Dave's Rabbitears.info Monograph

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Introduction: The admins of the Cord Cutting and Over the Air (OTA) Facebook groups ask posters to paste a link to their rabbitears.info report (see Appendix) before seeking antenna recommendations. In trying to help posters with fringe area reception problems, I found myself typing the same advice again and again, so I began cutting and pasting it into this monograph. It's based on textbook learning, but my hat's off to the professional installers and other posters who taught or confirmed much of what you find here.

Executive Shortcut: You probably already know that digital reception is no longer a matter of snowy or ghosted reception - its pretty much all-or-nothing. That makes digital reception a matter of **probabilities,** so you need to know your odds.

Rabbitears.info uses the FCC's open-source coverage prediction software, TVStudy, FCC license data, and topographic databases to estimate the field (signal) strengths of your stations, rate, and rank order them. TVStudy predicts the average but wave effects in the atmosphere and near where the signal goes to ground can cause your signals to vary significantly with antenna location, with time, and with weather.

The FCC established a minimum field strength for each band and UHF channel in 2004. Rabbitears compares your averages with those minima to give the "Signal Margin" of each station in dB. At 0 dB of Signal Margin, that is, right at the minimum, you have a 50/50 chance of receiving a signal depending on the location of your antenna because of the local variation. If you search for the signal (the good 50%) around you, you are likely to find it, though you may still lose it to weather 10% of the time. Unfortunately, the good 50% for one station can be in the bad 50% for another.

To the good, you can receive a station below the FCC's minimum field strength by using a higher gain antenna to capture more of the field as electrical signal and a low-noise preamp to establish a higher Signal-to-Noise-ratio. Either one gives you additional Signal Margin and improves your odds over 50/50.

Computer models like TVStudy and SPLAT can predict your average signal over irregular terrain, but they can't find your 50% "sweet spots" and they're are blind to local barriers to reception. For example, trees or structures in the horizon view of your antenna aren't shown on any topographic database, yet they can cause you heavy signal loss. Multipath, which caused "ghosts" in analog TV, can introduce data errors that are fatal to reception if they are strong enough. Even without those problems in remote areas, you're still playing the odds or trying to improve on them.

I can't guarantee what follows will solve your reception problems, but I hope it will help you dodge frauds you find on the on the web or judge the qualifications of an antenna installer. If you can't find an installer to help you or are truly dedicated to DIY, read all the way to the end in case it covers a difficulty you may face. If you find the issues foreboding, don't panic, keep reading. The are often fixes. That's the short answer. Now for the specifics.

Rabbitears.info https://www.Rabbitears/searchmap.php[1] combines the FCC's open source TVStudy software, TV Station license data, and topographic databases to estimate and rank the signal strengths of your stations. Good means that an indoor antenna should have good luck. Fair means that an indoor antenna may work, but an attic or outdoor antenna definitely would. Poor means you will likely need a good outdoor antenna. Bad means there is likely little or nothing that can be done to bring that signal in. The open question for Poor is "How 'good' an antenna will it take?" Rabbitears' ratings are as conservatively awarded as they are described and are unlikely to disappoint, but if yours discourages, please read on. There may be something you can do about it.

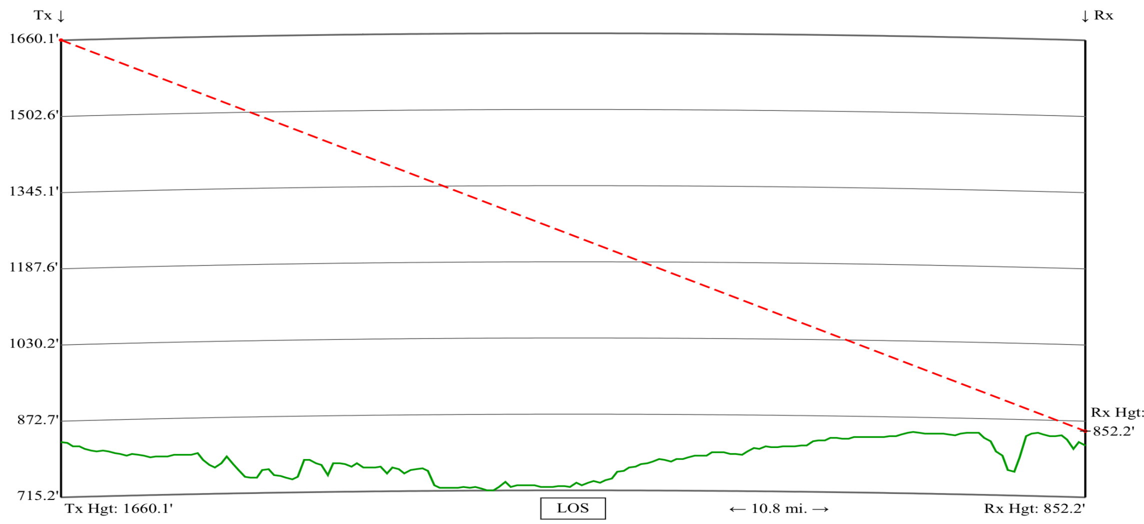
Some Cord-Cutters have posted Rabbitears reports that top out with a "Fair" station or two, followed most of their stations and in some cases, all of their major network affiliates rated "Poor" or "Bad". Mountain dwellers get this often because mountains obstruct their signals. Far suburban dwellers also get it because TV signals go to ground on the earth itself 70-80 miles away from the station even on apparently flat terrain due to the curvature of the Earth. A wave phenomenon called "diffraction" permits reception for some distance on the lee side of an obstruction, so all is not necessarily lost, but your antenna's location may be critical. More on that below.

