Building Cheap Homemade Mesh Antennas

Revised 5/04/2015

Connector Basics

- Different Type N Connectors

- TNC Connectors

- Reverse TNC Connectors

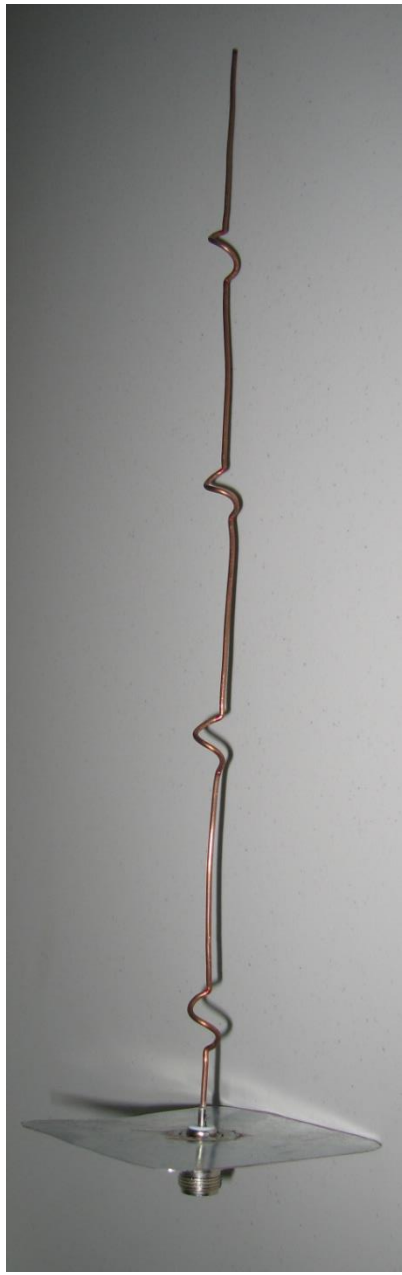
Connector used on WRT54x Routers

Good Measuring Tools

Omni directional Antenna

Collinear antenna

- Gain derived by narrowing vertical beam width
- Difficult to control where the peak in the vertical beam occurs
- It's my belief that directional lead to better operational parameters

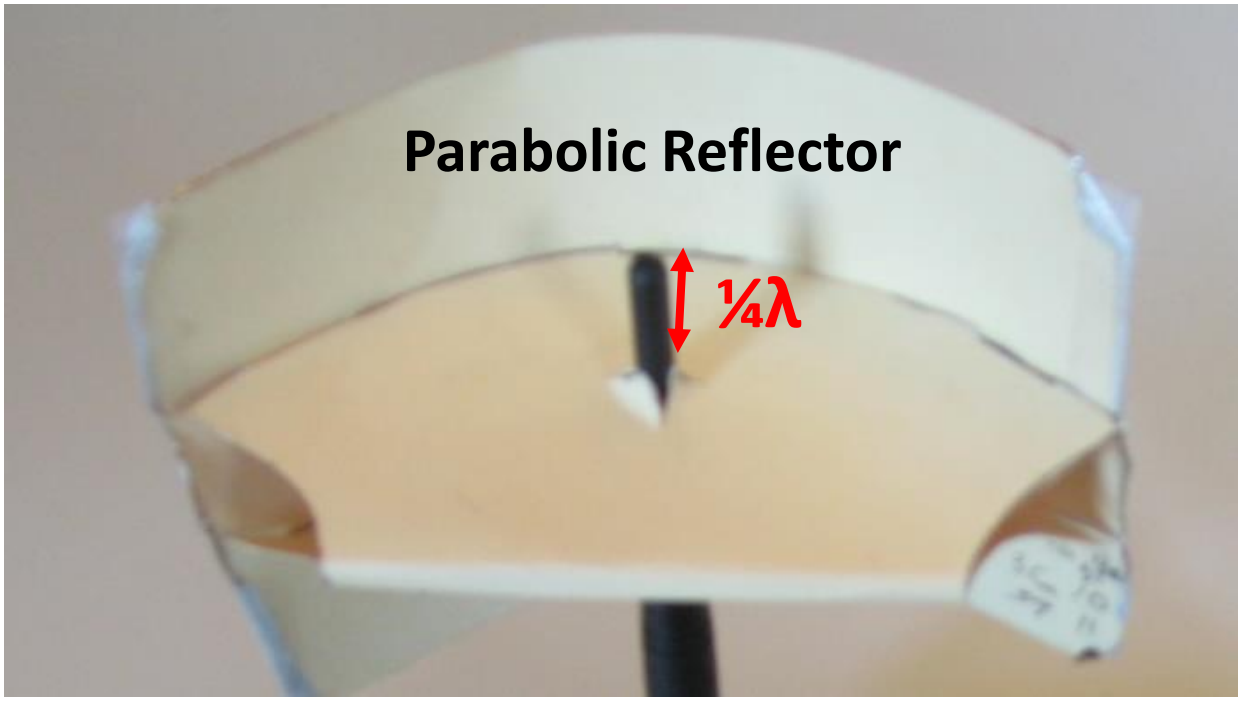


So on to some directional antennas!

The Cheapest of the Cheap

Good for ≈ 3 dB over the router dipole and about 10 dB front to back discrimination

The Cheapest of the Cheap



Cost

- Some light duty cardboard (I used a file folder)
- 1 Square Foot of aluminum wrapping foil

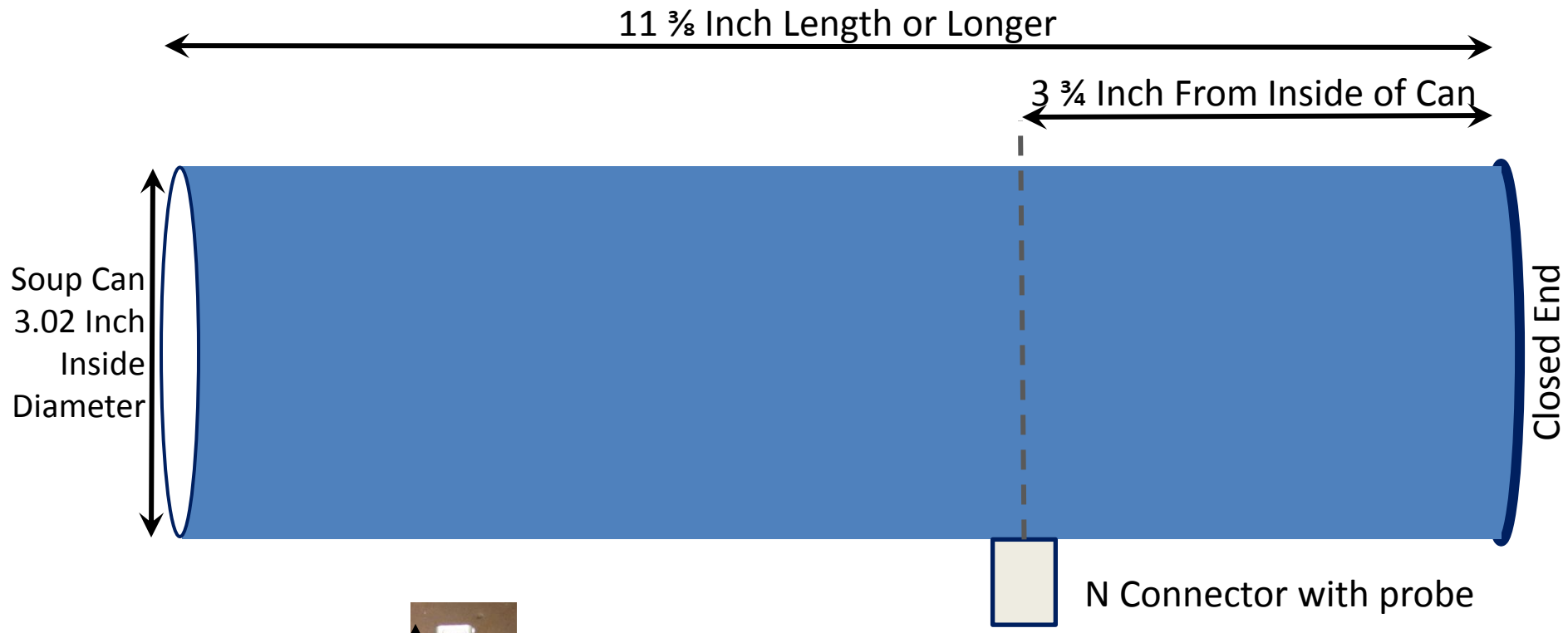
= Pennies worth of house hold items

HSMM Soup Can Antenna

Based on QEX article "High Speed Multi-Media 2 GHz Horn"

- Per article the minimum practical diameter and length for a circular horn with optimal gain and radiation pattern is 3 inches in diameter and just over 12 inches in length.
- The article down-plays tin cans, but I found that they work just fine, maybe ½ dB down from a expensive hard to find copper tube.

