# 40 Meter Mini-MOXON Beam Antenna


Designed, built, and presented by:

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# Design goals

- Some forward gain
- Good directivity  (high F/B and F/S ratios)
- Relatively small size
- Good Bandwidth (min. 200KHz @ <2:1 SWR)
- Light weight
- Easy construction and tuning
- Low cost

# Some current loaded 40M 2 El. beams

- Cushcraft  (now owned by MFJ)
  - 41 ft wingspan
  - Inductive loaded with capacity hats
  - Around $600
- Hygain (now owned by MFJ)
  - 44 ft wingspan
  - Linear loaded
  - $660
- Force 12 (240N)
  - 58 ft wingspan
  - Linear loaded
  - $1700 !
- Mosley (multiband only)
  - 44 ft wingspan
  - Inductor loaded (with traps for higher bands)
  - Price N/A

None of the commercial antennas mentioned met most of my goals

- Too big
- Too heavy
- Way too costly!

Over the years there have been a lot of home brew and commercial mini-beams presented and none offer near full size performance.

Lots of other schemes using loaded mobile antennas as beam elements such as the “Buddipole”, TGM B245 minibeam”, etc.

- None provide much if any gain
- All have low efficiency
- All have very narrow bandwidth

# Background

My QTH is on a “standard” city lot about 90 X 110 feet.   There is limited ground space in the back yard For radials etc. due to the swimming pool installed by the previous owners.

In 2005, when returning to Arizona after a long absence and with limited time, I put up an old Cushcraft R7000 “half wave” vertical to get back on the air.   Considering the lousy band conditions at the long bottom of the sunspot cycle, the R7000 proved to be a surprisingly good performer, especially on 40 meters.

In 2009 I acquired and installed a 55 ft. crank up tower and considered various antennas to put on top.

I had used cubical quads for many years and the decision for 20 meters and up was easy, but what to do For 40 Meters?

Some years ago I built a MOXON Rectangle antenna for 6 meters. The performance was excellent with good gain, great side and back rejection and seemed to work very well.  Cost to build was very low and Construction was very easy.

So……….Why not consider a MOXON or variant for 40 meters?

# MOXON Background

Several designs emerged in the 1970s for reduced size beam antennas implemented by folding the elements.

- VK2ABQ may have been the first to publish a design with his "square " antenna. Similar antennas have been around since the 1930s.
  - Elements were folded toward each other at about the 50% point (1/4 wave spacing required!!)
  - Narrow Bandwidth
  - Gain was relatively low
  - F/B and F/S ratios were good.
  - Design was fairly critical
  - Antenna is a square configuration with equal size elements and a stub to lengthen the reflector.

- Les Moxon G6XN discovered that a rectangular shape would improve the gain and lower the impedance
  - Rectangular shape means shorter boom
  - The tradeoff is a wider wingspan (about .35 wavelength)
  - F/B and F/S rejection ratios remain excellent (Cardioid radiation pattern typical of phase arrays).
  - good match to 50 ohm coax cable
  - The only critical requirement is the tip-to-tip spacing
  - Can be built with wire, tubing, or whatever

- L.B. Cebik W4RNL (sk) has published a huge amount of data on the www.cebik.com website about the MOXON and it's variants.

# Preferences

A “standard” Moxon for 40 meters  is about 46 feet wide and 18 feet long.

- An 18 ft. boom is doable and about the same as the quad that will share  the boom (in my case)
- The 46 ft wingspan is wider than I want…..
    - 46 ft wingspan requires  tubing elements to be reasonable self supporting, OR
    - Lots of support halyards or guys, OR…..
    - A large “X” frame to support an all wire MOXON

**For me, these options are either too large, heavy, untidy, and would have high wind load cross section.**

**Can the MOXON elements be loaded to reduce the size and maintain typical MOXON performance?**

**YES!**

Loading a MOXON has been shown to work well on the www.moxonantennaproject.com website.
A good example was the lumped inductor loaded MOXON designed and built by IK0GDH.

# Loading the MOXON

Inductive loading, "linear loading" similar to the 402BA and other shortened yagis, helically loading, or capacity hat loading can reduce element length.  Often a combination of these is used.

