

# Antrack-Pro

**FW v1.47.1**

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by Alex, HB9DRI

## **INTRODUCTION**

Of all the firmware updates released in the last two years, none are as significant as this latest one. With approximately 250 Antrack-Pro units sold, I've been able to gather enough information, recommendations, and special requests from many users. Firmware version 1.47.1 incorporates much of what you've indicated should be improved or even included as new functionality.

The Antrack-Pro is a project that, by its very nature, is a *“constant work in progress”*. To better understand the changes in the latest firmware, it's necessary to review some basic concepts to grasp the new features. My recommendation is to carefully read this guide before performing the upgrade, as it will be necessary to adjust some PWM settings for optimal performance with each specific installation.

The Antrack-Pro is a tracking system designed to work in different areas: Moon bounce, Radio Astronomy, Amateur DSN, Astrophotography; it is not a system dedicated solely to EME like many people think, is much more than that.

## **LET'S REVIEW SOME CONCEPTS**

- **The crossing from EAST to WEST when the antenna is in the Norther hemisphere:**

This will determine how the antenna controller is positioned in space and on the imaginary Cartesian plane to perform an East-West transition, which depends entirely on the antenna's location in relation to the Northern/Southern Hemisphere.

Thus, when the station, antenna, observation point, or whatever you want to call it, is in the NORTHERN hemisphere, the east-west crossing occurs over the SOUTH (180 degrees). The antenna in question will NEVER cross ZERO degrees. That is to say, if the AZ movement is decreasing, say when AZ=10 degrees decreasing by 1 degree every minute, when we reach ZERO degrees, the antenna will not cross NORTH towards 359.99 degrees; it will reverse its rotation, moving CW (clockwise), cross 180 degrees (SOUTH), and continue until it reaches 359.99 degrees.

- **The crossing from EAST to WEST when the antenna is in the Southern hemisphere:**

Thus, when the station, antenna, observation point, or whatever you want to call it, is in the SOUTHERN hemisphere, the east-west crossing occurs over the NORTH (0 degrees or 360 deg). The antenna in question will NEVER cross 180 degrees (or South). That is to say, if the AZ movement is increasing say AZ=170 degrees increasing by 1 degree every minute, when we reach 179.99 degrees, the antenna will not cross at 180 degrees; it will reverse its rotation, moving CCW (counterclockwise), cross 0 degrees (NORTH), and continue until it reaches 180.01 degrees.

Understanding this two-crossing points is very important to manage the antenna soft-limits introduced in this FW.

- **What means 1 LSB**

It's the smallest significant bit that the encoder can read and depends on the number of bits the encoder has. For example, for an HH12, ETS25, or similar encoder with a bit depth of 12 bits, 1 LSB is equivalent to 0.0879 degrees. This means that if we start from ZERO, the next reading will be 1 LSB = 0.0879 degrees, the next will be  $0.0879 \times 2 = 0.1758$  degrees, and so on. As you can see, working with a 12-bit encoder makes it IMPOSSIBLE to represent movements in tenths of a degree, such as 0.1, 0.2, 0.3, 0.4... up to 0.9, from where we return to ZERO and begin the incremental count in 0.1-degree increments.

Now many have wondered how other antenna controllers do it? Well, it's very simple: they round the values, representing odd increments as if they were mathematically precise to one-tenth of a degree. But these controllers are far from "precise." They round and approximate 1 LSB = 0.0879 to 0.1 to simplify the visual representation in the GUI and create the false image of a precision that in reality "DOES NOT EXIST."

It's important to remember that the error is cumulative; that is, after 20 degrees, the error will be 2.5 degrees if the numbers aren't "masked" with a sort of pseudo-algorithm that reduces the error every so often in the LSBs. But does it work? Yes, of course it works. It has worked for decades when the object of interest was simply EME.

And why? Well, because the Earth-Moon distance in astronomical terms is infinitesimally small, and because the angle subtended by the moon with respect to the Earth allows operation up to 10 GHz with medium-precision antenna

controllers. As I said before, the Antrack-Pro isn't dedicated to EME only; it goes much further, and for that, it's necessary to show the "real" LSB increments, not fictitious ones, for what one wants to see.