HSMM Soup Can Gain Antenna



HSMM Soup Can Antenna

Found Campbell's **CHUNKY** soup cans to have 3.02" ID

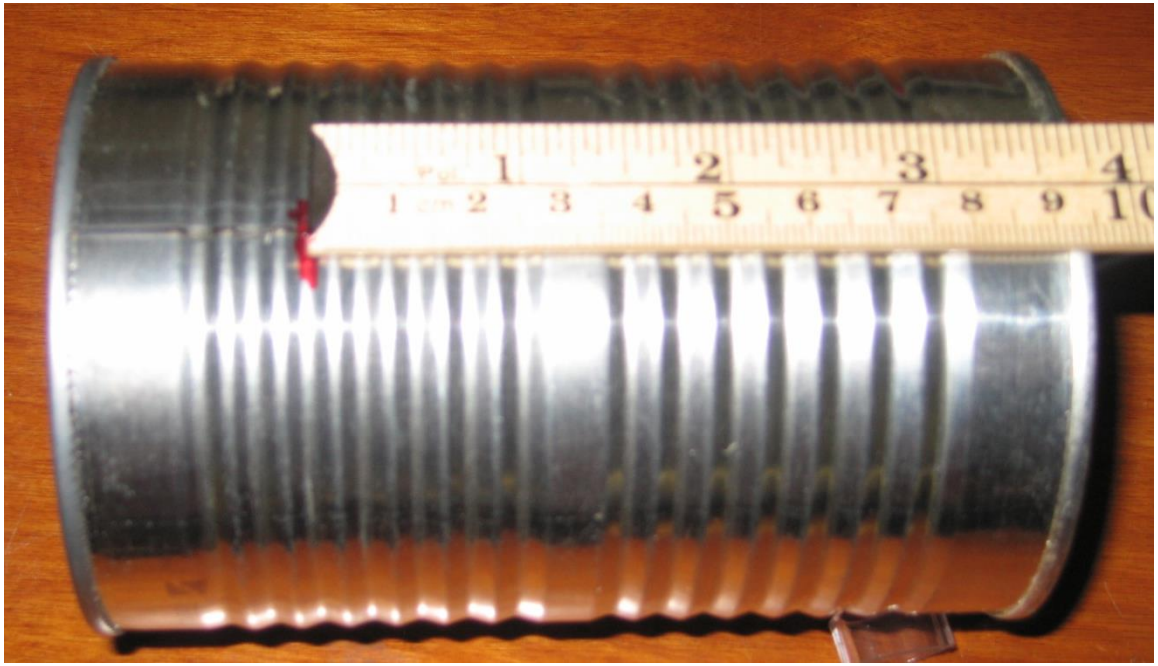
HSMM Soup Can Antenna

Preparing Cans

HSMM Soup Can Gain Antenna

HSMM Soup Can Gain Antenna

Drill Hole 3 ¾ Inches from Closed End



HSMM Soup Can Gain Antenna

Solder "N" connector with ¼ λ probe into hole

Spade lug added to top of probe to improve return loss per article

HSMM Soup Can Gain Antenna

Add a Reverse TNC to N Cable

OR

Reverse TNC to N Adapter

And some type of stand

HSMM Soup Can Gain Antenna

Gain has been measured to be 8 to 9 dBi
6 or 7 dB better than router dipole
Front to Back Ratio ≈15 dB

Cost

- Can's from the recycling trash
- Solder (1/10,000th of a roll) Pennies
- Type "N" connector (Junk box or $4.95 from equipment supplier)
- Reverse TNC to Type "N" adapter For WRT54x routers, not required for Ubiquity Routers ($5.95)

= Total $5 to $11

More GAIN

More GAIN

More GAIN

Add Funnel ?

HSMM Soup Can Gain Antenna

- A circular funnel made out of sheet metal was added to the recommended length of cans for more gain per the article.

HSMM Soup Can Gain Antenna

- A circular funnel made out of sheet metal was added to the recommended length of cans for more gain per the article.
- Cans where then sprayed with rust proof paint and a clear window added to the front.
- Suitable mount made out of PVC pipe was added so the antenna could be placed on top of a portable tower.

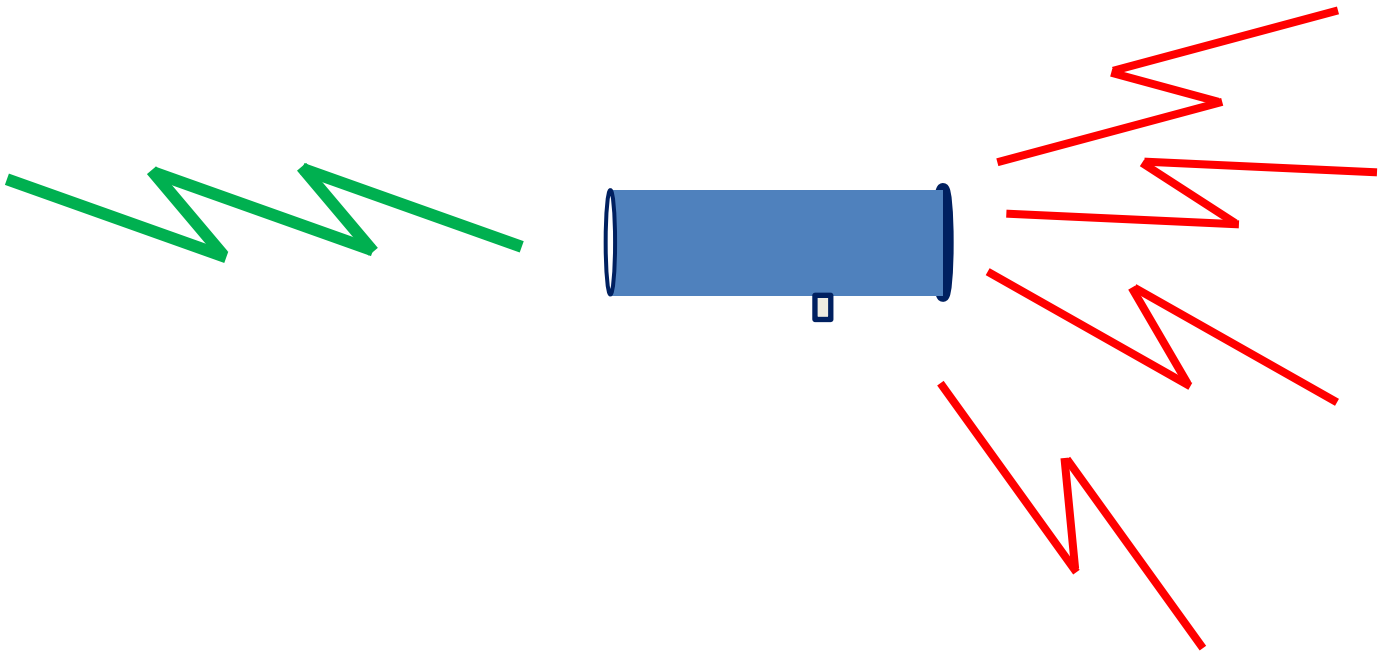
HSMM Soup Can Gain Antenna

Gain has been measured at 11 to 12 dBi with better than 20 dB front to back ratio.
≈ 10 dB better gain than router dipole

HSMM Soup Can Gain Antenna

- Why is Front to Back Ratio Needed?

We need to Maximize Signal to Interference Ratio



HSMM Soup Can Gain Antenna in Action

Cost

- Can's from the recycling trash cost $0.00
- Solder (≈1/10,000th of a roll) Pennies
- Type "N" connector (Junk box or $4.95 from equipment supplier)
- Sheet metal from Rectangular Heating Duct $3.49 but good of several antennas

= Total Under $10.00 or $1/dB

Let's Look Some More at Can Antennas

Calculations From QEX Article

Cylinder Diameter Determines the Lowest Propagation Mode

Lowest Frequency Supported – λ_L = **1.706 * Inside Diameter**

A Cylinder will support several Propagation Modes at different frequencies

Next Mode Supported – λ_H = **1.3065 * Inside Diameter**

Frequency in GHz = 300/λ(**mm**)

“S” Band Frequency Range 2.35 to 2.55 GHz for Channel 1

Diameter Range 3 to 3.7 Inches

Calculations From QEX Article

Inside a cylinder the radio wave travel much slower that the speed of light so a wavelength is much longer

$$Lg\ (\text{Inside WG}) = \frac{1}{\sqrt{\left[\frac{1}{\lambda}\right]^2 - \left[\frac{1}{\lambda c}\right]^2}}$$