Capacity hat loading is usually on or near the ends of the element for maximum effect and is not really practical For MOXON loop antennas.

- Since the coupling between the ends of the MOXON elements is critical  this is not usually practical for reasons that will be presented later.

Inductive loading is easiest and most practical.

- On a MOXON, the parallel elements are well supported or made from some kind of tubing and loading can be easily implemented.

**Consider that most of the radiation on an antenna is from the high current end of the elements (the end closest to the feedpoint in a dipole or ¼ wave vertical).**

- Lumped inductance:  Usually done with a single coil inductor located somewhere along the element
    - Close to the drive point (high current point on ½ wave element) has the most shortening effect  but is the least efficient  position on the radiator.
    - As the inductor is moved out toward the ends of the element, losses are less, antenna efficiency is higher but the inductance needs to be progressively higher.  Size and weight can become an issue.

**The lumped inductor approach was discarded for efficiency and weight considerations.**

# Loading the MOXON ctd.

**Linear loading** (making a folded back section) is somewhat mechanically complex and can add significantly to the wind loading.

**This method was also discarded.**

**Helically loading is very attractive for the MOXON design I had in mind.**
Helically loading is somewhat similar to lumped inductive loading but with the following advantages:

- Higher efficiency than a lumped inductor since the helix radiates in the “normal mode” and the lumped Inductor does not.
- Weight is distributed along a wider length along the element.
- In the case of my MOXON, the helically wound portion is about half way from the center of the element including the end wires between the elements. Efficiency is very good.

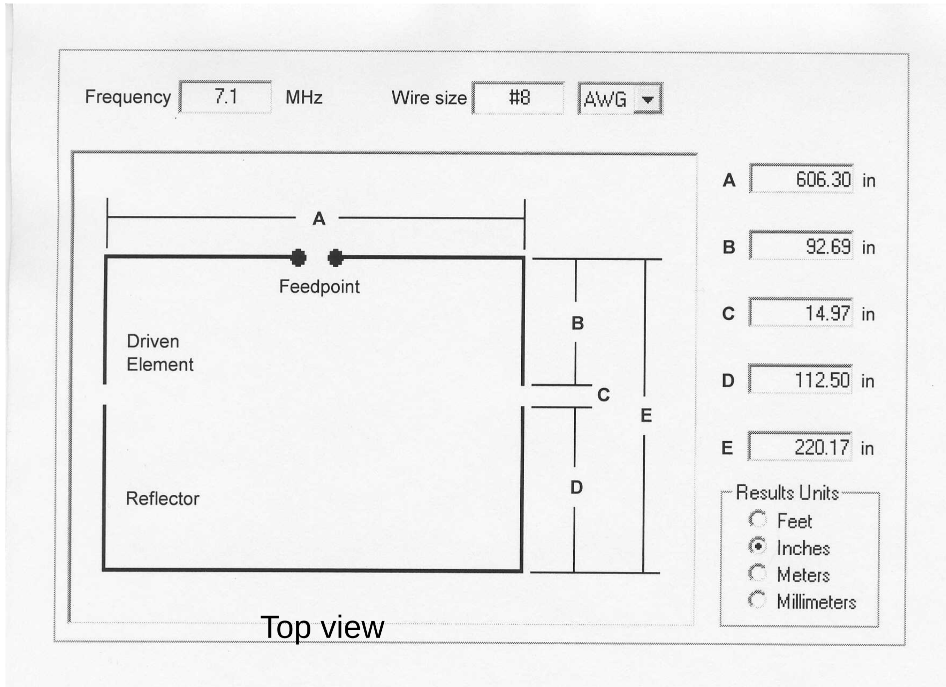
The only downside for some is that the helix must be wound on an insulator.
**This is an advantage for my design.**

**Helically loading a beam or vertical has been extensively discussed in the ARRL Handbook, Antenna Handbook, Moxon’s “HF Antennas For All Locations” for many, many years.**

**So let’s proceed to the Mini-MOXON project at W7XA**

# The MOXON

front




Top view

- The MOXGEN utility can calculate all wire or all tubing elements.
- A mix of wire and tubing needs to done somewhat experimentally.
- If tubes are used for element “A” length and wire for B & D, then use the wire dimensions for B & D and adjust “A” for resonance.

