

Design and Installation of Outdoor TV Antenna

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Summary

Digital television (DTV) transition June 12, 2009 (postponed from February 17) motivated us to review our existing outdoor antenna system and undertake an upgrade program during fall of 2008. We live in a rural area able to receive both Boston and NH stations. Boston stations are 42 miles away; nearest NH station is only 13 miles distant. This paper documents steps we took to evaluate requirements and install a new outdoor TV and FM antenna.

Over the air (OTA) TV reception has fallen out of favor with rise of Cable and Satellite providers. About 15% of American households rely exclusively on over-the-air TV. A significant number of Cable and Satellite subscribers continue to use OTA for one or more TVs. Transition to DTV may impact decision to use OTA. OTA quality is often better than Cable or Satellite because program is not recompressed (transcoded) to fit available channel capacity. Being free, except for cost of antenna, OTA may be preferable to paying a monthly fee for cost conscious customers. On the down side some viewers will have fewer stations available due to digital transmission characteristics. With analog TV picture degrades gradually becoming snowy as signal decreases. Digital is perfect until signal reaches a critical threshold, called the cliff effect. At that point receiver is no longer able to recover picture and sound. In many cases existing antenna will work fine for digital. In others, for optimum-viewing experience, requires installation of a better antenna.

Now that full power analog transmission has ceased and stations relocated to final channel allocation both station owners and OTA viewers are fine-tuning their systems. It will probably be a while before we can definitively determine how well DTV is working for OTA viewers.

Background

We live in southern NH. This gives us access to both NH and Boston stations. Being 42 miles from Boston in hilly forested New England requires a high gain outdoor antenna. Existing outdoor antenna was 20 years old. Thought it was a good time to see if anything could be done to improve reception. Old system consisted of separate VHF and UHF antennas mounted on gable side of house with mast-mounted preamp. Rotor allowed antenna to be repositioned between NH and Boston stations. A separate omnidirectional antenna was used to receive FM. TV and FM signals were carried over separate coax cables to outlets located throughout the house.

Design goal:

- Receive more stations
- Minimize or eliminate need for rotor
- Integrate FM distribution so all TV outlets have FM capability
- Improve Antenna grounding

There is no such thing as a digital TV antenna, digital antennas are marketing hype. Antenna does not care if it is receiving an analog or digital signal. Its purpose is to capture an electrical field and deliver it to the receiver. That being said DTV reception is more demanding than analog. Analog slowly degrades as noise increases showing up as snow. DTV is subject to cliff effect. Reception remains perfect until signal falls below a critical value. When that occurs receiver is no longer able to recover video and audio. [Longley-Rice](#) propagation modeling is used to predict DTV coverage area. During transition planning phase FCC and stations worked together to engineer desired coverage area. Modeling criteria has been criticized for producing overly optimistic results. Real world DTV coverage area tends to be worse than predicted due to cliff effect in rural areas and multipath interference in urban locations. Whereas with analog the viewer decides how much snow/ghosting to tolerate before deeming program unwatchable with DTV it is the receiver that makes the determination, reception is either perfect or nothing.

Digital TV, like analog, is affected by multipath. Ideally signal traveled over a single path from transmitter to receiver. In real world TV signals bounce off buildings, airplanes, mountains etcetera. Reflected signals are delayed in time relative to main signal. With analog [NTSC](#) TV multipath results in ghosts. Digital [ATSC](#) tuners used to be very susceptible to multipath. Newer designs do a much better job rejecting multipath but if extreme will still corrupt signal.

Fringe TV reception consists of two main components, antenna to capture weak signal and a preamp to boost signal to compensate for distribution losses between antenna and receiver. System must have enough gain to receive weak distant signals while not being overloaded due to nearby transmitters.

The more gain an antenna has the narrower its receiving window becomes. Rural viewers often have stations at wildly divergent compass headings. To deliver an acceptable signal antenna must be precisely aligned to each station. The most common way to achieve this

is by using a rotator. Rotor easily repositions antenna to any desired compass heading. The downside is only a subset of desired stations is available at any given antenna position. This is a serious problem for homes with multiple TVs or DVRs.

Cost and convenience must be factored in. Antenna height is normally dictated by structure used to mount antenna. It is possible to erect a tower to provide more elevation but that is usually not feasible due to cost and aesthetic considerations.

Antenna grounding is critical to safety. A properly grounded antenna bleeds off static charge caused by wind passing over the antenna. It also goes a long way to reducing damage due to nearby lightning strikes.

Interested readers are strongly encouraged to visit Ken Nist's [HDTV primer](#) site, particularly the antenna section. Much of the information in this paper was derived from Ken's site.

TV Broadcast History

In the US FCC standardized on NTSC format in 1941 but widespread commercial broadcast did not begin until after WWII. NTSC is an analog format as were subsequent color and stereo audio enhancements. For several years before analog phase out FCC authorized TV stations to simulcast programs in both digital and analog. This required separate analog and digital transmitters and a temporary allocation of second channel. Digital transmission offers a number of significant advantages but as with any change of this magnitude there are bound to be teething problems.

Digital TV refers to the way program is transmitted. The Advanced Television System Committee ([ATSC](#)) standard replaced the older National Television System Committee ([NTSC](#)) analog system. Digital TV and High Definition TV ([HDTV](#)) are often confused. Just because a program is digital does not mean it is HDTV. DTV is capable of broadcasting standard definition TV, HDTV or a combination of both. HDTV picture and sound quality is much better than [SDTV](#). HDTV is more like watching a movie. Digital transmission is spectrally more efficient than analog making it possible to deliver not only better quality but multiple programs, called sub channels. A TV channel that in the past was limited to a single analog program is now able to deliver multiple programs. Each TV station chooses which combination of HD and SD programs to broadcast. Being digital, sub channels may be used to provide new services impossible with analog.

As of June 12 2009 full power US TV stations terminated analog broadcast. Some stations provided a month of post transition nightlight service. This let viewers who were unaware of the transition know analog TV had gone away rather than simply getting a blank screen. Once analog transmission ceased some stations moved from temporary UHF channel back to their traditional VHF channel.

Low Power TV ([LPTV](#)) stations are not required to convert to digital. LPTV is often used for fill in purposes by full power stations. LPTV is also useful to reduce cost for stations serving small niche markets.

