The background of the image consists of numerous curved, glowing lines in shades of blue and green, creating a sense of motion and depth. These lines are arranged in a pattern that resembles the aurora borealis or the light trails of a satellite in orbit. The lines are most concentrated in the upper half of the image and become more sparse and horizontal towards the bottom.

BUILDING A SATELLITE GROUND STATION

Jack Weaver – AA5VZ



MOVING
FORWARD...

BEYOND THE
BASICS



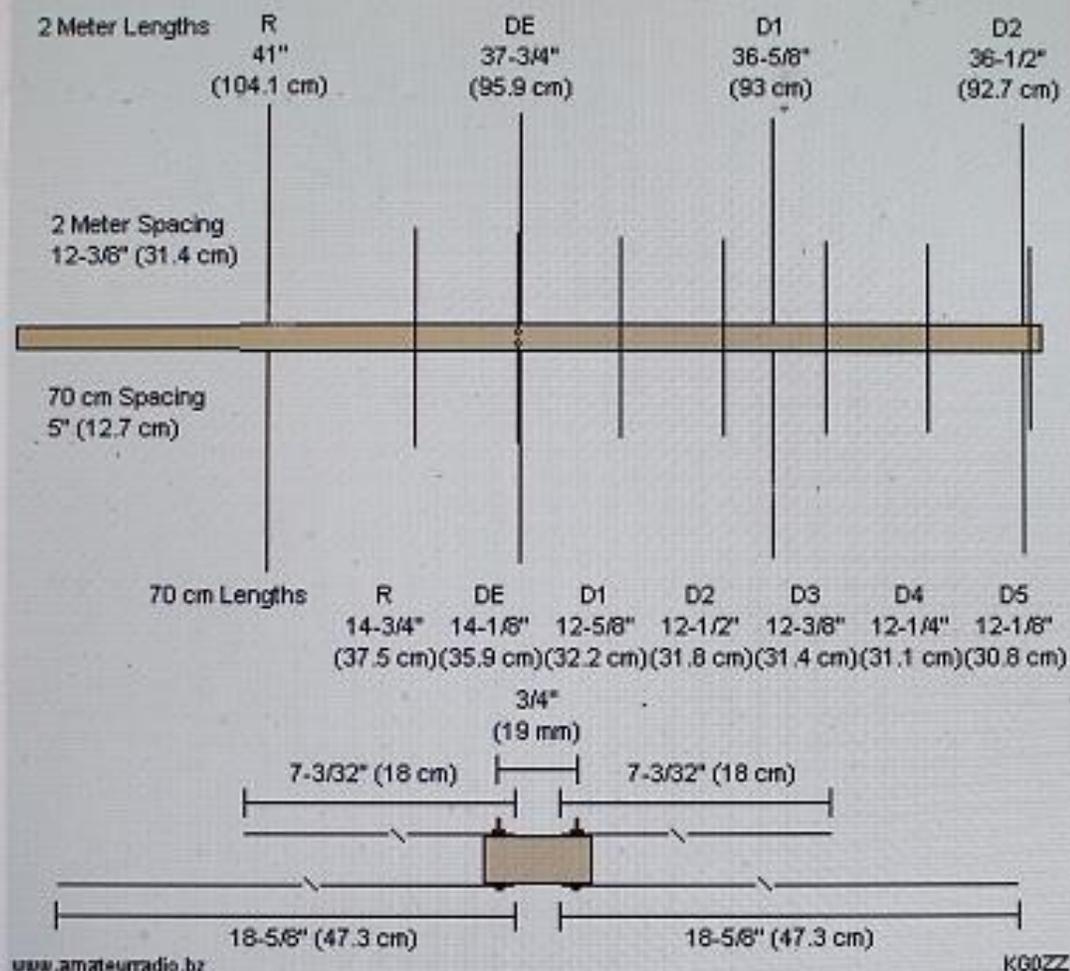


MY JOURNEY

- ▶ **Small beginnings**
- ▶ Home-built Yagi
- ▶ Got plans off the Internet
- ▶ Successful QSO on AO92, 1st Try

The \$4.00 Ham Radio Satellite Antenna

1x2 Wood Boom & Steel Coat Hangers



www.amateurradio.biz

KG0ZZ

The \$4.00 Ham Radio Satellite Antenna



MY JOURNEY

- ▶ **Initial Improvements:**
- ▶ Commercial Built "Arrow" Antenna
- ▶ Considerably "lighter" weight
- ▶ Added additional Tripod support
- ▶ Easy transport to "off-site" locations



MY JOURNEY

- ▶ Improvements continued:
- ▶ **Added Satellite Tracking Capability**
- ▶ Robotic Platform for Arrow Antenna (home brew)
- ▶ AZ-EL Orientation Sensing



MY JOURNEY

- ▶ **Satellite Tracking Capability**
- ▶ Arduino-based Controller (home built)
- ▶ Derived from W9KE "SimpleSat Controller for Arduino" article (with numerous local modifications).
- ▶ Features Manual and Automatic Control





MY JOURNEY

- ▶ Automatic Tracking in Operation
- ▶ Have enjoyed dozens of “hands-free” satellite QSOs using this system
- ▶ Including the ISS Cross-Band Repeater when it first came on’line
- ▶ But... I still had to drag all this stuff outside and put it all away every time I wanted to use it!