Dimension “C” is an insulator. I used Dacron (Phillistrand) cord.

This set of dimensions was made by the **MOXGEN** utility downloadable from the web at no cost

# The MOXON ctd.

I chose 13 ft CUBEX (cubical quad) fiberglass spreaders for the 4 pieces that make up the 2 elements

- I have lots of them
- They are strong and good insulators suitable for winding the helical loading.

I chose #8 Aluminum (electric fence) wire for the helically wound portion of the antenna and the side wires

- Light weight
- Large diameter wire means high surface area (lower RF losses)
- Easy to use
- Solderable with Aluminum brazing rod and a torch
- Low cost……….I purchased a mile of fence Aluminum fence wire for less than $150
- I have found the wire to be as reliable as copper in most antenna installations (including several Quads).

**How much wire to use for the Helix portion?**

Most of the previously mentioned literature suggests that about ½ wavelength of wire is needed for a ¼ Wavelength helix of the same resonance.

Considering the dimension “A” is 606 inches (50 ft), cut 4 pieces of wire about 70 feet long.

# Winding the elements

Starting at the thin end of the spreader, secure one end of the wire to the spreader with a small hose clamp.

**(This is the hardest part!).**

Wind about 180 turns of the wire around the fiberglass spaced about ½ inch turn to turn.  Secure the inside wire with another hose clamp.

The turns should be as tight as possible on the fiberglass!

The helix should take up about 7 ½  feet of the spreader length. Not critical!

Do not cut off the excess wire which should be about 8ft. or longer.

By now your forearms should resemble Popeye's!

Set the elements aside.

Now build the center boom to element support for the wrapped spreaders.

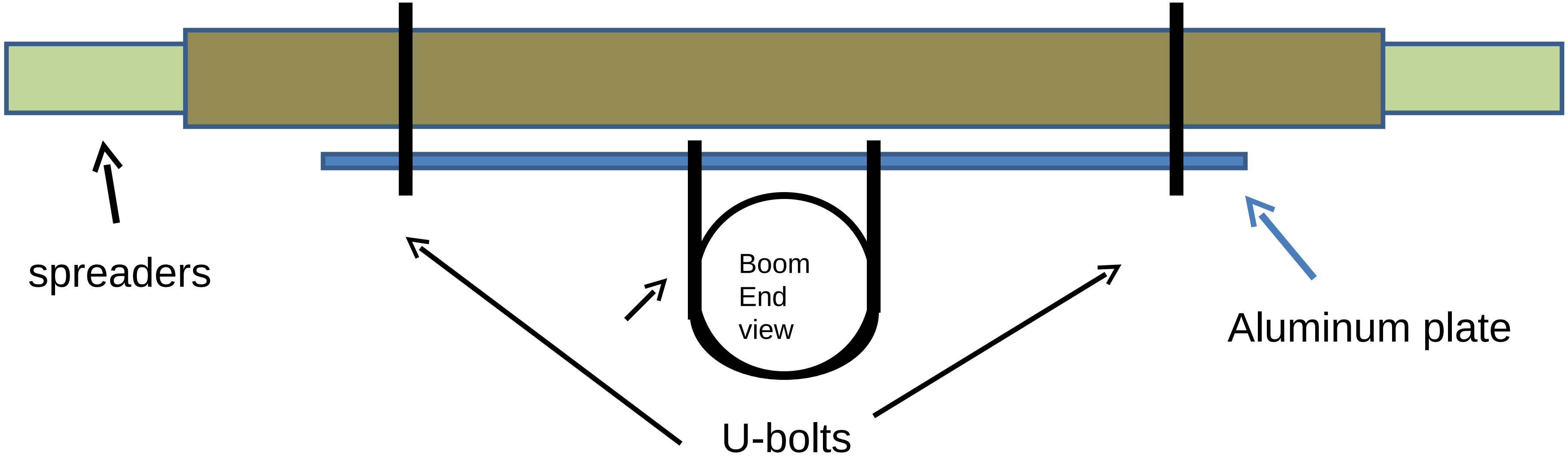
# Element to Boom Clamp

The Cubex quad spreaders are 1 ½ inch outside diameter.  Other spreaders or insulating support tubes may Be different.