As part of digital TV transition UHF Channels 52-69 are no longer used for TV in the United States. They have been auctioned off for other purposes. Antennas optimized for DTV channel allocation may provide better performance because they do not need to cover as wide a frequency range. So far post transition optimized antennas are rare. Canada and Mexico still use channels 52-69 so manufactures are reluctant to segment the market.

This is not the first time broadcast TV lost channels. Channel 1 went away back in the 1940's and channels 70-83 were lost in the 1980's. Channel 37 is reserved for radio astronomy. In some cities UHF channels 14-20 are used for two-way radio rather than TV. The FCC recently announced it is considering proposals to remove even more channels from over the air TV service and reassign them to mobile broadband.

Finding Stations

First step is to determine signal strength of nearby stations. The most popular modeling site is [AntennaWeb](#) run by the Consumer Electronics Association. Antenna Web is very conservative so it excludes weak stations receivable with a good outdoor antenna. In our case Antenna Web only shows 2 stations when in fact we reliably receive many more. [FCC](#) has its own signal strength modeling web site. It is much more detailed than Antenna Web and models weaker stations. We mainly use [TV Fool](#) by Andy Lee. Both TV Fool and FCC sites provide a detailed signal strength report. TV Fool has two options to analyze signal strength. Location may be specified by street address or exact map coordinates. Using street address is convenient but precise location results in more accurate estimate in hilly terrain.

TV channels occupy two frequency bands. Channels 2-13 are Very High Frequency ([VHF](#)) and 14-51 are Ultra High Frequency ([UHF](#)). VHF TV channels are split into two blocks, channels 2-6 (VHF low) and 7-13 (VHF High). VHF low is not ideal for DTV due to man-made noise and propagation characteristics. In most markets there are no digital VHF low stations.

FM is located between TV channel 6 and 7. FM reception is less demanding than TV but in rural areas reception benefits from using an outdoor antenna rather than the dipole typically supplied with FM radios. This can be accomplished by using TV VHF antenna or a purpose built FM only antenna.

Fringe viewers typically have access to multiple stations serving different markets. Because they are far away need a high gain directional antenna. Down side of directional antennas is pointing accuracy. Being in different markets stations are often at widely different azimuths. If antenna is not accurately aligned signal level is adversely affected.

Antenna rotator changes antenna direction to pick up dispersed stations. Rotors are the bane of multi TV households and digital video recorders (DVR). Changing antenna direction determines which stations are viewable. Rotors also present problems for DVR use because typical DVR is not able to change antenna direction to select desired station.

In designing antenna system need to carefully consider which stations are of interest to minimize need to constantly reposition antenna. Instead of using a rotor multiple antennas can be used. Antenna feeds must be combined in a way so as to not degrade performance of individual antennas. To optimally combine multiple antennas band pass filters are used so only the desired frequencies from each antenna are combined. If filter is not used not only are the desired signals combined but so is noise and multipath. This may not be a problem in strong signal areas but can be devastating in fringe. In some cases filtering is easy. For example VHF/UHF combiners are cheap and readily available as are VHF Lo/Hi. Only slightly more expensive are FM/TV combiners. Where design becomes more complex and expensive is if stations are at different compass headings requiring multiple antennas each supplying a few channels.

TV Channel Assignment (Late 2009)

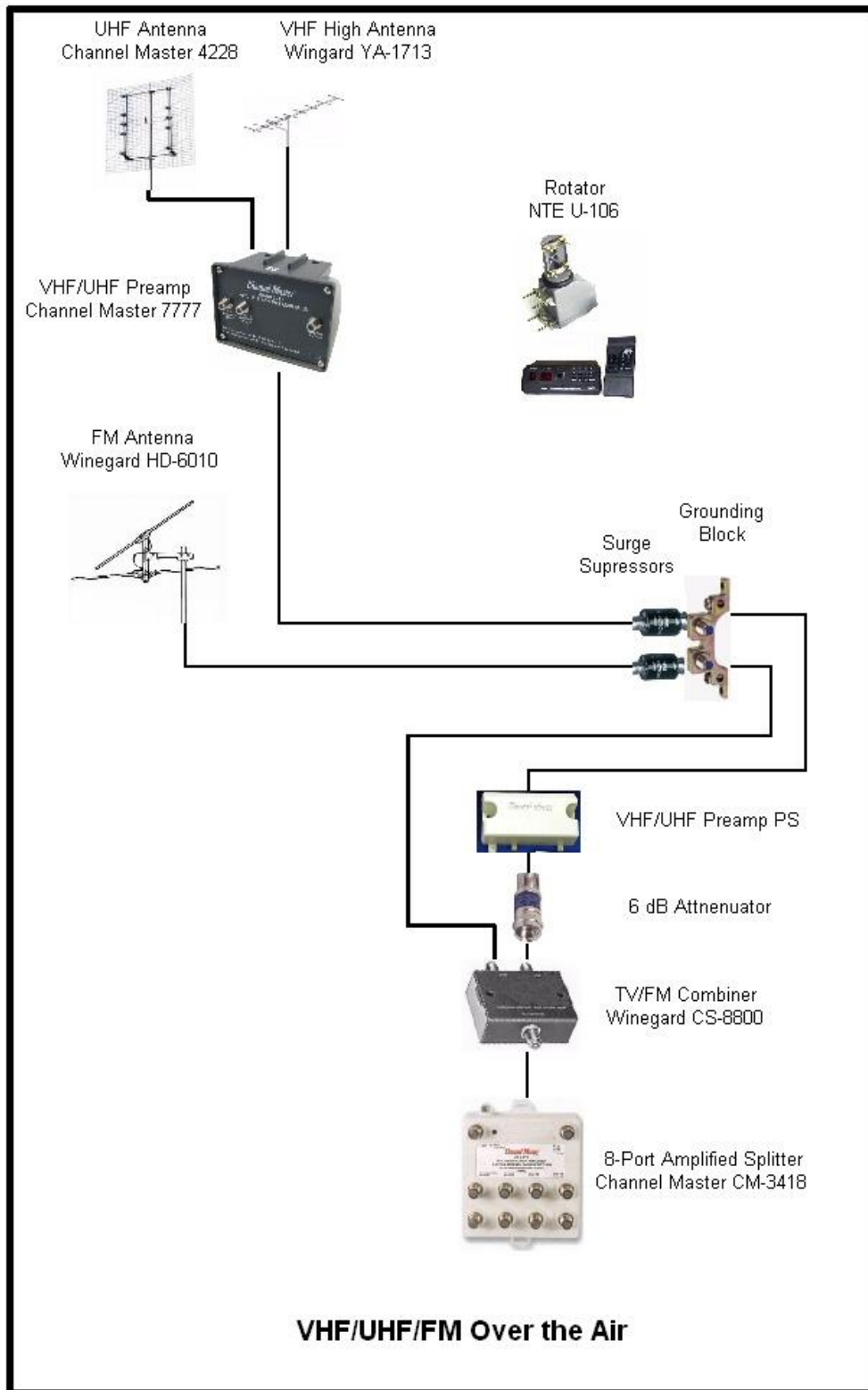
RF Chan	Virt Chan	Callsign	Network	TV Fool dBm	Dist Miles	Az True
2-6	VHF Low – No local stations					
88-174 MHz	Broadcast FM (88-108 MHz) and 2-way radio services					
7						
8	8	WMTW	ABC (ME)	-94.5	85.1	33
9	9	WMUR	ABC (NH)	-36.1	12.5	19
10						
11	11	WENH	PBS (NH)	-63.5	34.4	43
12						
13	13	WYCN	Ind LP (NH) – Analog	-86.5	11.1	108
↑ VHF UHF ↓						
14						
15						
16						
17						
18	62	WMFP	RTV (MA)	-84.5	41.7	147
19	2	WGBH	PBS (MA)	-82.9	41.2	148
20	5	WCVB	ABC (MA)	-83.0	41.2	148
21						
22						
23						
24	41	WVTA	PBS (VT)	-102.9	58.6	318
25	31	WNNE	NBC (VT)	-107.4	58.6	318
26						
27	66	WUTF	Tel (MA) (Spanish)	-76.1	31.1	163
28	28	W28CM	WYCN translator analog	-85.1	12.4	120
29	27	WUNI	Uni (MA) (Spanish)	-84.9	33.1	184
30	4	WBZ	CBS (MA)	-83.5	41.2	148
31	25	WFXT	FOX (MA)	-99.2	42.1	147
32	68	WBPX	ION (MA)	-99.1	41.7	147
33	21	WPXG	ION (NH) (WBPX sat)	-64.6	31.3	35
34	60	WNEU	TEL (NH) (Spanish)	-40.1	12.6	19
35	50	WZMY	MyN (NH)	-81.3	15.1	111
36						
37	Reserved for Radio Astronomy					
38	13	WGME	CBS (ME)	-106.5	97.5	38
39	38	WSBK	Ind (MA)	-93.7	41.2	148
40						
41	56	WLVI	CW (MA)	-90.6	42.1	147
42	7	WHDH	NBC (MA)	-88.8	41.7	147
43	44	WGBX	PBS (MA)	-88.8	41.2	148
44	6	WCSH	NBC (ME)	-100.7	87.2	34
45						
46						
47	48	WYDN	Daystar (MA) Religious	-99.8	41.7	147
48						
49						
50						
51						