ANTENNA

- ▶ **Dual Band Ground Plane**
 - ▶ **COMET GP-1**
- ▶ Experienced “Moderate” Success
- ▶ Inherent Limitations
 - ▶ Low Radiation Angles
 - ▶ Virtually No Gain
 - ▶ Requires Higher Transmit Power





- ▶ Dual Band GP
- ▶ **COMET “Discone”**
- ▶ Experienced “limited” success
- ▶ Inherent Limitations
 - ▶ Very low Radiation Angles
 - ▶ No Signal Gain
 - ▶ Required Higher Transmit Power
 - ▶ Experienced Higher Rx Noise Levels

ANTENNA



SO...

- ▶ **Where I am now, and Where We Begin:**
- ▶ **Ground Satellite Tracking System**
- ▶ **M2 Dual Yagi Antenna Array**
- ▶ **AZ-EL Positioning - Computer Controlled from Station Operating Position inside**
- ▶ **Can be positioned “manually” as well**
- ▶ **Potential for Remote Operation**

WHAT IS REQUIRED

- ▶ Technician Class License or Higher to operate satellites
 - ▶ Dual Band Radio (VHF/UHF)
 - ▶ AZ/EL Rotator with Controller
 - ▶ Cross-Boom (non-conducting)
 - ▶ PC Rotor Control Interface
 - ▶ Satellite Tracking Software
 - ▶ Antenna(s) – Directional / UHF-VHF/ Circular Polarized
 - ▶ UHF/VHF Duplexer
 - ▶ Cables/Connectors/Hardware/etc.
 - ▶ Satellites
-
- ▶ Subsequent slides describe what I used.
 - ▶ Your mileage may vary.



RADIO(S)

- ▶ Dual Band (VHF/UHF)
- ▶ **FM...**
- ▶ **Full Duplex - Preferred**
 - ▶ **I use a Kenwood TM-V71A (shown)**
- ▶ Half-Duplex works well too
 - ▶ I use a YAESU FT-991 (not shown)
- ▶ SSB / CW...
- ▶ Full Duplex – ideally preferred
- ▶ Half Duplex – Requires much understanding and skill
- ▶ Still learning about this...



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- ▶ YAESU G-5500DC
- ▶ AZ and EL Motors
- ▶ Controller Box included

ANTENNA ROTOR



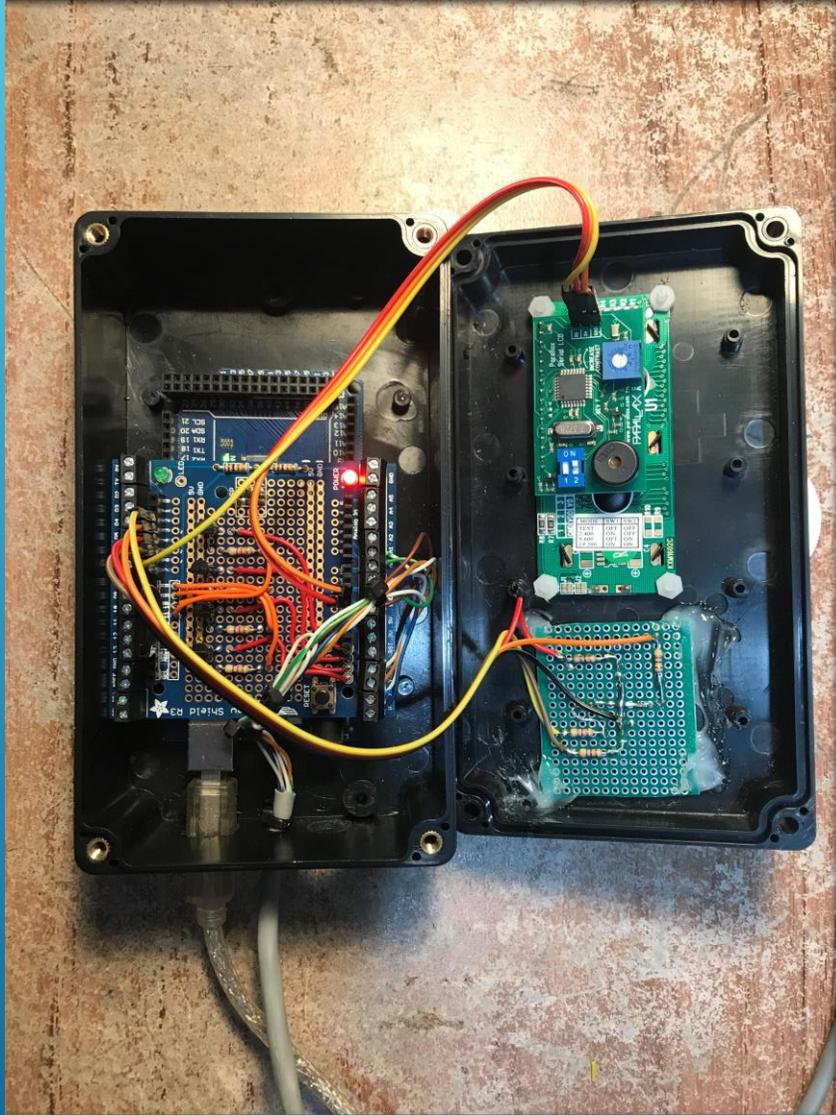
ROTOR CONTROLLER

- ▶ **YAESU G-5500DC Controller (left)**
 - ▶ **Included with Rotor**
 - ▶ **Manual Control of AZ-EL**
- ▶ **PC Control Interface**
 - ▶ **Several Options Available**
 - ▶ **I Use Arduino-based Controller**
 - ▶ **Non-commercial...DYI**
 - ▶ **Plans available on-line (free)**



