# Curtis Youngblood

# On 3D...

***Part 1 - Originally Published May 1996***

Welcome to the first of three articles dedicated to the topic of 3D helicopter flying. Tony Wright asked me to put together a few special articles covering some topics that might be of interest to those of you entering into 3D flying. By 3D I simply mean a style of flying that enables a pilot to explore all dimensions of helicopter flight. 3D has exploded in popularity in the last several years with people all over the world enjoying the ever increasing challenge of 3D helicopter flying. In this first article I am going to jump right into it and begin a discussion of one of the most asked questions, "How do you hold the tail rotor through all those crazy backward maneuvers?"

I would like to claim that it is all the pilot, but that would not be true. My gyro setup is largely responsible for the performance of my 3D helicopter. In fact, the development of modern gyros is one of the most important factors in the fast growth of 3D flying. So the next logical question is "How do you getthe gyro to hold so well"?

Well, there are many things that affect the gyros performance. Of course the specific gyro itself will help determine how well it will hold. But, some of the other things that affect the gyro are vibration levels, gyro mounting, servo arm length, servo speed, tail disk size, tail RPM, fin sizes and overall control free play. Since the gyro setup is so important to 3D, I will spend much of the first two articles covering each of these topics.

But, before I begin, it is important to point out that even with everything setup "perfect" on the gyro and tail rotor, the pilot will still have to fly the tail through 3D maneuvers. Even the best gyros will simply reduce the pilots workload. Some situations will still go beyond the gyro's ability to hold the tail. Even with my best machine, I am constantly flying the tail rotor during 3D maneuvers. So the important thing is to work on optimizing, not perfecting, the gyro for 3D.

What makes a good 3D gyro? The two most important things for 3D flight are a good hold of the tail and general mechanical reliability. A "good hold" consists of two main parts. The first is control around center, which means that the gyro senses and controls small drifts and pulses right around the initial position. The second part of a "good hold" is control during large displacements, such as a fast pirouette followed by a quick stop. And the general mechanical reliability simply means the gyro will hold up to the abuse given during 3D flight.

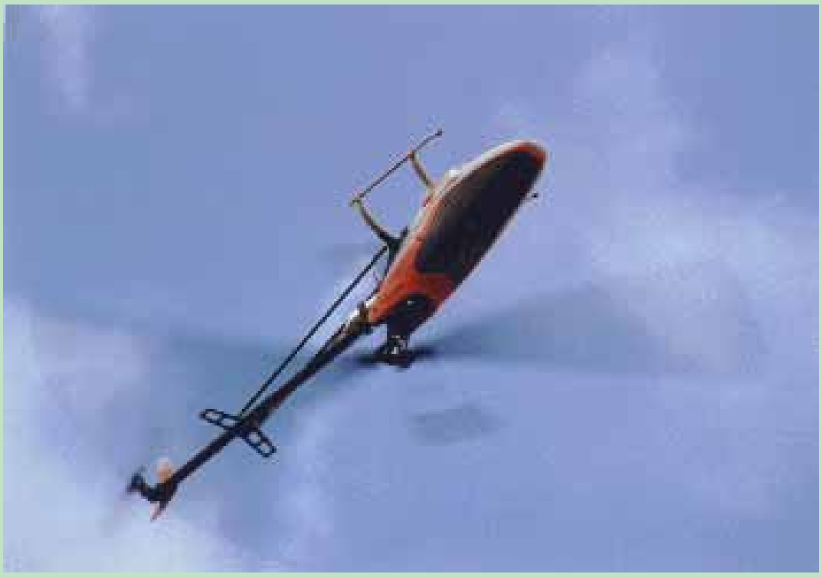
A good hold on the tail around neutral is important for flips and backwards flight. During backwards flight, a small change in the angle of the tail relative to the wind, can cause the helicopter to snap around quickly. However, a good gyro will help keep the tail straight at slow to moderate speeds. While in fast backwards flight, as the tail tries to oscillate from side to side, a good gyro will help hold the tail within a few degrees of straight.

Flips are similar to backwards flight, but they present another problem, vibration. Because of the continuous and high cyclic controls applied during flips, there is much more vibration from the rotor. This rotor vibration causes the entire helicopter to shake at frequencies that the gyro mistakes for tail movements, causing the tail to wag during flips. To stop the wagging, the gyro gain is reduced. The problem with setting the gyro lower is it does not hold around neutral or perform fast stops as well. This results in a "loose" tail, meaning the tail drifts a few degrees around center and over-rotates during stops in pirouettes.