(Yellow) Stations of interest

For readers without an engineering background [dB](#) (decibel) is a common method used to specify signal level. It is logarithmic rather than linear. Given huge differences in power it keeps numbers manageable and easy to add/subtract. Decibels are ratios between two quantities. For example a signal 3 dB larger is twice the power, 3 dB smaller half power, 10 dB ten times, 20 dB one hundred times and so on. When used to express power levels it is often referenced to 1 milliwatt, 0 dBm. Strongest signal we are interested in is about -35 dBm the weakest -95. 60 dB difference means there is a factor of one million between strongest and weakest signal.

Chart shows nearby stations and predicted receive signal level. Stations of interest are highlighted in Yellow. UHF stations, with the exception of WZMY, are within a degree of one another. NH VHF stations are more widely separated but being significantly closer are much stronger. In that case modest misalignment is not a problem. The weakest VHF signal of interest is -64 dBm and -99 for UHF. System must be engineered to reliably pick up signals that weak while not being overloaded by strong nearby stations.

Selecting Equipment



UHF Antenna

There is general agreement Channel Master 4228 8-bay antenna is the best all-around UHF fringe antenna. As mentioned on [Ken's site](#) even though billed as UHF only it can be used on VHF high. Channel Master recently announced a new version, 4228HD, which is lighter and specified for VHF high (channels 7-13) in addition to UHF. Unfortunately it appears to be less sensitive on UHF than old version. Luckily we are using the old design.

Another prime candidate for deep fringe is the Antennas Direct 91XG. Hopefully they will release a redesigned version optimized for channels 14-51. The gain curve for Yagi Corner Reflector antennas peak at the high end. Reducing bandwidth from channels 14-69 to 14-51 should result in improved gain at the upper end of the new TV band. This effect is not nearly as pronounced in 4-bay and 8-bay antennas.

Antennas increase gain by becoming more directional. A good analogy is a searchlight compared to a light bulb. Fringe area antennas need to be accurately aimed to work properly. Being large they are vulnerable to wind and snow damage. Directional antennas reject signal received off axis reducing problems with multipath. This is useful in our area due to mountain and rough terrain. More is not necessarily better when it comes to selecting an antenna. It does not make sense to use a larger antenna than necessary. The smallest antenna that receives the channels of interest is the best choice.

VHF Antenna

There are no VHF low stations in our area. We chose a Winegard YA-1713 VHF high antenna. VHF high antenna is smaller and lighter than antenna designed to receive entire VHF band.

Using separate VHF and UHF antennas allows VHF antenna to be offset by -105 degrees relative to UHF. When UHF antenna is pointing to Boston stations VHF is aligned with weaker NH station, WENH. This minimizes need to use rotor to position antenna.

VHF/UHF Preamp

The other key component for fringe viewers is a mast mounted pre-amp. Once antenna has captured weak signal do not want it degraded traveling over coax on its way to TV. Preamp function is often misunderstood. The preamp compensates for distribution losses between antenna and TV it cannot create a signal not captured by the antenna.

The other important benefit of a preamp in weak signal area is improved noise figure. Signal captured by antenna is tiny. It must be amplified before receiver is able to process it. In real world nothing is perfect. In addition to boosting signal amplifiers add noise. The more noise the more signal antenna must capture to overcome it.