Cylinder Length = 0.75 * Lg

Probe Location= 0.25 * Lg

A table using these formulas will make things easier

HSMM Soup Can Gain Antenna

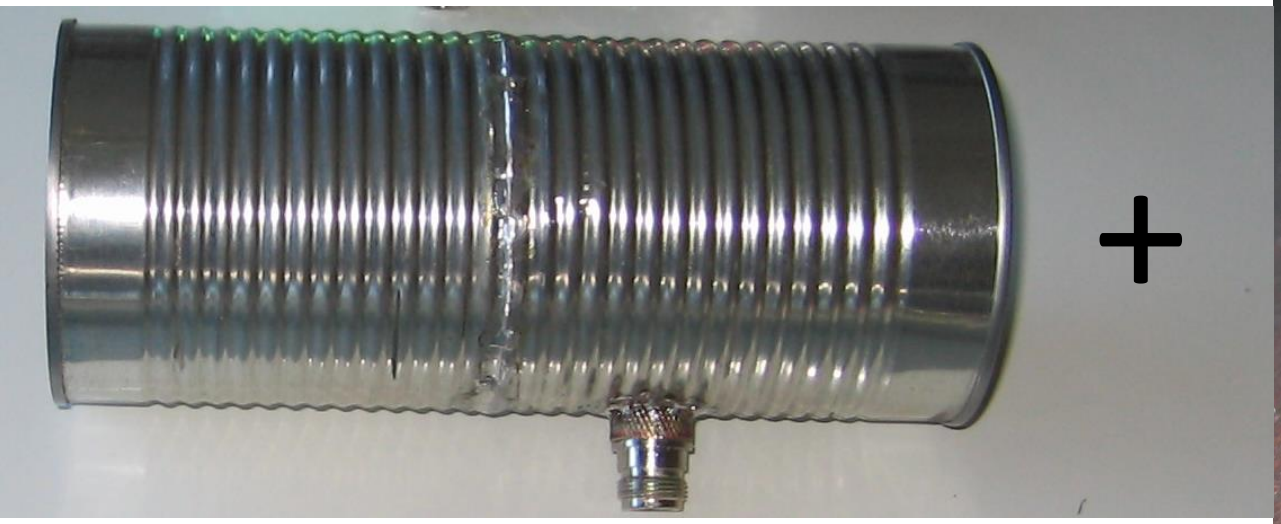
Center Frequency = 2.412 GHz

Can Size Inch	mm	Low Cutoff GHz	High Cutoff GHz	LG mm	0.25 LG mm	0.25 LG Inch	0.75 LG mm	0.75 LG Inch
2.90	74	2.387	3.117	872	218	8.58	654	25.74
3.00	76	2.308	3.013	428	107	4.21	321	12.63
3.05	77	2.270	2.964	368	92	3.62	276	10.86
3.10	79	2.233	2.916	329	82	3.24	247	9.72
3.20	81	2.164	2.825	281	70	2.77	211	8.31
3.25	83	2.130	2.782	265	66	2.61	199	7.83
3.30	84	2.098	2.739	252	63	2.48	189	7.44
3.40	86	2.036	2.659	232	58	2.28	174	6.85
3.50	89	1.978	2.583	217	54	2.14	163	6.42
3.60	91	1.923	2.511	206	52	2.03	155	6.08
3.65	93	1.897	2.477	201	50	1.98	151	5.95
3.70	94	1.871	2.443	197	49	1.94	148	5.82
3.75	95	1.846	2.411	193	48	1.90	145	5.71

HSMM Sauce Can Gain Antenna

HSMM Sauce Can Gain Antenna

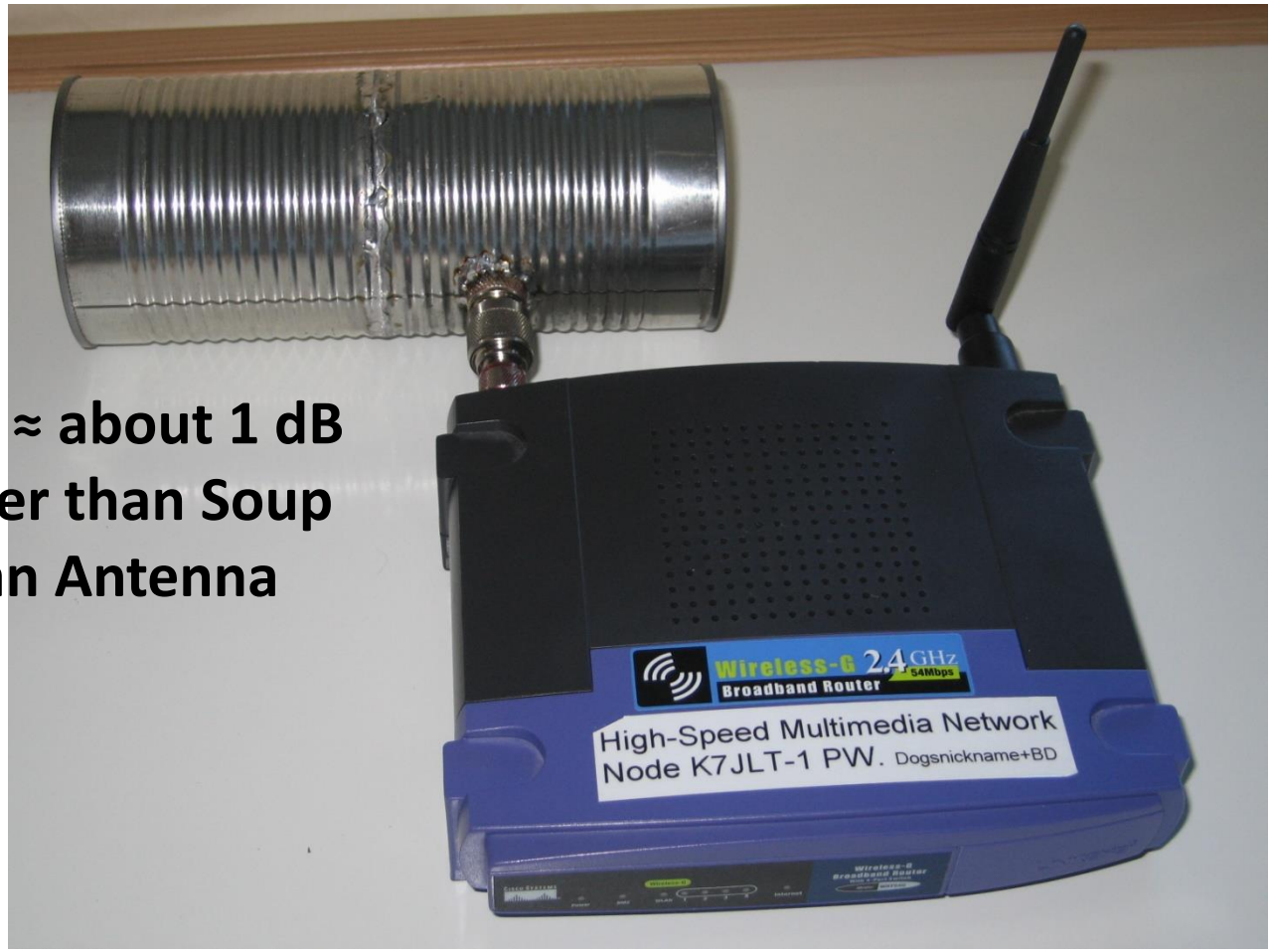
HSMM Sauce Can Gain Antenna



+

HSMM Sauce Can Gain Antenna

Gain ≈ about 1 dB better than Soup Can Antenna



Antenna Polarization ?

HSMM Bottle Gain Antenna

Center Frequency = 2.412 GHz

Can Size Inch	mm	Low Cutoff GHz	High Cutoff GHz	LG mm	0.25 LG mm	0.25 LG Inch	0.75 LG mm	0.75 LG Inch
2.90	74	2.387	3.117	872	218	8.58	**654**	**25.74**
3.00	**76**	**2.308**	**3.013**	**428**	**107**	**4.21**	**321**	**12.63**
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3.10	**79**	**2.233**	**2.916**	**329**	**82**	**3.24**	**247**	**9.72**
3.20	**81**	**2.164**	**2.825**	**281**	**70**	**2.77**	**211**	**8.31**
3.25	**83**	**2.130**	**2.782**	**265**	**66**	**2.61**	**199**	**7.83**
3.30	**84**	**2.098**	**2.739**	**252**	**63**	**2.48**	**189**	**7.44**
3.40	**86**	**2.036**	**2.659**	**232**	**58**	**2.28**	**174**	**6.85**
3.50	**89**	**1.978**	**2.583**	**217**	**54**	**2.14**	**163**	**6.42**
3.60	**91**	**1.923**	**2.511**	**206**	**52**	**2.03**	**155**	**6.08**
3.65	**93**	**1.897**	**2.477**	**201**	**50**	**1.98**	**151**	**5.95**
3.70	**94**	**1.871**	**2.443**	**197**	**49**	**1.94**	**148**	**5.82**
3.75	95	1.846	2.411	193	48	1.90	145	5.71

HSMM Pop Bottle Gain Antenna

HSMM Pop Bottle Gain Antenna

HSMM Circular WG Gain Antennas

3.5” Dia.

3.25” Dia.

3” Dia.

- As Diameter Increases the critical 75% length decreases as shown in this picture.
- WHY? **The wave is traveling faster!**

HSMM Soup Can Gain Antenna

Center Frequency = 2.412 GHz

Can Size Inch	mm	Low Cutoff GHz	High Cutoff GHz	LG mm	0.25 LG mm	0.25 LG Inch	0.75 LG mm	0.75 LG Inch
2.90	74	2.387	3.117	872	218	8.58	**654**	**25.74**
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3.75	95	1.846	2.411	193	48	1.90	145	5.71

HSMM Antenna
With Largest Possible Gain

- Find a can that must have a 3.65 to 3.7 inch inside diameter
- If size is larger that 3.75”, a multi-mode condition exists
- Must be at least 6 Inches long
- Can’t find any cans that met the criteria? So you will need to make one

HSMM Gain Antenna

- As the diameter increases multiple waves traveling in different modes of propagation occur.
- What happens when we get the faster wave and a slower wave of the same signal traveling together?
- **They add and subtract from each other!**

HSMM Large Can Gain Antenna

- Lets increase the inside can diameter to 3.95” and see what happens when we look at the antenna patterns after this presentation.

More GAIN

More GAIN

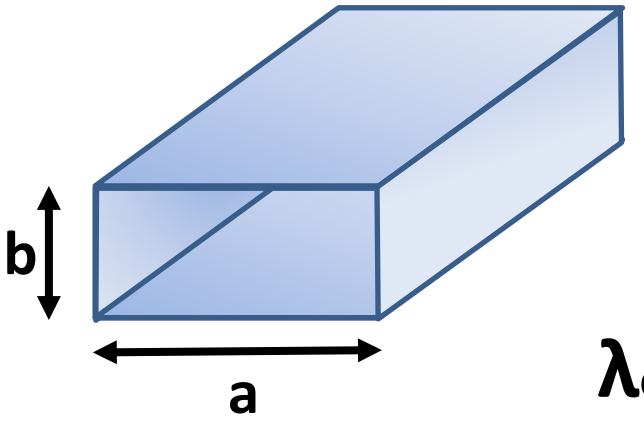
More GAIN

Rectangular Can ?

HSMM Rectangular Gain Antenna

- Rectangular Waveguide theory is used to derive the dimensions in a manor similar to using circular waveguide theory for the previous horns.
- Rectangular cans of the correct size are hard to find.