Cut two 2 foot lengths of 1 ½ inch inside diameter tube.
- I used heavy wall fiberglass tube available from Max-Gain Systems (MGS-4U.com)
- Aluminum tube is OK too but heavier.

- You will need four 2 inch U-bolts with saddles for each assembly. Two for each element support tube and two for the boom clamp (assuming a 2 inch boom).

- You will need two Aluminum plates, 3 X 12 inches,  minimum 1/8 inch thickness (thicker is better up to ¼ inch).
- Push the spreaders  6 inches inside the support tube and use two self threading screws to secure the spreade



# Assemble the elements

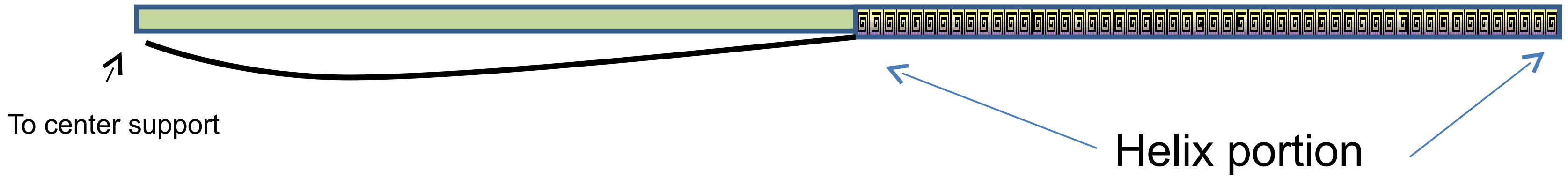
After the assembly of the spreaders to supports are completed do the following:

- Connect the inner wire lengths together
- Ideally raise the dipole to the top of a wooden stepladder as high as possible
- Check for resonance using a grid dipper.
- Adjust inner lengths for a resonance of about 9.75 MHz

- If using an antenna analyzer, do not connect the wires together to measure.

- Shorten the inner wires to get a 9.75 MHz resonance. You can either cut off wire (preferred) or wind some of the wire to increase the helix length.

Some playing around may be needed but in general, keep the wires to the center from the helix as long as possible. The wires can hang a little or be clamped to the spreader with another hose clamp.




Each spreader will look something like this

# Assembly

Now, cut the four wire side elements (B &D on the drawing on earlier slide)

- Cut the wires about 1 ft. longer than the B & D dimensions to allow for end loops
- Make a loop on one end of each wire


- Now, loosen the hose clamp on the end of the helix and wrap the non-loop end of the wires around the end of the helix in the opposite direction of the helical winding and tighten the hose clamp. The wire length from the end of the helix to the end of the loop should be precisely B or D.

- Final dimensions for B & D need to be fairly precisely measured!
- Mount the element assemblies on the boom, 18.3 feet apart.
- Cut two pieces of Dacron or Phillistrand cord to dimension C (plus about 1 foot).
    - This cord needs to be UV resistant!
- Tie to the ends of the wire so the final length of the cord is dimension C (precisely!)

# Tuning

This step is the most critical and needs to be done with patience

- Make sure that the B or D wires are both on the same elements respectively
- Raise the boom as high as possible above ground.
- On the reflector (the one with the D wires) connect the inner pigtail wires together
- On the driven element, make some kind of connection to a grid dipper or antenna analyzer
- Make sure that the pigtail lengths are the same from the helix to the center of the element!!!

- Measure for resonance (dip on the GDO or near 50 ohms and no reactance on the analyzer)

At this point you will see a dip or resonance well below 7 MHz.

Remember that the antenna resonant frequency will go up when the antenna is raised.
In my case, the resonance went up 200KHz or so when raising from 12 to 50 feet

Start trimming the inner wires to raise the resonant frequency **making sure that you cut all 4 wires by exactly the same amount.**

Trim for resonance of about 6.8 MHz and then hoist the antenna to some height and re-check the resonance and repeat .

Note: Should you get the resonance too high, the resonant frequency can most easily be lowered some by The addition of small spoke capacity hats on the ends of all the helical coils where the side wires are attached.