PC CONTROL INTERFACE

- ▶ **YAESU G-5500DC Controller**
 - ▶ Included with Rotor
 - ▶ Manual control of AZ-EL
- ▶ **PC Control Interface (right)**
 - ▶ **Computer control of AZ-EL**
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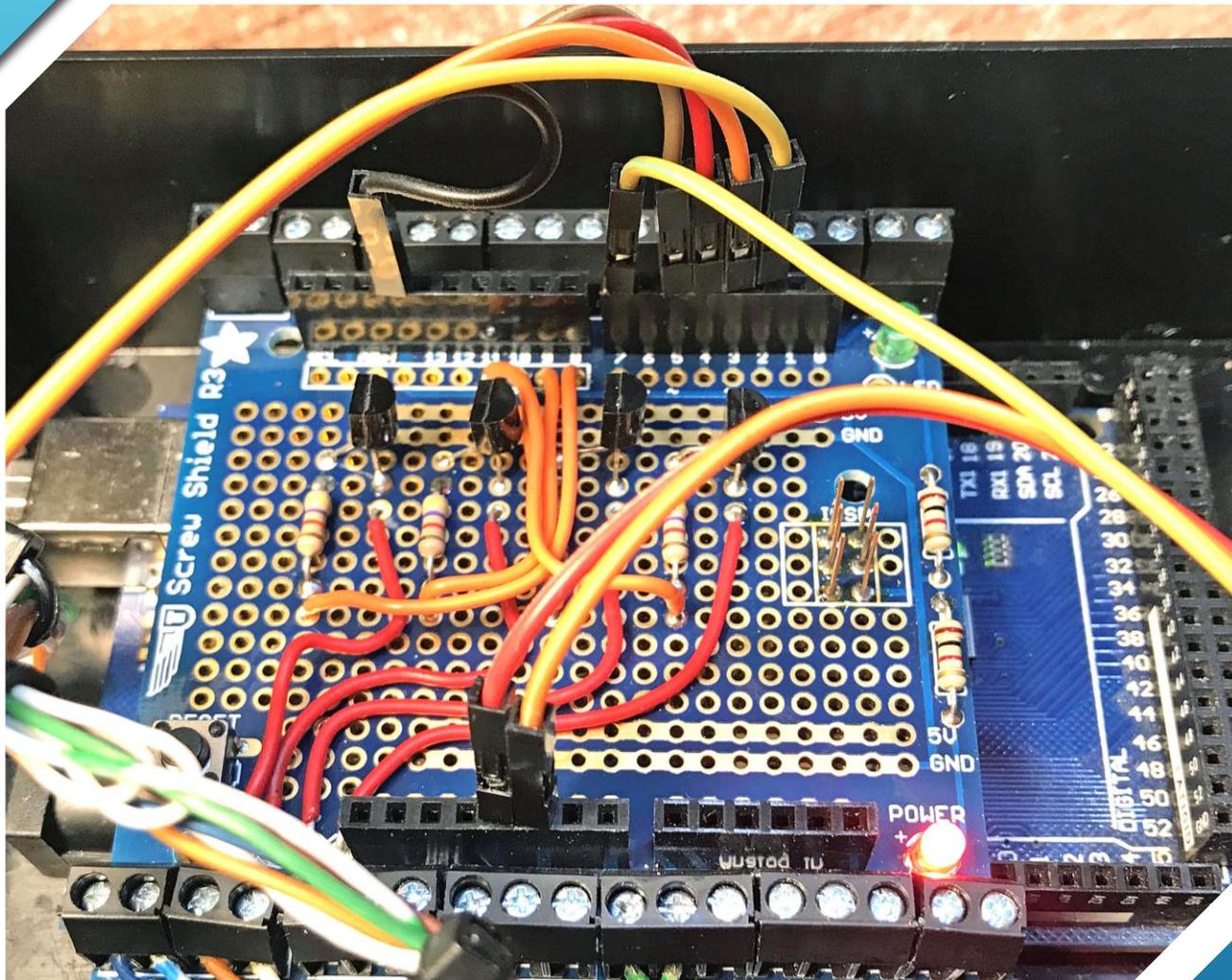


