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.

Both for back-up amateur radio communications, 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..

Introduction	2
Horizontal Antenna	3
Vertical Antenna	9
Suggested Material Lists	12
Cost Estimates	13

INTRODUCTION

In a previous report[1], I documented measurements that demonstrated the inadequacy for emergency communications of the current HF & VHF antennas at the Alachua County Emergency Operations Center. In order to better understand the antenna heights and frequency bands needed for 24-hour emergency communications to automated digital systems such as WINLINK on amateur bands, I conducted an 8-hour live testing sequence and documented the results.[2]

High frequency (HF) communications typically make use of the ionospheric "skip" to reach long distances without the requirement for complicated infrastructure, repeaters, or towers. A simple antenna can 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.

Discussions with EOC management had indicated a desire to put up a horizontal antenna on the south side of the building, which I believe will be the most-useful-- and thus primary---HF antenna. Ideally this antenna would serve all amateur and SHARES frequencies from 3 MHz through at least 14 MHz. 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 first priority for amateur radio emergency communications at the EOC. The design proposed is one that personally have used with great success as a WINLINK RMS server antenna over many different amateur bands.

However, the 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 extremely difficult. In order to take advantage of the vertical tower, I proposed five possible antennas with SWR-simulations calculated by EZNEC (demo version) for considerations by local ham radio colleagues.[3] Of these proposed antennas, I favored #4, a non-resonant fan dipole consisting of a 52-foot and 40-foot dipole connected at the center. I then constructed a full-size prototype of that antenna and made measurements (using a tree limb as support) that indicated the antenna was a surprising success.[4]

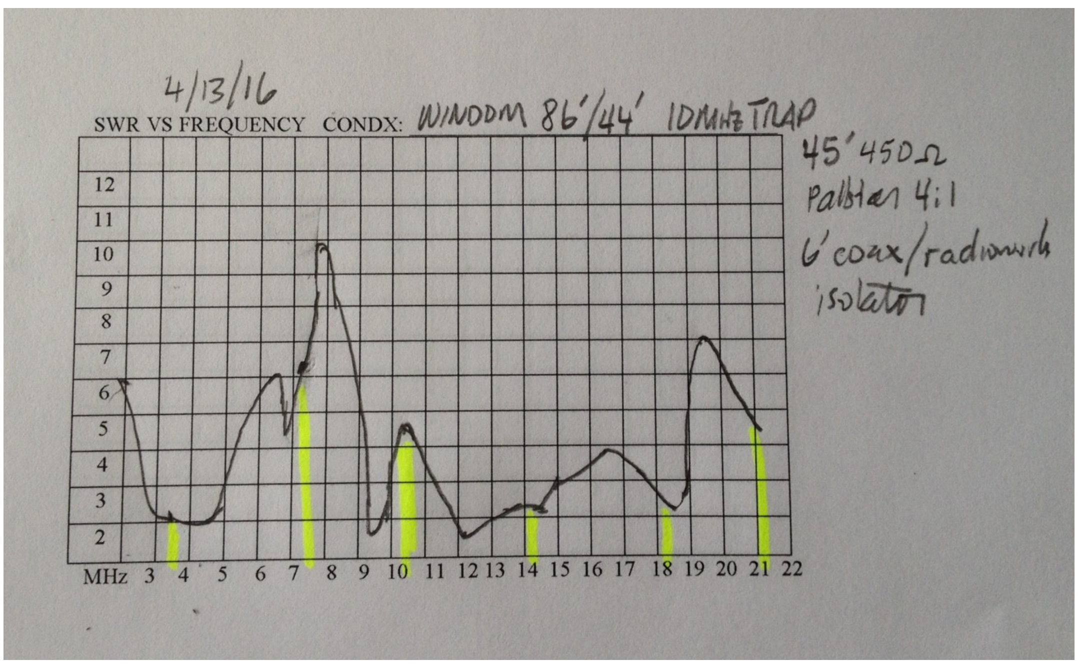
The remainder of this report gives the construction and materials details for these proposed antennas.

HORIZONTAL ANTENNA

GOAL: The horizontal antenna should cover amateur radio bands at 3.5 MHz, 7 MH, 10 MHz, and 14 MHz. 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 and have actual measurements of the SWR across a wide range of frequencies as shown in the following photo (using a 10 MHz optional trap):



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

This antenna in my experience was very easy to match on multiple amateur radio bands. 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).