# First pass Moxon on the tower

# Closer view

# Mechanical Revisions

The first pass MOXON used 1/2 inch thin wall Aluminum tubes instead of wire for the sides of the elements

- Too heavy with lots of droop and the elements had to be supported with guys.
- Spacing between the ends had to be adjusted (different than the wire version)

A second version was tried with Aluminum wire running inside thin fiberglass tubes for the element sides

- Still too much droop although a bit lighter in weight

The third and final version went back to plain wires

- Lightest weight and some droop but did not pull the elements toward each other (much)
- Predictable results with the end spacing from MOXGEN.

I used a 1:1 BALUN feed. Maybe not needed but I like to use them for pattern balance and reduced potential reduced feedline radiation.

Initial performance with the MOXON at 50 feet high results were excellent ……..

note: No real way to measure forward gain but …..
Could work DX stations that could not be heard on the old R7 vertical

# Final installation

I wanted the MOXON to be part of a multiband array on the same boom.
1.MOXONs can be on the same boom as other band antennas

Because of the MOXON side wires, interlacing with yagi type arrays may be difficult unless the MOXON is significantly wider than the longest yagi element.

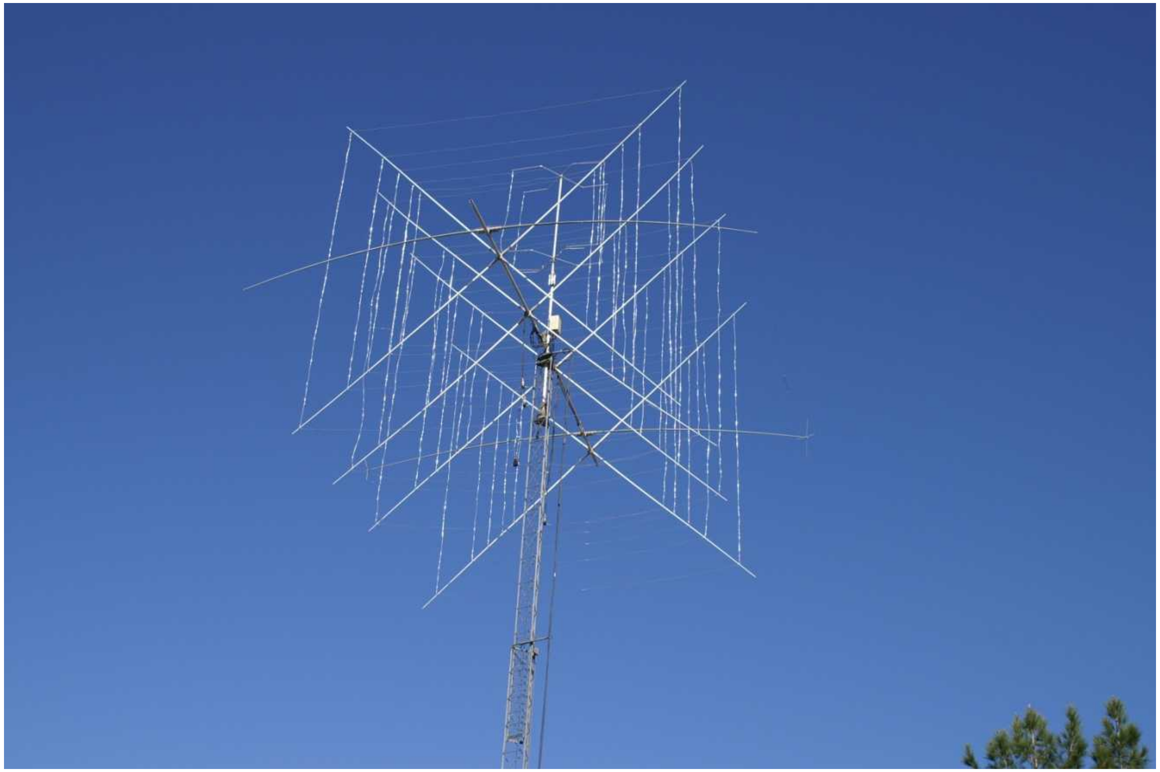
- Since my 40 meter Mini-MOXON is narrower than a 20 meter yagi , this is not really possible.