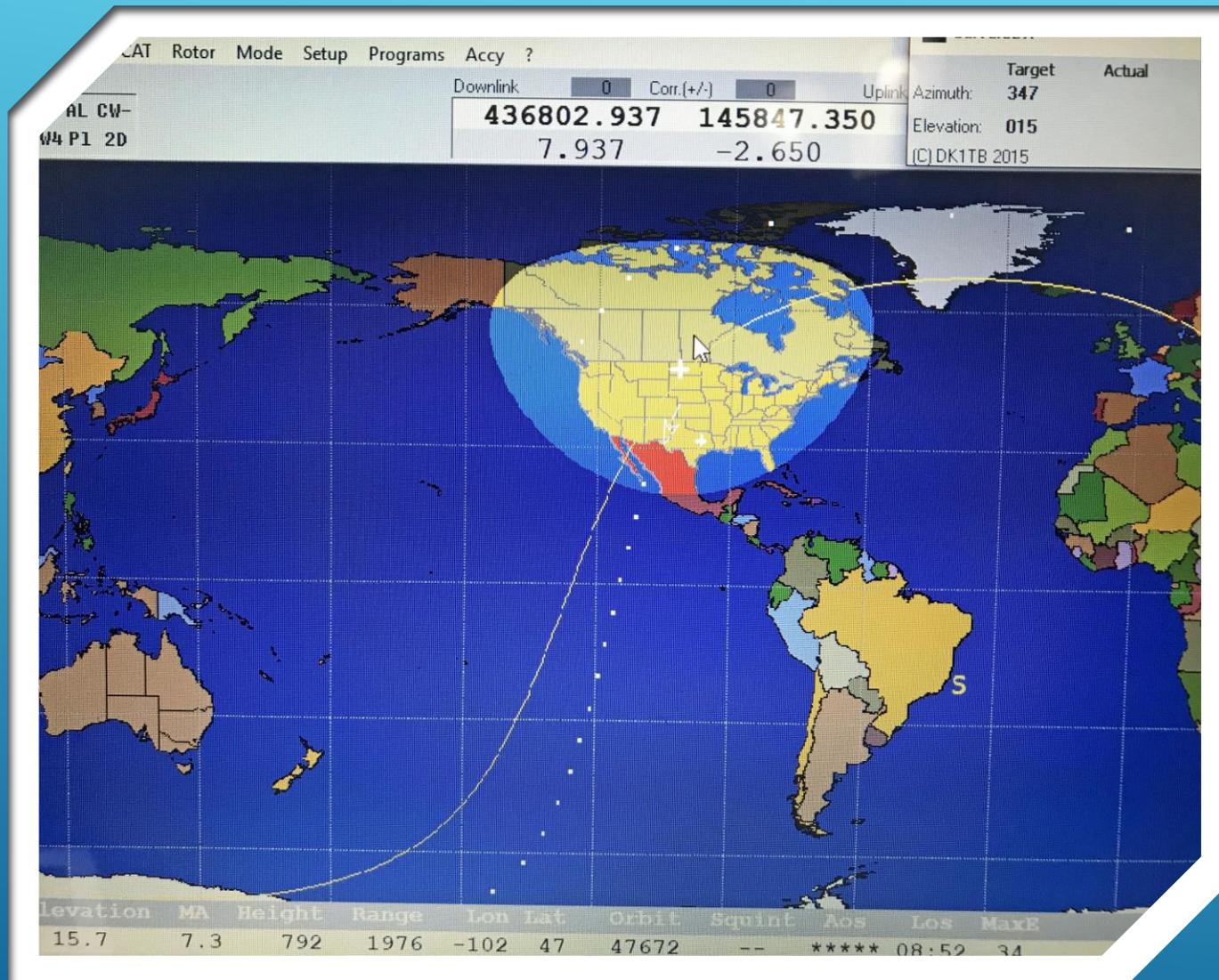
- ▶ **W9KE “SimpleSat” PC Controller Interface**
 - ▶ **Computer control of AZ-EL**
 - ▶ **An Arduino-based Controller**
 - ▶ **Designed for use with G5500 Rotors**
 - ▶ **Non-commercial...DYI**
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ARDUINO - PC
CONTROL
INTERFACE

ARDUINO - PC CONTROL INTERFACE

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PC AND SATELLITE TRACKING SOFTWARE

- ▶ I use SatPC32 (available from AMSAT.org store)
- ▶ You can download a free trial version on-line to begin with
- ▶ Works with W9KE "SimpleSat" PC Controller Interface and other commercial brands

ANTENNAS, MAST & CROSS-BOOM

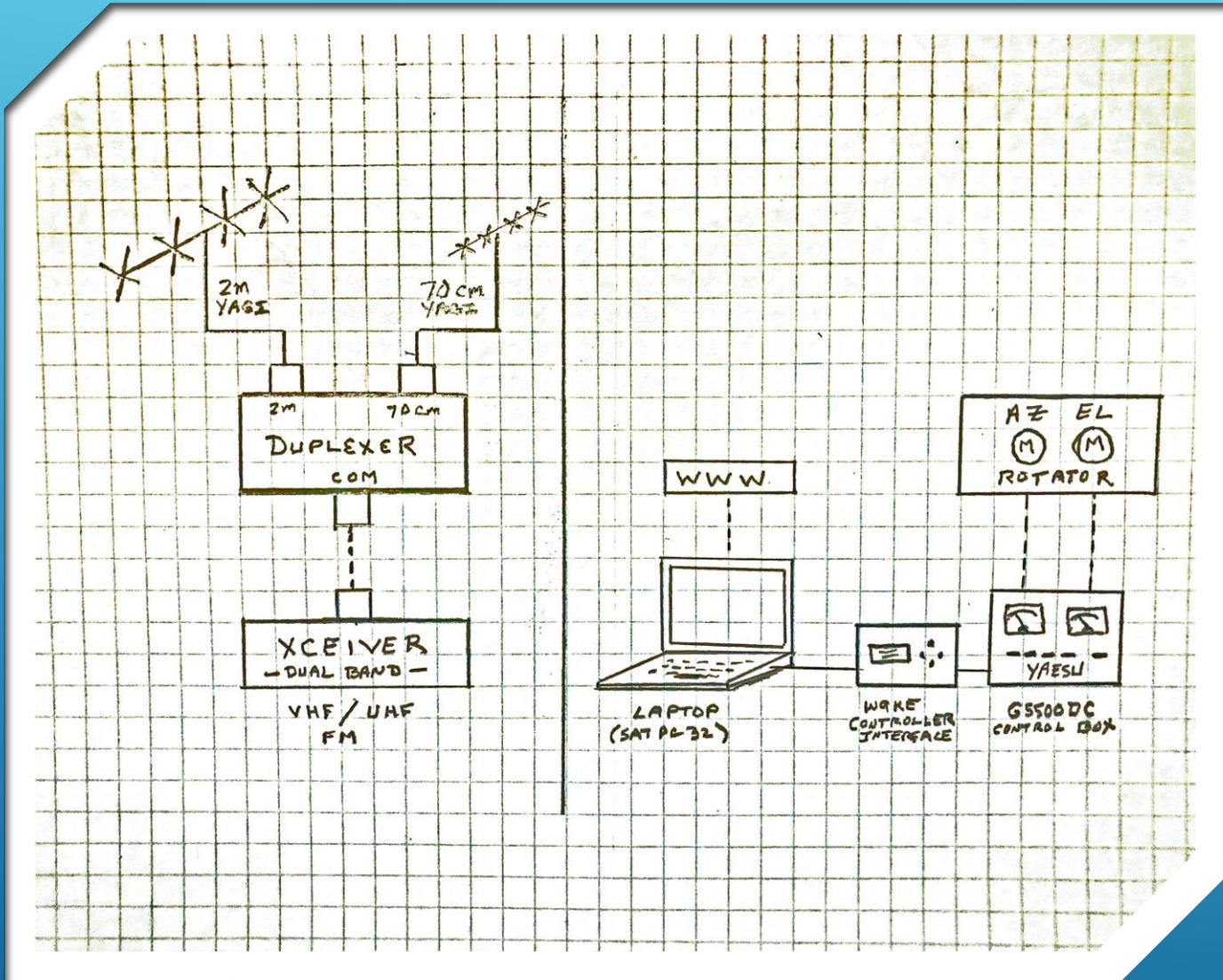
- ▶ Many Options Available
- ▶ I use M2 2m and 70cm, Circular Polarized Yagis (purchased individually)
- ▶ Cross-Boom available from M2
- ▶ Boom MUST be non-conducting!!!
- ▶ Use quality LOW-LOSS Coax throughout.
 - ▶ I use LMR-400 (for long run) and LMR-400 "Flexible" for Antenna-Duplexer run.