A "perfect" gyro would be able to filter out the vibrations and only respond to tail motions, allowing for the high gyro setting and a good hold. Since, no gyro is perfect, the next best thing is a good gyro that differentiates between most vibrations and tail movements. Or in other words a gyro that is well vibration isolated.

Mechanically, the "perfect" 3D gyro can withstand all the helicopter vibrations, without wearing out or reducing the gyro's performance. Also, the better 3D gyro would require the least amount of maintenance and general care.

Now that we know what makes a good 3D gyro, let's determine what kind of gyro fits 3D best. The two types of gyros are the mechanical gyros, like the JR 120 and Futaba 153, or the piezo gyros like the JR 1000 and the Futaba Piezo. Both types have their advantages and disadvantages.



The mechanical gyros have a couple of advantages, they are relatively inexpensive and generally hold well around center. But they also have several disadvantages, they wear out quickly, require more maintenance and their motors are susceptible to damage from vibrations.

Now, the piezo gyros have several advantages, they are low to zero maintenance, good hold in fast stops and are resistant to damage from normal vibrations. The disadvantage of piezo gyros is they can have small tail trim inconsistencies and the biggest disadvantage is they are expensive.

I personally stayed with the mechanical gyros for a long time after the piezo gyros came out, simply because a good mechanical gyro held better around center than the piezo gyro did. However, I now use the piezo gyros because of their reliability, low maintenance and good hold during fast stops.

Whether you choose a mechanical or piezo gyro, there are several things that can be done to help the gyro work better.

For both mechanical and piezo gyros you want a fast servo on tail rotor. Both JR and Futaba now have special high speed servos to go along with their piezo gyros. These high speed servos will allow you to turn the gyro higher before the tail will tend to oscillate. This higher gyro setting will make the tail hold better in all situations, whether you use piezo or mechanical.

Also, both gyros need to be vibration isolated. Even the piezo gyros, which have vibration dampers built in, need some external isolation to enable them to work to their full potential.

The most common types of isolation mounting are wrapping with foam rubber or mounting on double stick tape. Often the tape provided with the gyros work well, but sometimes a thicker or thinner tape works better. The best way to determine what works is to use the gyro itself, as a vibration sensor. Simply turn the gyro up high enough so it is susceptible to vibrations. Then try different types and thickness of tape of foam to find the combination that results in the least tail wagging. An important thing to note is, the best mounting for hover may not be the best for flips and aerobatics, because of the different levels of vibration. This means it will probably require a compromise. I personally use two layers of 1/8 inch (3mm) thick SIG double stick tape.

The location of the gyro is one of the most important factors in improving the gyro's performance. The most important thing is to mount the gyro in the location with the least vibration. It is not, however, important to mount the gyro close to the main shaft. In fact, near the shaft usually has some of the highest vibrations in the machine and could be one of the worst places to put the gyro. On my machines the gyro is mounted in the front of the radio tray. This puts the gyro as far as possible from the engine and gear vibrations. Once again, the gyro can be used to find the best location. Simply turn the gyro up as high and find the location that causes the least tail wagging.

Now, there are a couple of other things that can be done specifically to help mechanical gyros. First, the less free play the gyro motor shaft has the better it will work. To check for free play in the motor shaft simply shake the gyro. When the gyro is lightly shaken side to side, the motor shaft play will cause a rattling sound (do not shake hard, as this could damage the gyro). The more shaft play there is the louder the rattle will be. You want to find a gyro with the least amount of rattle. This shake test can be used to find the best gyro out of a couple of choices and to determine if a gyro is worn out. Unfortunately, there is not an easy fix for a motor with excessive motor shaft play. When you find one you simply know it will not work as well.

Secondly, the teeter bearings in the mechanical gyros can be rough from the beginning. So, I always take the lid off of the gyro and check the teeter bearings. To fix them, lift the motor and its teeter bearings out of the case. Then put a light gun oil in the bearings and spin them for a few minutes. This usually cleans out the bearings. Doing this greatly increases the life of the bearings and it is also good to do even if the bearings feel okay. Then, when putting the lid back on, make sure the wires from the motor are not hitting the case or any other parts that could impede the teetering of the motor. However, as a warning, taking the lid off might void the warrantee, so check with a dealer. If it does, have a hobby dealer or any qualified maintenance person do the work.

Well that is about it for this month, next month will continue this discussion of gyro setup. By covering the needed tail rotor setup, servos and gain settings.