(I have used a 402BA on the same boom as a 5 el. 20 meter yagi with good results)

I have had long experience with cubical quads and had everything I needed to build one,so this was the obvious choice for interlacing with the Mini-MOXON.

The MOXON was interlaced with a multi-element quad with no obvious change from the initial performance

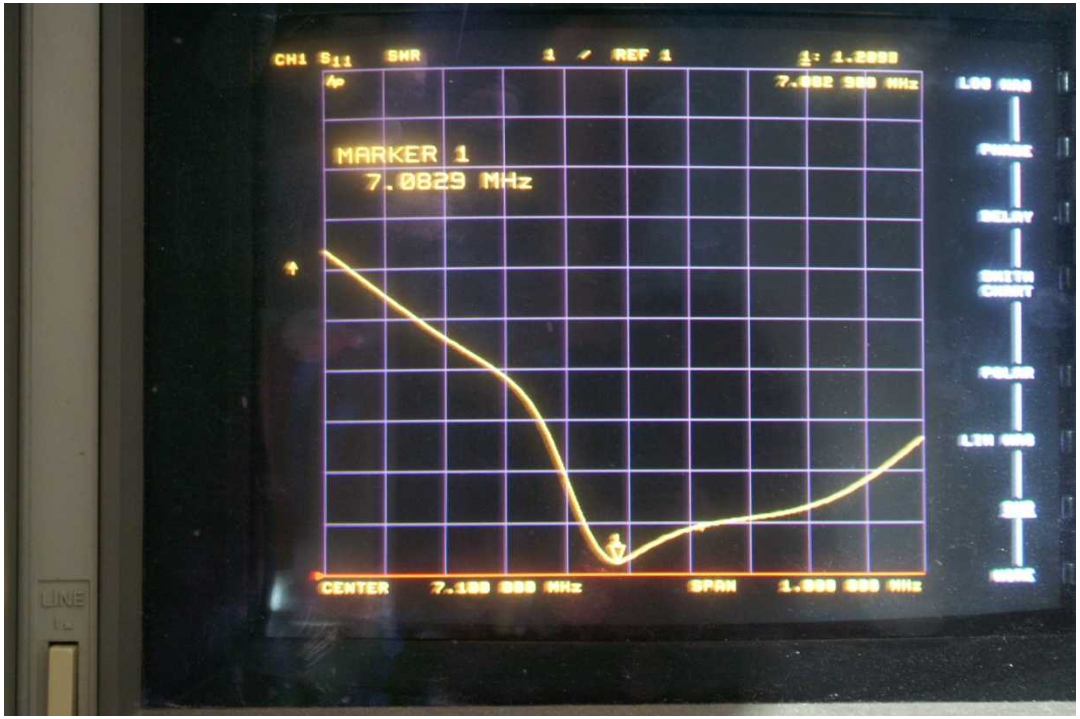
# Final Installation



40 meter Mini-MOXON, 1 el 30 mtr  hat loaded loop, 3 el 20, 17, 15M,  4 el 12 and 10 meters.
(the little antenna on top is a HB9CV quad for 6M)

# SWR bandwidth

(Mounted 55 ft high  and interlaced with the multi-element quad)

