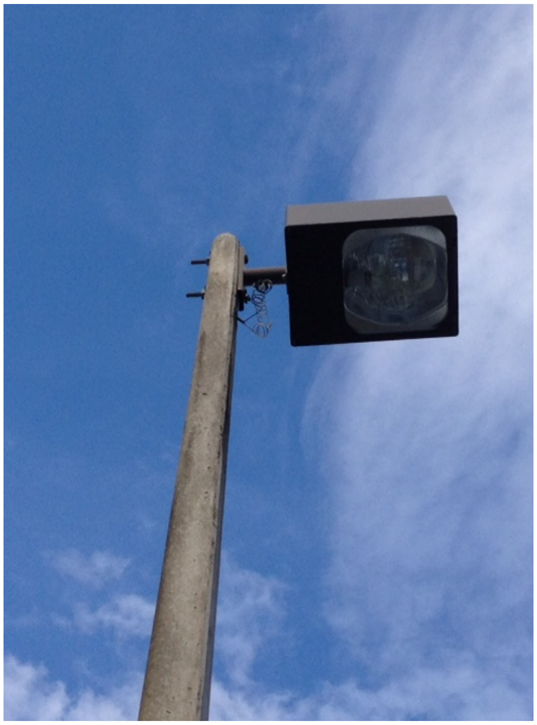
The most expensive part of constructing this antenna is the cost of transmission line and antenna tuner control line, by a considerable margin, depending on the path required to reach the antenna from the ham radio room. Since ceiling- and roof- installation of the transmission line and antenna tuner cable installation particulars will need to be chosen by EOC personnel, this report does not go into exactly how to route that cable. Within the radio room location, a PL-259 male connector should be crimped or soldered to the end of the cable, so that it can be connected to the Yaesu transceiver. Those techniques are likely very familiar to County personnel.

Construction Notes:

Antenna Wire: Should be construction from copper-clad stranded #14 AWG wire, soldered to transmission line and soldered at twisted loops at the ends.

End Insulators: Should be compression end insulators (http://www.amateurradiosupplies.com/product-p/10-72.htm); use a special strain relief insulator at the center (see materials list)

Pole Attachment: The poles include a long threaded bolt already in place to hold the light fixture (see photo). Using 2 washers and an addition nut, the antenna insulators can be supported with nylon rope as appropriate.



Threaded bolts extant on the EOC light poles.

Transmission line to antenna: Using a strain-relief mounting, 450-ohm ladder type 14-gauge ladder line should be connected at the off-center insulator, and routed with approximately 6 twists in the line, to the wall-mounted balun / antenna tuner. Provide a “drip loop” so water doesn't constantly run onto the balun.

Impedance transforming Balun: A 4:1 weatherproof balun should be mounted on the exterior wall of the EOC so that it can have very short connection to the YAESU automated antenna tuner..

Yaesu Antenna Tuner Mounting: Should be mounted on the exterior wall of the EOC so that it can connect to the BALUN (oriented with coax cable on lower side) . Located under the eave if possible. Coaxial cable and control cable entrances on the LOWER side. Drip loops on all cables connecting that would otherwise bring water to it.

Antenna Tuner to Balun Connection: The antenna tuner has an unbalanced output (signal + ground) in the form of an insulated post (center conductor) and case. The Balun has an unbalanced input (signal + ground) in the form of a coaxial SO-239 connector. In this case, a simple PL-259 with two insulated wires can screw into the balun, and connect by simple wires to the insulated post and case of the Yaesu Antenna Tuner. The Balun is simply a toroidial transformer that accomplishes a 4:1 impedance transformer over (presumably) a wide range of frequencies. It does not have a “fixed” input or output impedance. It's usage in this antenna system is simply to bring the impedance downward so a wide range of frequencies can be matched by the tuner. The choice of a 4:1 balun is a tradeoff compromise.

Coaxial Transmission Line from Tuner to Transceiver: RG8/U (alternate: LMR400, RG213 or any other similar performance fairly low loss 50 ohm coax) along with the shielded 6-conductor 24AWG (plus shield) cable (Belden 9536 or similar) should be run from the Yaesu Antenna Tuner, potentially via the roof, to a penetration point through the exterior wall of the building, and to the radio room location.   A "drip loop" should be utilized to avoid water running onto the Yaesu Antenna Tuner.   The coax connection should be on the downward side of the antenna tuner, and the insulated center post on the top side.

The key driver of the cost of this antenna is simply the distance the RG8 (or similar) coax and the shielded control cable for the Yaesu auto tuner need to traverse, to get from the radio room to the mounting point on the side of the building.

VERTICAL ANTENNA

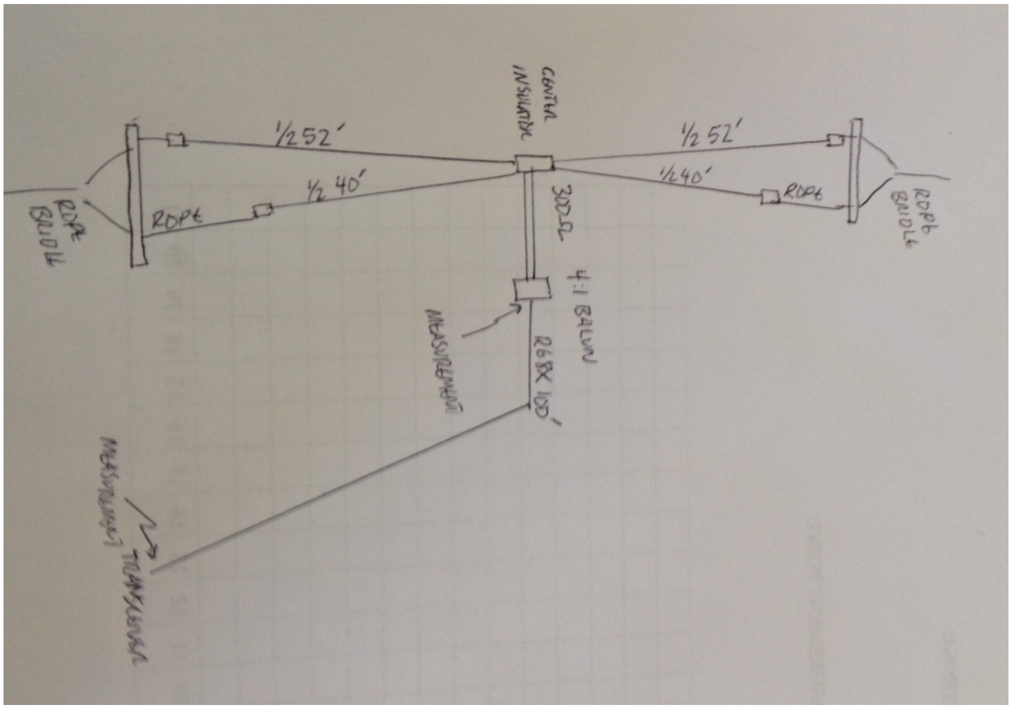
GOAL: Longer-distance daytime communications on the 10 MHz, 14MHz, 18MHz (and possibly 21 MHz bands) when the D-layer is making 3.5 and 7 MHz communications difficult. Act as a backup antenna for the primary horizontal antenna.

The current JVT-680 end-fed transformer-matched vertical antenna mounted on the fence of the antenna farm has extremely poor performance. I recommend that its valuable feedline be disconnected and instead used to feed the vertical dipole described below. The JVT-680 can be left in place without damage or risk. The dipole detailed below was designed to take advantage of the existing tall vertical tower and that existing coax feed line from the radio room. In order to achieve maximum bandwidth, a center-fed dipole system consisting to two dipoles was developed using a simulation package. (EZNec demo software.) Centerfed full half-wavelength dipoles avoid the considerable losses that are typical in the ground system or radial system of the more common ¼ wavelength vertical antennas.

A 52-foot dipole is constructed electrically in parallel with a 40-foot dipole. Their ends are separated using pressure treated 2x2 wood to provide 30 inch end-separation. In order to make it visually more appealing the top spacer (52 feet up the tower) will be sheathed in gray sunlight resistant electrical PVC conduit. This spacer will be made from a 5-foot section of 2x2 and can be cantilever supported from the tower using 3 U-bolts to clamp to the tower members.

The bottom separator can be just above ground level and provided modest tension (enough to keep the wires separated) using nylon rope to any suitable ground anchor. The antenna can be at any angle (not necessarily exact vertical) needed to accommodate the fenced antenna farm area.

Below is a diagram of the construction (shown horizontally).