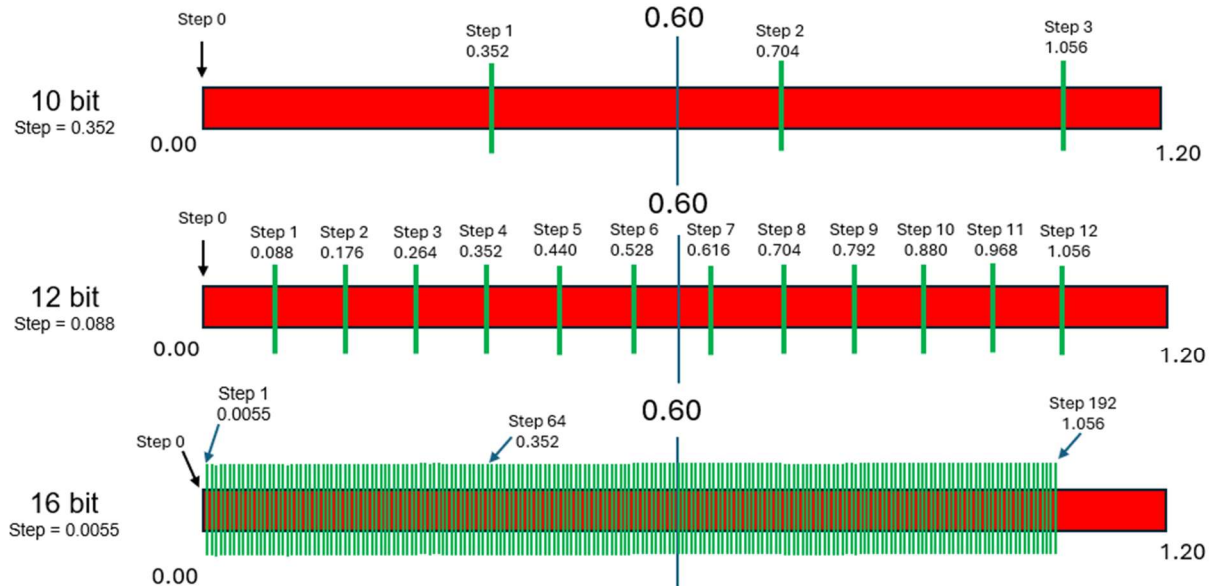
It's important to understand that between 1 LSB and 2 LSB there's a separation of 0.0879 degrees for a 12-bit encoder; in between, "there's nothing"—it's either 1 LSB or 2 LSB. This creates the impression of instability in the reading, which isn't correct. When only one decimal place is displayed, the hysteresis is extremely large, and the "forgiveness" factor is the short distance between the Earth and the Moon and the beamwidth of your antenna giving you the impression of high stability but is not, is just make-up. Does it work? Yes, it works, but only for EME up to 10 GHz if your mechanics are good, and most of the time are not.

A 16bit encoder will have 1 LSB = 0.0055 deg, that means in a 1 LSB from a 12 bit encoder the 16-bit encoder will have 16 counts more than the single 12bit, a challenge for your mechanics for sure.

Here one slide from my presentation in the EME conference in Trenton 2024, the figure is self-explanatory.

Pay attention in the 10 bit “Step 1”, this green tick is 1LSB = 0.352 deg. In the same position just move to the 12bit graph and you will see 1 LSB in 10bits represent 4 LSB in 12 bit encoders, means a 12bit encoder between 0 to 4 LSB has 4 steps more than 10bits, now see the graph for a 16bit encoder, in the same position a 16bit encoder will have 64 more steps to count when a 10bit has only 1 and 12 bit only 4, now is clear why a higher bit depth give you higher resolution BUT the accuracy is another story, people trend to ignore “ACCURACY” and flag the performance of a encoder just based on the numbers of bits, just to give you an example the ETS25 encoder has 12bit resolution with 1 LSB = 0.0879 and accuracy of 0.3 deg, the SOLAR360 inclinometer with 15bit resolution has 1 LSB = 0.011 and accuracy of 0.03 deg at 20 Celsius deg, the compensated temperature error is in the range of 0.001 deg/celsius deg

# The AnTrack-Pro and high precision Absolute Encoders



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20th EME Conference Trenton NJ 2024, Alex Artieda, HB9DRI

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A common mistake is to omit accuracy values and use only the number of bits as a measure of precision. The best way to evaluate an absolute encoder is by assessing its characteristics according to the three main types of technology, which are summarized in the following table:

| Feature                   | Hall Magnetic Enc.                                                                 | Optical Enc.                                                             | Capacitive Enc.                                                       |
|---------------------------|------------------------------------------------------------------------------------|--------------------------------------------------------------------------|-----------------------------------------------------------------------|
| <b>Physical Principle</b> | Measures magnetic field angle from a rotating magnet using Hall or AMR/TMR sensors | Measures light passing through a coded disk (transmissive or reflective) | Measures changes in capacitance between patterned rotor/stator plates |
| <b>Typical resolution</b> | 12–16 bit (0.088°–0.0055°)                                                         | 18–24 bit (0.0014°–0.00002°)                                             | 16–22 bit (0.0055°–0.0003°)                                           |
| <b>Accuracy</b>           | ±0.1° to ±1°<br>(depends heavily on magnet quality, alignment, temperature)        | ±0.01° to ±0.001°<br>(highest precision)                                 | ±0.01° to ±0.0005°<br>(highest precision)                             |

|                              |                                                            |                                             |                                               |
|------------------------------|------------------------------------------------------------|---------------------------------------------|-----------------------------------------------|
| <b>Temperature Stability</b> | Bad — drift from magnet temp coefficient and sensor offset | Low–medium — LED aging and photodiode drift | High — capacitance is stable over temperature |
| <b>Cost</b>                  | Low                                                        | High / Very High                            | High                                          |