Antenna Strategy: Before buying anything, start at the top of a Rabbitears search and work your way down until you've accumulated a list of the stations and network affiliations you want. Rabbitears identifies the RF (originally the analog) channel of each station in (parentheses) as well as the virtual "dotted" channels that display on screen. The RF channel(s) determine the type of antenna you'll need - Low VHF (CH2-6,) High VHF (CH 7-13,) UHF (CH 14-36,) or a multi-band antenna. Rabbitears highlights the Low VHF stations in red because antennas designed for them are so large as to be useful only outdoors or in a very large attic. If you can receive a Low VHF station's network from a High VHF (highlighted in yellow) or UHF (white or blue) station further down the list, you may wish to forego the Low VHF one to avoid a huge antenna for just one or two stations. Virtually any antenna will work for Good stations, so make purchase decisions based on the Fair stations and the Poor ones you want to try for.

Lines-of-Sight: Distances on a Rabbitears report are links to a diagram of the signal path over the ground topology in between. If Rabbitears finds no ground obstruction in the topographic database, it thinks you have a line-of-sight path and "LOS" will appear in a box beneath the diagram. LOS reception is predictable because there is one and only one path from the station's antenna to yours. The signal weakens predictably with just distance, so Rabbitears can easily calculate how much you get as long as it hasn't passed through trees or buildings that aren't in the topographic database.

1 A similar site, www.tvfool.com also repurposes the FCC's coverage model to provide a similar "Noise Margin," but its station database has not been maintained and it is often offline. Yet another site, www.antennaweb.com, makes sponsored antenna recommendations that may or may not work for you.

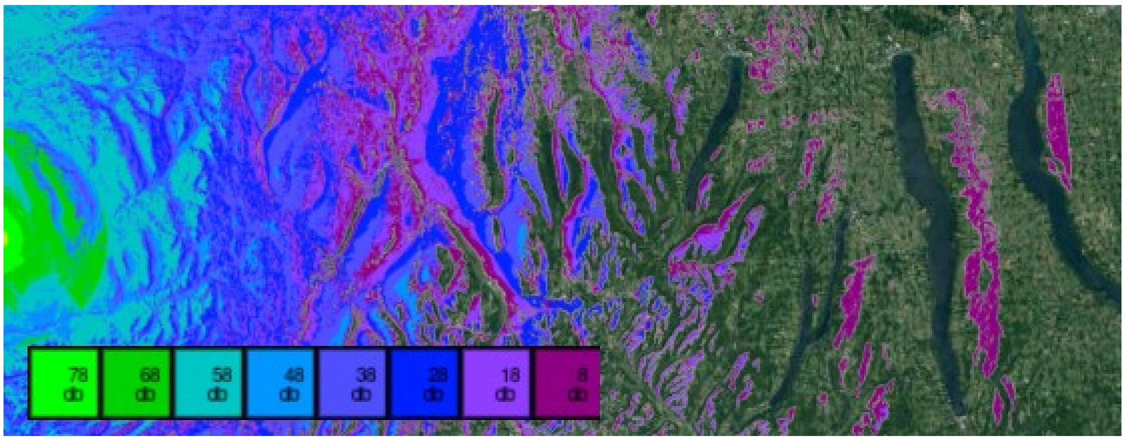
Local Obstructions: Rabbitears' diagrams have an exaggerated vertical scale that makes it look as though the signals fall out of the sky. More likely, they come in less than a degree above the horizon. You should look (maybe in your mind's eye) from your future antenna's height and position towards the horizon in the direction of your stations for trees, buildings, or other man made obstructions that aren't in topographic databases. We'll discuss those further below.



"Knife Edge" Diffraction: If Rabbitears finds ground obstruction(s) in the topographic database, "1-EDGE," "2-EDGE" or "TROPO" will show in the box and dashed blue lines will show a path.

The red line is the line-of-sight that is blocked by the Earth. The blue lines are the shortest path, but the signal doesn't really bend. Each mountain is a 2D slice through a 3D topographic feature. The TV signal can cover a mountain ridge for miles (think into and out of the page,) and every point along the ridge re-radiates signal omni-directionally into the valley beyond. If you live in the valley or on its far slope, your antenna gets signal from all of them at once, but since they're waves, they may combine to a well-above-average signal, ...or cancel out to nothing. This happens on wavelength scale, so that can make your antenna location critical down to a few feet in any direction. To the good, a mountain's shadow isn't dark, but its not evenly lit.

This is a typical path loss cloud for a mountainous area generated by the W5GFE Signal Server:[2] The purple areas behind the mountains contain potentially receivable signals, though there will be sweet spots and dead spots within them that the resolution of the graphic and even the Longley-Rice model behind TVStudy and SPLAT cannot explore.



Speckle (Wave interference): Where a signal of near-single wavelength illuminates a rough surface like the earth, the entire surface reflects it omni-directionally. The surface roughness randomizes the path lengths from across the surface to any particular observation point, where because they are waves, the reflections are as likely to subtract as they are to add. This is often observed as the fine grained "speckle" surrounding a laser beam reflected from a wall if you look at the reflection closely. **You must never, of course, look into a laser beam or a mirrored reflection of one. To see this, use a Class 2 Laser pointer at a distance from a flat painted wall.** A TV signal is similarly monochromatic, but has a wavelength a million times longer so the speckle pattern is also a million times larger – on the order of feet.

Troposcatter: "TROPO" in the box means there are too many topographic obstructions for predictable reception by re-radiation from the earth. The station may still be receivable from time to time because the atmosphere can bend radio signals like light due to layers of different temperature (think mirages.)

Now we now need some numbers, but thanks to the magic of decibels, we can leave the math and statistics to the FCC, TVStudy, and Rabbitears.info To do that, we use "decibels."

The Decibel aka the **dB**, is a comparison of one thing with another. Appending a letter tells us with what, for example, the dBv compares to one volt; dBm to one milliwatt, and so forth. In

2 https://splat.w5gfe.org/

antennas, you'll see dBi, which compares with a perfectly omnidirectional, "isotropic" antenna that no one knows how to build, but its mathematics are simple.

dB's (without a reference letter) can be either comparisons between two similar things or an improvement or degradation. We describe an antenna with 18 dBi "gain" as having +8 dB "more" gain than a 10 dBi antenna. It will capture +8 dB "more" electrical signal from a given field strength. Adding 100 feet of RG-6 coax cable that "loses" -2 dB per 100 feet makes that equivalent to a 16 dBi antenna. Adding a splitter that loses -3.5dB more makes it equivalent to a 12.5 dBi antenna, and so on and so on.

