

# R/C Antenna Experiments

## Does Rx Antenna Length Really Matter?

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*What happens when you lengthen, shorten, wrap, or otherwise torture your R/C receiver's antenna? Well, if you have ever wondered, then please join us for a little bit of experimentation.*

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Most R/C manufacturers advise that we should install the Rx (receiver) antenna so that it is fully extended. On a large model this is easily accomplished. On smaller park flyers we often have to get creative. So, some folks end up winding, crisscrossing, or chopping the wire aerial so that it fits in a smaller area. And this trickery seems to work out for us most of the time.

There are many opinions on what happens if your R/C Rx's antenna is changed from the factory recommendation. In general, I think we all fall under one of four categories. Some folks insist on following the hard coded rule that the physical length is simply based on the speed of the magnetic wave ("the wavelenthers"). Others, say that longer is better since a bigger profile earns more RF current ("the profilers"). Another group insists on impedance matching ("the R+j'ers"). The last group says that the antenna can be coiled into shorter lengths with impunity ("the winders"). So, which group are you in?

There is no argument from me about how physics define a good antenna. For good RF efficiency, the antenna needs to have a compatible impedance for the input of the receiver. A resonant antenna is common because it helps manage this. But it is naive to think that these parameters are solved with simple math that is based on textbook wavelength formulas. That is because impedance and resonance can be enticed by installing reactive components (inductors and capacitors) in the Rx's "front end" (antenna input). And the input impedance of the Rx is up to the designer. So, blindly changing a stock antenna to an "ideal" one is often the wrong thing do.

By the way, some low cost park-flyer R/C Rx designs deliberately use short antenna lengths to reduce sensitivity. This surely decreases range, but also reduces the Rx's sensitivity to unwanted interference. "Improving" the antennas on these designs can punish you with more glitches. So, be careful of what you wish for!

Please keep in mind that reliable R/C range is not entirely defined by the antenna's length. The R/C installation will also affect it. The way the servo and battery wires are routed, the construction of the model, and the ultimate placement of the antenna, will affect the radio's range too. Add to that such variables as transmitter/receiver performance and local EMI/RFI from onboard electrical devices; the net result is that no two models will be exactly the same, even if they look identical to you.

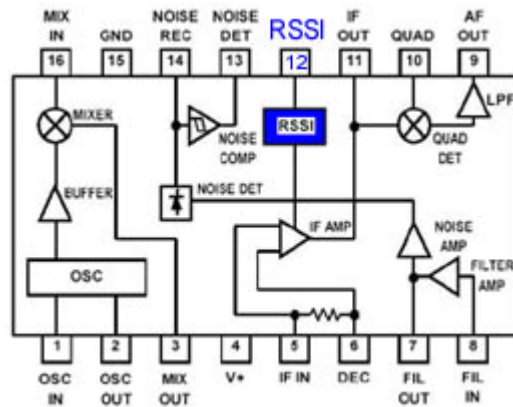
The scope of this white paper is to discuss the relative impact of R/C Rx antenna length changes. The other factors that affect reliable radio range are not the topic for today.

## It's All Relative

The impact to antenna installation tricks can be demonstrated by performing simple range tests at the flying field. But this is a bit crude and does not offer the precise data that is needed to make good comparisons.

Luckily, there is a clever way. Some R/C Rx's use a FM demodulator IC that has an RSSI (Relative Signal Strength Indicator) output signal. This signal provides a scaled voltage that can be used to measure the effective RF signal strength.

For example, the Toshiba TA31136 demodulator IC has an RSSI signal at Pin 12. It provides up to 80dB of relative dynamic range in the form of a voltage that represents RF signal strength. This IC is used in several popular R/C Rx's. The drawing on the right shows the IC's pinout. The RSSI function is indicated in blue.



So, to make practical measurements all we need is a fairly RF-quiet environment, a donor R/C Rx with RSSI, and a digital voltmeter. That is not a problem around here. So, off to the lab we go.