- ▶ Many Options Available
- ▶ Must be rated above wattage you'll use
- ▶ I use a COMET CF-4160
- ▶ Mount unit close to antennas
- ▶ Protect it from the environment!
- ▶ I use a large PVC J-Box (with water-tight gasket) mounted to the mast.

DUPLEXER



SYSTEM DRAWING

- [x]Prepare J-Box for Mounting
 - [x]Cut Access Hole in bottom for attachment to PVC Pipe
 - [x]Cut Access Hole(s) for Rotator Cable
 - [x] Cut Access Holes for Coax Cable(s)
- [x]Mount J-Box to PVC Pipe and secure to Mast
- [x]Calibrate Rotor Control Box
- [x]Mount Rotor Assembly atop Mast (Protect Connector Receptacles)
- [x]Prepare PVC Tubing for House ground to eave access hole
- [x]Pull Cables
 - [x](Coax - House to Mast Junction Box)
 - [x](Rotor Control - House to Mast Junction Box to Rotors)
 - [x](All - House base to Radio Room)
- [x]Identify and Label AZ-EL Control Cables (both ends)
- [x]Terminate Coax Cable End with PL-259 Connector and secure to Duplexer ("common port") inside J-Box
- [x]Terminate AZ Control Cable and connect to AZ Rotor
- [x]Terminate EL Control Cable End and connect to EL Rotor
- [x]Apply protective coverings and sealing tape to AZ-EL Rotor Connectors
- [x]Cover Under-Eave Access Hole
- [x]Install PL-259 connector to coax end in Radio Room
- [x]Connect AZ Cable to Rotor Box terminal strip
- [x]Connect EL Cable to Rotor Box terminal strip
- [x]Apply Power and test Rotors for proper operation
- [x]Calibrate rotors on bench IAW instruction manual
- [x]Install AZ-EL rotator assy. onto mast, aligned to true north
- [x]Attach insulated cross-boom to rotator assembly and test AZ-EL functions
- [x]Assemble and Install M2 Satellite Antenna Array onto insulated cross-boom
- [x]Apply sealant to all cable connections
- [x]Attach antenna cables to Duplexer associated ports
- [x]Test system to verify operability

DEVELOP A WORK-PLAN / CHECKLIST

GETTING STARTED

- ▶ **Cable Access Area:**
- ▶ Remove existing J-Box & Connectors
- ▶ Re-purpose area to become access port for LMR coax and two rotor cables
- ▶ Use clothesline rope for measuring cable length and for a pull rope
- ▶ Fabricate new cover-plate to accommodate PVC Conduit





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GETTING STARTED



▶ **Conduit Burial:**

- ▶ Ensure conduit correctly sized to accommodate all cables
- ▶ Determine path for conduit run
- ▶ Dig trench
- ▶ Assemble conduit sections
- ▶ Seal all joints with approved PVC joint sealant
- ▶ Place temporary cap on end pieces (w/o sealant) to prevent entry of dirt or moisture during construction

PREPARE CABLE ROUTE



- ▶ **Conduit Burial:**
- ▶ Ensure conduit correctly sized to accommodate all cables and pull-rope
- ▶ Determine path for conduit run
- ▶ Dig trench
- ▶ Assemble conduit sections
- ▶ Seal all joints with approved PVC joint sealant
- ▶ Place cap on end pieces (w/o sealant) to prevent entry of dirt or moisture

PREPARE CABLE ROUTE



- ▶ **Mast/Conduit Burial:**
- ▶ Select properly sized mast for rotor attachment
- ▶ Use post-hole digger for burial (2 feet min.)
- ▶ Attach long bolts to mast end to form cross-tee. This will prevent mast from turning later.
- ▶ Set mast in hole, ensure true vertical alignment, secure with temporary guy wires and fill hole with quick-set cement.
- ▶ Route conduit through trench to mast base. Vertical section should align with bottom center of large PVC J-Box.
- ▶ Seal couplings (at least) with silicon sealant to prevent water intrusion from rain-water or sprinkler systems.