Decibels are actually logarithms of ratios that can compare potentially huge ratios with just a digit or two, but you don't need to understand logarithms. Just remember that 0 dB means equal, positive dBs are greater, negative dBs are less, and that we can usually just add or subtract them as we make changes. We'll start with your Rabbitears' Signal Margins as our reference then add or subtract decibels as we find more signal or introduce less noise.

All or Nothing: Digital turned the sometimes snowy, ghosted, or blurry pictures of analog TV into an all-or-nothing proposition. The line between all and nothing is "pixellization" and just below that cliff, the difference between all and nothing is just a dB or two. For comparison, in analog TV this could have been 25 dB or more, depending on how much snow you were willing to watch through.

Probabilities: The all-or-nothingness of digital required the FCC to adopt a *probabilistic* definition of coverage area, which it defined in 2004 as having boundaries along which a digital station is received at 50% of locations, 90% of the time, or "F(50,90)."[3] The 50% represents diffraction beyond where the signal has hit a mountain or wave interference where it has gone to ground because that can be usable coverage if you're in the right place and willing to move your antenna. The 90% (actually the remaining 10%) is the allowance for atmospheric conditions or occasional Troposcatter.

Planning Factors: The FCC surveyed antennas and receivers as they stood in 2004 and published its "Planning Factors" for a *typical* fringe area receiving system of antenna, coax cable, and TV receiver without a preamp or splitter(s.) With no disrespect, we'll call that combination the "FCC Antenna." The FCC Antenna in turn, determined the minimum signal (field) strength for F(50,90.) The FCC chose the "Longley-Rice" propagation method for determining a station's licensed power and the limits of its F(50,90) coverage area consistent with what would eventually become the "Repack." That led to the FCC's open source TVStudy software which Rabbitears combines with station licensing and topographic databases to generate your report.

Signal Margin: In addition to the Good/Fair/Poor ratings, Rabbitears compares the estimated signal strength from each station with that FCC-determined minimum for F(50,90). This is called the "Signal Margin." It allows us to at least *try* to answer that question of "How good an antenna?" A 0 dB margin means you live on the limit of a station's coverage area.

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3 https://transition.fcc.gov/oet/info/documents/bulletins/oet69/oet69.pdf The "Planning Factors" for the viewer's antenna, coax cable, and set are found in Table 3.

You should get F(50,90) with the "FCC Antenna." If you located it arbitrarily, you'd have a 50/50 chance of getting that station and a 10% chance of losing it to weather from time to time.

The Good News is that antennas have improved and low noise preamps have been introduced that can improve on the FCC's Planning Factors and give you more Signal Margin than Rabbitears predicts for the FCC Antenna. This table shows the substitution of a Televes 148281 antenna with its internal low noise preamp for the respective FCC Planning Factors. This is not intended as a recommendation, but as an example.

	Signal Margin	Low VHF CH 2-6	High VHF CH 7-13	UHF CH 14-36	
Remove FCC Antenna Gain		-4.0	-6.0	-10.0	dBi
Replace w/Televes Antenna Gain		-3.0	8.5	18.0	dBi
Remove FCC Receiver Noise Figure		10.0	10.0	7.0	dB
Replace w/ Televes Preamp Noise Figure		-3.0	-2.0	-2.0	dB
Remove FCC Downlead Loss		1.0	2.0	4.0	dB
Replace w/ w/c TV Receiver Noise Contribution		0.9	0.9	0.6	dB
Signal Margin for F(50,90)	0.0	-1.9	-13.4	-17.6	dB

The bottom line shows that as much as 17.2 dB of additional Signal Margin can be had at UHF. Antenna Gain and Noise Figures will be further explained below.

The author ran experiments with on the open source SPLAT implementation of Longley-Rice. SPLAT is similar to TV Study, but more easily scripted for alternatives to F(50,90.) The "Need" column in the table below shows the added Signal Margin required for higher probabilities. Longley-Rice may not be the best model for knife edge diffraction, but it's what the FCC used and Rabbitears uses it. Its authors described the path loss distribution as being normal, which suggests these results based on the quantiles of SPLAT's path loss cloud are probably valid[4]. These results might differ for VHF or they might be totally wrong at UHF, but its what the SPLAT implementation of the "Longley-Rice" model suggests FWIW.

		Rabbitears.info Signal Margin			
		Low VHF	High VHF	UHF	
With Televes 148281 Antenna	Need	CH 2-6	CH 7-13	CH 14-36	
Signal Margin for F(50,90)	0.0	-1.9	-13.4	-17.6	dB
Signal Margin for F(50,95)	1.1	-0.8	-12.3	-16.5	dB
Signal Margin for F(70,90)	3.5	1.6	-9.9	-14.1	dB
Signal Margin for F(90,95)	9.7	7.8	-3.7	-7.9	dB
Signal Margin for F(95,95)	12.1	10.2	-1.3	-5.5	dB
Signal Margin for F(98,98)	16.2	14.3	2.8	-1.4	dB

4 These margins are based on the means and standard deviations of path loss clouds generated with the Signal Propagation, Loss, And Terrain analysis tool (SPLAT,) an open source version of the Longley-Rice propagation model. Path loss distributions were obtained for WNJU-DT in Linden, NJ, WICS-TV in Springfield, IL, and WLPX, Charleston WV to include a range of topographies. The sensitivity of the quintiles to margin was remarkably consistent across topographies: 0.0, 0.8, 3.5, 9.5, 12.0, and 15.8 dB for F(50,90), F(50,95), F(70,90), F(90,95), F(95,95), and F(98,98) respectively.