Here a table comparing the most used encoders by Radio Amateurs

|                        | <b>MAB25</b>    | <b>ETS25</b> | <b>HH12</b> | <b>HH12 Incln</b> | <b>A2-2-s</b> | <b>SOLAR360 Incln.</b> | <b>DL-27</b> | <b>DL-66</b>  |
|------------------------|-----------------|--------------|-------------|-------------------|---------------|------------------------|--------------|---------------|
| <b>Res. BITS</b>       | 12              | 12           | 12          | 12                | 12            | 15                     | 21           | 22            |
| <b>1 LSB</b>           | 0.0879          | 0.0879       | 0.0879      | 0.0879            | 0.0879        | 0.011                  | 0.0002       | 0.00008       |
| <b>Accuracy In deg</b> | 0.3 to 1        | 0.3 to 1     | 0.3 to 1    | 0.3 to 0.5        | 0.05 to 0.1   | 0.03 w/temp Compens.   | 0.015        | 0.005         |
| <b>Price EUR</b>       | 65.00 (retired) | 85.00        | 65.00       | 100.00            | 400.00        | 255.00                 | 1,500 Min 10 | Not available |
|                        |                 |              |             |                   |               |                        |              |               |

Reading both tables give you any idea about which technology is the best related with the accuracy you want to reach, the impact tin the performance and the implementation cost, high precision is not cheap.

#### **FEW WORDS ABOUT CHINESSE ABSOLUTE ENCODERS:**

In recent years, we have seen the emergence of absolute Chinese-made encoders with up to 22-bit resolution. Their prices range from \$30 USD to \$400 USD. They are primarily sold on eBay and AliExpress and are presented as high-precision components.

These encoders, as is traditional in the mass electronics industry from China, are manufactured by one or two large factories. One of them is Jilin Province Sansheng Sensor Technology Co., Ltd., whose main product is the SE58S10 or E58S10 series encoder. There is also the TR-Electronic factory, which markets the same line of encoders under the CMV58 designation. We also have the well-known BRITER encoders, which are offered with resolutions from 10 to 18 bits.

All these Chinese products have one thing in common: they are produced by one or two manufacturers and then offered wholesale on Alibaba, where the minimum

order is 100 units. Each buyer then labels the same product with his own brand and model. These products have some degree of technological sophistication, but they are far from being technically comparable to their Western counterparts.

One of the biggest problems is how they declare their specifications. None of them mention ACCURACY, REPEATABILITY, or JITTER; they simply use well-developed phrases like "high-precision encoder," "18-bit optical encoder," etc.

The only thing I've been able to find is that one of these subsidiary firms does publish an interesting piece of data for the CMV58 encoder line, which is very similar, if not identical, to the SE58S10 or E58S10 series.

It declares a "Precision of +/- 0.1 to 1 degree," an average and unspectacular precision, similar to Western products like the MAB25, ETS25, and HH12, which are only 12-bit.

The same company, TR-Electronics, presents its CEV58 line as an optical encoder with a precision of +/- 1 digit. This way of presenting precision is quite strange and outside of any international standard, since... The standard is to present it in degrees, tenths, hundredths, or thousandths of a degree, or alternatively in Arcmin and Arcsec.

This is where the Chinese industry typically presents us with a biased figure that is far from the truth. First, most of these Chinese encoders don't provide accuracy information, and when they do, like TR-Electronics, they list a number that is very far from the truth. Declaring 1 digit of accuracy refers to 1 LSB; we have already discussed this concept. At 12 bits, 1LSB = 0.0879 deg, at 16 bits = 0.00549 deg, and at 18 bits = 0.00137 deg. There is no encoder with an accuracy equal to 1 LSB. Why? Because the accuracy of an encoder is a product of the electronic imperfections of the technology used (Hall sensor, magnetic, optical, or capacitive), plus the mechanical imperfections... Eccentricity mechanics, shaft wobble, and bearing play. In short, normally if an encoder has a 12-bit resolution, for example, its accuracy is 1 to 2 bits below its maximum resolution. My conclusion is that you can't trust these mass-produced products sold with misleading specifications in eBay and AliExpress. The problem is those encoders are cheap and unfortunate Amateur Science has a natural tendency for cheap solutions.