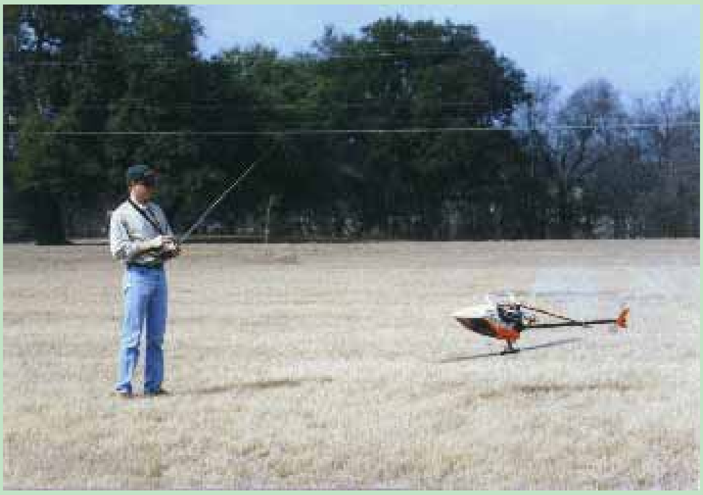
***Part 2 - Originally Published June 1996***

This month's discussion is a continuation of how to get the gyro to hold during 3-D flight. Covered in last month's article, were the two basic types of gyros, along with how and where to mount them. Now, I will try to answer one of the most asked questions about the gyro..."What gyro setting should be used? 50%? - 60%? - 90%?"

Unfortunately, there is no good answer to that question. Assuming everything else is the same, two gyros of the same brand often require a different setting to give the same response. Then, one must realize the servo characteristics and the tail rotor setup greatly affect the gyro setting. So, just stating the gyro setting is not enough. In an attempt to properly answer the question, this article will cover how servo characteristics, the tail rotor setup and the gyro gain affect the hold of the tail rotor system.

To begin with, it would be helpful to define some of the key terms used in this article. First, 'servo characteristics' include, the servo speed and control arm length. Second, the tail rotor setup includes the tail rotor rpm, tail disk size and vertical fin size. And finally, the 'gyro setting' simply means the gyro gain.

Since the servo characteristics, tail rotor setup and gyro setting interact, how do you possibly find the best setup? The "so-called solution" ...trial and error. By testing different servos, control arms, disk sizes, fin sizes and tail speeds, the best combination can be found for a given helicopter. However, there is a basic method to follow when experimenting with the tail rotor system setup.

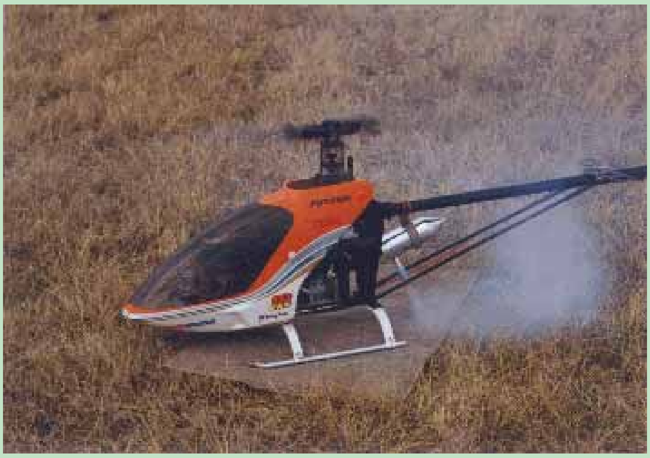


The best place to start is with the tail rotor servo. As I said last month, the faster the tail servo is the better (assuming the servos are of high quality). I use the high speed JR 2700G servo on tail rotor. A faster servo, allows the gyro gain to be increased, resulting in a better hold.

The next step is to reduce the size of the vertical fin. The main point of the vertical fin is to make the helicopter stable in forward flight by acting like a wind vane. But, if the helicopter is stable in forward flight, it is unstable in backwards flight. To improve the backwards flight stability cut down the size of the vertical fin. But, in addition to improving the backwards flight stability cutting down the fin improves the general performance of the tail rotor. A larger fin blocks the airflow to and from the tail rotor reducing the effective working area. The smaller the fin, the less the tail is blocked, resulting in increased tail rotor performance for a given rotor diameter. Once the servo and vertical fin are set, move on the tail rotor speed or RPM.