## Measure Twice, Record Once

It is important that the test setup be carefully devised to reduce measurement errors. We won't be making laboratory grade measurements, but let's insist that we do our best to keep things fairly accurate.

We must ensure that the antenna polarizations are the same (both Tx and Rx antennas are horizontal and parallel). All nearby surfaces must be wood (RF passive). For extra authenticity, the tests should be performed at least one wavelength (> 13 feet) above ground; the second story of a wood building is an easy solution. Even our own body, which can impact the RF environment, must be in a location that does

not affect the measurements. Lastly, the measurements are performed at least twice, at different times, to ensure repeatability.

One of the things to keep in mind is that the receiver's antenna also relies on the servo wiring in the model to achieve good performance. That's right, your model's ratsnest of wiring acts as a counterpoise and can impact the overall gain of the antenna. Although we are not interested in the absolute antenna gain, the test measurements will command more respect if the test setup reflects a real installation.

So, to keep things as authentic as possible, I modeled the R/C installation off one of my electric park-flyers. A 40" wingspan model was recreated as a paper template. It was outfitted with a 4.8V NiCD battery pack, on/off switch harness, and four servos: aileron (X2), elevator, and rudder.

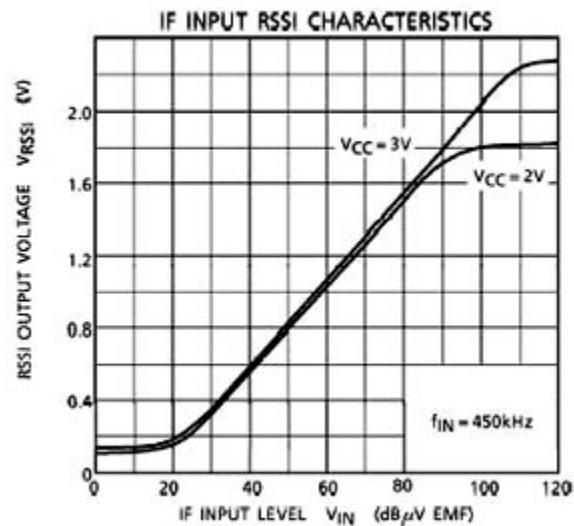


Instead of a throttle servo or speed control, I purchased a very tiny voltmeter. It is not much larger than a standard servo (see photo above). It was connected to the receiver using a six inch cable that was fabricated from standard R/C servo wire. The meter is used to measure the RSSI signal, and since it is installed the same as a servo, it will not impact our measurements. Most important of all, **everything** must remain undisturbed during the test session. So it was all taped in place.

I decided to use a 72Mhz GWS Pico Rx as the test subject. It uses the TDA31136. It does not have AGC (automatic gain control), so it simplifies our setup. We would need to disable the AGC feature if it was present. If you use a different Rx then your results may vary a bit from what we will see here. But I suspect your findings will be similar.

First, the RSSI voltage associated with the Rx's noise floor is measured. This was done by grounding the antenna input and observing the RSSI voltage. Then the R/C transmitter was turned on and the maximum signal strength was measured by observing the highest RSSI value with the Tx near the Rx antenna.

In our setup, the difference between the two measurements was 1.63V. This voltage represents a theoretical 80dB of relative dynamic range, which was derated to 70dB (a more honest span). This leaves us with a  $\sim 0.024\text{V/dB}$  slope, which closely follows the data sheet's RSSI IF plots.



## Decibels for Dumbbells

Before we go on, let's talk about the unit of measurement. Our data will be normalized and reported as relative changes in **dB** (decibels). It is not necessary to really understand what a dB is. However, there are two things that are important to know:

(1) For every three dB of change, the *RF signal strength* has changed by a factor of two. That is to say, if a signal is reduced by -3dB, it is 1/2 of its former power. If the signal increase +6dB,

then it has increased four times in power. What does this mean? Well, if we report that an antenna configuration reduces the signal by -3dB, then it is 1/2 of its prior strength.