So the example Televes 148281 or equivalent antenna and low noise preamp *might* get you to F(98,98) probabilities on stations down to -1.4 dB of Rabbitears' Signal Margin, avoiding the need to search for a critical antenna location or one that works on multiple F(90,98) stations, and potentially improving bad weather immunity.

Evaluating an Arbitrary Antenna/Preamp: Gains and noise figures are specified only by the best antenna and preamp manufacturers. For the lack of any industry certification, they are on the honor system for telling you what their products will do, but if you trust them, you can create a "figure of merit" for an antenna/preamp combination as follows:

RAW (Unamplified) ANTENNA GAIN (dBi)
- Preamp NOISE FIGURE (dB)
- 0.5 (dB) (an allowance for receiver NF contribution to system NF)
= Figure of merit (dB)

For the 2004 FCC assumptions behind TVStudy and rabbitears, the corresponding figures-of-merit are -7 db for Low VHF, -6 dB for High VHF, and -1 dB for UHF; so for example, an 18 dBi UHF antenna less a 2.5 dB Noise Figure preamp gives you 16 dB more Signal Margin than Rabbitears' predicts for a UHF station with that 2004 setup. The previous table suggests how much good that might do.

Walking your Roof: If you have difficult Rabbitears report, you might find the search for a single antenna location that gets your desired stations to be a miserable procedure involving much climbing and patching holes in your roof for antenna locations that didn't pan out. I suggest hiring a professional installer who has specialized instruments such as a Spectrum Analyzer and the skills to "walk your roof" while measuring multiple signals at once and the patience and/or luck to find a workable antenna location for the stations that matter to you. For an extreme example, see Peter Putman's YouTube video "Fun TV Antenna Tricks[5]. Those signals would rate Bad on a Rabbitears report, yet there they were.

Indoor Antennas require more Signal Margin than outdoor antennas because homes and buildings reflect some signal and absorb some and even more so at UHF than VHF. Also, indoor antennas lack the performance of outdoor antennas because of their necessarily small size. Although the primary topic here is fringe area reception, here are estimated *minimum additional* margin requirements for indoor reception with "rabbit ears" or another indoor antenna based on a single reference the author could find[6]:

- 17 dB more for a Low VHF channel between 2 and 6,
- 17 dB more or a High VHF channel between 7 and 13,
- 24 dB more for a UHF channel between 14 and 36.

5 https://youtu.be/hVQNo6ifMNY Peter Putman, KT2B

6 Average of penetration loss among building types for each band per 2604/BMEM/R/3/2.0 – building_materials_and_propagation.pdf this could use more study

This is dependent on materials and construction, and other researchers found building losses as high as 31 dB in UHF. This could use a lot more study. For what it's worth, adding building losses to additional margin required for higher reliability, you need 40 dB to 47 dB of Signal Margin for 98% reception indoors and a Good rating on Rabbitears. Some viewers have plenty of Good stations with 100 dB or more of Signal Margin, enough for indoor reception in a solid masonry apartment building, in the middle of a deep forest, using an unamplified indoor "Mudflap" antenna placed under the sofa. More about "Mudflaps" below. At least they *shouldn't* cost much to try for Good stations if you buy an inexpensive un-amplified one.

Local Obstructions: If you could stand on your roof where your antenna would be, look in the direction of your stations, and have a clear view of the horizon, your probably don't have any local obstructions. If you do and are comfortable using geo-coordinates, the Radio Fresnel[7] web site can draw the LOS line and the Fresnel Zones as a .KML file that you can view in 3D imagery by opening it in Google Earth, with results like this….

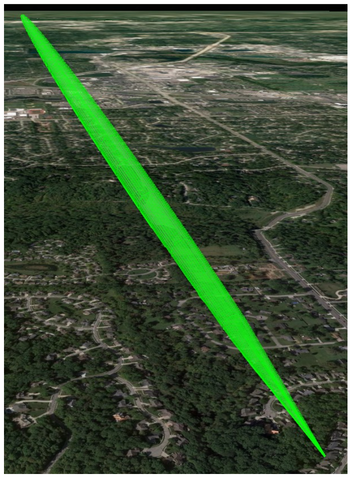
..or in Street View, like this

7 http://www.radiofresnel.com/

These KMLs correspond to the above Rabbitears LOS diagram near its right margin where the signal approaches the earth.

The tree canopy and homes aren't in the topographic database, so Rabbitears rates the signal as Good based on the station's transmit power and LOS distance. Signal measurements with a test dipole and spectrum analyzer, however were ≈40 dB lower, indicating substantial path loss in those trees, structures, and the composite roofing. The amplified gain of an attic located Televes Ellipse Mix provided about 25 dB of Signal Margin over all four seasons with little seasonal variation. There was some multipath or diffraction off the tree boles that required moving the antenna slightly for a flat spectrum on that station. The subject of foliage loss needs a lot more study. The author's property was surrounded by "mesic" forest, but the only result of a Google search was that tropical rain forest is reportedly around -0.5 dB/foot of path.[8]

Multipath is the Achilles' Heel of digital television. In analog, it caused blurring or ghosts too fine to see without having your nose against the screen, but to digital signals its noise and can cause digital reception to fail completely[9]. It's caused by reflections from terrain or structures within an imaginary football-shaped volume with its pointy ends at the station's antenna and yours (the "2nd Fresnel Zone.")



Radiofresnel.com can draw them as wireframes for 3D viewing in Google Earth. The station's end is isolated by its tower, but yours is at the mercy of trees, neighboring homes, buildings, billboards or other structures, and everything else nearby. The FCC conveniently assumed that your having a 9.1m (30') antenna height would avoid those, but that may not be enough. Multipath can completely kill downtown hi-rise reception. Strong signals give no relief because the reflections are likely to be strong as well. Receiver manufacturers have proprietary equalization algorithms for minimizing the resulting "inter-symbol interference" and data errors, so there are reportedly differences among brands.

To follow are some deeper details that may help in diagnosing reception problems.