Drawing of fan vertical antenna (shown horizontally)

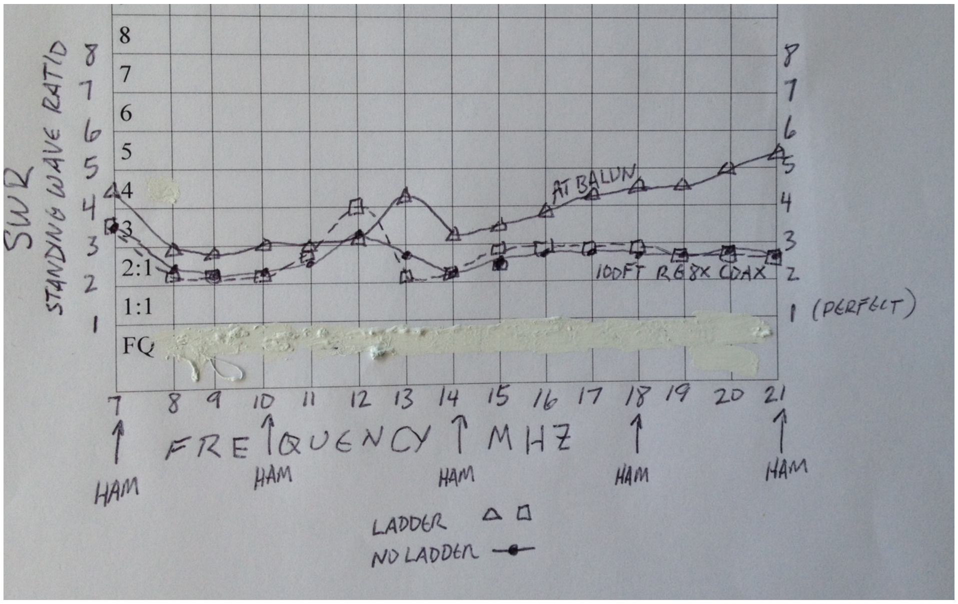
Starting from the transceiver, the components are:

> *Transceiver → manual antenna tuner → long coax to antenna farm → tower-mounted balun → short 300 ohm ladder line → center-fed 2-element fan dipole*.

A full size prototype of this antenna was constructed, mounted vertically from a tree limb, using a ladder as a simulation of a nearby tower, and tested for SWR response.

View of vertical fan dipole from below.

The results were much better than simulation had suggested:



Actual measurement results of vertical antenna prototype. SWR was measured at the end of 100 feet of RG8X coax, and additionally directly the end of the 4:1 balun. SWRs were quite manageable from 7 MHz to 21 MHz.

For this antenna construction, the 4:1 waterproof balun should be affixed to the tower near the center of the antenna, and connected to the antenna with 300-ohm ladder line. Existing coax cable should then be connected to the coaxial connector on the 4:1 balun and secured to the vertical tower.

This antenna will require a manual tuner in the radio room, but the low SWR across such a wide range of frequencies will result in quite manageable losses in the coaxial feed, and easy matching in the radio room. With vacuum tube transmitters, the antenna could be used without any matching network; the manual tuner will be required with solid state transmitters as these typically reduce their output power for any SWR higher than 2:1

SUGGESTED MATERIALS LIST

ANTENNA WIRE: Stranded copper clad steel #14 $0.19/foot, need 140 feet for horizontal, 100 feet for the vertical, suggest purchase 250 feet. https://thewireman.com/antennap.html #511 Estimate: $48 + shipping

RG8 or similar 50 ohm coax. Similar products are RG213, or LMR400. Typical price runs $0.35-0.80 per foot in quantity. Here is an example: https://www.amazon.com/RG8u-Spool-Coaxial-Cable-500Ft/dp/B00BJCDU6O/ref=sr_1_4?ie=UTF8&qid=1467041624&sr=8-4&keywords=RG8u
The county probably has a preferred provider. If necessary to squeeze through the wall, you can switch to a smaller diameter 50 ohm coax such as RG58/U for several feet without any significant problem. ***I don't know the exact length you are going to need for the run from the horizontal antenna auto tuner on the outside wall to the inside radio room, but I would guess 150-200 feet to reach the antenna room.*** For the vertical antenna, should check to see if the existing cable has 25 feet available to reach up the tower the required amount. Estimate @ 200 feet: $100

450 ohm ladder line for horizontal antenna: (need 44 feet or less)
http://www.amateurradiosupplies.com/product-p/30025.htm 50-foot length for $31

300 ohm ladder line for vertical antenna: You need such a small length that a donation will be made to the County of enough for the job.

4:1 Balun, waterproof, one for the horizontal and one for vertical antenna: example
http://www.gigaparts.com/Product-Lines/Baluns-Ununs/MFJ-913.html?gclid=Cj0KEQjwncO7BRC06snzrdSJyKEBEiQAsUaRjDmEzk9KAiNT9EINlsdb0Tp__qwt-JL3mj7C0EhVleIaAmDJ8P8HAQ $28 each. Total $56 + shipping

Antenna Tuner Control Cable: Belden 9536 or similar, $0.79/foot. (Ref: http://www.wireandcabletogo.com/Belden-9536-24-AWG-6-Conductor-Shielded-Computer-Cable.html?gclid=Cj0KEQjwncO7BRC06snzrdSJyKEBEiQAsUaRjB4SAe1trEiOj8W_LcP3CsJ-yreQMWYt_1wGFuKBsPYaAp-X8P8HAQ) Estimate at 200 feet: $158

End Insulators: (2 for horizontal, 4 for vertical antenna)
http://www.amateurradiosupplies.com/product-p/10-72.htm $4 each. Estimate $25

Ladder line strain-relief center insulator; one for horizontal and one for vertical antenna:
http://www.universal-radio.com/catalog/antsup/5461.html $13 ea.; toal $26

2x2 pressure treated wood encased in electrical pvc for top vertical antenna support: This will be fabricated and donated to the county.

2x2 pressure treated wood for the bottom vertical antenna support: this will be donated to the county.

Miscellaneous PL-259 and other connectors.

COSTS ESTIMATES (Both antennas together)

(Listed without shipping, heavily depends on transmission line run length to the horizontal antenna; estimates below are based on 200 feet transmission line length.):

Antenna wire	$48	includes both horizontal and vertical
Antenna end insulators	$24	includes both horizontal and vertical
Center strain relief insulators	$26	includes both horizontal and vertical
300 ohm transmission line (vertical)	gift	vertical antenna only
450 ohm transmission line (horizontal)	$31	horizontal antenna only
50 ohm large dia. Coax ransmission line	$100	horizontal antenna only—200 feet
6 conductor shielded wire to auto tuner	$158	horizontal antenna only—200 feet
4:1 baluns	$54	includes two, one for each antenna
Miscellaneous	$10	

TOTAL ESTIMATED COST: $451 + shipping (covers both antennas)

APPENDIX ONE: Ground Elevations

SHELTER NAME ADDRESS	GROUND ELEVATION MSL	ANTENNA ISSUE
1 Talbot Elementary 5701 NW 43 St, Gainesville	178 ft MSL	Good location for a simple repeater
2 Williams Elementary School 1245 SE 7 Ave, Gainesville	132 ft MSL	
3 Shell Elementary School 21633 SE 65th Ave Hawthorne	148 ft MSL	
4 Archer Community School 14533 SW 170 St, Archer, FL	88 ft MSL	
5 Eastside High School 1201 SE 43rd Street, Gainesville	125 ft MSL	
6 Kanapaha MiddleSchool 5005 SW 75th St, Gainesville	96 ft MSL	
7 Oakview Middle School 1203 SW 250 St, Newberry FL	84 ft MSL	Expect to require 50 foot tower, high gain antenna on top, low loss coax.
8 WaldoCommunity School 14450 NE 148 Pl, Waldo, FL	155 ft MSL	
9 High Springs Community Sch 1015 N Main St, High Springs	64 ft MSL	Expect to require 50 foot tower, high gain antenna on top, low loss coax
10 SantaFe High School 16216 NW US Hwy 441, Alachua	120 ft MSL	
11 Meadowbrook Elementary 11525 NW 39th Ave, Gainesville	130 ft MSL	Note that land rises to 182 ft MSL just immediately west – this school is on a HILL— hence not a good location for a repeater.
12 Gainesville Senior Center 5701 NW 34 St, Gainesville	185 ft MSL	Good location for a simple repeater
13 Newberry Archer Center 24880 NW 16 Ave, Newberry	84 ft MSL	Expect to require 50 foot tower, high gain antenna on top, low loss coax
14 Lawton Chiles Elementary 2525 School House Rd, Gainesville	75 ft MSL	Could be a problem. Likely to require further evaluation, probably a tower.
A Rawllings Elementary 3500 NW 15th ST Gainesville	150 ft MSL	

B Westwood MiddleSchool 3215 NW 15 Ave, Gainesville	110 ft MSL	
C Buchholz High School 5510 NW 27 Ave, Gainesville	175 ft MSL	Good location for a simple repeater.
D Alachua Elementary School 13800 NW 152nd Place Alachua	90 ft MSL	

APPENDIX TWO: EOC EXISTING ANTENNAS REPORT

Gordon L.Gibby BEE MS (E.E.) MD KX4Z
15216 NW 41st Avenue
Newberry, FL 32669
Cell: 352 246 6183

May 14, 2016

TO: Jeff Capehart W4UFL
Assistant Section Manager
Northern Florida ARRL Section
Dave Donnelly
Emergency Management Director
Alachua County, Florida
Steve Waterman K4CJX
President, Amateur Radio Safety Foundation, Inc.

RE: Antennas & Digital Modes For Emergency Communications, Alachua County Ham Radio EOC

Executive Summary

There are new and amazing digital radio techniques that both Federal (NCSHARES) and private (ham radio) high frequency as well as VHF participants can use to provide efficient backup-email and structured communications, even including structured ICS Forms. The ham radio communications facilities at the Alachua County EOC are primed and ready to be able to use those techniques under either Ham or Federal systems---except for a ***major, glaring deficiency***.