TV designers are not overly concerned with [noise figure](#) (NF). Most viewers receive TV programs via Cable or Satellite presenting a strong signal to tuner. Most of the rest are in fringe areas relying on OTA antenna and mast-mounted preamp. In that case preamp noise figure dominates not the NF of the TV. Noise figure isn't normally even listed on TV specifications. In testing [DTV receivers](#) FCC found typical UHF NF to be around 7 dB. A good mast mounted preamp will have a much lower NF. In order to ignore receiver noise figure preamp must have enough gain to overcome distribution losses and receiver noise figure.

We selected a Channel Master 7777 preamp with a UHF NF of 2 dB and VHF of 2.8. That means UHF signal can be 5 dB weaker than if TV was directly connected to antenna. That is a lot of bang for the buck. The 7777 has separate inputs for VHF and UHF amplifying each separately and then combining the resulting output.

Rotator

TV stations are at multiple compass headings requiring a rotator. Rotors are the bane of multi TV and DVR households. Optimizing antenna for one channel interferes with others. We are lucky NH stations we are interested in are on VHF and Boston stations on UHF. By offsetting VHF antenna by -105 degrees when UHF antenna is aimed at Boston VHF receives both NH stations.

Rotators do not track antenna position directly. They use two synchronous motors, one in the control head and another to rotate the antenna. Being synchronous both motors move through the same number of degrees, assuming no slippage. This works well enough but errors build up over time necessitating occasional resynchronization of control head and antenna.

Higher end TV rotators dispense with motorized control head. Instead a microcontroller tracks antenna heading, controls antenna motor and processes IR remote control commands. The microcontroller counts power line transitions to maintain synchronization with rotor motor. It is much easier to jog rotor a few degrees with microcontroller based unit than electromechanical unit. Our desire was to minimize how often rotor is used. Wanted to control rotor from control head and **NOT** be forced to use IR remote control. We choose NTE U-106 rotor. Controller has several alphabetic keys used to preset antenna position and clockwise and counter clockwise buttons for fine-tuning. Azimuth display is only two digits. The least significant digit is not displayed. Getting antenna perfectly aligned with true North is difficult so lack of least significant digit is not a major issue.

To fine tune antenna position we monitor TV signal strength indicator and use manual buttons to jog antenna clockwise or counterclockwise.

A nice feature of the controller is it remembers current position when turned off. This eliminates need to resynchronize controller after power failure or when turning controller on.

FM Antenna

TV Fool has a sister site [FM Fool](#) to calculate FM signal levels. This is handy to determine if nearby FM stations are strong enough to cause TV interference. In general signal overload is not a problem unless FM transmitter is nearer than 10 miles. Luckily strong signal overload is not a problem for us.

FM stations we are interested in come in fine using automobile whip antenna or properly positioned twin-lead dipole. FM stations of interest, as with TV, are in various locations. I was concerned using the directional VHF High TV antenna, pointed toward NH, would not yield adequate reception of Boston stations.

We choose a Channel Master HD-6010 omnidirectional FM antenna. Basically it is just two dipoles stacked on top of one another offset by 90 degrees. Gain for this antenna is 3 dB less than using a single dipole since energy picked up by one dipole is radiated out the other. The advantage is omnidirectional coverage so antenna picks up stations equally well in all directions. This is not precisely correct but works well enough. Luckily FM reception is not nearly as demanding as TV.

Combining TV and FM

Old design distributed FM and TV over separate coaxes. This led to problems because when we built house did not provide FM drops at each room. Design goal of new system was to distribute TV and FM over a single coax so any room with a TV outlet has access to FM antenna.

When combining signals from multiple antennas need to take care not to degrade noise margin. I could have used a regular two-port splitter to combine FM and TV signals. Using a splitter would incur a 3.5 dB loss but that is not a major issue as amplifier has adequate gain. Typical multipoint splitters are not frequency sensitive; they will cheerfully combine or split all signals, including noise and multipath. Winegard has a clever device called a FM combiner (CS-8800) to address this problem. Combiner has two inputs one for TV one for FM. TV input filter attenuates range of frequencies used by FM, 88-108 MHz. FM input has a band pass filter that only passes FM frequencies. Using this device allows TV and FM to coexist on the same coax while not degrading either.

Splitter

Residence has 7 TV/FM outlets. This requires an 8-port splitter. We are currently using an 8-port amplified splitter. Active splitter results in 4-dB gain for each drop compared to 11 dB loss with passive splitter.

UHF Signal Budget

TV Fool and FCC sites provide a rough estimate of real world performance. Modeling takes into account terrain but not obstructions like nearby buildings and trees or multipath effects on receiver. Goal is to capture enough power to present a recoverable signal to the receiver.

UHF Signal Budget	
Thermal noise floor 6 MHz TV channel	-106.2 dBm
Minimum ATSC SNR	15.2 dB
Antenna preamp noise figure	2.0 dB

Absolute minimum Rx signal level	-89.0 dBm
Antenna Gain (Chan 31)	16.0 dBi

Absolute minimum antenna signal level	-105.0 dBm
Atmospherics impairment fudge factor	10.0 dB

Desired field strength at antenna	-95.0 dBm
VHF Signal Budget	
Thermal noise floor 6 MHz TV channel	-106.2 dBm
Minimum ATSC SNR	15.2 dB
Antenna preamp noise figure	2.8 dB

Absolute minimum Rx signal level	-88.2 dBm
Antenna Gain (Chan 8)	11.0 dBi

Absolute minimum antenna signal level	-99.2 dBm
Atmospherics impairment fudge factor	10.0 dB

Desired field strength at antenna	-89.2 dBm

http://www.hdtvprimer.com/ISSUES/erecting_antenna.html

<http://www.tvfool.com/>

Thermal noise floor for 6 MHz TV channel is -106.2 dBm. ATSC specification requires a 15.2 dB signal to noise ratio. Receiver must be able to decode signal if it is at least 15.2 dB stronger than background noise. Mast mounted preamp has 2 dB UHF and 2.8 dB VHF noise figure. Noise added by the amplifier increases the amount of signal antenna must capture to meet receiver minimum sensitivity. UHF antenna has 16 dBi (isotropic) gain on worst-case UHF channel of interest, VHF antenna has lower gain 11 dBi. Isotropic gain is gain compared to a theoretical antenna that receives equally well in all directions. Combining these factors yield an absolute minimum signal level at antenna of -105.0 dBm for UHF and -99.2 for VHF.