The tail rotor speed is set by the gear ratio. In general, any reasonable gear ratio can be made to held well just by changing the rest of the setup to match it. Personally, a tail rotor gear ratio of about 4.6 to 1, which gives about 7600 RPM on the tail, works well. The problem with higher gear ratios, such as 5 to 1 or higher, is they take away too much energy from the main rotor during autorotation. The extra loss of energy comes from the smaller disk used with the higher gear ratios, resulting in a system that loses head speed easily during autos. The important thing is to decide on a gear ratio and adjust the rest of the setup to match it. Generally, the ratios that come in the helicopter work fine. Now that the servo speed, vertical fin size and the tail speed have been set, the tail disk diameter, servo arm length and gyro gain can be addressed.

The problem with the tail disk diameter, servo arm length and gyro gain is they interact with each other to a large degree. For example, assume the gyro is turned up as high as possible, without the tail oscillating in forward flight. If the servo arm length is increased the tail will oscillate in forward flight, or if the original servo arm length is used, and the tail diameter is increased, there will be the same tail oscillation in forward flight. To stop oscillation in either situation, simply reduce the gyro gain. Or the other way around, if the servo arm is shortened or the tail disk diameter is reduced simply increase the gyro gain to get back near the point of oscillation. But, what makes one better than the other?



Basically, the gyro should be set as high as possible, so it can respond to even the smallest pulses of the tail. But, the tail disk should be as long as possible, so the tail can respond quickly and powerfully when the gyro sends an input. Also, with the gyro turned up high, a long servo arm is needed to help "overdrive" the tail rotor to get a good pirouette rate. The problem is, if the gyro is set high, with a long control arm and a big tail disk, the tail would oscillate badly in forward flight. So, which is more important, a high gyro gain, a long control arm or a big tail disk?

An important factor in deciding which is more important is the control precision. In this case, control precision is measured by what percentage of tail control movement is taken up in free play. As an example, if the tail push rod moves a total of 1 inch to achieve a given pirouette rate and has 1/5 inch of control play, it can be said it is only 80% precise. While if it only moves 3/5 of an inch for the same pirouette rate and still has 1/5 of an inch of free play, it is only 67% precise. The setup that only moves 3/5 of an inch might get the same pirouette rate as the 1 inch setup, but the tail will not hold as well because it is much less precise.

Unfortunately, all tail rotors have some free play in the control system, so it is best to move the control mechanism as much as possible to increase the precision. For this reason, start the tail rotor setup by putting a long arm on the servo (1.5-2 cm). Along with increasing control movement and precision the long servo arm will increase the pirouette rate which will help in over-driving the gyro.

The term "over-driving" means the servo can put in more control than the gyro, at high turn rates. With the longer arm you will have to turn the gyro down some to keep the tail from oscillating. But, it should still hold as well as a shorter arm with a higher gain. And the maximum pirouette rate will be increased.

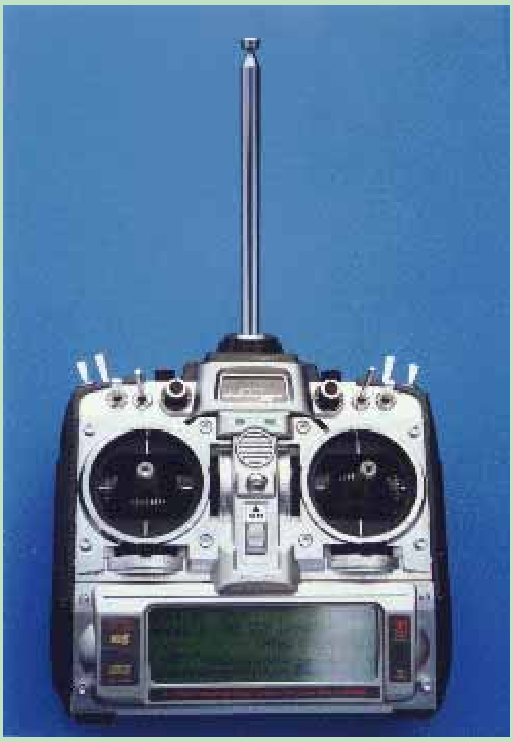
For the over-driving to work, set the travel adjusts as high as possible (150%). This will result in the tail pushrod jamming and bending at full control, but in flight, the gyro does not let this happen. The reason is, when a large control input is given for a pirouette, the gyro will take out a percentage of control input in an attempt to stop the pirouette. A fast pirouette results when there is more control to cause the pirouette than there is gyro to stop it. This is done by making the gyro control a smaller percentage of the total control by using a long servo arm, using full servo movement and turning the gyro down.