Individualized connection cables are now in place for the HF (Yaesu Series 600) and two VHF transceivers (ICOM and Yaesu). The County has provided capable radios with plenty of power to reach throughout the County, throughout Florida and even nationwide. An inexpensive digital connection Signalink device is on order to enable these new digital forms of communication, and will arrive soon. Free and versatile software can easily be installed; free high frequency email accounts can easily be created with a tested and proven system. If NCSHARES[1] licenses are obtained, trained personnel in addition to volunteer ham radio operators can be obtained easily.

The one remaining deficiency that will make all the above of little value, is that the antenna situation is so poor that almost zero communications are ever likely to occur on HF frequencies, and if repeaters go down, the same will be true of the ham radio VHF frequencies. When they are really needed, those radios are almost certainly going to be useless. Multiple inexpensive fixes to that problem are possible, and are outlined below. Government NCSHARES frequencies and digital communications are available for the asking, but will do no good at all, given the current antennas.

INTRODUCTION

Thanks to the generous donation of Jeff Capehart's Saturday afternoon, I was able to spend four hours working to give the Alachua County EOC ham station full digital capabilities. My background in electronics is that before I changed careers into Medicine (becoming a practicing physician in Anesthesiology as an Associate Professor at the University of Florida, involved in liver transplantation as well as the general practice of Anesthesiology), I was an Electrical Engineer and a ham radio operator since the days of vacuum tubes. More information about my background is in an endnote.[2] I also operate a volunteer free digital email server station in Jonesville, based on the WINLINK system. I wanted to put together all the connections needed for the equipment at the EOC to be able to transact any type of digital communication, whether direct (simplex) or via email-repeater stations (WINLINK), and also on either amateur radio FCC frequencies, or on Federal (NCSHARES) frequencies. And I wanted to evaluate the effectiveness of the equipment there at the EOC by performing routine connections to my own station and to others throughout Florida and the Southeastern United States. I have previously run a similar evaluation of the backup ham radio communications possibilities at the local Red Cross. Both these facilities are very accustomed to using local repeater stations, including one that is connected to the Florida SARNET[3]. However, those repeaters could easily go down in a true emergency, and even the SARNET appears vulnerable to being severed and split into noncommunicating portions at some of its point-to-point microwave links.[4]

RESULTS

We had success at connecting up the equipment. We soldered together individual unique cables so that three different radios – the YAESU System 600 HF transceiver, the ICOM IC-228 VHF transceiver, and the YAESU FT-2500M VHF transceiver – could all independently connect to one of the most popular inexpensive interconnections devices on the market – the Signalink-USB ($115)[5]. We verified with a laptop computer (since the relevant software is not yet installed at the EOC) that each radio could now perform both digital reception and transmission in a variety of formats. Free software such as FLDIGI[6] includes 19 major formats and a couple dozen sub-format.

We also verified that the system would work with WINLINK RMS EXPRESS software. Briefly, this is a radio-based world-wide system[7] of digital email (and attachment) communications that is used both by ham radio operators on land and sea on a daily basis (passing over 50,000 messages monthly), performed admirably during Hurricane Katrina, and is used by many stations in the Federal NCSHARES system including the State of Florida EOC (call sign NCS358). Robert Little of the State EOC has an email server station in Tallahassee is rolling out another such station at the Logistics Center in Orlando for emergency backup communications in the event of disaster. I am putting together what should be the third state-wide NCSHARES WINLINK email server at my house, to complement the ham radio WINLINK server that I already operate there (KX4Z). My station provided over 2 Mbyte worth of radio-delivered information in the last 21 days, and I am by no means one of the major stations.

The following illustration shows some of the world-wide WINLINK privately provided (volunteer) email servers. The Federal government and state governments operate many additional NCSHARES email servers with virtually the same systems and software, just on different frequencies. These system would still provide communications if the entire telecommunications system and Internet of the United States were to disappear (e.g., from cyberattack). Some of the WINLINK stations are likely

EMP-hardened and would continue to provide some level of RF forwarding and message pickup service even in the even of an EMP strike[8]

When we reached the point of actually testing the communications effectiveness of the station equipment, we began to be greatly disappointed:

VHF:
One radio, the ICOM 225M, was just able to make a connection with a 2-meter RMS email server operating temporarily at my house. However, we were unable to transact a complete email message due to signal dropout. The other VHF radio was unable to make any connection at all.
.
VHF Comparison results:

1. The Red Cross can easily make direct connection to that 2 meter RMS email server; even with 5 watts of power and an antenna balanced on my knee sitting in a truck in their parking lot, I could make contact easily.

2. My experience from the Jonesville location is that I am able to receive very adequate signals (estimate, 10 dB+ above the noise floor) from Windsor, as well as High Springs. The Windsor location that gets completely adequate signals from my station is 33% farther away than the Alachua County EOC, but has an antenna at roughly 90 feet AGL.

High Frequency (HF):
We attempted to make HF communications with the following automated stations:

KX4Z (my station) 15 miles, 7104 kHz.
N0IA (Orlando), 7104 kHz and 14074.9 kHz
AJ4GU (McDonough, GA, roughly 300 miles) 7089.5 kHZ

We were ***unsuccessful at every connection we attempted***. Once, I thought I audibly heard a response from my 7104 kHz station 15 miles away, but the computer did not hear it.

We heard almost no other stations on any band. There were only three or four that we could hear when surveying bands that are normally quite busy during the daytime (40 and 20 meters). This is extremely concerning. Although we could get digital copy on some weak digital stations, we could not get solid copy on any.

HF Comparison results:

1. As soon as I got home, I directed my home station – same power (100 watts output) as your station – to contact AJ4GU and immediately made contact and downloaded two messages waiting for me. His signal was at least 2 “S” units above the background atmospheric noise, suggesting roughly a 10 dB+ S/N ratio.

2. There were so many stations audible that I could not attempt contact with N0IA because the channel was busy with other stations – which I simply could not hear at the Alachua County EOC. As I went up and down the frequencies of the 40 meter band, there were dozens and

dozens of plainly audible signals.

3. Local friends and I have considerable experience with communications in and around Gainesville, Florida on HF frequencies. 40 meters (7000 kHz frequencies) is reliably great for communications from High Springs to Windsor, using NVIS propagation. Signals from the Oaks Mall area and High Springs are blastingly strong at my Jonesville station normally.

4. As I write this, I can hear station after station coming through on my automated email server as it flips through the frequencies and is occasionally accessed by users. My station has handled email from stations as far away as 5,000 km.

DISCUSSION

Clearly the antennas at the Alachua County EOC ham radio installation are not performing. The high frequency (HF) station there is **simply not hearing the vast majority of signals that are easily picked up by my home station using a simple dipole antenna hung in an elm tree**. The EOC station is unable even to reach my home station, and is unable to reach a powerful nearby Florida station (N0IA, 200 watts), nor a very useful Georgia Station just south of Atlanta. In a disaster situation, that transceiver – whether on ham or Federal frequencies, will be nearly worthless. The VHF station at the Alachua County EOC ham station is able to communicate using very well placed repeaters....and simply not able to provide effective direct (simplex) communications, and evidenced by its inability to key my 2 meter email server, 15 miles away. It radius of communications without the repeater is probably in the 5 mile range. By comparison, a friend of mine with a well placed but very simple no-gain omnidirectional antenna reaches out to at least 67 miles on 2 meters—direct, without a repeater! My signal –despite my home being behind some hills – is easily able to make it to the Red Cross, High Springs, and Windsor.

I investigated to see what might be the cause of the severe antenna failures and what might be the solutions. Here is what I found:

LIKELY CAUSES OF THE PROBLEMS

1. On VHF, the installed antennas are mounted relatively low, with bases at the top of fencework, and are quite effectively shielded by the sheer mass of the excellent tower that the EOC has for communications. They will be at a severe disadvantage attempting to reach towards Gainesville proper, as the tower is right in the way.

2. On HF, the situation is more complex.

◦ An excellent automated wide-ranging antenna matching component from YAESU is functioning apparently normally, but is located within the ham radio communications room. That means that its potentially high-impedance output is mismatched and connected to a 50 ohm coax cable. Not only is this a risk for arcing and possible damage to the matcher or radio, but it is damaging your signal and received signals. On 14 MHz, you could easily have a 10:1 SWR with the antenna employed, and even with extremely high quality LMR-400 at peak performance, only 65 of your 100 watt output would reach your antenna. The voltage on your coax could reach 700 volts RMS under those conditions, which thankfully is below the arc-over limit of LMR400 in good condition.

◦ Worse, the antenna selected is a JTV680 all band vertical[9]. This antenna consists of a vertical element of approximately 24 feet, believed to be connected to a stepup transformer (in an attempt to match the impedance) with ***no radials or ground plane***.[10]

Using EZNEC 6.0 Demo, the following feed point impedances can be found for the 24 foot vertical element:

FREQUENCY	REAL PART OF IMPEDANCE	REACTIVE PART IMPEDANCE	SWR versus 50 ohms
3..5MHz (80 Meters)	6.66	-j1576 ohms	>100
7 MHz (40 Meters)	29.23	-j483.1	>100
14 MHz (20 Meters)	212	J664	46

◦ *These are horrible impedances and SWRs* for the transformer that is thought to be built into the base of the antenna to attempt to match. The losses are probably exceedingly high – on both receive and transmit. This may be why the manufacturer limits this antenna to only 250 watts of power. I've run home made dipoles at much higher levels than that as a teenager!