DTV transmission suffers from cliff effect. As long as signal is even slightly above minimum threshold image/sound is perfect. If signal drops even a little receiver is unable to process it, causing program to pixelate or freeze. To minimum signal level we added a 10 dB atmospheric impairments fudge factor. This compensates for signal fade due to changing atmospheric conditions. Factoring in atmospheric yields desired field strength of at least -95 dBm UHF and -89.2 VHF at antenna.

On paper antenna system is not adequate to receive several weak UHF channels. Weakest UHF channel of interest is -99 dBm and VHF -64. In addition even with roof-mount the antenna is significantly lower than nearby trees. Trees do not have much effect on VHF but almost totally block UHF. Need to accept we will not be able to receive weaker stations 24/7/365. Some will exhibit high occurrence of dropouts making them unwatchable. The good news is in winter when trees lose their leaves reception will improve.

Distribution Loss Budget

Having expended this effort capturing weak TV signal want to make sure it is not lost before arriving at TV. For this we need to examine losses between antenna and TV. System gain should be such that signal arrives at receiver 10-20 dB stronger than at antenna. TV receiver NF is about 7 dB. Want to insure weakest signal at antenna arrives at TV well above TV's internal NF. On the other hand need to be careful amplifier does not have too much gain. Excessive gain will cause strong stations to overload TV front end.

Signal Distribution Loss Budget			
	FM	VHF	UHF
Preamp	n/a	23.0 dB	26.0 dB
Antenna mast coax 10'	-0.2 dB	-0.3 dB	-0.6 dB
Surge Suppressor	-0.2 dB	-0.2 dB	-0.2 dB
Roof ridge coax 30'	-0.6 dB	-0.9 dB	-1.8 dB
FM/TV combiner	-0.4 dB	-0.4 dB	-0.4 dB
Attenuator	n/a	-6.0 dB	-6.0 dB
8-way amplified splitter	4.0 dB	4.0 dB	4.0 dB
TV drop coax ~ 40'	-0.8 dB	-1.2 dB	-2.4 dB
	-----	-----	-----
Signal at Rx relative to Ant (no split)	1.8 dB	18.0 dB	18.6 dB
Signal at Rx relative to Ant (2-way split)	-1.7 dB	14.5 dB	15.1 dB
Signal at Rx relative to Ant (4-way split)	-5.2 dB	11.0 dB	11.6 dB

First length of coax connects TV preamp and FM antenna outputs to mast mounted grounding block surge protector. Signal loss increases with frequency. A given length of coax has greater loss on UHF than FM. RG-6 coax is the preferred cable for TV distribution systems. Second cable section runs from gable-mounted antenna to attic

wiring closet. FM/TV combiner injects separately captured FM signal so it can be distributed over the same coax used for TV. Residence has 7 TV/FM outlets necessitating an 8-way splitter. Lastly need to account for coax loss from splitter output to TV outlet. Cable from individual TV outlet to TV is typically RG-59 rather than RG-6. It has higher loss than the RG-6 but being only a few feet long is not a significant contributor to overall loss budget.

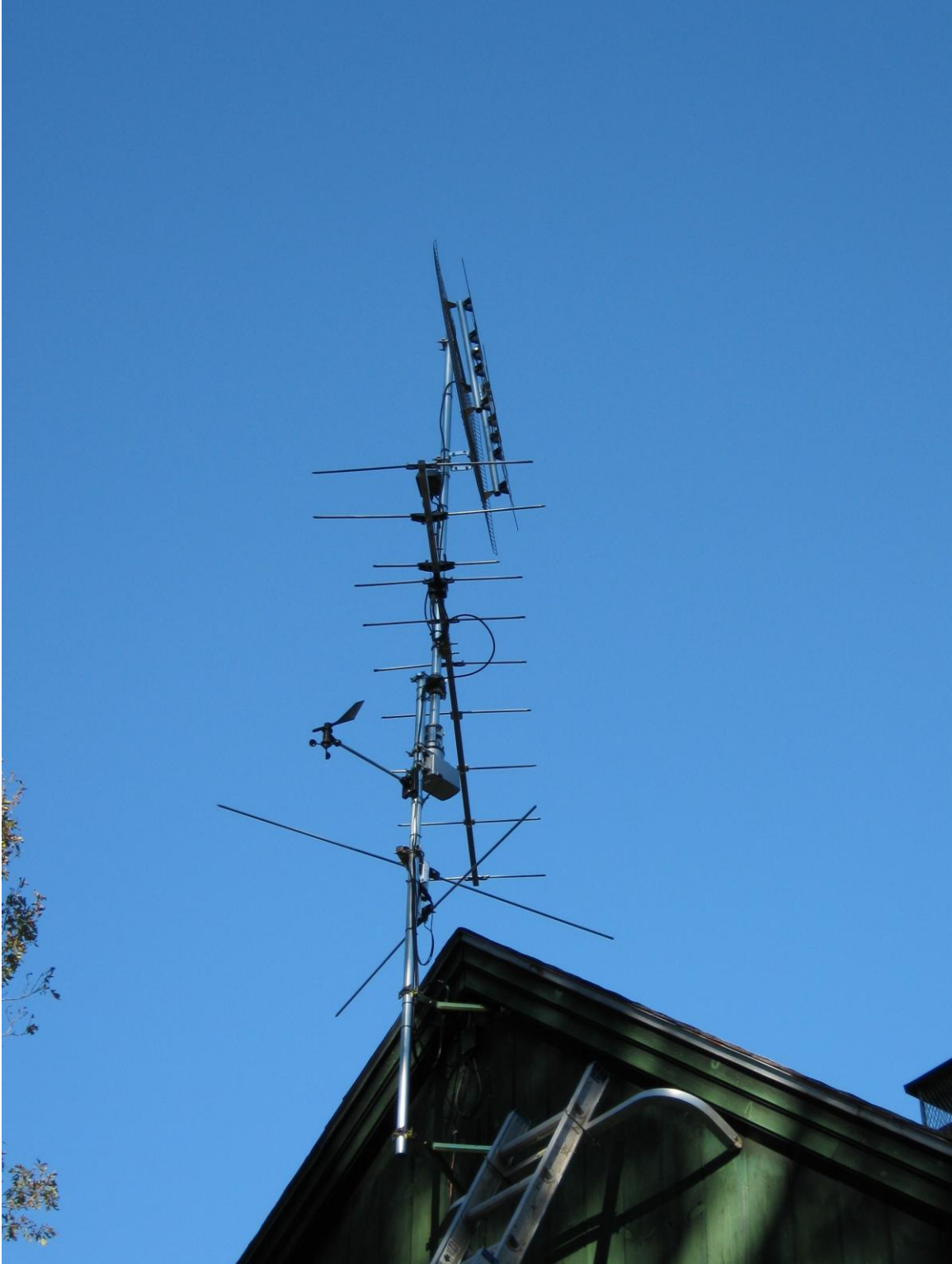
If FM radio is used at same location as TV need to factor in 3.5 dB loss from 2-way splitter. TV/FM combiner can be used to separate TV and FM at the TV with lower loss (.4 dB) then using a splitter but they are more expensive. If TV, FM and DVR are connected need to use a 3 or 4-way splitter. This results in loss of about 7 dB.