Rectangular Waveguide Calculations



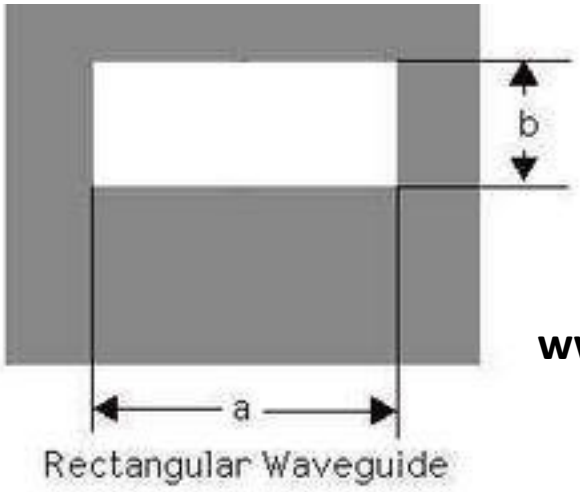
$$\lambda_c = \frac{2}{\sqrt{\left[\frac{m}{a}\right]^2 + \left[\frac{n}{b}\right]^2}}$$

Frequency in GHz = 300/λ(mm)

HSMM Rectangular Gain Antenna

Net Weight 32 oz
Size Inside – 98 mm Wide, 64 mm Tall

HSMM Tetra Brik Antenna



Input

a:	98	mm
b:	64	mm

Perform Calculation

www.learningmeasure.com/cgi-bin/calculators/rectwgm.pl

Cutoff Frequencies in GHz for m,n Mode

	n=0	n=1	n=2	n=3	n=4	n=5
m=0		2.342128578125	4.68425715625	7.026385734375	9.3685143125	11.710642890625
m=1	1.52955335714286	2.79733797543608	4.92765649961788	7.19094082582909	9.49255465593242	11.8101096685887
m=2	3.05910671428571	3.85275228451788	5.59467595087216	7.66343463321874	9.85531299923576	12.1036065204192
m=3	4.58866007142857	5.15183147313581	6.55729108374809	8.39201392630824	10.4319155323766	12.5775577185266
m=4	6.11821342857143	6.55119087143869	7.70550456903577	9.31679301292995	11.1893519017443	13.2125581349449
m=5	7.64776678571428	7.9983687765159	8.96831098449167	10.3854914807583	12.0936924564912	13.9866898771804

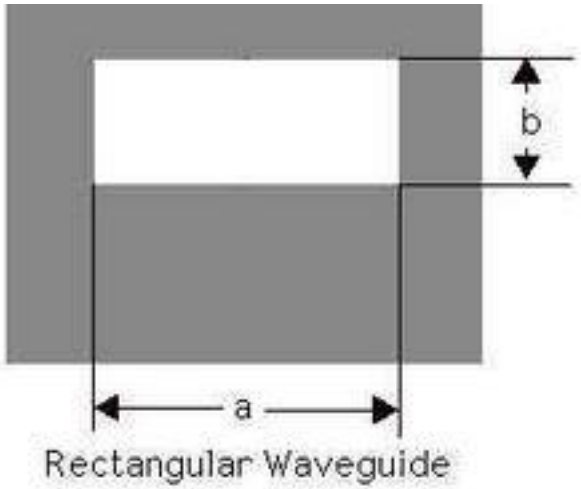
HSMM Tetra Brik Antenna

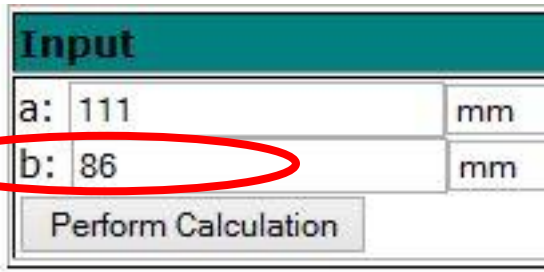
- A reference for this antenna is included in the appendix
- I found it not very sturdy
- Per the chart it is not the correct size for single mode operation
- Could never get the smell out of the container

Rectangular Aluminum Can Gain Antenna

- Went looking and found a discarded Aluminum outdoor electronics container.

Rectangular Aluminum Can Gain Antenna





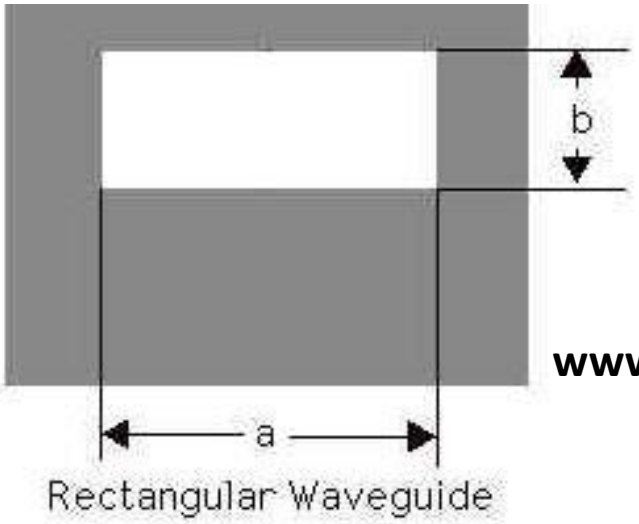
www.learningmeasure.com/cgi-bin/calculators/rectwgm.pl

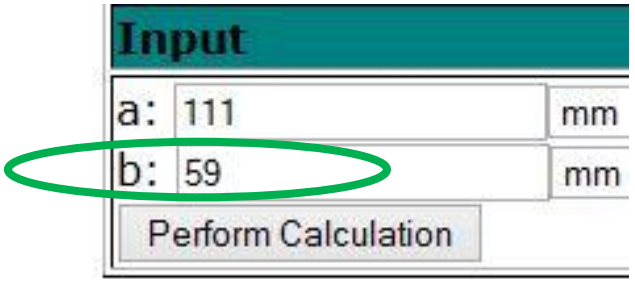
Will Propagate 3 different modes!

Cutoff Frequencies in GHz for m,n Mode

	n=0	n=1	n=2	n=3	n=4	n=5
m=0		1.74297940697674	3.48595881395349	5.22893822093023	6.97191762790698	8.71489703488372
m=1	1.35041647747748	2.20490405137903	3.73838648553392	5.40050178973655	7.10149703041286	8.81890327599003
m=2	2.70083295495496	3.21441687771137	4.40980810275807	5.88526070525986	7.47677297106785	9.12381109949103
m=3	4.05124943243243	4.41028334429083	5.34457957339622	6.6147121541371	8.06351395944126	9.61051779522879
m=4	5.40166590990991	5.6759115404865	6.42883375542274	7.51796445326711	8.81961620551614	10.2531665806671
m=5	6.75208238738739	6.97342052218364	7.59885026952413	8.54004751066245	9.70557839473707	11.0245202568952

Rectangular Aluminum Can Gain Antenna





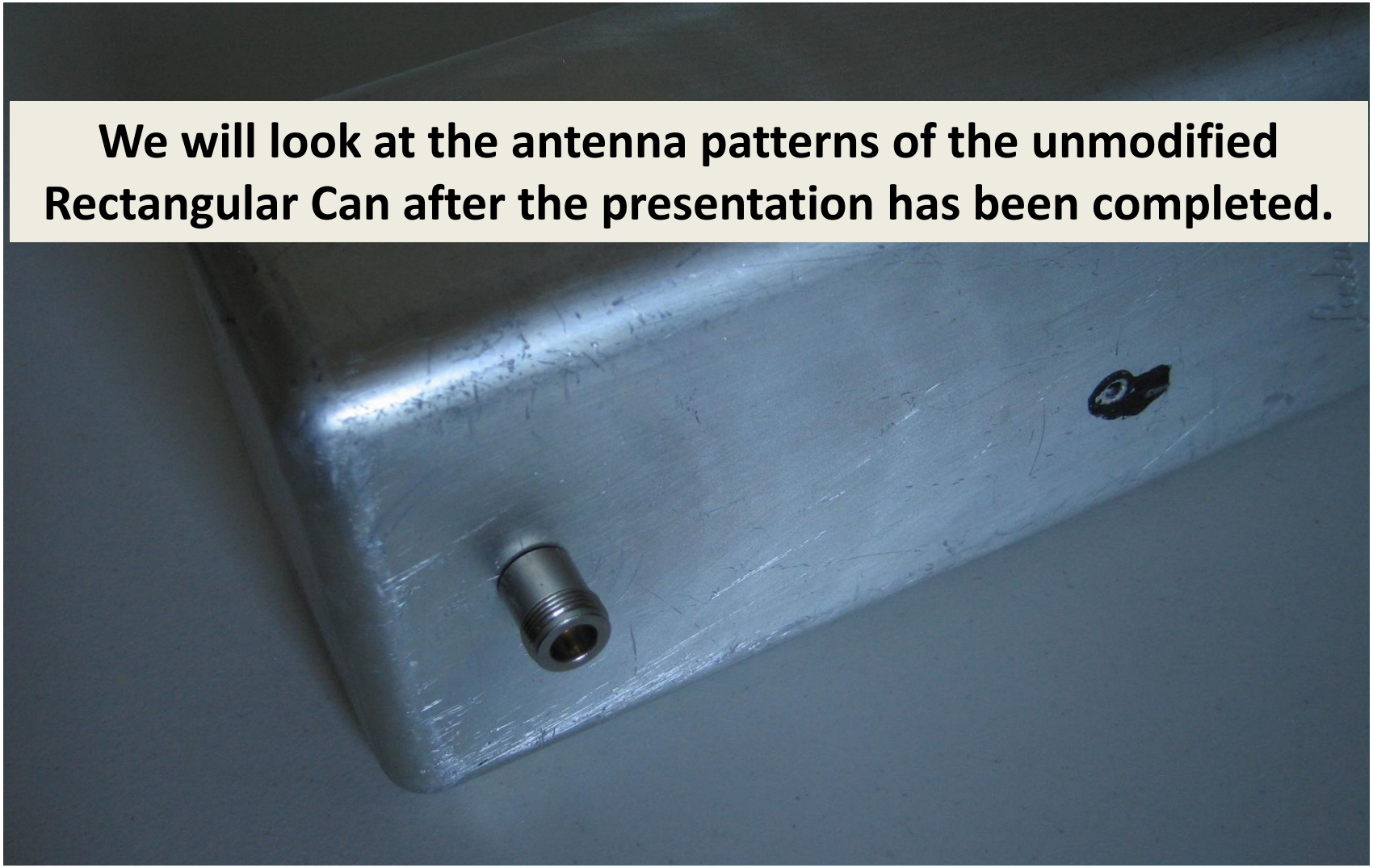
www.learningmeasure.com/cgi-bin/calculators/rectwgm.pl