Signal-to-Noise-Ratio (SNR) is *everything* in decoding a Digital TV signal. For ATSC, **15.2 dB** of Signal-to-Noise-Ratio is required down deep in your receiver where it finally happens. Just a dB or two below that lies the "cliff" of pixelization and "No Signal." Signal to

8 https://www.researchgate.net/publication/245554022_Path_loss_modeling_for_near-ground_vhf_radio-wave_propagation_through_forests_with_tree-canopy_reflection_effect

9 This is a consequence of "VSB-8" modulation and was well known when the ATSC standard was adopted. Some experts suggested an alternative known as OFDM, but the FCC forged ahead at the behest of broadcasters who wanted minimal power costs and change (read minimal costs) to their analog transmitters. The FCC's "solution" was to assume that the viewer could and would use an outdoor antenna and mount it at 9.1m/30 ft above ground to get it above any reflection(s) from nearby structures. Back to the 50's, so to speak

Noise ratio gets established in the very first circuit of your preamp or TV receiver where the relatively weak but noise-free signal from your antenna meets the noise generated within that first circuit. Further amplification is of both signal and noise, so the ratio is unchanged.

Noise Figure: Ideally, about half of that first circuit's noise is "thermal" or "kTB" noise named after the equation that calculates it. It's generated by the electrons getting' kicked around because that circuit is above absolute zero. Absolute zero or 0°K is like -273°C or -459°F, so there's nothing you can do to reduce circuit noise short of liquid Helium and that's hard to come by. Every real world electronic circuit generates additional noise of its own, a critical specification called its "Noise Figure."

Receiver Sensitivity is a common question posted to the Facebook OTA groups – Which brand is best? Probably none, at least none consistently. Sensitivity is determined by the Noise Figure of the set's first stage. The term means nothing to the consumer and it's never stated by TV manufacturers even though the difference between the best and the worst brands and models is reportedly as high as 10 dB and enough to matter. That's why the table in this monograph assumes a preamp. You can choose it for low Noise Figure and adequate Gain so whatever noise your receiver contributes is diluted and doesn't amount to much.

Antenna Gain: The *un-amplified* "gain" of your antenna specifies how much of that precious noise-free electromagnetic field passing by it captures as an electrical signal. Note that its **all** downhill from there. Coax cable (RG-6) loses about 2 to 5 dB per 100 feet depending on band. Splitter(s) lose an additional 3.5 dB per split. Those cost you the pure signal but have no effect on the following circuit's noise, so they count directly against your Signal-to-Noise-Ratio dB for dB. That's why a preamp works best when its built into the antenna or mast mounted and connected to it by a very short cable.

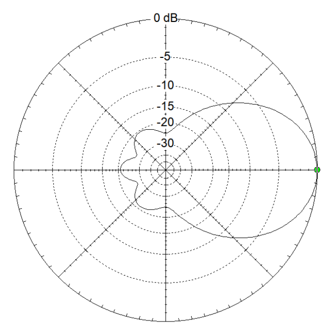
Gain Games: Unamplified antenna gain ranges from a little less than 2 dBi for ordinary rabbit ears to as high as 18 dBi for a 40" long or 40" wide monster. (The dBi is a comparison with a theoretically omni-directional antenna.) Some manufacturers properly state the unamplified gain or better yet, plot it for their products; others give amplified gains which are useless without the actual gain and the amplifier's noise figure; still others give 200 mile range claims. Even then there can be games: if a balun transformer is used, is its loss included or not? Is the gain number for the one best channel in the band? ...or the one you really want? You can choose an antenna based on brand loyalty alone, or how complicated it looks, or buy from a manufacturer that describes what its product will deliver, though there's no industry certs, so you have to trust them to deliver on it. The author is partial to Televes for that, yet not all of its products are completely specified because the Gain Games of competitors might make its products appear inferior when they are not.

Your Coax Downlead and any signal splitter(s) should be behind your preamp, that is, between it and your receiver(s). At that point, they lose amplified signal and amplified noise equally, so they don't impair Signal-to-Noise Ratio. Your TV receiver has a Noise Figure of its own in its first circuit, an unknown and not necessarily a low one. Having at least 10 dB of preamp gain “left over” after all coax and splitter losses reduces the worst case receiver noise contribution to less than 1 dB. 20 dB of excess would reduce that to 0.5 dB if you don’t have “IM.” More about IM below.

Preamps: Some preamp (re)sellers pretend not to know what Noise Figure is. They'd rather sell you Gain because its cheaper to make. A preamp's Noise Figure usually differs between VHF and UHF and varies with channel across UHF. Some competitive measurements posted by Televes’ Javier Ruano to the Facebook OTA groups suggest that even some name brands' "low noise" preamps are actually quite noisy at least in some bands. Those are worth the search before you buy. The lower and more detailed the Noise Figure specification you find in a preamp's spec sheet, say comparable to Kitztech's or some of Televes', the more likely it is that the manufacturer knows what it is and means it.

Antenna Range Claims: There is a lot of marketing fluff, wishful thinking, and outright fraud in the antenna market. There's nothing special about a "digital" antenna. Every VHF or UHF signal goes to ground around 70 to 80 miles from the station if not closer, so a "digital" antenna claiming "200 mile range" or more is bogus. An occasional viewer might have seen “tropo” that far away once. Don’t be fooled.

Directivity: Antenna gain and directivity (directionality) are interrelated. You can’t have one without the other. Not all manufacturers publish “azimuth” pattern diagrams like the one at right, which shows that the more signal an antenna captures from its "forward," direction, the less it will capture from its sides and back. Directivity is desirable when all of your stations are in one direction. It can help reduce multipath from surrounding structures and interfering signals from markets in other directions. The downside of directivity is when you live between two markets or your stations are scattered in all directions around you. If the Signal Margins are so low that you need antenna gain, you might need multiple antennas or an antenna rotator, either of which which introduces problems of its own.