Initially we used a passive 8-way splitter. With passive splitter receiver signal was 10 dB higher than at the antenna. When using a 2-way splitter (3.5 dB loss) at TV noticed on very weak stations bypassing splitter improved reception, as expected splitter had no effect on most stations. This led to the conclusion that slightly higher signal at the receiver would improve weak signal viewing experience. Replaced passive 8-way splitter with an active splitter. The active 8-way splitter has 4-dB gain per drop as opposed to 11-dB loss of passive device.

Gain is a double edge sword. One does not want an amplifier with too much gain. Doing so may result in overload from strong nearby stations. As long as gain exceeds distribution loss plus receiver NF there is no benefit of additional gain. I was concerned about possible overload from nearby VHF station when I installed the amplified splitter. Connected a 6 dB attenuator between preamp output and TV input of TV/FM combiner. Experiments with and without attenuator produced identical results. That may change during winter when trees lose their leaves and signal level increases. As a precaution I left attenuator connected.

Had been using a dedicated VHF amp to boost FM signal to compensate for 11 dB loss through passive splitter. Removed FM amplifier when I installed the active splitter. Have not noticed any change in FM performance even though signal level at receiver is slightly lower than before.

Installation



In general higher the better for antenna, toyed with mounting VHF above UHF antenna to reduce wind loading. In the end opted to mount UHF antenna on top to maximize signal. VHF antenna is mounted three feet below and offset by -105 degrees. Rotor is two feet below VHF antenna. Used thrust bearing to reduce rotor loading and increase stability. Bottom of rotor is two feet above roof peak. FM antenna is centered between roof peak and bottom of rotor. This provides 3 feet of separation between antennas. The greater the separation the less antennas interact with one another. Heavy-duty wall mount secures mast to gable wall.

New antenna stack is about three feet taller than old one. Being gable mounted it is not practical to guy antenna. To reduce possibility ice or wind will take it down used heavy gauge 1.5" diameter mast rather than more common 1.25". Most mast sections are 5-foot. It is possible to order 10-foot heavy duty 16-gauge mast. Instead opted to use 1-1/4 EMT (electrical metallic tubing) commonly known as conduit. 1-1/4" trade size conduit has an OD of 1.510" with .065" wall thickness resulting in very strong mast. Each mast section ended up being about 8-feet long. In December 2008 soon after we installed the antenna Southern NH experienced a severe ice storm. Many trees were knocked down and we were without power for a week. In December 2009 strong wind stripped shingles off the roof. Antenna came through with flying colors both times.

Antennas are directional in both azimuth and elevation. Rotor takes care of pointing antenna in correct direction. Given marginal signal wanted to do everything possible to maximize capture efficiency. If signal arrives more than a few degrees above or below antenna horizontal centerline signal strength is reduced. This is not a significant factor for FM or VHF but is for UHF.

We live in wooded area. View toward UHF stations is blocked by 70' high tree line 200' away. Even though antenna is mounted on roof trees are about 40' higher than antenna. Trees block almost all UHF signal. To antenna looks like signal originates at treetop level. Tilting antenna up 10 degrees points it at skyline maximizing signal pickup.

Since I chose electrical conduit for mast thought it would be easy to contact local electrical contractor and have conduit bent 10 degrees. Turned out no one was interested in doing a one off bend or they did not have the proper equipment. Contacted local muffler shop but they did not want to do it. Concerned their equipment would crush conduit.

Fell back to plan B. Built bracket to offset lower antenna mount made from four "L" reinforcing brackets. This resulted in a hollow box 3.75" on a side. Hole spacing on bracket is close to antenna U-bolt pattern minimizing filing and drilling. Because UHF antenna is no longer parallel to mast was careful not to deform antenna mounting bar. Supplied U-bolts were too short due to large mast and tilt offset, replaced them with 1/4 - 20 bolts. Bracket tilts antenna up about 8 degrees. Was not able to conduct test with antenna mounted normally and tilted so do not know if tilting antenna is effective at increasing signal.

Channel Master Preamp has two switch selectable options, 1) combined or separate VHF/UHF input and 2) FM trap on/off. Switch access requires removing amp from housing. We use separate VHF and UHF antennas so selected separate inputs and switched FM trap in since we are using a separate FM antenna.

Coax from VHF/UHF preamp needs a loop between upper and lower masts so upper mast is able to rotate. To minimize stress on coax sleeved upper and lower section where it is Ty wrapped to mast with short length of small diameter automotive hose. This insures coax experiences a gentle bend radius.

Fabricated antenna and wired it up. Temporally mounted antenna to deck for testing by drilling 1.5" holes in a couple of scrap 2x4s and screwing them into railing.

Removed old antenna and installed new heavy duty wall brackets. Brackets were drilled for 1/4" fasteners and came with lag screws for building attachment. Did not think that was adequate. Drilled out holes and used 5/16" toggle bolts.

Complete assembly is pretty heavy and unwieldy. I was not about to walk up ladder with entire antenna stack. Removed VHF antenna, FM antenna, and lower mast section from stack. Upper mast section now consists of just UHF antenna, preamp, rotor, and wiring. Attached lower mast to house bracket set just high enough so when upper section is attached rotor temporally rested on upper wall mount. My son went up on the roof and I climbed ladder with upper section. Connected upper mast section to lower mast. Then we used a short section of 2x4 to raise assembly high enough to attach VHF antenna. I was careful to mark correct antenna position during preassembly. Then we used longer 2x4 to set antenna at correct height. Attached FM antenna and weather station to lower mast. Bolted everything tight and congratulated ourselves for job well done and not falling off roof.