MAST, CONDUIT & CABLES



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MAST, CONDUIT & CABLES



MAST, CONDUIT & CABLES

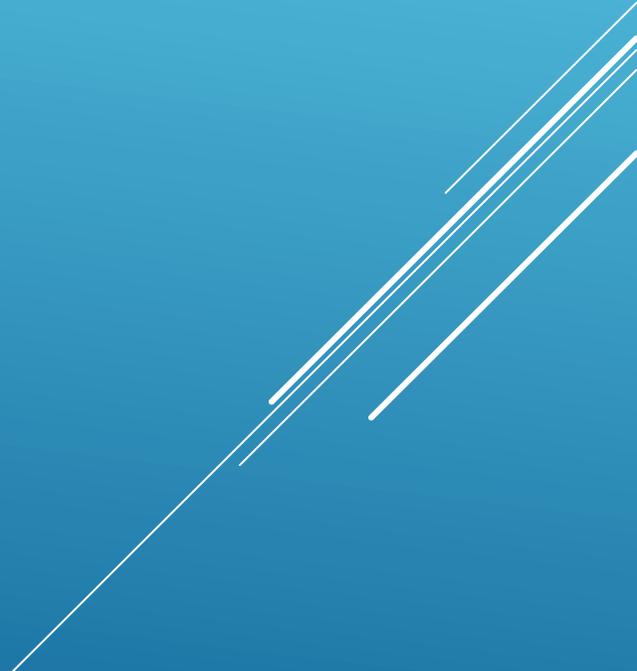


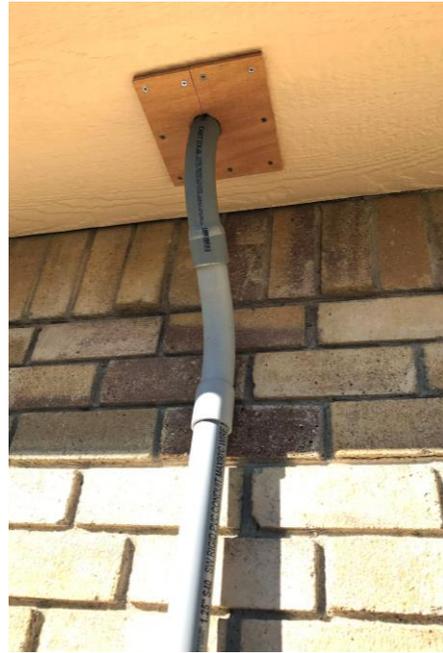
- ▶ **Mast-mounted J-Box:**
- ▶ Using sewer snake (entering from the j-box), pull cables (2 rotor and 1 coax) plus a “future-use” pull rope from the conduit end at the house foundation.
- ▶ Note: This requires someone at each end to feed, and receive, the cable bundle.
- ▶ Pull enough “rotor” cable to eventually reach the rotor assembly (and beyond) atop the mast. You must include a service loop that permits 450 degrees of azimuth rotation.
- ▶ The “coax” cable will terminate here, at the duplexer “com” port.
- ▶ Installing a plywood backboard inside the j-box helps keep things organized and neatly mounted.
- ▶ The center PVC coupling is tall enough to prevent any water intrusion into the box from entering the conduit going underground.

MAST, CONDUIT & CABLES



MAST, CONDUIT & CABLES





- ▶ **Cable Run to Radio Room:**
- ▶ From the foundation end, slide conduit pieces onto the cable end and continue to slide the pieces down the cable until they meet up with the foundation tail-piece stub.
- ▶ Attach the 3-wire cable ends to a pull-rope coming from the radio room and attic, and hanging down from opening in the eave.
- ▶ **From inside the attic**, use the pull-rope to draw the wires into the attic from outside until all the wires are taut and the vertical conduit is pulled up against the building wall. It's best to have a helper outside guiding the process.
- ▶ **Use cell-phones or 2-way radios to communicate with each other.**
- ▶ **From outside**, ensure the vertical sections are connected together and to the tail-piece protruding from the ground.
- ▶ Center the conduit inside the eave access-hole, and secure it using the pre-fabricated cover-plates. The vertical conduit can be anchored to the house as needed for support.
- ▶ Continue to bring the wires into the radio room. Install proper terminals and connectors, and connect them to the radio and Rotor Controller, as necessary.

MAST, CONDUIT & CABLES



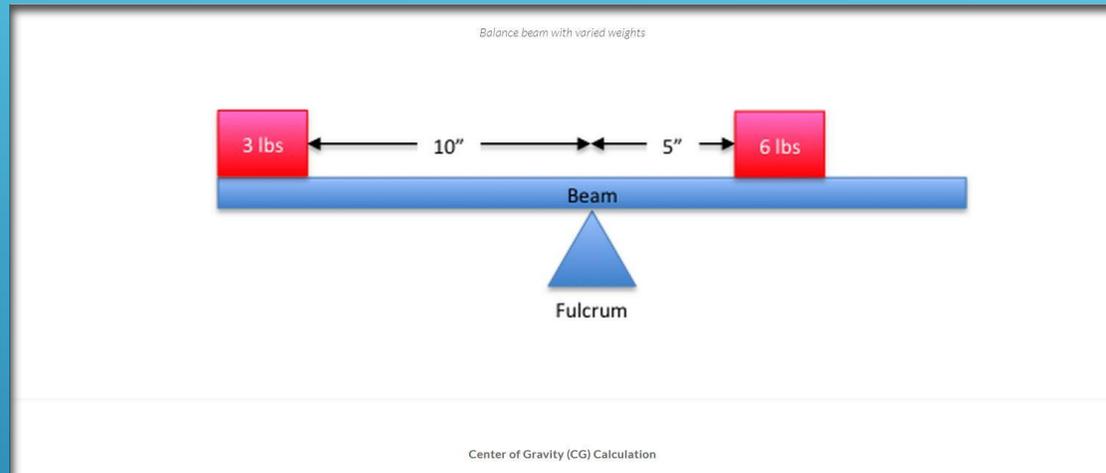
- ▶ From rotator calibration steps performed earlier, ensure Rotor is electrically pre-positioned to “North”.
- ▶ Mount rotor on mast, but do not tighten the four base-housing clamps against the mast.
- ▶ On a clear night, standing directly behind the rotor (or mast), locate the North Star (Polaris) and visually align the star with the rotor top (center) or the mast. Locate, make note of, or mark any physical objects directly in-line with your sighting. You may need the assistance of a flashlight or “head” lamp to find these.
- ▶ In this case, the object was a round vent-pipe (hidden from view)
- ▶ Wait until daylight to complete next step.