◦ *Yet it gets worse*. A vertical dipole of this sort is missing the complementary "bottom" portion of the standard antenna, and typically must have multiple radials[12] or an excellent and very low resistance ground connection for good performance. This antenna does not have that, so it must use unbalanced currents on the outside of the coax to make up for it. Indeed, my laptop computer was reset multiple times by RF interference when we attempted to operate this antenna on 14 MHz (20 meters) despite ferrite chokes placed liberally on all possible signal lines.

◦ *And worse*. A vertical antenna does not do well for in-state communications because instead of having high-angle radiation (nearly vertical) which is useful to reach needed communications partners at the State capital or in nearby states – a vertical has extremely low angle radiation. That is exactly why it is the favorite of direct line of sight 2-meter transceivers. But this antenna is right beside a huge vertical absorber – the tower – which may well both sheild and ABSORB huge chunks of power from this antenna.

It is difficult to imagine just how much the performance of this HF station is harmed by its unfortunate antenna situation. With such a capable automated antenna matcher already in your possession, in a real emergency, you would be well advised to take a 60 foot stretch of #14 stranded household wire, completely disconnect the JVT680 vertical, connect the #14 stranded wire to the center conductor of the PL-259 coming from the ham radio center, and use a rock to toss the far end out over a nearby tree so that the antenna approximates a nice NVIS sloping horizontal long wire at about 15-30 feet above ground level. You are likely to have far, far better communications with stations in Florida and the Southeast.

SUGGESTIONS:

1. Inexpensive VHF vertical dipoles, J-poles, or SLIM JIMS placed 25-30 feet up your tower, and on the NORTHWEST side would give you far far better coverage of much of your county. Putting the 2nd VHF antenna on the opposite side of the tower might allow you to have easy direct communications even in the event of repeater failure, to mobile or portable stations throughout your entire county.

2. The HF antenna situation is so incredibly dire that there are a host of solutions that would be improvements. The first would be to do as suggested above, and ditch the JVT680 and replace it with a simple 60-100 foot end-fed sloping "long" wire (well above vehicle height), connected to a rope coming from some tree limb.[13]

3. There are many other solutions to the HF problem **I believe the absolute best would be to hang a simple dipole antenna of 65-130 foot length between and amongst the trees on the southern edge of your property, up perhaps 25-35 feet.** A slingshot and an hour's work and this would be done for less than $10 worth of wire. Because you are likely to want to use NCSHARES, you will want your antenna to function on many, many frequencies, so the only length requirement is that it be an appreciable fraction of a half wavelength at the lowest desired frequency. You could easily position a 4:1 balun[14] at the center point of the dipole and feed it with coax that would go over the carport protecting your communications vehicle/trailer. More optimally, you would instead feed it with inexpensive low-loss "ladder" line and position your very useful YAESU automated antenna matcher on the outer exterior wall of your premises (even protected by the carport!) giving an extremely efficient antenna that will radiate virtually ALL of your power effectively.[15] **Such an antenna will optimally reach Florida and nearby states.**

4. A third solution to your HF antenna issue would be to create a modest inverted V antenna, hung from about 25 feet up your tower with a simple insulating standoff, with the unstressed ends in a straight line reaching to the farthest possible points of your antenna area fencing. Such an antenna is still going to be a compromise, but with the quality automated matcher that you possess, it is likely to function moderately well on 10 MHz and above, and may perform reasonably well to Florida and nearby states.

5. A fourth solution to your HF antenna issue would be to position a full vertical dipole on standoffs running up one side of your tower, approximately 50 feet. The transmission line should be positioned through the tower and run downwards the other side of the tower. For the sake of reaching my station as well as Tallahassee, I suggest you position the vertical along the north west side of the tower, offset by perhaps 4 feet. This antenna could be under relatively little tension and present negligible wind loading. If constructed of copperweld wire, it should last decades. (A copperweld antenna I built in high school lasted until my father sold the house.) The tower will interact with the antenna, most strongly where your tower is a ¼ wavelength; it will act either as a director or reflector (sort of a 2-element vertical beam); and this interaction can be adjusted if need be.[16] As the radiation from a vertical antenna is very low-angle, this type antenna will not be optimal for Florida or nearby states, but will likely

perform well at both near and very far distances. I would expect it to reach my station and to be heard well on the West Coast, for example. Since the NCSHARES system includes stations all over the US, as does the WINLINK system, this may be an acceptable outcome.

In conclusion, I would like to thank you and Jeff Capehart for allowing me to try and improve the readiness of your emergency communications backup techniques, and I hope that my ideas will be of benefit to you and your mission. I'd be happy to assist with any of them.

Sincerely,

Gordon L. Gibby MD KX4Z

REFERENCES:

1 Department of Homeland Security, Shared Resources High Frequency Radio Program. https://www.dhs.gov/shares

2 My first ham radio license came in high school, where I built several HF (high frequency) transceivers, and designed and built a 750 watt HF amplifier. I completed a Bachelor's degree in Electrical Engineering at the Georgia Institute of Technology, working as a Co-op student with the C.I.A. With a National Science Foundation Fellowship, I completed a Master's Degree in Electrical Engineering at the University of Illinois (Urbana-Champaign) but then entered Emory University to complete an MD. After residency in Anesthesiology at the University of Florida, I stayed here to work in the Operating Rooms of Shands Hospital as a faculty anesthesiologist. I've been involved in HF ham radio for over 45 years, and recently developed an interest in VHF as well. In my lifetime, I have built or assisted in the building of literally dozens of antennas.

3 http://www.sarnetfl.com/

4 http://www.sarnetfl.com/yahoo_site_admin/assets/docs/160514_FDOT_UWAVE_Map_with_UHF_coverage.13462123.pdf The system has redundancy over most, but not all of its point to point links, notably the northwest chain including the State EOC. Even in the region with redundancy, a 2 point failure might down the system.

5 http://www.tigertronics.com/

6 http://www.w1hkj.com/

7 http://www.winlink.org/

8 http://www.arrl.org/files/file/Technology/tis/info/pdf/98622.pdf In a four-part series written by the Acting Assistant Manager of the Office of Technology and Standards, national Communications System (US), in 1986, multiple systems were successfully tested for EMP resistance and easy to implement protection strategies were explained. Subsequent tests have confirmed that many electronic systems can survive even EMP.

9 http://www.jetstream-usa.biz/product_info.php?products_id=68501

10 http://www.antennasbyn6lf.com/files/radial_system_design_and_efficiency_in_hf_verticals.pdf Very high losses are to be expected without significant radials in an HF vertical antenna even if it is properly designed.

11 EZNEC Antenna Software by W7EL. Finite element analysis of antenna performance. https://www.eznec.com/demoinfo.htm

12 http://www.antennasbyn6lf.com/files/radial_system_design_and_efficiency_in_hf_verticals.pdf

13 http://www.icom.co.jp/world/support/download/manual/pdf/AH-4_Eng_2.pdf Such a random “long wire” is exactly the suggested antenna for a similar product from ICOM. A good ground connection might be obtained by connecting to the tower/fence or other connections.

14 http://www.mfjenterprises.com/Product.php?productid=MFJ-913

15 http://www.w0ipl.net/ECom/NVIS/nvis.htm Good practical information on real antenna performance

16 http://rudys.typepad.com/files/tower-coupling-study.pdf Real study of interaction between vertical antennas and

APPENDIX THREE:
Real-Life Propagation Study To Evaluate Proposed Antenna Installations at Alachua County EOC and Red Cross

Gordon L. Gibby MD KX4Z

May 23, 2016

Version 1.1 Corrected misspellings & added explanation about limitation of transceiver

Executive Summary

Testing designed to simulate possible antenna performance at both the Alachua County Red Cross and Alachua County EOC was carried out on Saturday, May 21, 2016, for a total of >6 hours, from morning until past noon, and from dusk to well past dark, in an attempt to capture most of the important phases of sun-induced ionospheric propagation changes, while actually attempting to make contact with WINLINK automated email servers (RMS stations).

This study provided realistic examples of the likelihood of successful high frequency (HF) email transition throughout the 24-hour day. It is applicable both to amateur radio and NCSHARES frequencies.

The results demonstrated that twenty to 25-foot high horizontal dipole, loop, or inverted-v antennas are likely to be very successful for email communications via the WINLINK system except during the mid-day period, when excessive D-layer absorption of signals appears to require the higher frequency bands (>= 10 MHz) and higher positioned antennas (e.g. 40-60 feet elevation) with lower angles of radiation in order to reach potential email servers. To cover the heat of the day, the EOC might wish to position a shorter antenna (designed for 10-18 MHz) more than 30 feet up its tower

Factors that increase the probability of rapid connection success included: having easy electronic ability to shift frequencies instantly to quickly move from potential recipient to potential recipient; having multiple bands available to best meet changing ionospheric conditions; and having multiple modem technologies (WINMOR + PACTOR) to allow using the greatest possible number of stations.