(2) For every 6dB of change, the *practical R/C range* is affected by a factor of two. That is to say, if the signal is reduced by -6dB, the R/C system's reliable distance is cut in half. If the signal increases by +12dB, the range has increased four fold. What does this mean? Well, we can ignore tiny dB changes. But antenna configurations that result in moderate dB losses will severely reduce our R/C model's range.

Read those two important points again to become fully acquainted with the practical effects of our dB measurements.

## The Data

First, a 40 inch antenna was measured. We will use it as the reference, which is labeled "0 dB". In case you are curious, we could have used any length as the reference. But, the 40" length was selected because it is the typical length for a R/C Rx antenna. The antenna length was changed in increments of about one inch during the tests.

Below are the results of our findings. Not all measurements are shown, just interesting samples:

Antenna Length	Normalized RSSI VDC	Relative dB	Notes
19"	0.880V	-7.7dB	Stock GWS Pico
21"	0.890V	-7.2dB	
26"	0.930V	-5.6dB	
32"	1.000V	-2.7dB	
38"	1.056V	-0.4dB	
<b>40"</b>	<b>1.065V</b>	<b>0dB</b>	<b>Reference</b>
42"	1.080V	0.6dB	
44"	1.106V	1.7dB	
50"	1.145V	3.3dB	
62"	1.210V	5.9dB	Max Signal
74"	1.163V	4.0dB	
86"	1.085V	0.8dB	
92"	1.064V	0.0dB	

Carefully compare the 40" reference length data to the other antenna sizes. It is interesting to see the impact. For example, did you notice that the antenna signal peaked at 62 inches? I suspect that for this installation, the ideal impedance matching, or effective antenna resonance, was achieved there. At 92", the longer aerial performed no better than the 40" length. I'll bet that surprises some of you.

For this 72Mhz Rx, you would probably conclude that the popularly used antenna length of 38" to 44" is great. Interestingly enough, the GWS Pico we used was supplied with a 19" long aerial. However, from reviewing the data it looks like it would have more than twice the range with a ~40" antenna. But as I mentioned before, improving the antenna on entry level Rx's may result in more glitches from environmental interference. So, in this case, a "better" antenna would probably result in worse performance. The manufacturer usually knows best, so stick with what they suggest.

It would definitely be interesting to repeat these tests on a high quality 35Mhz or 40Mhz R/C system. They too use 39" to 41" (~1 meter) long antennas. A casual observer may claim that they violate the physical wavelength concepts. But remember, there are other ways to achieve good performance from an antenna beyond the conceptual lengths determined by simple math.

## Who Got the Short Straw?

One of the popular methods of installing a long Rx antenna in a small model airplane involves winding it around a short plastic straw or wooden stick. The concept is based on the opinion that you can do nearly anything to the antenna as long as the wire's length is not reduced. So, let's find out what really happens.

Two antennas were tested. Both used a plastic fast-food drinking straw. The first experiment used a 40" antenna wire. There was a 4" straight length from the Rx. It was then carefully wrapped about thirty times around the straw (with loose spacing). It ended with a 6" tail. Overall length was 16". This is similar to how I have seen many modelers do this. Please see the photo below.



It may look otherwise, but none of the wires on the straw cross over each other. Some modelers insist that perfectly spaced wires are necessary and will make a remarkable difference in range. I'm sorry to say that I did not improve the performance when the six inch coiled wire spacing was wrapped to perfection. However, in a practical sense, neatly wrapped wiring can increase the length of the straw, and the longer antenna profile length will increase range.

The data is listed below. It shows that creating a short antenna like this will reduce range to a fraction of its former self. The -11dB measurement reflects an antenna signal *reduction* of nearly 12X. R/C model range will be about 1/4 of what it would have been with a full length antenna. It is hard to say what this reduction will be in absolute feet, since the reduced range will depend on the performance of your R/C Tx and Rx.