ROTOR MOUNTING AND ALIGNMENT



- ▶ In the daylight, visually align the rotor-top (center) with the object or any physical markings identified the night before. In this case, (for illustration purposes) the object was a round vent-pipe.
- ▶ Once aligned, tighten the housing clamps to the mast.

ROTOR MOUNTING AND ALIGNMENT



- ▶ **Center of Gravity**
- ▶ When mounting an antenna perpendicular to a cross-beam, or a pair of antennas onto a cross-beam oriented perpendicular to the mast, it is imperative to maintain center of gravity (balance) in all planes.
- ▶ Balance is achieved when the weight of the object (antenna) on one side of the fulcrum (cross-boom or mast) multiplied by the distance away from the fulcrum EQUALS the weight of the object (antenna) on the opposite side multiplied by the distance of that weight away from the fulcrum (cross-boom or mast).
- ▶ Thus, a 6 lb. antenna mounted 5 ft. away from the mast will be in balance when a 10 lb. antenna on the opposite side is mounted 3 ft away from the mast.
- ▶ $(6 \times 5) = (10 \times 3)$
- ▶ $(30) = (30)$

ANTENNA MOUNTING

ANTENNA MOUNTING

- ▶ With rotor control cables connected to the rotor and controller on each end, command the “elevation” rotor to stop at “zero” degrees.
- ▶ Install antennas to cross-booms, each antenna oriented toward the “north”.
- ▶ Pay very close attention to ensure equal center-of-gravity on all mounting planes upon final assembly. Position and mount each antenna horizontally (facing north), using a level, ensuring proper balance along the boom-length.
- ▶ Clamp both Antennas onto the Cross-Boom at a distance that ensures equal weight-balance between them. This distance can be calculated mathematically a formula for determining weight/distance ratios from the fulcrum of a balance-beam. In this case, the fulcrum is where the Mast intersects the Cross-boom, or where the antenna boom intersects the cross-boom.
- ▶ This is simple algebra...can be Googled on-line if necessary.



ANTENNA CABLE ROUTING

- ▶ Attach coax cables to each antenna and route them to their respective Duplexer ports inside the J-Box.
- ▶ **Follow manufacturer instructions** for routing cables along and away from these antennas.
- ▶ I used a 50-foot Flexible LMR-400 Jumper Cable with N-Connectors pre-attached on both ends. I cut the cable in half and attached an N-Connector to each antenna. After routing both cables to the Duplexor, I cut and terminated each wire-end with a PL-259 connector, which I attached to their respective ports.