Indoor Antennas: The basic indoor antenna is the familiar rabbit ears - two telescoping metal rods for VHF channels 2-13 and a wire loop for UHF channels 14-36. The rods are an example of a "dipole," the basic 2 dBi building block of all antennas, and they deliver around 2 dBi of gain when extended to 15." That means they are -4 to -8 dB *below* the 10 dBi FCC Planning Factor, so they produce that much *less* Signal Margin. The loop is used only for UHF and depending on its shape, delivers about the same. The metal rods might be bowtie shapes, or hairpin loops. They may be visible, contained in a futuristic looking plastic case, or sandwiched in a flexible "Mud Flap." Appearance doesn't really matter, though the UHF gain of a Mud Flap might be as high as 5 dBi if it’s tall enough to hide two dipoles. For VHF channels, most mud flaps are just a flattened 2 dBi rabbit ears.

Amplified indoor antennas try to sell you amplifier gain as antenna gain, but they're *not* the same thing because of the noise discussed above. The unamplified gain is never specified, nor is the Noise Figure of the amplifier. The amplifier is of little use indoors unless you are locating the antenna in a window of one room and coaxing the signal 50' or more into another room or splitting it for multiple sets. The amplifier also means another wall wart you have to find a place to plug in because the amplifier is likely to block everything if you don't.

A problem common to all indoor antennas is that that they are indoors and people are nearby. Wood frame construction, exterior sheathing, composite roofing, and drywall absorb signals while aluminum siding, moisture barrier sheathing or metal wall studs reflect them (towards your neighbors as multipath.) All cost you signal strength indoors. People also reflect signals so they are best kept away. Rabbit ears have an attached cable long enough for the set top, but more elaborate indoor antennas have 10 or 15 foot cord so you can hang them high on a wall, more out of your way. A flat ("mudflap") antenna's sensitivity is bidirectional and greatest *perpendicular* to itself. There is less pick-up off its ends or edges, so ideally you have a wall or window that is perpendicular to your stations and within 10 or 15 feet of your set.

Attic Antennas are a way of avoiding towers, rooftops, and people. They work well if you have nonmetallic roofing material and room between the rafters for whatever aim you need. Even composite roofing contains copper particles to resist mildew and reportedly absorbs between -3 and -6 dB compared to the same antenna outdoors. If you have enough Signal Margin on your weakest desired station, this loss may not matter and the attic mount can be a decided convenience. The writer's attic antenna is mounted to a 1" vertical pipe on a rectangular frame made of 1" PVC, four elbows, and a tee from the Big Box store. The frame is wider than the space between two ceiling joists so it could be moved around and aimed for optimum signals.

Outdoor Antennas: The most basic outdoor antenna is a weatherproofed version of rabbit ears. It has no cord, so you supply your own coax cable to connect it. One pair of VHF rods is usually evident and like rabbit ears, they are a 2 dBi dipole. Unless 40" or more in width, the Low VHF (CH 2-6) gain is lower. Some manufacturers claim over 2 dBi on High VHF (CH7-13.) There are sometimes two of four UHF loops, also encased in plastic. These demonstrate the general principle for getting more gain: *doubling the* number of 2 dBi dipoles or loops for *each* 3 dB of additional gain. Size and wind load cause this approach run out of steam above 18 dBi.

Outdoor Dipoles: Like rabbit ears, mudflaps, or other indoor dipoles, the outdoor dipole receives equally well from the front and back. This is desirable if you live between two markets that aren't too far away or your stations are scattered across town. Some outdoor models have a metal reflector screen (sometimes an option) that shields the antenna from signals on its back side and reflects signals from the back into the dipoles. This adds two or three dB of gain to the front by subtracting more than that from the rear.

"**Multi-bay" antennas** increase gain by doubling up dipoles top to bottom, side by side, or both, so multi-bay antennas are tall and/or wide, but not necessarily deep. They usually have a reflector screen or bars behind the dipole elements so their rated gain is for stations in front of the reflector.

"Yagi" antennas obtain gain by combining dipoles front to back. Not all of them need to be connected to have their effect. The Yagi antenna is thus lengthy instead of tall or wide. Yagis can have considerable gain, but are very directional and so must also be aimed at the stations of interest. There are deeply held opinions that either a Multi-Bay or a Yagi is superior to the other. What matters most is the VHF and UHF gain specs and maybe whether it might fit in your attic.

More about Multipath: If you have multipath problems at your location, there may be little you can do except raise the antenna height above neighboring property. Although reflected signals appear to come from a slightly different direction than the station, there is no commercial antenna directional enough to reject them. Multipath often appears as an ensemble of paths that act like diffraction and form sweet and dead spots. A higher gain and hence more directional antenna *might* limit the included reflections and find an acceptable ensemble for a few channels. Improved multipath rejection is among the claimed advantages of the ODFM used in the new ATSC3 standard aka NexGen, though some comparative tests have yielded conflicting results.

Intermod (IM): A preamp used without coax loss or splitters behind it can cause problems of its own by overloading the receiver. This can cause strong TV and LTE/5G wireless signals to combine into noise on *other* channels that can bury the weaker signals you sought to gain. Better preamps have LTE filters, but TV signals can also mix if they are strong enough and those can't be removed. IM is level sensitive: for every 1 dB that a pair of signals increase, the noise products increase 3 dB. Worse yet, there can be more than two signals in play, so be careful with preamp gain and keep it to the minimum described above if you can adjust it. More than 10dB excess gain isn't necessarily better. Too much more can be a whole lot worse.

5G/LTE: If a strong LTE signal causes an IM problem, there are filters specifically for that which will have little or no effect on desired stations. If a strongest TV signal presents an IM problem, you can always “pad” it with an inline attenuator to take advantage of the 3:1 non-linearity, but that is at the expense of all of your stations. You may be able to purchase a channel stop filter specifically for that strong channel but now you are in the wheelhouse of a professional.

Multiple Markets: Birds of a feather flock together and so it is with TV stations. Tower space is costly and the FCC encourages tower site sharing. Thus in many markets, most of your stations will be in the same direction. Rabbitears and TVfool present a polar (“bulls-eye") diagram. If the stations in your list are all in one direction or lie within a 45° angle of each other, you may be able to get them all with a single VHF/UHF antenna compromise-aimed mid way between them. Some azimuth plots like the one shown above calibrate the radial scale to show how the gain in dB falls with off-bore-sight aim in degrees.