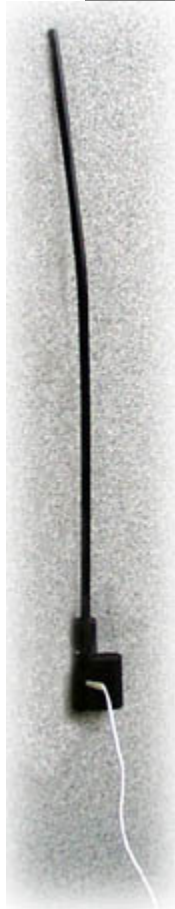
Antenna Length	Normalized RSSI VDC	Relative dB	Notes
40" Straight	1.065V	0dB	Reference
19" Straight	0.880V	-7.7dB	Stock GWS Pico

40" Coiled to 16"	0.795V	-11.0dB	
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In this experiment we find that when the antenna is cut from 40" to 19", it has twice the signal strength as a 40" antenna that is compacted to 16" by wrapping it around a straw. Both methods severely reduce the range, but which would you use in this situation?

The second straw antenna used the stock 19" GWS Pico antenna wire. It had a 3" straight length from the Rx. The remaining wire was carefully wound on a 4" long plastic drinking straw. Here we find that compacting the length to 7" resulted in severe signal strength reduction.

Antenna Length	Normalized RSSI VDC	Relative dB	Notes
19" Straight	0.880V	-7.7dB	Stock GWS Pico
19" Coiled to 7"	0.562V	-20.8dB	



## Whip Me:

Besides the drinking straw tricks, R/C'ers can also purchase fancy base loaded Rx antennas. The "base load" is simply an inductor (RF choke) that fools the antenna system into thinking it has an electrically longer element. Have you ever wondered if these nifty looking antennas reduce range? Well, let's test one and find out.

A hobby store bought [base loaded whip](#) was installed on the test setup. This is a popular antenna that is commonly used on R/C helicopters. The loaded whip is about 8" long and has an integral 4" flying wire lead. The Rx antenna was installed exactly as directed by the provided instructions.

The flexible wire leads were taped perfectly straight and horizontal. The whip antenna assembly was tested in both the vertical (V-Polar) and horizontal (H-Polar) orientations while the transmitter antenna remained horizontal. Lastly, it was retested in the H-Polar orientation, but this time the Rx's wire lead was bunched up a bit (like I see on many model helicopters) to about 5" long (versus 8" when straight). This subtle change had a big impact. Results are shown below.

Antenna Length	Normalized RSSI VDC	Relative dB	Notes
40" Straight	1.065V	0dB	Reference
Loaded Whip,	0.785V	-11.5dB	

V-Polar			
Loaded Whip, H-Polar	0.863V	-8.2dB	
Loaded Whip, H-Polar	0.780V	-11.9dB	Rx wire bunched up. See text.

## No Gain More Pain:

We are fortunate that modern R/C receivers have incredible sensitivity. The amount of sensitivity that we can utilize is called the *gain budget*. The gain budget is sufficiently large so that poorly implemented R/C Rx installations still work to our satisfaction. Well, at least most of the time. You can help avoid problems by sticking with good antenna installation techniques. Hopefully you learned something here about basic antenna performance.

## Epilog:

A high quality R/C receiver, with an advertised range of "beyond visual sight," is still reliable for most of us when the range is cut in half. But do that to a park flyer Rx with an advertised range of a few hundred yards, or a full range receiver installation that has other problems, then all bets are off. So follow the manufacturers recommendations where possible. Above all, perform a thorough ground range test at the flying field, as instructed by your R/C system supplier.

## The Small Print:

All information is provided as-is. I do not offer any warranty on its suitability. That means that if you perform these experiments, you will do so at your own risk.