Cutoff Frequencies in GHz for m,n Mode

	n=0	n=1	n=2	n=3	n=4	n=5
m=0		2.540614[illegible]084746	5.08122810169492	7.62184215254237	10.1624562033898	12.7030702542373
m=1	1.35041647747748	2.87721122234816	5.25761387742546	7.74054923509401	10.2517871977748	12.7746474920732
m=2	2.70083295495496	3.70799385192778	5.75442244469632	8.08622139499299	10.5152277548509	12.9870124560909
m=3	4.05124943243243	4.78198094090175	6.49857684306635	8.63163366704448	10.9402074043229	13.3334397605371
m=4	5.40166590990991	5.96931439594585	7.41598770385557	9.34186664433584	11.5088448893926	13.8038396283922
m=5	6.75208238738739	7.21424537435694	8.45041392995166	10.182489595592	12.2010709633164	14.3860561117408

OK

Rectangular Aluminum Can Gain Antenna



More GAIN

More GAIN

More GAIN

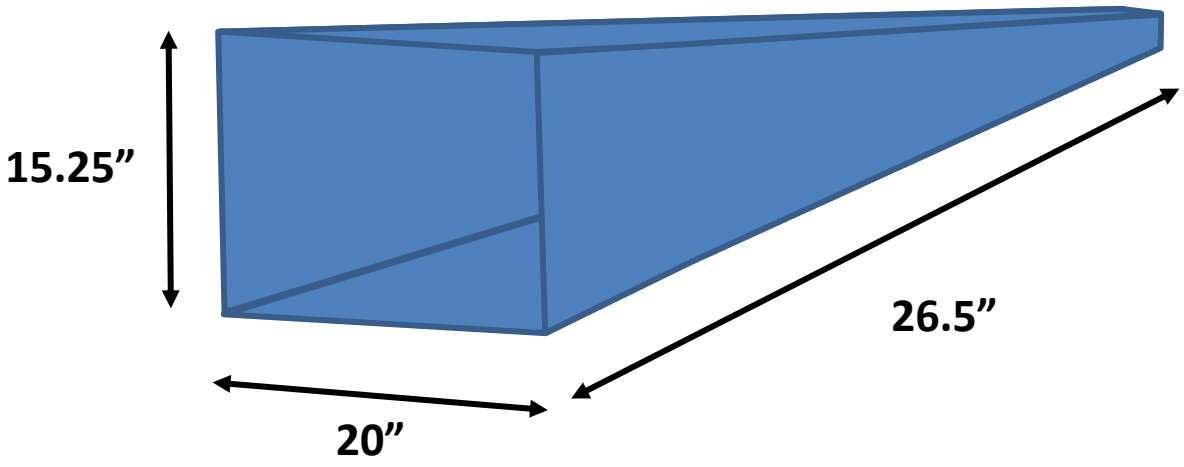
Bigger Horn ?

HSMM Cardboard Gain Antenna

- This is an adaptation of a S-Band Satellite Antenna for HSMM
- Measured Gain is about 20 dBi
- Based on a 2002 article by Anthony Monteiro AA2TX that also appears in the ARRL Satellite Handbook
- Article gives good assembly instructions except for the feed instructions presented here

HSMM Cardboard Gain Antenna

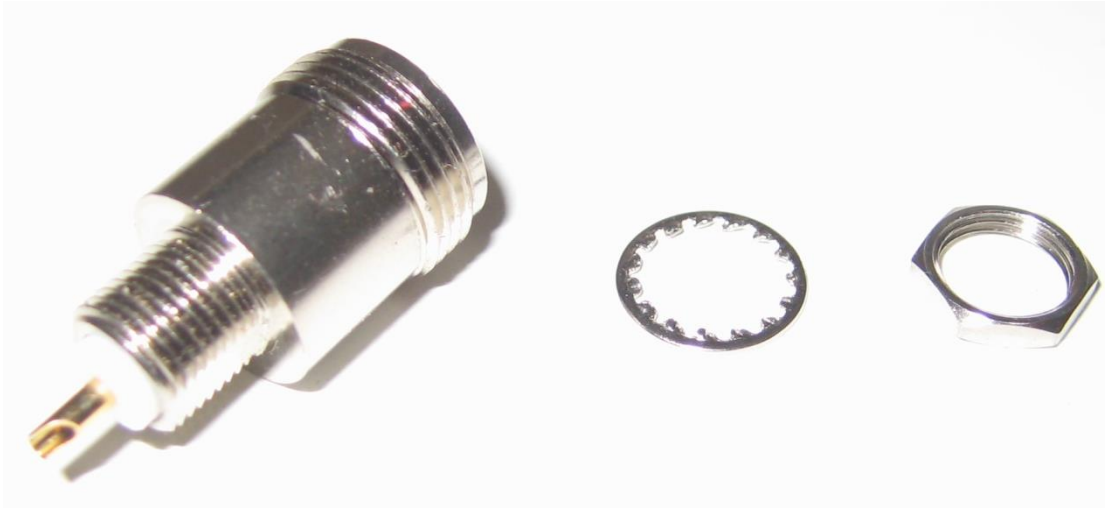
Basic Pyramidal Horn



HSMM Cardboard Gain Antenna

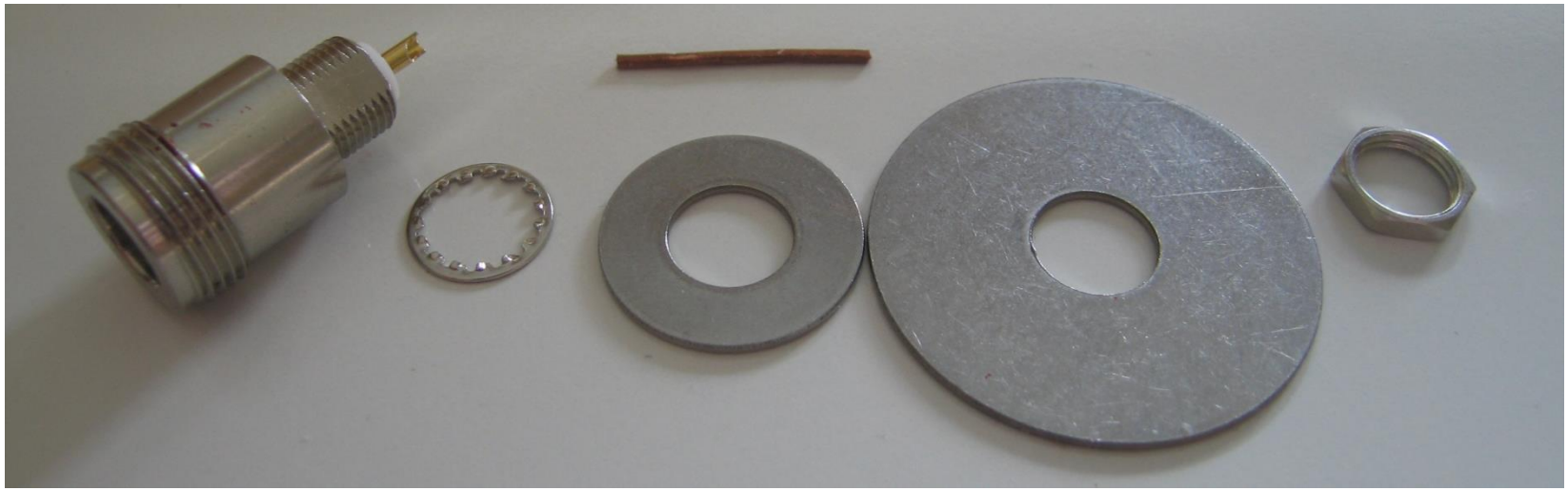
HSMM Cardboard Gain Antenna

- Feed Details
- Uses a “N” connector like this



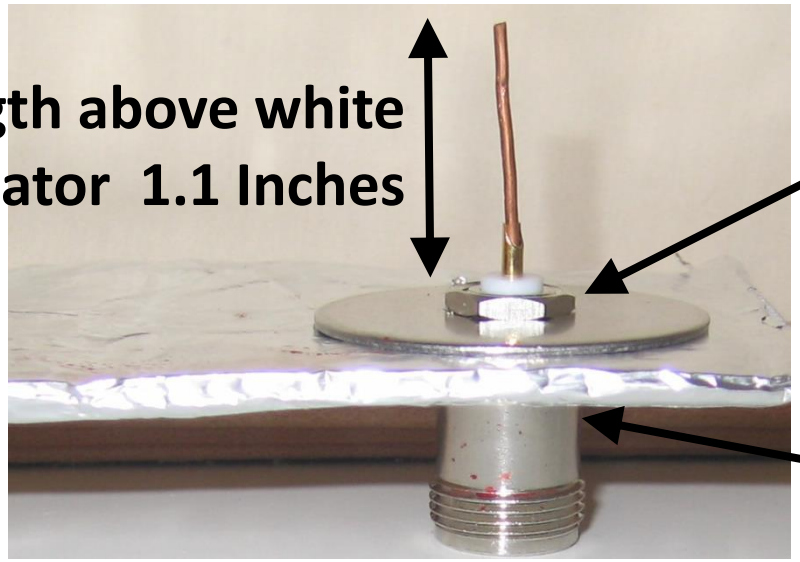
HSMM Cardboard Gain Antenna

- Feed Details
- Uses a “N” connector like this
- Add small & large washer plus copper wire