INTRODUCTION

After the Katrina disaster, more people recognized that traditional communications systems (towers, repeaters, trunking repeaters) can be literally wiped out by catastrophic weather, cyber warfare, extended power loss, or EMP. Stand-alone high frequency (HF) transceiver stations can still function. Wire-based simple HF antennas are easy to reconstitute with hand tools, slingshots, and rope, if they have sustained damage, and do not require careful aiming. Equipment and software have matured. HF is quite different from reliable point-to-point VHF communications, because of the vagaries of the ionosphere. However, solutions to the variability have been found. The WINLINK email-over-ham radio system that has been in use over two decades providing HF email and marine weather reports to ships at sea, has been recognized by many as a useful backup communications system that offers digital written (instead of spoken) email; the ability to pass attachment files; a large number of widely dispersed server stations, and provisions to operate successfully even in the total absence of the Internet.[i] Although throughput is modest, due to the limitation of static, limited bandwidth, and interference on HF bands, hospitals and EOCs are increasingly using WINLINK as a valuable backup communications tool.

In a typical month, over 50,000 emails will be transacted over the WINLINK email system.

There are a finite number of HF WINLINK email server stations (known as RMS; radio message servers) as shown in the accompanying map. The author operates KX4Z, a 100-watt PUBLIC WINLINK RMS email server, on the 80, 40, 30, 20 and 17 meter bands, using PACTOR and WINMOR protocols, with automated solar backup power, and potential generator backup power, using an inverted V antenna at approximately 50 feet. Temporarily (possibly permanently) the service also includes access on two meters (146.49 MHz). However, the station is in a valley, located at about 100 foot MSL (based on Google Earth data) west of I-75, making VHF access more problematic. It is hoped that soon, a separate NCSHARES server will also be operating at this location.

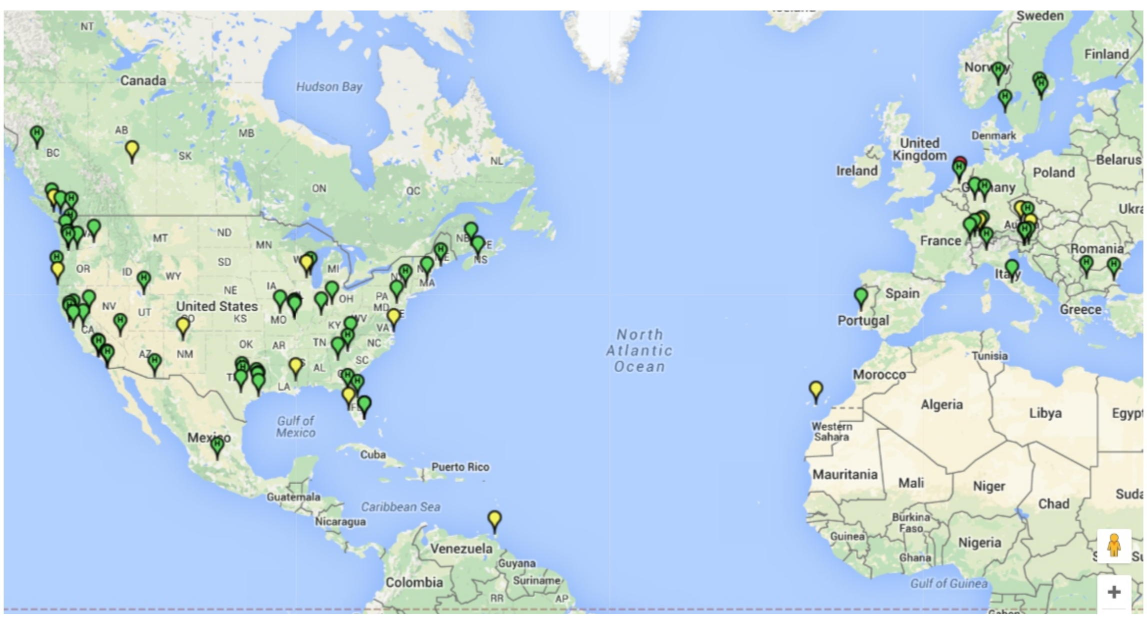


Illustration 1: Real-time map of WINLINK public stations on May 22 2016

On U.S.Federal frequencies, there is a comparable, but significantly more sparse, array of U.S. WINLINK stations available for members of the NCSHARES system to exchange email over radio. These stations enjoy clearer frequencies, which is a significant advantage, compared to the PUBLIC ham radio frequencies which may (particularly on the 7 MHz 40 meter band) have interference from voice communications, CW and other communications.

WINLINK can also be applied to VHF, with more reliability (once the point-to-point requirements are surmounted) and even faster throughput using higher speed modems. However, even the slower speed HF modems can be successfully utilized on VHF WINLINK.

The purpose of this study was to obtain real live experimental data on actual propagation, throughout significant portions of the day, using antennas similar to possible antennas for local emergency service agencies, to buttress the predictions from antenna theory and personal experience.

PROPAGATION BACKGROUND

VHF signals are generally line-of-sight signals, with moderate refractive effects that extend the radio horizon" slightly. Exceptions include refraction by temperature inversion, tropospheric ducting, and sporadic intense E-layer ionization – but Emergency Communications providers cannot depend on these effects. For VHF communications, the link budget deficiency is solved by adequate height of antennas, adequate power, and if necessary, repeaters.

HF signals are anything BUT line-of-sight. While the very lowest frequencies do have some ground wave coverage (able to follow the curvature of the earth over obstructions for brief distances) , and line-of-sight is always a possibility, the major advantage of HF signals (usually 3-25 MHz) is their ability to be refracted by the charged ion cloud layers that reside scores to hundreds of miles above the Earth's surface, and return to Earth,depending on the situation, at any lateral distance from 0 to more than a thousand miles away. Multi-skip is also possible [ii]

Drawing of the Ionospheric ionized layers.[iii]

I remember the function and usefulness of the ionization layers with the following descriptive names:

Layer	Name / Function
D	Daytime Destroyer – main function is to obliterate radio waves, particularly lower frequency (longer wavelength) waves
E	Extraneous – not of any real importance most of the time to HF waves
F	Fantastic – It is the F layer (or sublayer of it) that does most of the long distance skip refraction

The Daytime Destroyer D layer is made of ionized nitric oxide NO molecules (among others) brought about by intense ultraviolet and X-ray radiation from the sun. It disappears at night, builds up in the morning and wanes as the sun's rays become less direct.

The Fantastic F layer is made of ionized oxygen atoms created by intense ultra short ultraviolet radiation from the Sun. Thankfully, it retains some ionization to cause refraction throughout the night. Lower frequency waves are more easily refracted sufficiently so that the geometry allows return to the Earth. Lower amounts of refraction are more easily achieved than 180 degree return, and hence can be accomplished for higher frequencies of radio waves. Above a certain frequency (MUF; maximum usable frequency) radio waves of higher frequency cannot be bent to achieve any return to the earth at all. This MUF (maximum usable frequency) varies during the 24-hours, during the year, and during the 11-year sunspot cycle, and from cycle to cycle. The maximum frequency that can be refracted 180 degrees – and hence return to earth to allow communications at very nearby distances of only a few miles – is known as the Critical Frequency (CF) and is commonly measured every 15 minutes by a number of radio-ionosonde stations scattered around the globe, whose results are immediately available over the Internet. Our nearest such station is at Eglin Air Force Base.

We are currently in the middle of a sunspot cycle, with neither the lowest nor the highest amount of ionization. Critical frequencies are typically above the 3.5-4.0 MHz (80 meter) ham band during the night, and reach above the 7 MHz (40 meter) ham band during the day, meaning that contact with even very close RMS servers (such as mine) is theoretically possible 24 hours a day, were it not for the D layer. Maximum usable frequencies are well into double digits during the daytime, allowing higher frequency bands (with less D-layer destruction) to be utilized to reach RMS servers hundreds to thousands of miles away.

ANTENNA BACKGROUND

For the purposes of digital HF email, most stations would do well with a horizontal dipole (generating horizontally polarized waves) although a vertical antenna can be used, because the ionosphere alters the polarization anyway.

There is an interaction between the ground and the antenna, such that the energy radiated downward by a horizontal antenna, striking the ground, is reflected back upwards, and then, depending on geometry, either adds or subtracts to the strength of the final radiated wave depending on the elevation angle from the antenna. For our purposes, it is sufficient to know that an antenna that is within 0.2 wavelengths of the ground will send relatively more of its energy fairly straight up, and is therefore more useful for contacting stations within a couple hundred miles. This mode is known as NVIS (near-vertical incidence skywave). An antenna that is considerably higher than this sends less and less of its energy nearly straight up, and more and more of its energy out at angles closer to the ground, and thus geometrically sends more energy that can reach a more distant station on one jump through the ionosphere.

METHOD

Beginning relatively early in the morning (setup began at approximately 0700) a temporary amateur radio communications station was set up in the cab of a Chevrolet Silverado pickup truck, using a “dropbox” of communications gear.