It is important to keep water out of coax connectors. At antennas and grounding block used Coax-Seal to wrap connectors. Stuff is pretty tenacious so install it only after system has been fully tested. Plastic is degraded by Solar UV. Used black, rather than White, Ty wraps to minimize UV degradation.

Used a small plastic utility box as a junction box mounted under the eaves. Cable for rotor is spliced in J-box, as is wiring for weather station.

Lightning Protection

TV antenna is likely highest object near your home. As such makes unintentional lightning rod. Lightning packs a tremendous amount of energy. Lightning protection is designed to provide low impedance path to Earth and bond all metallic conductors together to minimize potential differences during lightning events.

Years ago when I installed original antenna common practice used 8-gauge solid Aluminum wire to bond antenna mast to building ground system, typically a nearby

copper cold water pipe. Grounding and bonding requirements have tightened over the years. National Electrical Code ([NEC](#)) Article 810 requires antenna be bonded to building ground system. Antenna is at opposite end of house from service entrance, installed a supplemental grounding electrode for antenna. Bonding conductor must be 6-gauge copper or larger. Typical ground electrode sold for TV antenna use is only 5 feet long. Longer is better, so purchased standard 8-foot ground rod used to protect building electrical service entrance. Used 6-AWG bare copper wire to connect antenna mast to ground rod and ground rod to building ground system. PVC conduit and conduit body protect cable below siding until it enters the ground.

Two coaxes enter building, one for TV, one for FM. A dual F connector grounding block, mounted on mast wall bracket, grounds both coax shields. Each coax is protected by a gas tube surge suppressor connect to grounding block. Protectors limit voltage between center conductor and shield in event of lightning event. Rotor cable and old aluminum ground wire enter building at the same location. Reconnected old ground wire to mast even though grounding job has been assumed by improved grounding/bonding system.

Good grounding and bonding is not just for lightning protection. Air movement over antenna builds up static charge, just like a Van de Graaff generator. Proper grounding provides a path to drain off charge rather than having it discharge through expensive electronics. Proper grounding also potentially improves reception by minimizing current flow through coax shield.

Wiring Closet

TV, FM, and rotor control cables terminate in second floor wiring closet. TV coax connects to preamp power supply through 6-dB attenuator to TV input of FM/TV combiner. FM coax connects directly to FM input of combiner. Combiner output feeds input of amplified splitter. Individual drop cables feed coax outlets throughout the house. Incoming rotor cable is spliced to two cables. Intent was to allow rotor controller to be used at multiple location within the house but have never actually done so.

Post DTV Transition Experience

As to be expected with anything as significant as transition from analog to digital transmission there is a lot of post transition tweaking. In our area the most significant change was WHDH's decision to remain on UHF. Initial plan was to move back to VHF Channel 7. VHF DTV coverage turned out to be smaller than expected resulting in numerous viewer complaints. VHF coverage area problems seem to be [common](#) as documented by [Rabbit Ears](#). WHDH staying to UHF was fortuitous. Now all Boston stations are on UHF.

In our area many stations are continuing to make changes to transmitter and antenna. Most of the changes have been approved by the FCC and are in various stages of implementation. A couple of stations have change requests not yet approved by the FCC. Stations go through multiple steps to build or modify broadcast facilities. They submit an application that is reviewed by FCC. If FCC accepts application station is granted a construction permit. Once construction is complete and verified station license is updated.

“Technical Data and Screenshots” at [Rabbit Ears](#) or FCC [TV Database Query](#) can be used to check station status. For our purposes the important FCC record types are:

DT – Prefix denotes full service digital station
DT-LIC - Full service digital operating license
DT-CP or DT-CP-MOD - Full service digital construction permit
DT-APP – Full service digital modification request
DX – Prefix denotes auxiliary backup digital transmitter
CA – Prefix denotes low power – analog station
LD – Prefix denotes low power – digital station
TX – Prefix denotes translator transmitter

[TV fool](#) signal strength modeling is based on FCC license and construction permit data. Optionally TV Fool allows modeling based on station application requests. Application requests are proposed changes not yet approved by the FCC. Being able to see predicted signal strength based on application requests provides a heads up on future changes. Caution is advised about using application data as it may be withdrawn or modified by FCC or station.

There is another modeling quirk to be aware of. Once FCC grants a construction permit TV Fool uses that information to predict receive signal strength. Unfortunately there is no easy way to identify when a station completes its upgrade. This means viewing experience may differ significantly from prediction.

If you are having difficulty receiving a station check Rabbit Ears or FCC database, may find reassuring information that station is working to increase DTV coverage area.

TV Fool Station Ranking (Nov 2010)

Callsign	Ntwk	RF Chan	Virt Chan	Current dBm	Future dBm	Shared Tower	FCC Status
WMUR	ABC	9	9	-36.0	-36.0		DT-CP
WNEU	TEL	34	34	-40.6	-40.6		DT-LIC
WENH	PBS	11	11	-63.7	-63.7		DT-LIC
WPXG	ION	33	21	-65.2	-65.2		DT-CP
WUNI	Uni	29	27	-76.2	-76.2		DT-LIC
WGBH	PBS	19	2	-80.9	-80.9	Needham	DT-LIC
WCVB	ABC	20	5	-81.1	-81.1	Needham	DT-LIC
WBZ	CBS	30	4	-81.6	-81.6	Needham	DT-CP
WMFP	RTV	18	62	-82.0	-82.0	Newton*	DT-LIC
WPX	ION	32	68	-82.5	-82.5	Candelabra*	DT-CP
WUTF	Tel	27	66	-82.8	-82.8		DT-CP-MOD
WHDH	NBC	42	7	-85.7	-85.6		DT-APP
WZMY	MyN	35	50	-85.7	-85.7		DT-LIC
WGBX	PBS	43	44	-86.9	-86.9	Needham	DT-LIC
WLVI	CW	41	56	-88.5	-87.5	Candelabra	DT-APP
WYDN	Ind	47	48	-87.8	-87.8	Needham*	DT-CP-MOD
WSBK	Ind	39	38	-91.8	-91.8	Needham	DT-LIC
WFXT	Fox	31	25	-92.3	-92.3	Candelabra	DT-CP-MOD
WMTW	ABC	8	8	-96.1	-96.1		DT-LIC
WVTA	PBS	24	41	-99.0	-99.0	Ascutney	DT-LIC
WNNE	NBC	25	31	-103.4	-103.4	Ascutney	DT-LIC

Note 1: WNEU, WPXG, WUNI, WUTF, WYDN, WMTW, WVTA, WNNE don't care stations.