HSMM Cardboard Gain Antenna

- Feed Details
- Uses a “N” connector like this
- Add small & large washer plus copper wire
- Added to cardboard horn as shown below <u>before assembling horn sides</u>



HSMM Cardboard Gain Antenna

The Problem with a lot of GAIN

WRT54G with Vertical Dipole

Sig	Chan	Enc	SSID
-34	1		BroadbandHamnet-20-v3
-77	6	*	brad_bros
-78	11		xfinitywifi
-78	11	*	HOME-B5A2
-80	1	*	CenturyLink3173
-80	2	*	CenturyLink3892
-82	4	*	3MONKEYSONTHEBEACH

Ubiquity Bullet with 20 dB Horn

Sig	Chan	Enc	SSID
-39	1		
-61	6		
-69	6		
-69	6		
-71	6		
-72	6		
-79	1		
-80	1		
-80	1		
-84	1		
-84	1		
-84	6		
-85	2	*	CenturyLink3892
-86	11		
-86	11		
-86	1		
-87	11		
-87	1		
-88	11		
-88	1		
-88	1		
-88	1		
-88	6		
-89	1		
-89	1		
-89	1	*	HOME-9F0E
-89	1	*	unknown
-90	1	*	HOME-3A0C
-90	1	*	unknown
-90	6	*	protect this house
-91	1		xfinitywifi
-91	1	*	SANDMAN450R
-91	1	*	unknown
-91	1	*	unknown
-92	1	*	CTR500-537
-92	1	*	Divemaster2_EXT
-92	2	*	3MONKEYSONTHEBE
-95	1	*	HOME-D5EF

1 Router on Channel #1 & 1 Router on Channel #2

23 Routers on Channel #1 & 2 on Channel #2

Ubiquity Bullet ≈ 8 dB better receiver & 10 dB higher output transmitter

Let’s Make it cheaper

- For a WRT54x router, can we eliminate the type “N” connector and the reverse TNC adapter?

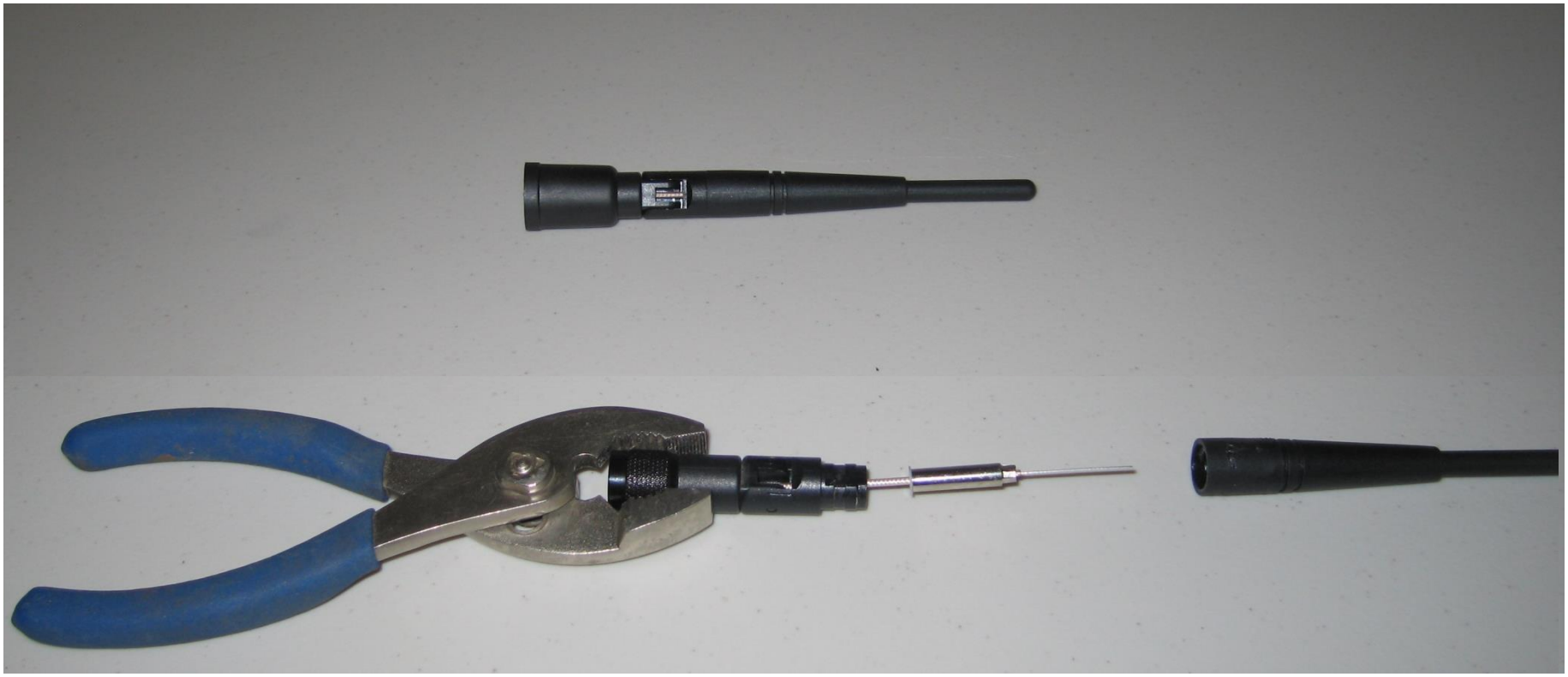
Eliminating the Type “N” connector & adapter

I don’t know if this will work for all WRT54x antennas.

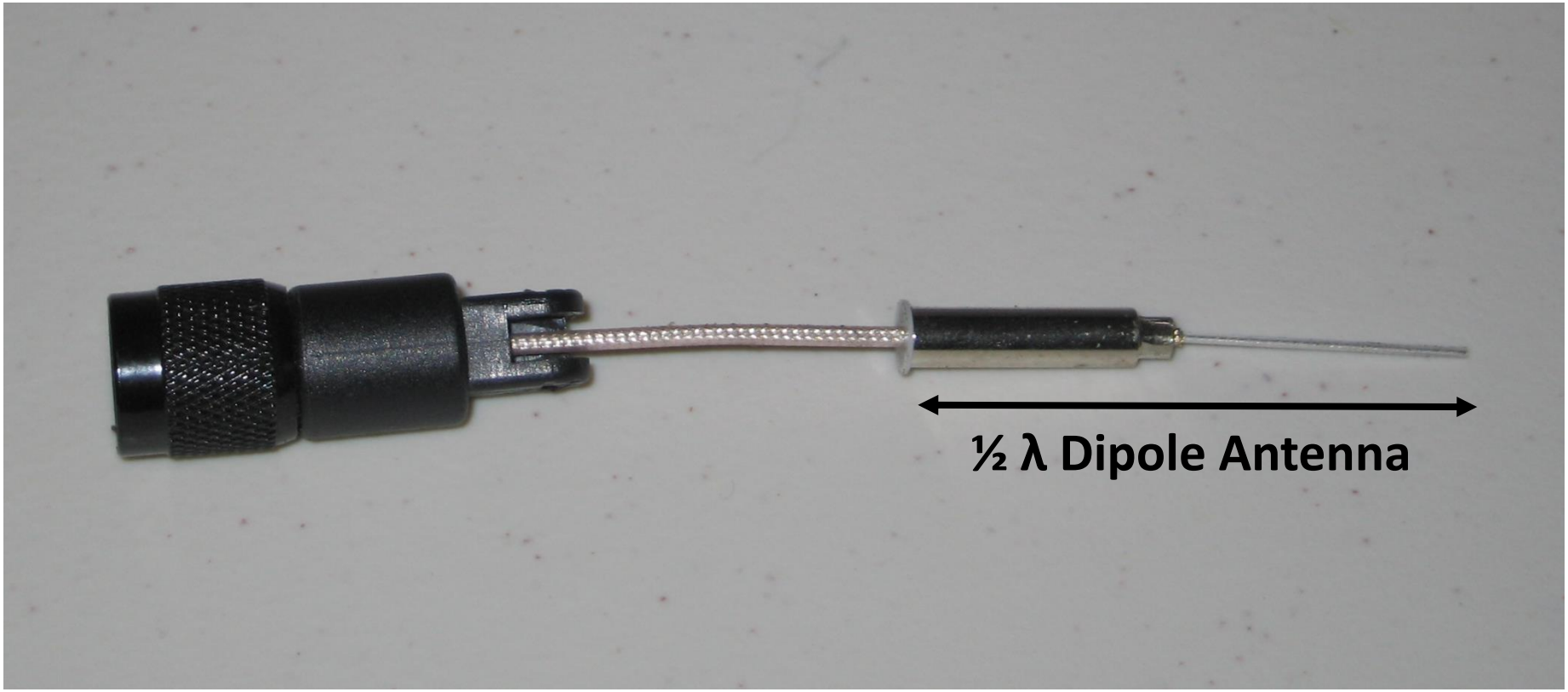
Caution should be used, some antennas my be constructed differently!