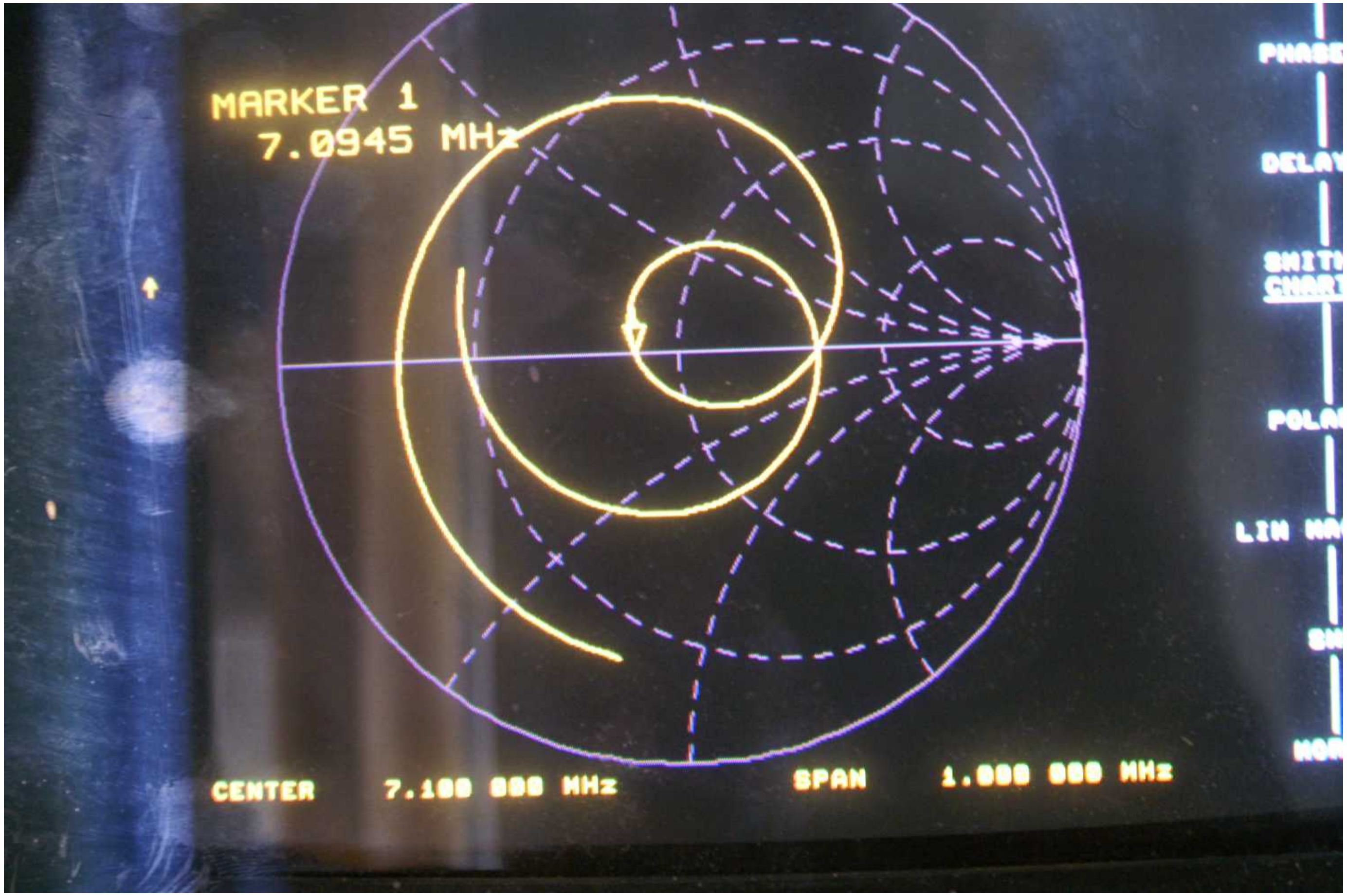



HP 8753 network analyzer display

✓ Bandwidth  200KHz  (2:1 SWR)