Note 2: WZMY, WYDN, WVTA, WNNE never received.

Note 3: WMFP, WPX and WYDN currently share Newton tower. WPX and WYDN construction permits relocate antenna in addition to increasing power.

Green – good signal

Yellow – occasional no signal

Red – frequent no signal

Empirical ranking of weak digital stations (best to worst)

WPX

WLVI

WGBX

WMTW (Poland Springs ME)

WSBK

WFXT initially modeled very weak which was confusing because reception is excellent. This turned out to be due to the way FCC license data was documented. Once that was corrected predicted results fell into line with other Boston stations.

WGBX was a big disappointment, as we watch a lot of PBS. Reception is worse than stations modeled with lower signal strength. I contacted station and was advised they are transmitting at full rated power and using licensed antenna.

WZMY is a no show. Contacted station and was informed they are transmitting at full licensed power. Station uses relatively low power but more important here in hilly NH antenna is rather low.

Not able to receive any low power analog stations. This is where terrain poses a serious challenge. Low power stations typically use fairly low antenna so terrain obstructions are serious impediment to reception

WMTW came as a surprised, had not considered checking for Maine stations because they are so far away. WMTW is near heading we use for NH VHF stations. WMTW would probably come in more often if antenna were better aligned. It is the only Maine station we receive, not able to pick up UHF stations that far away. We already receive MA and NH ABC affiliates so there is not a lot of practical value other than weather sub channel, mainly just fun being able to receive such a distant station.

Not able to receive either nearby Vermont stations WVTA and WNNE. Both were very snowy in analog.

The good news is with WHDH on UHF and WZMY a no show rotor is no longer needed. Use is limited to fine-tuning antenna direction. We can use rotor to switch between MA and NH ION stations. NH station is very strong. Under ideal condition even receive it with antenna pointed toward Boston. Both ION stations have construction permits. Once that is implemented signal from Boston WBPX should be much stronger.

Overall fairly pleased with upgrade, able to consistently receive 8 of 13 local stations of interest. Based on FCC data WLVI, WBPX ought to move to green bringing total to 10. Last winter reception of WGBX and WSBK did not improve as much as hoped. Stations were viewable just a small percentage of time.

Bill of Materials

Total parts cost was about \$500. We replaced everything except cabling within home.

Qty	Description	Mfg	Pt #	Price
1	UHF antenna	Channel Master	4228	\$50
1	VHF high antenna	Winegard	YA-1713	\$40
1	FM antenna	Winegard	HD-6010	\$30
1	VHF/UHF preamp	Channel Master	7777	\$50
1	Rotor	NTE	U-106	\$70
1	Thrust bearing	NTE	TB-105	\$22
A/R	Rotor cable			
A/R	RG 6 coax			
2	1½" 16 gauge mast		1 ¼" EMT	\$31
1	HD wall mount 12"	Channel Master	9034	\$20
5	4" 5/16" toggle bolts			\$5
4	3-1/2" L brackets			\$3
1	Dual ground block	Holland	GRB-2DHR	\$1
2	Surge suppressor		4251 TV	\$8
1	Junction box (rotor)		15523 BX	\$2
A/R	#6 stranded bare wire			\$.44 ft
1	8' ground rod			\$11
1	Lug (ant mast)			\$3
1	Clamp (ground rod)			\$5
1	Clamp (water pipe)			\$5
1	#6 Split bolt			\$2
1	½" plastic conduit		½" NMT	\$2
1	½" conduit body			\$3
1	FM combiner	Winegard	CA-8800	\$16
1	6-dB attenuator	RMS	CA-1121M-6dB	\$3
1	8-Port active splitter	Channel Master	CM-3418	\$45
A/R	Black TyWraps			
1	Connector seal	Coax-Seal	25-7955P	\$9
1 pk	100 RG6 F connectors	Digicon	DS6_100	\$32
1 pk	100 Coax clips		SKY32213NW	\$2

				~\$500

Suppliers

[Electrical Supply of Milford](#)

[Marlin P. Jones Associates](#)

[Solid Signal](#)

[Tech Tool Supply](#)

[Warren Electronics Distributing Co.](#)

Tooling

Having expended a lot of effort to extract signal out of the air did not want to lose it due to poor coax connector termination. TV distribution uses 75-ohm coaxial cable and [F series](#) connectors. Unlike other coaxial connectors F series does not have a center pin. Inner conductor of coax connects directly to female receptacle. Connector outer shell provides threaded fitting and extends shield. Key to good high frequency operation is to minimize signal perturbation introduced by connector.

F connectors fall into two broad categories, crimp and compression. Crimp style connectors slide over shield and under outer jacket. A ring is crimped over cable jacket making electrical contact between shield and inner portion of connector. The problem with crimp connectors is crimp has multiple faces while cable is round. This results in unequal contact between connector and shield. Crimpers come in two styles narrow and wide. Typical bargain store crimpers are only about a 1/8 of an inch wide, commercial quality crimper is about 1/2 inch.

The best F connectors are compression. Compression style connectors have been adopted by the Satellite TV industry, as frequencies they use extend much higher than OTA or Cable. Compression connectors consist of inner and outer concentric sections. Compression tool pushes both sections together with great force resulting in high quality 360-degree contact with shield.

I decided to use compression connectors. Purchased Ripley Universal-FX compression tool (\$65) and Cable pro PSA596 coax stripper (\$30). Stripper makes precise cuts to remove outer jacket and inner insulation. Another handy tool is Holland CIT F-connector wrench (\$10). Wrench is convenient for tightening coax connectors in tight places.

When purchasing compression tool be sure it is correct model for specific brand of connector you are using.

		
Ripley Universal-FX Compression Tool	Cable Pro PSA596 Coax Stripper	Holland CIT-1 F-Connector Wrench