- Using a slingshot and braided fishing line, after two tries, a 3/8” synthetic rope was positioned over a branch of a pine tree, estimated at > 60 feet height.
- A 2-meter homemade SLIM JIM type vertical antenna was positioned directly above the center insulator of a random 100-foot dipole antenna in the inverted V configuration (common lamp cord #18 AWG gauge wire)
- This was hoisted to various heights, with markings on the 2-meter coax transmission line being used to measure the height.
- The inverted V random length antenna was fed with 60 feet of commercially available, flexible 450-ohm 18-gauge ladder line.[iv]
- An ICOM AH-4 automated antenna tuner provided correction to 50 ohms Although intended for unbalanced end-fed long wires fed against ground, this antenna tuner is known to *successfully feed balanced high impedance lines.
- An MFJ-2912 RF Isolator[v] was positioned on the HF coax feed line near the SWR meter, and ICOM 728 100-watt SSB/CW frequency-controllable transceiver.
- For 2-meter tests, a YAESU FT-2900 (75 watts output maximum) was utilized.
- Signals were generated using RMS EXPRESS free client software, and modulation provided either by a Tigertronics Signalink interface, or an SCS PTC-IIe P3 PACTOR modem.

All equipment was operated off 12-13.8 VDC from the cigarette lighter of the pickup truck. A LENOVO G50 Windows 10-based portable computer was utilized.

The ICOM 728 transceiver used for this test is old and used, and cannot transmit on the 18 MHz ham band, so this band (which is used by many boaters accessing KX4Z) could not be tested.

Illustration 2: 20 Foot Antenna (Center height)

*Illustrat ion 3: 50 foot antenna*

RESULTS

Stations Contacted	Location	Approximate Distance
KX4Z	Jonesville, west of Gainesville	25 miles
N0IA	Deltona FL	95 miles
KI4WPI	Parkland FL	270 miles
AJ4GU	McDonough, GA	275 miles
KQ4ET	Virginia Beach, VA	625 miles
KB8UVN	Johnstown, OH	723 miles
KC0TPS	St. Louis, MO	755 miles

Several stations were used more than once – reliable stations are very helpful.

It is important to realize that when a communications attempt to a WINLINK RMS is unsuccessful, there are more possible explanations than just "propagation failure." These stations are privately maintained, volunteer stations using generally home-crafted antennas and sometimes older equipment. Each station usually cycles continuously among multiple frequencies (e.g., KX4Z cycles through five frequency bands), spending a few seconds listening on each band before moving to the next one. Therefore causes of failure include:

- station equipment failure—sudden or chronic
- software failure
- station occupied on another band actually passing data to a client
- unlucky timing so that station never heard request (less common)
- propagation failure

The tables below attempt to summarize hours of connection attempts. As much relevant information on antenna height, orientation, and mode attempted (PACTOR versus WINMOR) is presented as possible. Power output was generally very near 50 watts, but varies slightly between modes. In the first hours of these tests, equipment was re-adjusted often, until it was clear that signal levels were within the linear range of amplification. All times are Local Time to Gainesville, Florida, EDT.

Critical Frequency (CF) and Maximum Usable Frequency (MUF) data are from data gathered at the appropriate times at Eglin Air Force Base, in the Florida Panhandle.[vi]

TIME: 0830 Local time CF: 6.4 MHz MUF: 23 MHz
ANTENNA HEIGHT: 20 feet, HF favoring NW/SE (2 meter omnidirectional)

BAND:	80 meters (3.5-4 MHz)	40 meters (7-7.3 MHz)	30 Meters (10 MHz)	20 Meters (14-14.35 Mhz)	2 Meters 146.490
COMM RESULTS:	50% Strong signal from KX4Z	0% / 2 stations	0% / 2 stations	0% / 2 stations	Success at 30watts output

TIME: 0900 Local Time
ANTENNA HEIGHT: 40 feet, HF favoring NW/SE (2 meter omnidirectional)

BAND:	80 meters (3.5-4 MHz)	40 meters (7-7.3 MHz)	30 Meters (10 MHz)	20 Meters (14-14.35 Mhz)	2 Meters 146.490
COMM RESULTS:	0% / 3 stations	0%/3 sttations	50% /4 stations KC0TPS OK KB8UVN good signal		

Note: There were occasional equipment issues that hampered communications as I became more facile at tuning transmitters, in the cramped space of the truck front seat area.

TIME: 0945
ANTENNA HEIGHT: 40 feet, HF favoring NW/SE (2 meter omnidirectional)

BAND:	80 meters (3.5-4 MHz)	40 meters (7-7.3 MHz)	30 Meters (10 MHz)	20 Meters (14-14.35 Mhz)	2 Meters 146.490
COMM RESULTS:		0% / 2 stations	0% / 3 stations		Connect to KX4Z with 75 watts; fade. Failure at 20 foot antenna.

TIME: 1030 CF: 4.7 MHz MUF: 15.5 MHz
ANTENNA HEIGHT: 50 feet, HF favoring NW/SE (2 meter omnidirectional)

BAND:	80 meters (3.5-4 MHz)	40 meters (7-7.3 MHz)	30 Meters (10 MHz)	20 Meters (14-14.35 Mhz)	2 Meters 146.490
COMM RESULTS:	0% / 1 station	0%/2 stations	66% / 6 attempts		Unable to connect to KX4Z

			KQ4ET good signal 2 connects; email sent KB8UVN good signal, Pactor, 2 connects; email sent		

TIME: 1130
ANTENNA HEIGHT: 20 feet, HF favoring NW/SE (2 meter omnidirectional)

BAND:	80 meters (3.5-4 MHz)	40 meters (7-7.3 MHz)	30 Meters (10 MHz)	20 Meters (14-14.35 Mhz)	2 Meters 146.490
COMM RESULTS:		0% / 1 station	20% / 5 attempts WB8UVN, success at 50 watts, WINMOR	0%/4 attempts	

TIME: 1130
ANTENNA HEIGHT: 20 feet, HF favoring N/S 2 meter omnidirectional)

BAND:	80 meters (3.5-4 MHz)	40 meters (7-7.3 MHz)	30 Meters (10 MHz)	20 Meters (14-14.35 Mhz)	2 Meters 146.490
COMM RESULTS:		Significant interference. 0%/1 attempt	0%/2 attempts	0%/1 attempt	

TIME: 1230 (approximate) CF: 6 MHz MUF: 17.9 MHz
ANTENNA HEIGHT: 50 feet, HF favoring N/S (2 meter omnidirectional)

BAND:	80 meters (3.5-4 MHz)	40 meters (7-7.3 MHz)	30 Meters (10 MHz)	20 Meters (14-14.35 Mhz)	2 Meters 146.490
COMM RESULTS:		0% / 8 atttempts	50% / 8 attempts Connect to KQ4ET, KB8UVN, KQ4ET, KQ4ET	0% / 1 attempt	

EVENING

TIME: 2010 CF: 6.4 MHz MUF: 20 MHz
ANTENNA HEIGHT: 25 feet, HF favoring N/S (2 meter omnidirectional)

BAND:	80 meters (3.5-4 MHz)	40 meters (7-7.3 MHz)	30 Meters (10 MHz)	20 Meters (14-14.35 Mhz)	2 Meters 146.490
COMM RESULTS:	66% / 3 attempts KX4Z very strong N0IA very strong	66% / 3 attempts KQ4ET very strong Pactor KX4Z (7061.5) strong	100% / 2 attempts KQ4ET x 2, emails sent		Brief good signal (1 bar) on 75 watts.

TIME: 2100
ANTENNA HEIGHT: 25 feet, HF favoring N/S (2 meter omnidirectional)

BAND:	80 meters (3.5-4 MHz)	40 meters (7-7.3 MHz)	30 Meters (10 MHz)	20 Meters (14-14.35 Mhz)	2 Meters 146.490
COMM RESULTS:	100% 2 attempts KI4WI weak N0IA strong; 2 emails passed	0% / 1 attempt, significant interference	100% / 1 attempt KQ4ET strong, email sent		

TIME: 2200 CF: 6.1 MHz MUF: 19 Mzh
ANTENNA HEIGHT: 25 feet, HF favoring N/S (2 meter omnidirectional)

BAND:	80 meters (3.5-4 MHz)	40 meters (7-7.3 MHz)	30 Meters (10 MHz)	20 Meters (14-14.35 Mhz)	2 Meters 146.490
COMM RESULTS:	100% / 1 attempt N0IA winmor	25% / 4 attempts significant interference; AJ4GU very strong signal	50% / 2 attempts KB8UVN instant capture; very strong signal; email transfer KB8UVN good signal		

CONCLUSIONS

VHF:

2-meter communications were basically impossible from the test location back to my home (located in a valley) due to intervening terrain obstructions higher than the absolute altitude of the antennas used. However, unexpected refraction from some sort occurred during the earlier portion of the morning, and briefly around dusk.

GoogleEarth Elevations:
The ground at the testing site is at approximately 100 feet, and VHF antenna height of up to 50 feet tested, giving a total height of 150 feet above sea level. This height was **insufficient** to reach my 3rd floor beam antenna in Jonesville, with a house at approximately 100 foot ground level. By comparison, a colleague east of the EOC, with a ground level of approximately 120 feet and an antenna at approximately 90 feet (210 total above sea level) can reach directly to my third-floor beam as well as to an elevated residential antenna in High Springs. That station has reached >60 miles directly (simplex). With an EOC elevation of approximately 130 feet, a VHF antenna 80 feet up a tower would likely have a commanding reach throughout the county.