Eliminating the Type “N” connector & adapter

Eliminating the Type “N” connector & adapter



Eliminating the Type “N” connector & adapter



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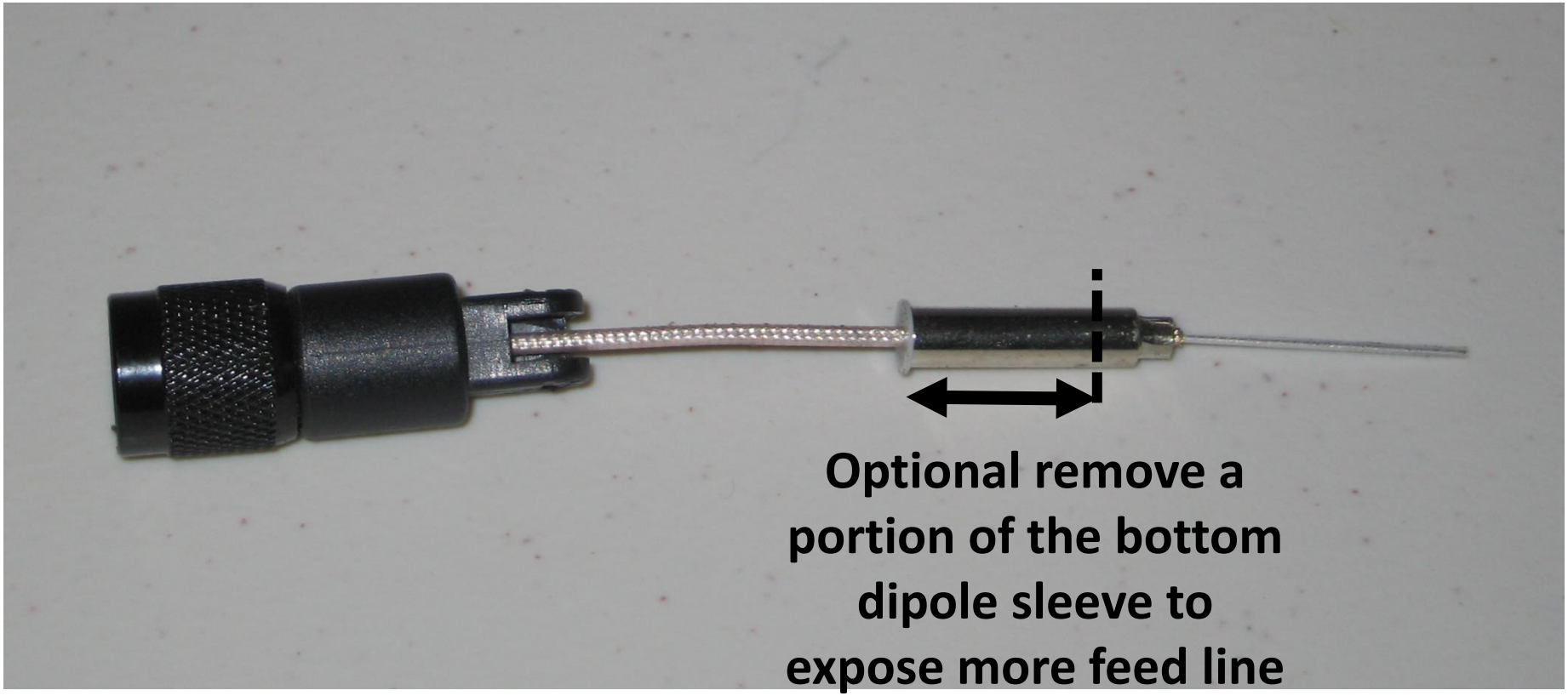
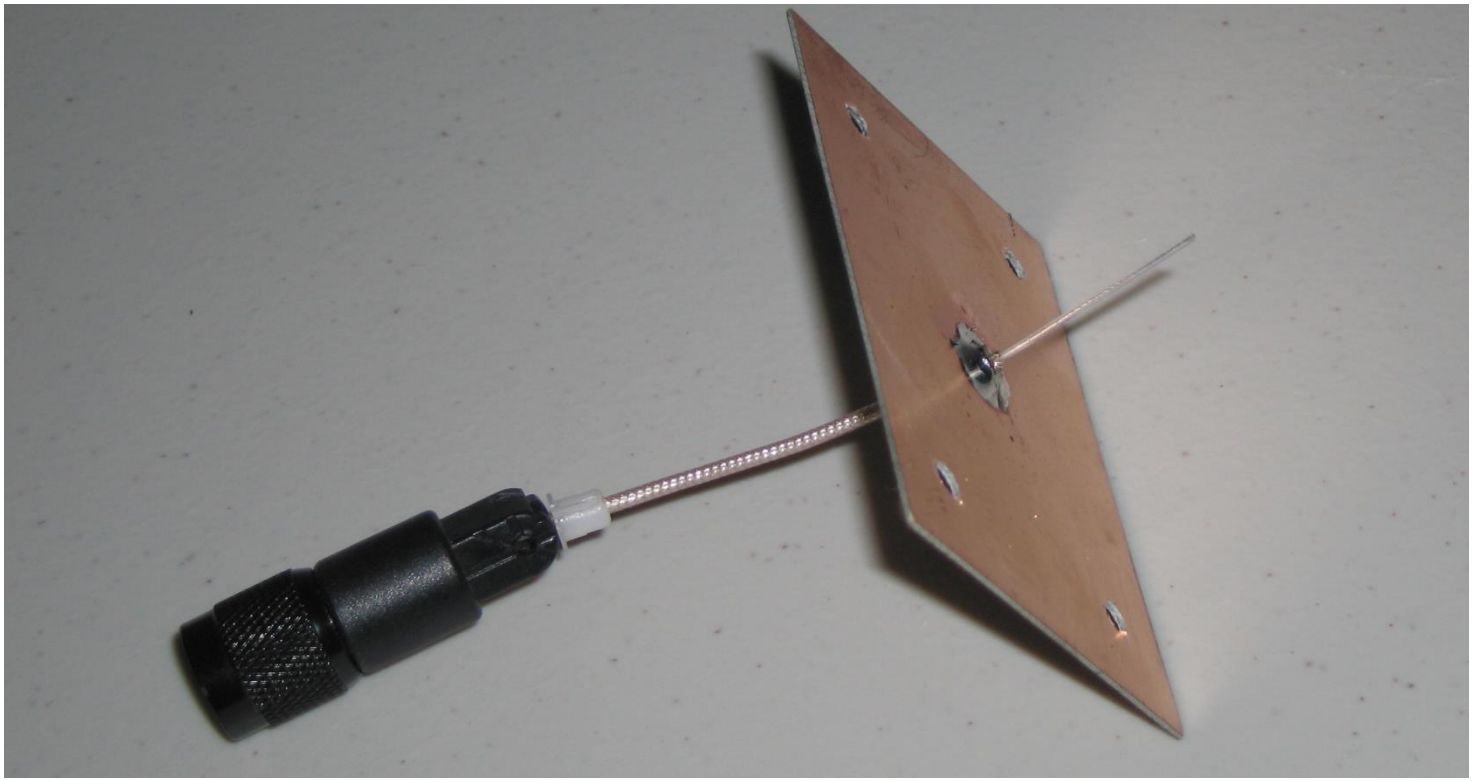
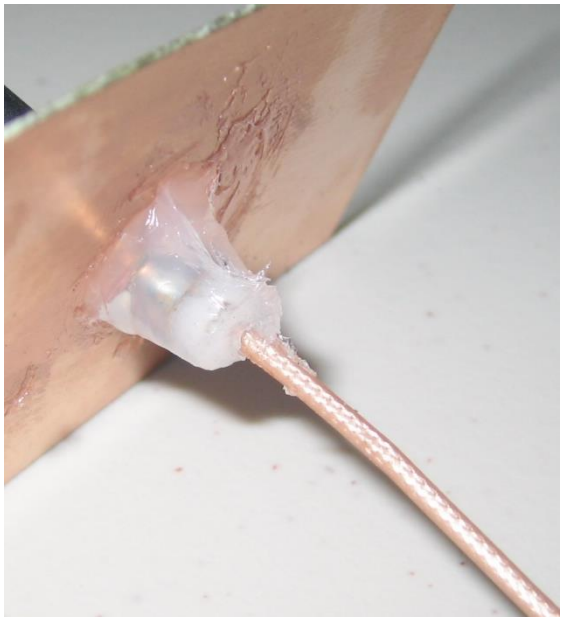


Eliminating the Type “N” connector & adapter

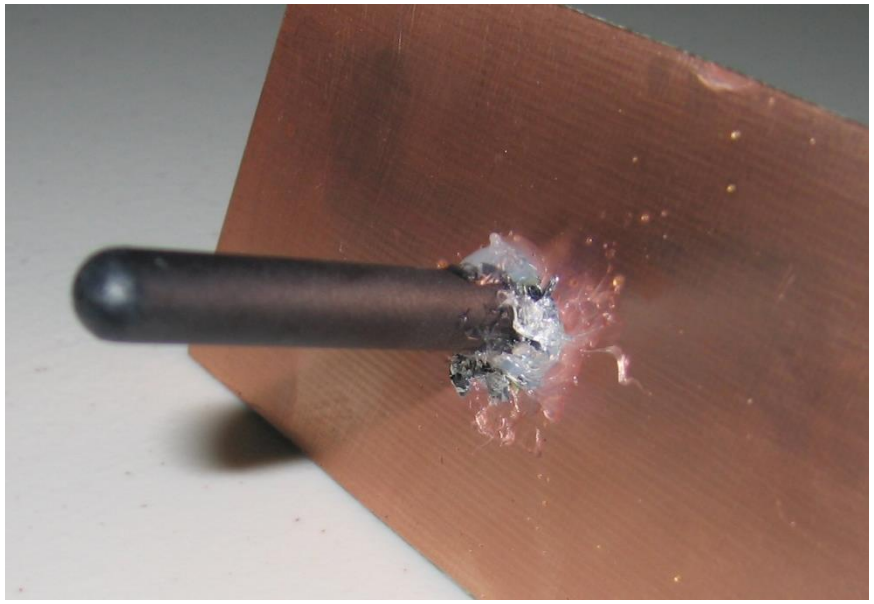
Solder a piece of scrap printed circuit board to the center of the dipole portion of the antenna