Antenna Rotators are recommended by most installers over attempting to combine antennas with splitters but they are disparaged by others for Poor reliability. They also cannot be controlled by DVRs.

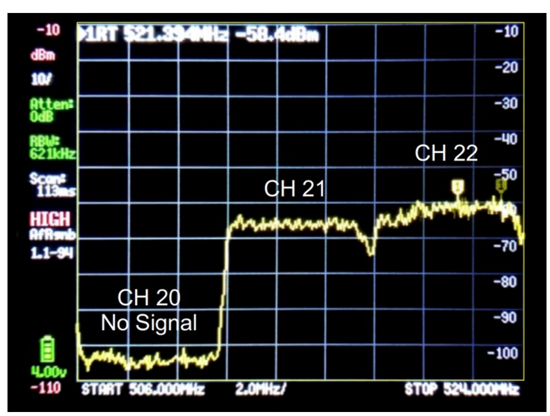
Combining Antennas are prone to disappoint because the same signal received from two antennas that aren't perfectly matched, perfectly vertical, and perfectly aimed, will come in misaligned in time because the path lengths to each will inevitably be slightly different. The result is a distorted sum which is all the receiver can distinguish and which it is less likely to decode than either antenna alone.

Diplexers: If you are shooting for UHF stations in one direction and VHF stations in another, you may be able to combine UHF and VHF antennas in a specialized UHF/VHF splitting combiner (aka a “diplexer”) so the same signal is never combined from two different antennas.

Avant-X: The Televes Avant-X is a remarkable piece of kit for accepting signals from multiple antennas at different locations and re-channeling them into different blocks of receive channels that can be received by multiple sets, watched by different viewers, or tuned by DVRs simultaneously. While more costly than any single antenna, the Avant-X should be considered a one-time purchase and viewed in light of the installed and maintained cost of a rotator thereby avoided.

Network Tuners such as the Silicon Dust's HomeRun and Flex series can be used, one for each antenna, on a shared network because your router will assign them different IP addresses. The Channels Plus DVR server, if not others, will recognize multiple network tuners. Control over which antenna and tuner are used for a given station can be managed by disabling that channel on the other(s.).

Optimizing and Aiming: Most digital TVs have a signal strength and/or signal quality meter, usually a bar chart or two accessible from a service menu. It can be used for antenna optimization, but finding a sweet spot that is common to multiple stations can be time consuming. The readings apply only to the single channel then tuned in. Subtle defects in the signal may produce an undesirable pixelation only every few minutes, requiring a long evaluation period on each channel or when a new configuration is under test. Some TVs take several seconds to find a new signal and lock.



Spectrum Analyses: A Spectrum Analyzer is a receiver that scans a desired frequency range in MHz (the scan width) and displays whatever signal or noise power in dBm that it finds within its “resolution” bandwidth. The tinySA is a relatively new and inexpensive (<$60) Spectrum Analyzer[10]. It’s small, battery powered, covers the VHF and UHF TV bands, and in the Author’s experience with a genuine one,

10 https://tinysa.org/wiki/pmwiki.php?n=Main.Buying

accurate. You will need some Type-F to Type SMA coaxial adaptors to connect to it and would be well advised to have a 10dB inline attenuator to protect it from strong signals.

You must get used to the channels being defined in MHz ranges (the channels numbers in the thumbnail were were hand drawn in,) and able to identify them with a scan, but you will be able to assess them all at once. Viewing three channels at once puts them in neat 3-divisions each. The author published a YouTube video demonstrating how to measure a single signal and identify multipath.[11]   Basically, the vertical height of a signal on screen indicates it strength and its flatness the quality. *Poor* Signal *Quality* in the presence of *Strong* Signal *Strength* is evidence of a damaged signal due to multipath, diffraction, or possibly IM. The first two are far more common and the "fix" is an experimental one to re-aim or move your antenna.

The tinySA can identify ATSC3 signals by fleeting notches that flash occasionally at the top or bottom edge of the channel. These appear when tinySA's scan happens to coincide with the "bootstrap" signal sent a few times every second that is 4.5 MHz wide instead of 6 MHz. Tiny's scan rate is too slow for you to see them all and you won't see both of them in the same scan.

Co-Channel Interference: Not even Avant-X can reject co-channel interference from a station on the same RF (not dotted x.y virtual) channel from another market. If strong enough, such interference can completely prevent reception of a local channel. Although the FCC spreads out channel reuse to avoid this, since the repack they have fewer channels to assign and "troposcatter" occasionally brings in co-channel stations from hundreds of miles away. There are TV "DX'ers who live for those moments when those far-distant signals land on a locally empty channel.

I strongly suggest a professional installer if Rabbitears shows that you are at the coverage limit of any station you really want or if you have diffracted signals or multipath. Professionals installers became rare in the age of Cable and Satellite, but they're now desperately needed by cord-cutters. If you live in a tough location, hopefully there is one who services your area. Satellite and Cable installs were relatively simple because the dishes looked into the sky or the set top boxes connected to amplified signals. Hopefully this monograph will help you test a candidate installer's ability to do the job. Show them your Rabbitears report and ask how many stations they expect to get for you and how. If you must go it alone, I hope this monograph helps you avoid things that clearly won't work.

Good Luck, and to the Hams, 73's

Dave
AD9DP

Postscript: ATSC3, aka Nexgen, is a menu of advanced capabilities in new receivers that broadcasters can turn on to provide new services like 4K or higher resolution. It is becoming table stakes for flat screen manufacturers because new set buyers demand the latest and

11 https://youtu.be/T8HDpqwo-0Y

greatest, but its still optional for local broadcasters. ATSC3 can approach the theoretical (“Shannon”) limit of how much data can be transmitted and how fast over a 6 MHz TV channel. Since spectrum is ultimately limited that is hard to argue against. ATSC3 takes back much of what was given away as VSB-8 to make ATSC acceptable to broadcasters that didn't want to completely replace analog transmitters or increase their power costs.