HF Communications can be summarized in this table:

Time Period	Successful Propagation
Cooler portion of morning daylight	With lesser D-layer absorption, able to reach close-in KX4Z, as well as other regional stations, on lower frequencies, even with low antenna.
Mid-day	With stronger D-layer absorption, successful communications options declined significantly in number, and only more distant stations (Virginia, Missouri) were possible, using 10 MHz; higher antenna required.
Evening into Nighttime	Many times larger pool of successful options compared to Mid-Day; successful contacts made at both local, regional and distant stations, using a 20-25 foot high antenna.
Night	Although not tested, experience suggests that the large number of stations will still be possible, with a decline in the performance of the 10MHz and higher bands in the hours just before sunrise.

The implications for backup Emergency Communications for Alachua County EOC and Red Cross are that physically longer antennas (100 foot range) at modest heights (20, 25 feet) will give considerable success on bands from 80 meters (3.5 MHz) through 30 meters (10 MHz) and beyond, in all parts of the day except the heat of the day. A prime finding of this study was that extreme antenna height is not a requirement for much of the 24 hours of the day/night. The lightpole-based antenna proposed for the EOC, and the Roof-Edge antenna model for the Red Cross are therefore likely to be very successful. (The electrical design of the specific antenna is outside the scope of this current paper.)

However, during the heat of the day with higher D-layer absorption, the lower frequencies become unworkable, and higher frequencies (30, 20, 17 meter bands) must be used to sustain communications, and with higher antennas that allow for lower angles of radiation that geometrically "reach" the desired station. The transceiver used for this test was incapable of operating on the 17 meter band; so additional opportunties for heat-of-the-day communications, less impacted by the D layer, could not be studied. This band is a favorite of high seas boaters, however. Thus, it would also be advisable for the EOC to place a physically smaller antenna made for these bands, higher up on their tower.

APPENDIX FOUR
TEST OF TOWER MOUNTED VERTICAL HF ANTENNA PROPOSAL FOR ALACHUA COUNTY EOC

GORDON L. GIBBY
June 22, 2016

INTRODUCTION

The goal of this study was to experimentally verify a proposed High Frequency (HF) antenna for mounting on the vertical antenna tower at the EOC. It is assumed that the EOC will have a long horizontal antenna with good NVIS (near vertical incidence skywave) coverage; the goal of an additional HF antenna mounted on the antenna tower is to provide redundancy and to give an improved long-distance antenna option that will perform better in the heat of the day on frequencies 10-21 MHz, where the NVIS horizontal antenna may not be optimal.

The following table helps explain which types of antennas are preferred for HF communications during various portions of the 24-hour day.

Communication Goal	**Best Antenna(s)**	**Comment**
Up to 1000 miles on lower frequencies at night	Horizontal antenna of > 120 feet mounted below 40 foot height	Goal is high angle of signal take off
Commmunication during heat of the day when absorptive D layer is strong	Horizontal antenna mounted as high as possible; Any high quality vertical antenna	Goal is low angle of signal takeoff

Prior to this study, five different vertical antenna designs were studied theoretically with a demonstrator version of antenna prediction software. The fourth of those five seemed the most promising. It consisted of two vertical dipoles connected together at the center, often called a “fan” dipole because of the way the wires fan out toward the ends, where they are held apart by an insulating separator. The design called for a 52 foot dipole connected at the center to a 40 foot dipole, both fed with a 6 foot section of 300 ohm balanced line cable to span the distance between the antenna (on standoffs away from the metal tower sections) and a tower-mounted BALUN (balanced-to-unbalanced RF transformer) providing a 4:1 impedance stepdown, and allowing coaxial cable to run from that position on the tower all the way to a matching network or transceiver within the EOC.

The goal of the design was to provide wide bandwidth and minimal standing wave ratio (SWR) so as to minimize losses in the coaxial cable, and to allow the EOC not only the option of amateur radio bands, but also the option to use many of the available SHARES (federal) frequencies, which are not published.

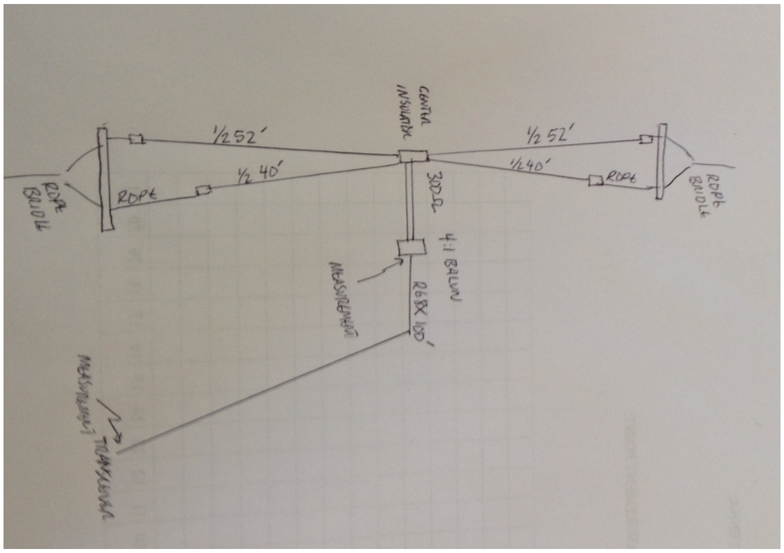


Figure 1. Drawing of the proposed antenna
(which would be installed vertically,not horizontally)

Theoretical SWR results for this antenna, measured right at the BALUN, on the 50 ohm side, were as shown in the following graph:

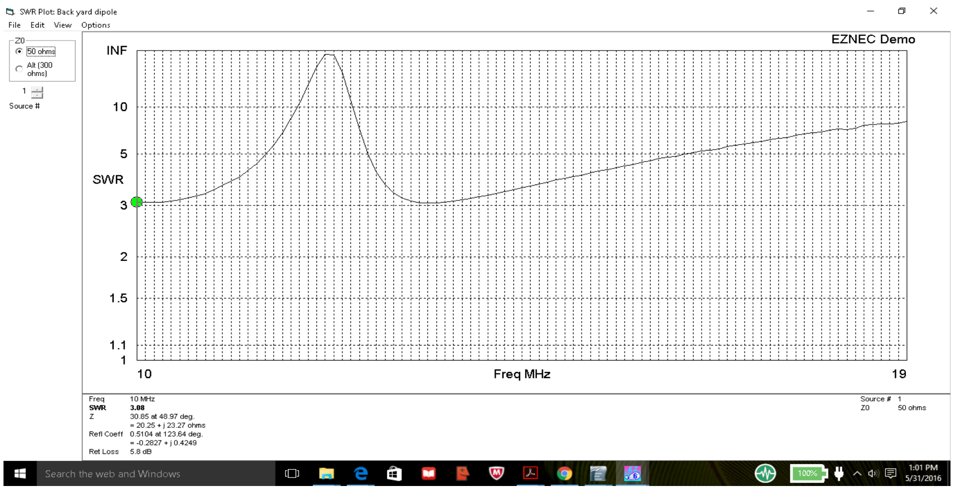


Figure 2. EZNEC theoretical results for the SWR of the proposed antenna.

These theoretical results suggested that the SWR's would be able to be matched easily by a manual antenna tuner of the typical T network variety, and even likely by an automated L network tuner except in the region of 13 MHz.

The purpose of this study was to test these theoretical results in real conditions.

METHOD

A test antenna was constructed using the following components:

- 52 foot length of black #14 stranded THNN house wire, cut in the middle
- 40 foot length of black #14 stranded THNN house wire, cut in the middle
- Homemade center insulator and end insulators from 1/2" electrical PVC (sunlight resistant) with appropriate holes drilled
- 32" 1x2 end separators with holes drilled 30" apart for wire separation, and roughly 28" apart for the rope bridle
- 3/16" nylon rope to allow the 40 foot dipole ends to reach the 1x2 end separators
- Approximately 7 feet length of 300 ohm #18 ladder-line transmission line suitable for considerably > 100 watts power (LL300-18, $0.44/foot, from http://www.davisrf.com/ladder.php)
- 4:1 voltage balun (mfr. States rated for "1000 W SSB" https://packetradio.com/catalog/index.php?main_page=product_info&cPath=49&products_id=2784&zenid=03187fb1f69b6ecc98d3931f2d81759f)
- 100 feet of RG8X coax cable

The ends of the 52 foot dipole were simply tied to the insulating wood separators due to a lack of additional insulators.

After being hung straight overnight to take out the inherent curls in the #14 wire, this antenna was easily wrapped around a typical 5 gallon home depot "homer" bucket and transported to the test site.

A slingshot/fishingweight/braided fishing line was used to establish a line over a 45' tree limb with good access, and the antenna was hoisted near-vertical, with the balanced line and balun and RG8X coax maneuvered somewhat at right angles to the antenna, as shown in the photo below:

NOTE: The final antenna mounted on the real tower should have the balun mounted at the closest edge of the tower, and should have a clear path for the the short segment of balanced transmission line, which should

a) be more than 4" from any metal structures if possible throughout its length and
b) should have a bit of droop to allow excess length should the antenna be blown away, stretching the balanced line.