The next step is to find the best tail disk diameter. The tail disk diameter needs to be small enough to allow the gyro to be turned up high, but large enough to allow fast pirouettes. However, the limiting factor in how large the disk can be is the control sensitivity. With a larger disk the tail is more sensitive and a more sensitive tail is good only up to a point. The problem is, if the tail is too sensitive the gyro will have to be turned down to stop oscillations. The lower gyro gain will hurt the gyro hold.

The limiting factor on how small the tail disk can get is the problem of tail rotor stall. As the tail rotor disk is made smaller, the angle of attack of the blades is greater for a given lift. A high angle of attack combined with strong cross winds can result in the tail rotor stalling. The tail rotor stalling can be seen with a strong cross wind hitting the right side of the helicopter. As the tail blades stall, they emit a "swooshing sound" and the model pirouettes slowly to the left, away from the wind. There are two things that can be done to prevent this type of stalling; the blades can be lengthened or the tail RPM increased. Both of these will result in a lower angle of attack of the tail blades and reduced stalling. But, keeping the disk small and increasing the RPM can hurt the autorotation performance, as mentioned earlier.

So, the minimum tail disk size for a given tail RPM can be found using this cross wind hover test. While exceeding the maximum tail disk size shows up as an overly sensitive tail rotor. For a tail RPM of 7600 a disk size of 27 to 28 cm works best. For a higher (lower) RPM the best disk size will be slightly smaller (larger). While experimenting with different lengths use increments of 1/2 cm in diameter. If the blades need to be lengthened slightly, temporarily glue on a piece of balsa wood, or other light wood, to test the length. To achieve the best hold, the tail disk should be just long enough to get the fastest pirouette needed at full control. If the pirouette is faster than needed, then the tail rotor system has not been optimized. It would work better with shorter blades and an increased gyro gain.

Once the disk size is set, the only remaining adjustment is the gyro gain. The gyro should be set as high as possible, without oscillating. To set it, fly in fast forward flight and turn the gain up until the gyro starts to oscillate. Then turn it down slightly to eliminate the oscillation.



As a recap, to get a good hold of the tail rotor, find the lowest vibration spot to mount the gyro, usually the radio tray and then soft mount it, usually using double stick tape. Then use a fast tail rotor servo with a long control arm to increase precision. Next select the tail rotor gear ratio and reduce the size of the vertical fin. As the next to the last step, set the disk size as small as possible while still giving the needed pirouette rate. And finally, turn the gyro gain up as high as possible to get a good hold in 3-D flight.

Next month I will continue this 3D discussion by covering how to setup the tail compensation curve and other important mixes that make 3D easier.

***Part 3 - Originally Published July 1996***

This third section covers the flying techniques for the final setup of the compensation. Before beginning the setup of the compensation it is important to quickly review the basic mechanical setup of the tail rotor itself.

*First, it is important to run a servo arm length of at least 16mm.*

*Second, set the servo movement high enough, at least 120%, to hit the ends of the tail rotor stops. This "overdriving" of the tail rotor will help in achieving higher pirouette rates.*

*Third, set the servo arm at 90 degrees to the push rod when the tail rotor blades have about 4 degrees of right pitch.*

*Fourth, use a tail rotor disk size in the range of 27cm and a gear ratio of about 4.5 to 1. This will result in a powerful tail rotor that will be able to perform any of the present 3-D maneuvers.*

The next step is the initial radio setup of the tail compensation.

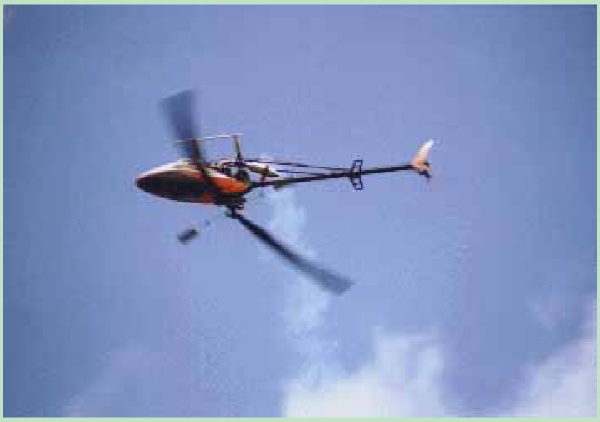
The first step in setting the tail compensation, is to enter the basic compensation curves into the transmitter. In this article, I will use the JR PCM 10SX to describe the compensation curves, but a simplified version of this curve can be entered into the more basic radios, using the percentage values on the curves discussed.