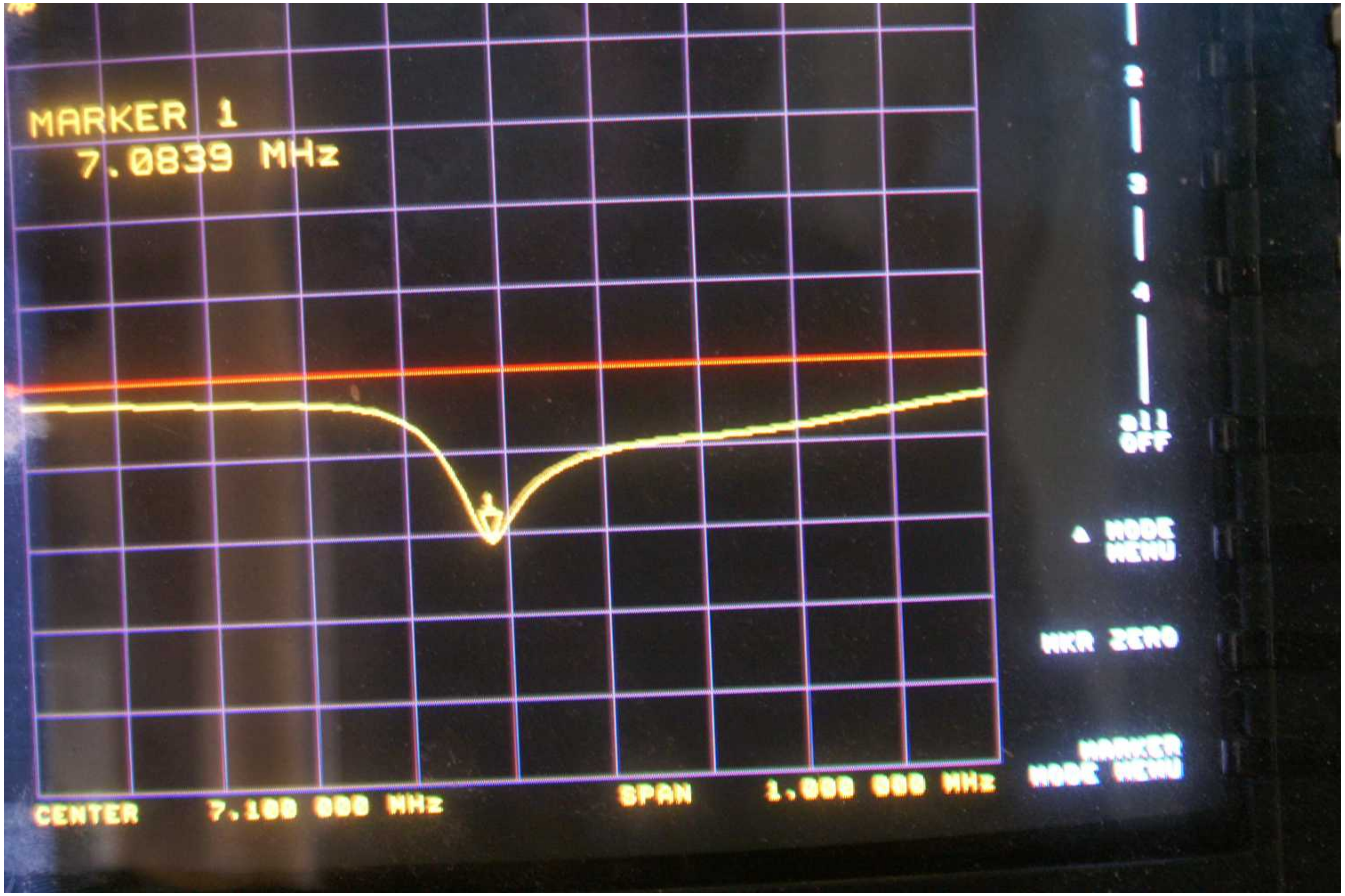
(Measurements taken at the end of about 150 feet of RG213 cable)

# Smith Chart Plot




✓Impedance at resonance 41 ohms resistive

# $S_{11}$ (21 dB)


MARKER 1
7.0839 MHz
all OFF
MKR ZERO
CENTER 7.100 000 MHz
SPAN 1.000 000 MHz

# Results

Some additional 'tweaking' can be and should be done to:
1. Raise the feedpoint impedance to 50 ohm
2. Increase the bandwidth a bit
3. Lower the resonant frequency

However, not being a purist, the measurement results are quite satisfactory

**On the air performance is the true test of any antenna!**
(using a L4B Amplifier at 800 Watts output)

140 countries worked on 40M from Jan. 1 to Mar. 8, 2010 on CW and SSB

The mini-MOXON seems to be very competitive with other locals

# Design goal versus Results

- Some forward gain…I can't directly measure but probably around 4 to 5 dBi
- Good directivity (high F/B and F/S ratios) …..~20dB F/B, ~25dB F/S*
- Relatively small size………26 ft wingspan, 18.3 ft. boom length
- Good Bandwidth (min. 200KHz @ <2:1 SWR) …………200KHz
- Light weight………..about 12 pounds (plus the weight of the boom)
- Easy construction and tuning ……construction easy, tuning took a while and needs more work!
- Low cost……My cost near zero. New parts (spreaders and wire) ~$250

* F/B and F/S measurement estimates taken from listening to DX stations.
* Close in (local) measurements show almost no directivity.