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

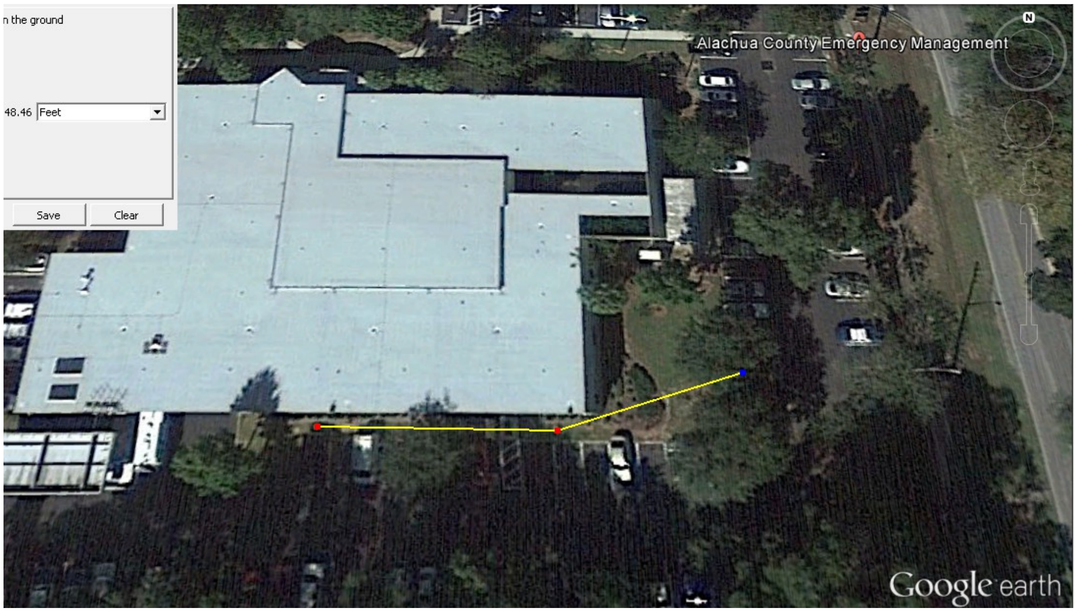
Starting from the transceiver, the components of this antenna system are:

> *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

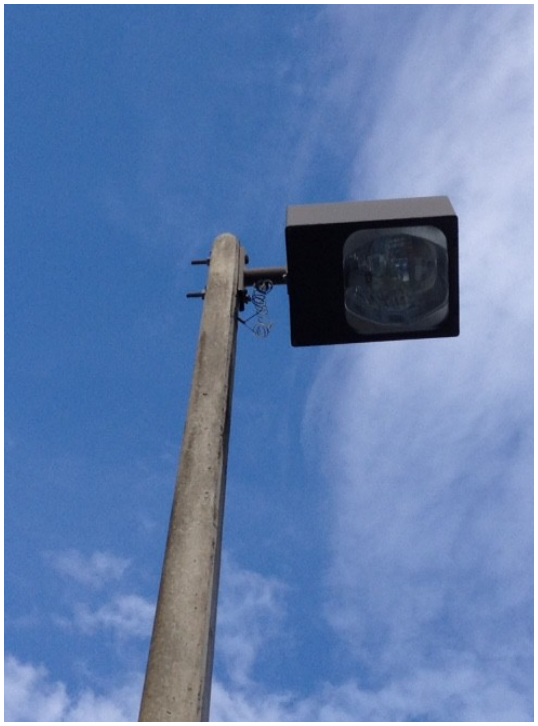
The 84-foot section of the off-center fed antenna should be installed at the (clear path) west end, allowing the feed point to be near the center light pole and simplifying transmission line support. The 44 foot remaining segment can be supported by light nylon rope from any of the remaining three lightpoles, 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.

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. 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