The basic 3-D tail compensation curve looks like a "V" curve. This compensation uses a mixing function, mixing collective pitch to rudder. This "V" curve starts with no compensation at neutral, right rudder is added as the collective stick is moved to the full positive position. The curve also adds in right rudder as the collective stick is moved from neutral to full negative position. The "neutral point" or bottom of the "V", corresponds to the collective stick position that sets 0 degrees on the blades. For the end points of the "V" curve start with full high and full low positions at 15% tail offset. This is a starting point, the exact percentage setting will be made in flight testing. The initial radio setup is now complete. The next step is to flight test enabling the trim and exact compensation settings to be determined.

Start with a common point of reference, by mechanically trimming the tail rotor to hover straight, in no wind. For this trimming, adjust the length of the tail push rod, not the position of the servo arm.

Once this is done, move on to setting the tail rotor in forward flight.

When trimming the tail rotor in forward flight, turn off any mixes that involve the tail rotor. This includes the tail compensation just created. With all the mixes turned off, the tail rotor can now be trimmed in forward flight. To trim the tail, it is important to set the tail straight. The question is at what torque setting should the tail be trimmed straight. If the helicopter is in a fast climb the trim would be different from regular forward flight because of the difference in torque. To get a symmetrical tail compensation curve the tail should be trimmed at near zero torque. Then when extra torque is applied, as in fast climbs, the tail compensation curve will compensate for this increase in torque.



One method of finding this zero point in torque is to fly along in slow speed forward flight and reduce collective pitch to near 0 degrees. As the model continues to fly forward and descend slowly, the model is at a point of low torque. This is where the tail rotor should be trimmed to fly straight. The tail can be trimmed either mechanically or from the radio. Mechanically trimming the rudder straight will probably result in a more symmetrical setup of the tail. However, I choose to trim the tail rotor using the stunt trim. This allows the trim to be set while still in forward flight. Also this enables the pilot to quickly re-trim the helicopter after crashing, by mechanically trimming the tail straight in a hover.

To help fine tune the trimming of the tail rotor in forward flight, perform this low torque trimming technique while flying into the wind, down wind and cross wind, both ways.

The helicopter will tend to turn into the wind slightly, but testing the trim from all these directions will result in the most accurate setting.

Once the trim is set, turn the tail compensation back on. To set the compensation, start in forward flight. Increase the collective to full pitch and watch what the tail rotor does. If the tail moves to the right, move to a lower percentage such as 12% and continue to decrease until the heli flies straight. If it moves to the left, increase the percentage until the heli flies straight. One important point to note is, this technique assumes the RPM does not change significantly as the collective is increased to full. If the RPM does decrease (increase), as the pitch is increased to full, the helicopter will rotate more to the left (Right) at full stick. If the tail compensation curve is set with this decrease in RPM, the compensation will be correct at the end point, but incorrect over the rest of the range. The best way to fix this problem is to change the pitch and throttle curves so the RPM does not change. If you are unable to remove the RPM change, then allow the rudder to move slightly to the left (right) at full collective, as the RPM decreases (increases). This will improve the compensation over the rest of the range, and it will be the best compromise for the situation.

This compromise solution to the change in RPM is assuming the radio does not have the flexibility to add extra points to the pitch to tail rotor mix.

However, if the radio can add extra points to the curve, this can be used to more accurately fix this problem. These extra points would normally be added at the 1/4 and 3/4 position. To set these positions, fly the helicopter with the collective stick at the 3/4 position and use the mix as if it was a trim. Increase or decrease the mix as needed for the tail rotor to fly straight.

So far I have only discussed the positive portion of the tail compensation curve. In general, the negative part of the curve will have the same percentages as the positive part of the curve. For those comfortable with inverted flight it is recommended to set the full low position by flying in slow inverted flight and moving to full negative. Set the mix, as needed, for the tail to fly straight. Then move the stick to the 1/4 position and set the mix there as well.

The tail compensation should now be set.

The point to remember about this compensation is it is not perfect. As wind conditions, maneuvers, and directions change the rudder will move some. However, this compensation is a good compromise and should be close to correct for all 3-D maneuvers.

This discussion of tail compensation ends my three article contribution to W3MH. I hope all of you have enjoyed these articles and I hope you have found W3MH to be a good and useful new source for helicopter information and entertainment. Keep practicing and I will see you around the flying field.

*Curtis Youngblood*