Eliminating the Type “N” connector & adapter

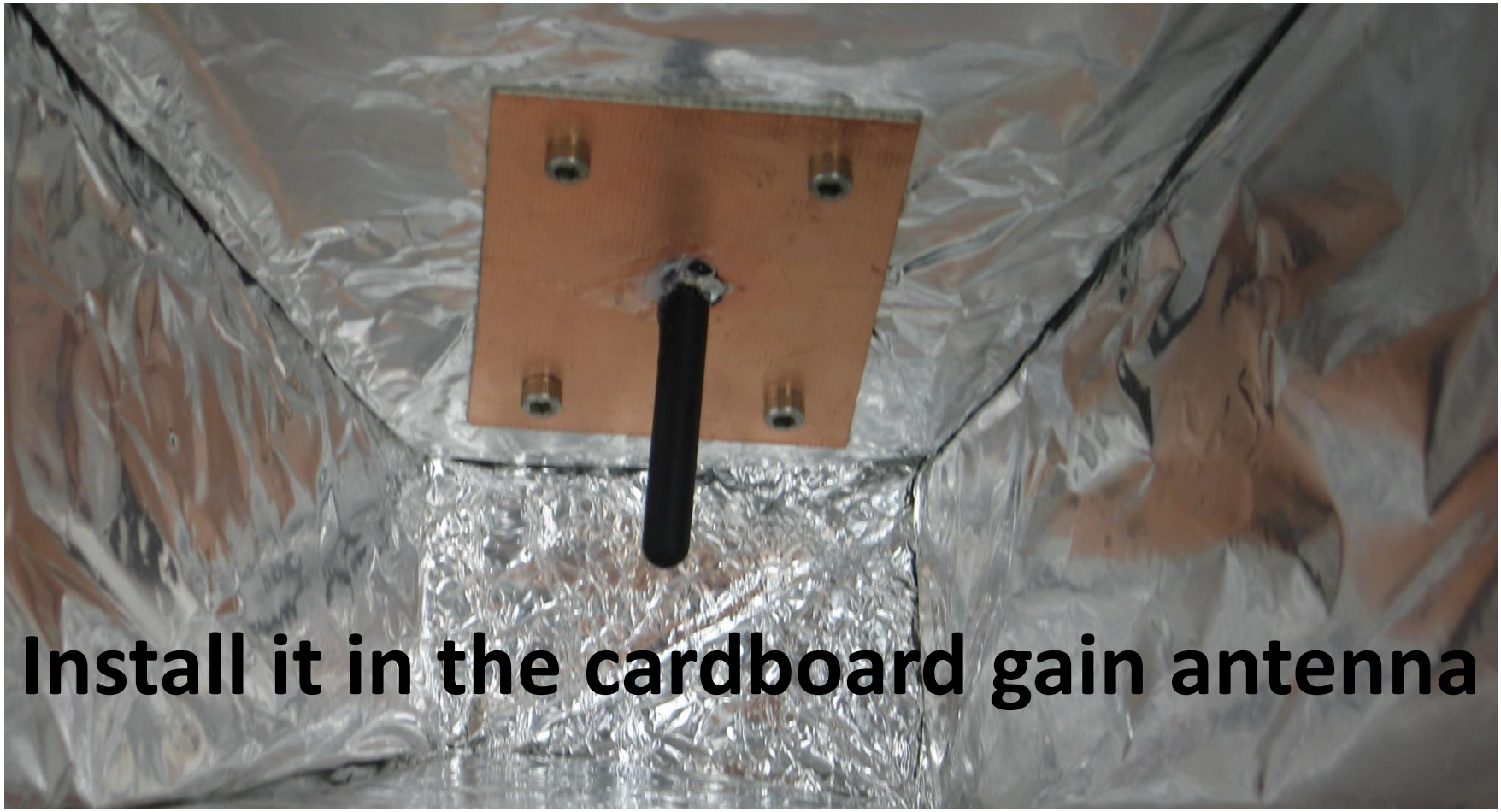


Add sealant to protect coax to dipole transition



Cutoff and add the top portion of the previous dipole cover using sealant

Eliminating the Type “N” connector & adapter

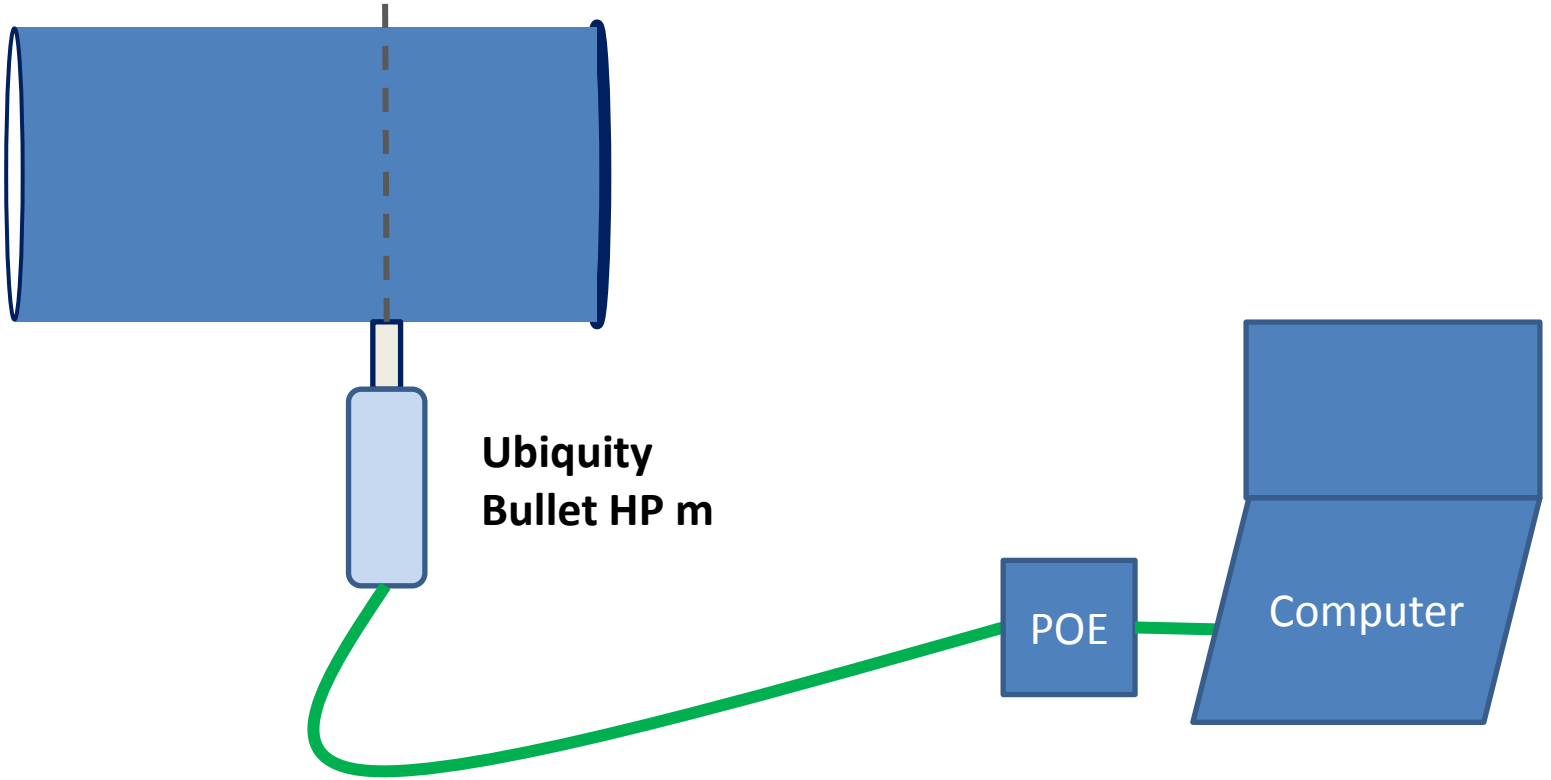


Eliminating the Type “N” connector & adapter

What you get is a good <u>inexpensive</u> attic or inside antenna that uses only common household items. Cost is only the labor!

What's next?

- Let's look at gain and patterns.



The cardboard gain antenna is located here along with a dipole on a WRT54 router

Article Index

- Collinear Omni Antenna
  - http://www.vais.org/wirelessnetw/wndw_06_08_03.html
- Very Cheap Ez-12 D.I.Y Parabolic Reflector
  - http://www.freeantennas.com/projects/template2/
- High Speed Multi-Media 2 GHz Horn
  - An All Purpose High Gain Antenna for 2400 MHz
    - QEX – January/February 2011 or on the internet under the Article Name
- Tetra Bk
  - http://www.drivebywifiguide.com/TetraBrikHowTo
- Rectangular Waveguide Calculator
  - www.learningmeasure.com/cgi-bin/calculators/rectwgm.pl
- 2.4 GHz Satellite Antenna
  - http://barc.org/ao40_antennas/rxantenna
    - and ARRL Satellite Handbook issue 1 chapter 6

The End