The final antenna should be mounted with a moderate amount of tension on both vertical wires, so that the wires will not entangle themselves. A short (6 ") insulating spacer may be placed a couple of feet away from the center insulator to establish a spacing. Such a spacer may be commercially made, or may be constructed from sunlight-resistant PVC electrical conduit with two holes drilled.

Figure 3. Side view of the vertical antenna. Notice that it is difficult to see but it stretches from the ground to the first tree limb with needles in the top center of the picture.

Figure 4. Upwards view of the antenna, allowing the wires, center insulator, and balanced line transmission line to be seen against the sky.

Measurements of SWR were then conducted at the transceiver end of 100 feet of RG8X coax.

A ladder was then positioned near the antenna as shown below. The purpose of the ladder was two-fold – it allowed access to the balun to make SWR measurements without the loss introduced by the 100 foot section of coaxial cable; and it also provides a simulation of having the antenna mounted onlly a few feet from a vertical tower.

Figure 5. View of the antenna and ladder positioned nearby to simulate tower presence.

Measurements of SWR at frequencies from 7 MHz to 21 MHz were repeated from the transceiver end of the 100 foot RG8X with the interference of the ladder present.

Then the ladder was climbed to gain access to the 50 ohm side of the balun, the 100 foot length of coax was disconnected, and the antenna analyzer was connected to the balun with a 2 foot length of RG58 50 ohm coax and measurements of SWR at frequencies from 7 MHz to 21 MHz were repeated. Of course, it was not possible to make measurements of the SWR at the balun without the ladder being present.

Figures 6 and 7 give more details as to the construction of the center of the antenna and the components of the inexpensive balun device.

Figure 6. Inside view of the balun, including the toroidial 4:1 transformer

Figure 7. View of the center insulator. Wires are soldered. For long term use, the balanced line would be wrapped ¾ around the center insulator as a stress relief and held in place with a non conductive fastener such as nylon rope or sunlight resistant zip-tie.

RESULTS

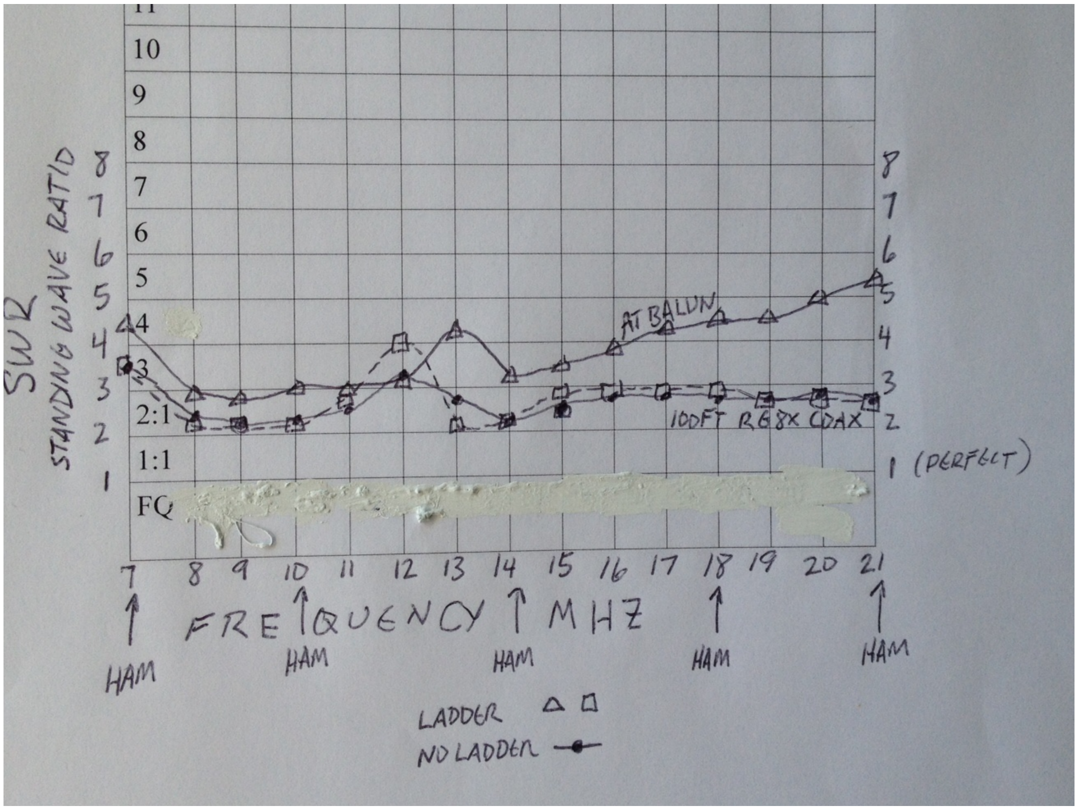


Figure 8. SWR versus Frequency for three conditions: at the transceiver end of 100 foot RG8X coax without ladder (dots), with ladder (open squares); and at the 50 ohm side of the balun (open triangles).

Measured at the transceiver end of a 100 foot section of RG8X coax, the SWR is at or below 3:1 for huge swaths of frequency ranges. The presence of the ladder has minimal effect.

Measured directly at the balun, as expected the SWR is somewhat higher, tending toward 5.5:1 at the extreme 21 MHz end.

DISCUSSION

The antenna appears to be an outstanding success! The measured SWRs even at the 50 ohm side of the balun, are quite reasonable, easily matched by common tuners, and will result in acceptable losses over even 100 feet of high quality LMR400 or RG8 coax to reach the transceiver.

Because this antenna is a vertical antenna, it will have a very low angle of radiation, sending much of its power toward the horizon or slightly above it. Thus it will function well during the heat of of the day when commmunication is difficult due to the high absorption of the ionized D layer During this portion of the day, HF communications are really only feasible using frequencies that are up higher toward the Maximum Usable Frequency (MUF) for any desired distance. This is reason this antenna was not designed to function on the 3.5 MHz (80 meter) amateur band.

Conflict with Theoretical Predictions: The demonstration version of EZNEC simulation software utilized is limited in the number of finite segments that can be used to perform the simulations; this may account for the ***considerably better performance of the real antenna*** compared to the predicted performance.

Coaxial cable has an inherent loss due to imperfect insulating dielectric with radio frequency voltage impressed across it from the center conductor to the shield. Because an imperfect SWR results in even higher voltages and currents, those losses go up with higher SWR. Coaxial cable losses also go up with increasing frequency. The following table gives approximate losses for LMR400 style cable. [vii]

Condition	Loss at 21 MHz
LMR400 @ 21 MHz; 100 feet; Perfect 1:1 SWR	0.6 dB
LMR400 @ 21 MHz; 100 feet; SWR 5:1	1.3 dB

These levels of transmission line loss are quite acceptable. It is likely that there is an additional loss in the 4:1 balun, which is of simple construction. A more expensive balun may result in less loss – but paradoxically a higher measured SWR.

The reason for this is that a lossy system almost always makes the SWR appear “better than it really is”. This is the reason that the SWR measured right at the balun is considerably higher on the higher frequencies, than it is, measured after 100 feet of RG8X coaxial cable (which has a total loss of 2.7 dB).

There are commercially manufactured “wide bandwidth” antennas which obtain much of their wide bandwidth by simply dissipating power uselessly in a loading resistor[viii], or lossy transformer[ix], in order to make the SWR appear better. For the best results for the EOC, it is desirable that we NOT purposefully inject losses into the system to create a better apparent SWR, but to conduct as much of our available received and transmitted power with the lowest losses possible.

USAGE: This antenna may perform somewhat differently when next to a 100 foot tower, however the presence of the ladder made relatively little difference, so the impact of the tower may be modest.   The use of higher quality LMR400 cable instead of the higher-loss RG8X used in this test will result in SWRs being perhaps as high as 4:1 at the upper end of the frequencies tested.   However, such an SWR is easily tolerated by EMP-resistant vacuum tube gear, and is easily matched by manual or automated antenna tuners to allow solid-state radio gear to achieve full power.

This antenna has acceptable SWR performance even down to the 7 MHz (40 meter) ham band, although the efficiency may be somewhat reduced on that band,   It could be used for very long distance communications at night on the 7 MHz 40 meter amateur band, or on SHARES frequencies nearby.   It should be a high performing antenna on the 10 MHz (30 meter), 14 MHz (20 meter), 18 MHz (17 meter) ham bands, and acceptably performing on the 21 MHz (15 meter) amateur bands. Furthermore, there are numerous SHARES high frequency bands scattered within this wide frequency range, and this antenna should perform quite well on most or all of them.

[i] Www.winlink.org

[ii] https://en.wikipedia.org/wiki/Ionosphere

[iii] https://en.wikipedia.org/wiki/Ionosphere

[iv] http://www.thewireman.com/antennap.html#553

[v] http://www.mfjenterprises.com/Product.php?productid=MFJ-2912

[vi] http://ulcar.uml.edu/DIDBase/ and results for Eglin Air Force Base: http://car.uml.edu/common/DIDBYearListForStation?ursiCode=EG931

[vii] http://www.qsl.net/co8tw/Coax_Calculator.htm

[viii] http://www.jpier.org/PIERB/pierb29/14.11021904.pdf

[ix] Comet Vertical Antenna: http://www.g8jnj.net/cometcha250b.htm