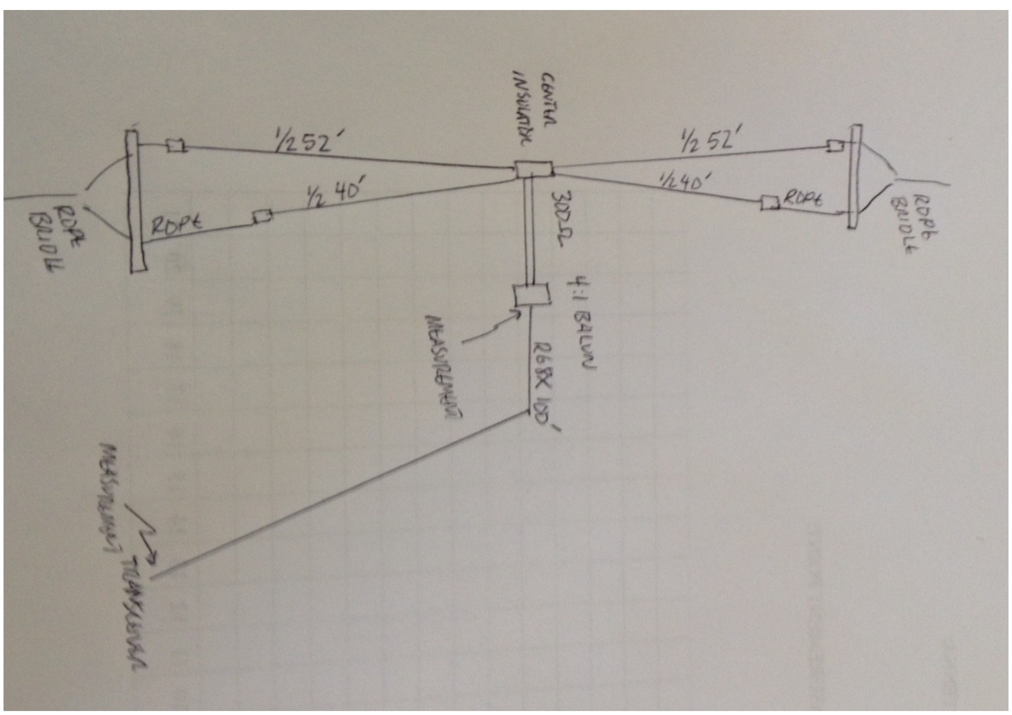
GOAL: Longer-distance daytime communications on the 10 MHz, 14MHz, 18MHz (and possibly 21 MHz bands) when the D-layer is making 3.5 and 7 MHz communications difficult. Act as a backup antenna for the primary horizontal antenna.

In order to utilize the existing vertical tower, and existing coax feed into the antenna farm area, a vertical antenna was designed. In order to achieve maximum bandwidth, a center-fed dipole system consisting to two dipoles was developed using a simulation package. 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).

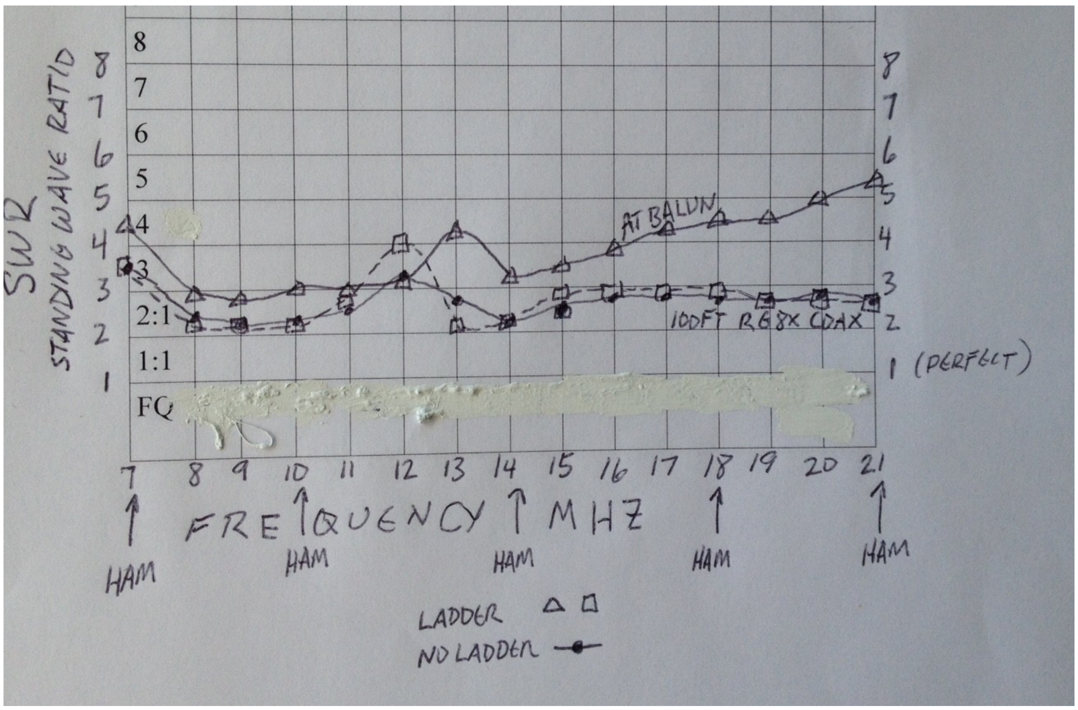


Drawing of fan vertical antenna (shown horizontally)

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. 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

(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)

1 EOCReport, May 14, 2016, Gordon L. Gibby.

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

3 EOCAntennaOptions, Gordon L. Gibby

4 Test of tower mounted antenna proposal for Alachua County, June 22, 2016, Gordon L. Gibby.