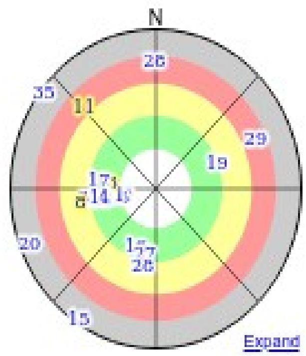
In perhaps ten years, ATSC3 might be FCC-mandated to free up ATSC channels for wireless carriers. ATSC3 adopts OFDM (see footnote above) for increased robustness in the presence of multipath, but at the same time, it replaces the fixed 15.2 dB Signal to Noise requirement of ATSC with options that range from 5.5 dB (more robust) to as high as 36.54 dB (higher Signal Margins required.) That exposes the raw tradeoffs between "payload" such as resolution, transmit power, and coverage area. Most of the present Nexgen stations are "lighthouses" that duplicate one or more local network affiliates at 720 or 1080P High Def. There should be no difference with ATSC except potentially higher multipath rejection. When you see more than that, you should expect to PPV or subscribe for it.

Appendix

Typical rabbitears.info report.

Result List

Instructions	Click here.
Study Location	39.91**, -86.02**
Study Date/Time	2022-01-17 17:10:34ET
Receive Height	30' (AGL); 863' (AMSL)
Search Distance	50 miles
Sort By	Field Strength
Units	dBuV/m
Hide Off-Air	No
Current Station Search List	Post-Repack Search List
Current Station Search Map	Post-Repack Search Map



Channel	Callsign	Network (436187)	Community of License	State	Map	Transmitter Distance (Miles)	Direction (True)	Direction (Magnetic)	Field Strength (dBuV/m)	Signal Margin (dB)	Repack Info
6-1 (25)	WRTV	ABC	INDIANAPOLIS	IN		9.6	265.3°	270.3°	112.99 Good	73.14	
59-1 (22)	WXIN	FOX	INDIANAPOLIS	IN		9.7	261.2°	266.2°	112.11 Good	72.55	L
29-1 (15)	WTTK	CBS	KOKOMO	IN		9.7	261.2°	266.2°	109.40 Good	70.57	L
20-1 (21)	WFYI	PBS	INDIANAPOLIS	IN		9.5	265.3°	270.3°	106.49 Good	67.03	
13-1 (13)	WTHR	NBC	INDIANAPOLIS	IN		8.6	278.4°	283.4°	99.45 Good	63.45	
40-1 (7)	WHMB-TV	REL	INDIANAPOLIS	IN		9.8	263.5°	268.5°	97.43 Good	61.43	L
8-1 (9) 23-1 (9)	WISH-TV WNDY-TV	CW MY	INDIANAPOLIS MARION	IN IN		9.9	261.9°	266.9°	96.32 Good	60.32	
19-1 (16)	WDNI-CD	TLM	INDIANAPOLIS	IN		8.2	201.4°	206.4°	95.83 Good	56.89	L
69-1 (23)	WDTI	Daystar	INDIANAPOLIS	IN		9.8	263.5°	268.5°	95.36 Good	55.7	L
47-1 (36)	WBXI-CD	IND	INDIANAPOLIS	IN		9.8	263.5°	268.5°	94.51 Good	53.65	L
28-1 (24)	WUDZ-LD	IND	Indianapolis	IN		9.8	263.5°	268.5°	94.44 Good	54.68	
30-1 (30)	WSDI-LD	IND	Indianapolis	IN		9.8	263.5°	268.5°	94.44 Good	54.12	
8-1 (26) 23-1 (26)	WISH-TV WNDY-TV	CW MY	INDIANAPOLIS MARION	IN IN		9.9	261.9°	266.9°	94.41 Good	54.46	
46-1 (17)	WALV-CD	MeTV	INDIANAPOLIS	IN		8.6	278.4°	283.4°	93.10 Good	54.06	L
4-1 (27)	WTTV	CBS	BLOOMINGTON	IN		35.4	191°	196°	92.96 Good	52.91	L
34-1 (34)	WIPX-LD		INDIANAPOLIS	IN		9.8	263.6°	268.6°	92.54 Good	51.86	
49-1 (19)	WIPB	PBS	MUNCIE	IN		35.6	69°	74°	86.62 Good	47.37	L
33-1 (31)	WQDE-LD	IND	Indianapolis	IN		9.8	263.5°	268.5°	85.11 Fair	44.69	
63-1 (28) 42-1 (28)	WIPX-TV WCLJ-TV	ION Bounce	BLOOMINGTON BLOOMINGTON	IN IN		35.6	190.9°	195.9°	82.59 Fair	42.45	L
17-1 (8)	WIIH-CD	IND	INDIANAPOLIS	IN		9.9	261.9°	266.9°	77.47 Fair	41.47	
18-1 (11)	WLFI-TV	CBS/CW	LAFAYETTE	IN		45.5	316.8°	321.8°	53.69 Poor	17.69	
15-1 (29)	W29EL-D		LIMA	OH		13.3	65.1°	70.1°	49.51 Poor	9.28	
51-1 (28)	WJSJ-CD	REL	Tipton	IN		26.3	359.3°	4.3°	42.81 Poor	2.67	L
21-1 (20)	WSWY-LD		Indianapolis	IN		34	249.2°	254.2°	28.41 Bad	-10.95	
15-1 (15)	WREP-LD	IND	MARTINSVILLE	IN		38.5	213.4°	218.4°	24.67 Bad	-14.16	
35-1 (35)	WPBY-LD	ABC/MY	LAFAYETTE	IN		55.4	308.1°	313.1°	22.69 Bad	-18.08	
16-1 (17)	WPBI-LD	FOX/NBC	LAFAYETTE	IN		55.4	308.1°	313.1°	14.61 Bad	-24.43	