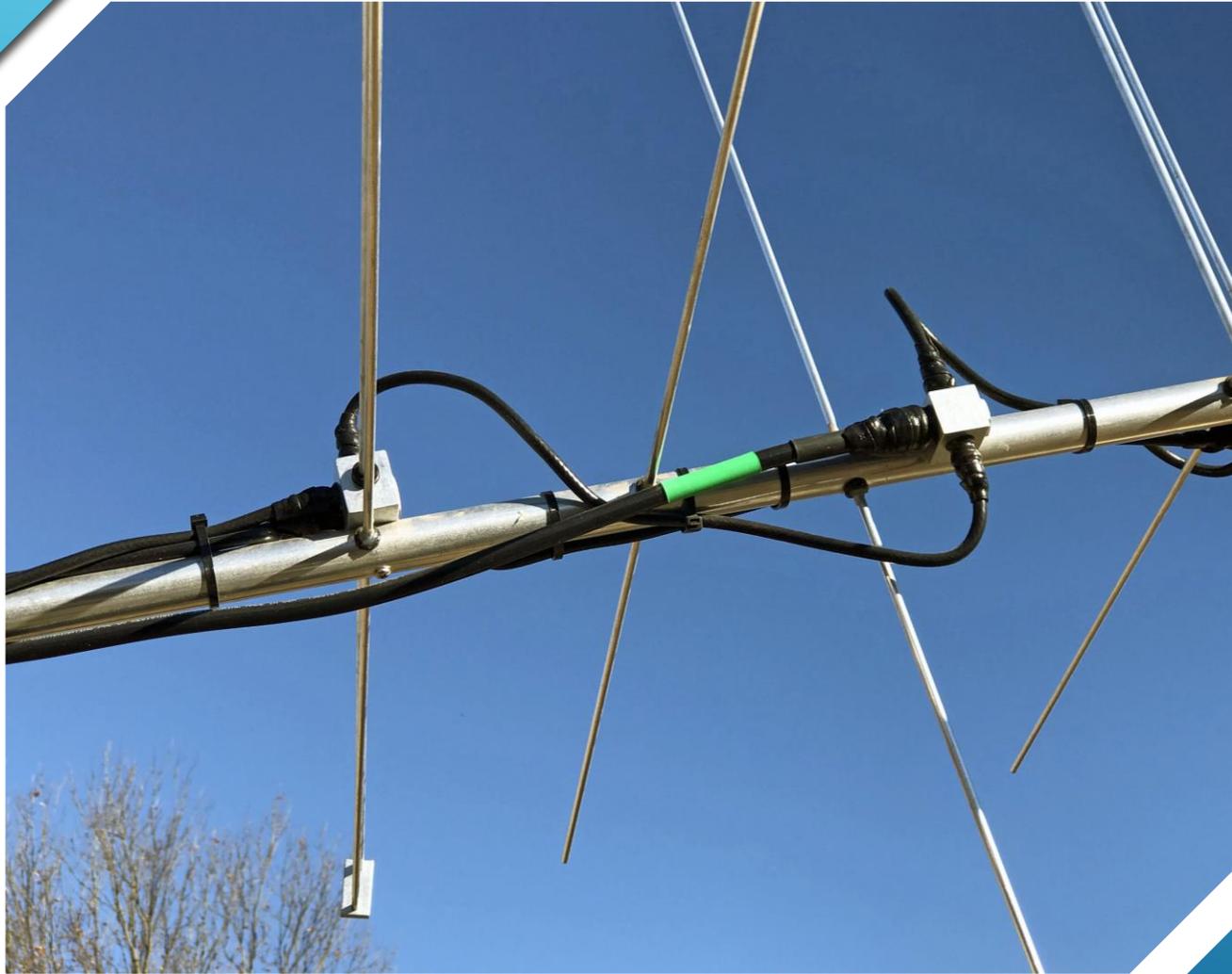




J-BOX CABLE TERMINATIONS

ANTENNA CABLE ROUTING

- ▶ Ensure all exposed cable terminations are “sealed” from water intrusion and corrosion using recommended sealants or tapes.
- ▶ I prefer to use a “Coax-Seal” tape product, available from HRO. For more information, visit www.CoaxSeal.com





- ▶ Although the antenna array is only 9 feet above ground, it is very top-heavy and requires guy-wire support for high-wind protection.
- ▶ I improvised a guy-wire ring by using metal L-brackets (3) and a hose-clamp. This arrangement is NOT corrosion-proof, but will serve to support the mast and array for the moment.

GUY WIRE INSTALLATION

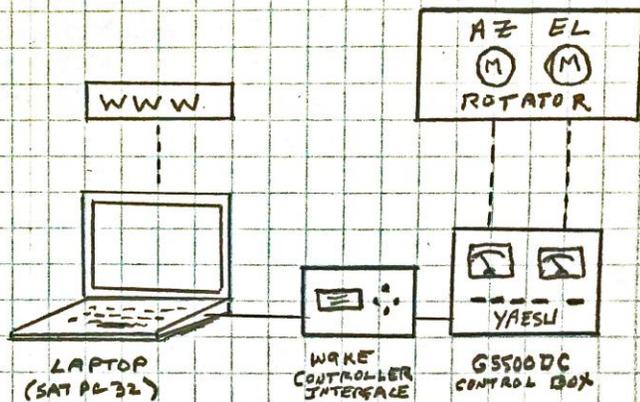
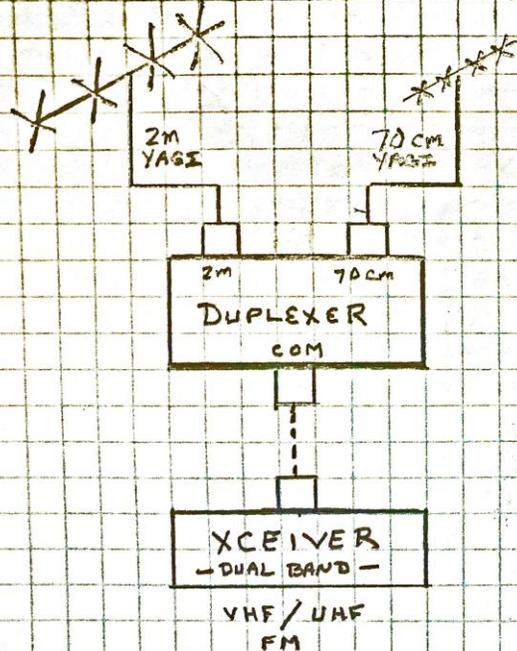


- ▶ Instead of using traditional metal stakes, I opted to secure the guy-wires to three “cork-screw” style anchors.
- ▶ Turnbuckles are used to maintain proper tensioning of the wires.
- ▶ Again, it is NOT corrosion-proof, but will serve to support the mast and array for now.

GUY WIRE INSTALLATION

SYSTEM DRAWING

- ▶ When all is said and done, ensure the installation is assembled and connected per manufacturer instructions and IAW the plan.
- ▶ The rest is a matter of equipment and software configurations, getting lot's of practice, and continuous learning as you go.
- ▶ Have fun...there's MUCH to be had!!!



- ▶ www.AMSAT.org
- ▶ K5SLD – Wednesday night AMSAT INFORMATION Net (21:00 L)
- ▶ K5SLD.com – Presentations tab – January 2021 - Getting Started with FM Satellites
- ▶ YOUTUBE videos
- ▶ GOOGLE (etc.)

RESOURCES

QUESTIONS / TESTIMONIALS