My experience with TOP Absolut encoders is with the firm NETZER from Israel, those products are military grade, personally I have the DL-66 (the top of the line) with a resolution of 22bits and accuracy = 0.005 deg, the other encoder from NETZER is the DL-27 with resolution bits up to 21 and accuracy = 0.015 deg. What made those encoders special, they are not HALL Magnetic or optical, they are Capacitive encoders with a proprietary MCU on board to do DSP to the signals.

TO CONCLUDE ABOUT THE ENCODERS: Are you interested in just EME up to 10GHz with good mechanics then you can stay with cheap MAB25, ETS25, HH12 encoders, even the Chinese encoders could work.

If you want to do serious EME above 10Ghz (24, 47Ghz), DSN or serious Radio Astronomy the NETZER is your way. I have access, time to time, to a limited number of DL-27 capacitive encoders if somebody is interested

- **Soft limits, hard limits and “fail save”**

"Soft limits" refers to software limits where the antenna is not allowed to cross a pre-set boundary. This is typically used to prevent the antenna from entering areas where the rotation mechanism is compromised, where there is an obstacle, or where there is no reason to position the antenna.

This function is usually configured with "limit switches." These mechanical switches are installed in the antenna's rotation plane and, when activated, interrupt the DC current flow to the motors. These are "hard limits" and are considered failsafe.

Soft limits, on the other hand, have no physical implementation; they are configured in software and therefore are not fail-safe, meaning they "can fail" for various reasons related to the computer that operates them. Hard limits or limit switches, per se, are physical implementations that can only fail if the device is destroyed or its cables are cut. They guarantee an interruption of the motors and, at the same time, guarantee the possibility of reversing the rotation and moving out of the cut zone.

From the beginning, many users complained that there were no soft limits. I personally refused to implement them because I believe that when an operator has the option of implementing a soft limit, they forget to implement a true physical limit switch. That's why this new functionality is delivered "at the user's own risk," who is obligated to provide a mechanical limit switch and not rely 100% on a software soft limit switch.

# What's new in FW 1.47.1

This new firmware includes three important fixes:

**1. Touchscreen sensitivity:** A few users have reported that the screen's sensitivity often causes the same digit to be entered twice. This problem has been corrected.

**2. A new screen has been added where you can configure separate PWM variables for AZ and EL.** This is especially useful for those who reported that a fixed PWM value does not match the electrical characteristics of their DC motors, and particularly for those with 12VDC motors. Originally, the average value was equivalent to 165 (the PWM configuration ranges from 0 to 255, (with 255 being the maximum motor speed)). In some cases, the default value was too low, and in others, too high, for stopping/continuing the motor at low speed when the antenna approached the target and was already within the 5-degree window before the target.

Some users reported overshooting, others undershooting. For this reason, these parameters have been added, configurable only from the GUI using the touch screen (they are not present in the web interface, since this calibration is performed only once unless the motors are changed, then you need to re-calibrate). I will explain how to perform this calibration later.

**3. SOFT LIMITS** have been incorporated. From the beginning, I opposed having software-defined soft limits. Unfortunately, many users, when using soft limits, do not incorporate true limit switches (which are safer and considered failsafe). Finally, I have added SOFT LIMITS but with the warning that any implementation of soft limits via software is not failsafe and therefore must be implemented with hard limit switches that interrupt the passage of DC to the motors when they are activated, that is, when the antenna reaches a position considered dangerous or unacceptable for mechanical reasons.

**4.- INVERSE EL ENCODER:** now is possible to inverse the EL encoder without changing physically the position, same as the AZ.



## **CONFIGURE PWM FOR AZ AND EL FOR OPTIMAL TRACKING SPEED.**

When our antenna begins its tracking movement, the controller performs an incremental ramp with PWM to overcome the inertia of the antenna's weight and prevent an abrupt start of the motors.

For 2.5 seconds, the PWM value goes from 0 to 255, which is the maximum speed at which the antenna begins its movement toward the target. There is an approach window called the tracking window where the controller slows the PWM value from 255 to a value that was formerly predetermined and fixed in 165. This entry into the window occurs 5 degrees before reaching the target.

The antenna decelerates and prepares to come to a slow stop at the target without causing an abrupt halt. This process is known as slope-up and slope-down. When the antenna is within the 5-degree window, the PWM value must be sufficient to move the antenna to the required position but not too fast to overshoot

If this value is too low, the DC motor, due to its characteristics, may stop working BEFORE the antenna reaches its target, resulting in undershooting. The antenna never reaches its target because the motor does not have the appropriate PWM value to reach it. If this is the case, then we will have to change the AZ Tracking value to a higher one.

In the opposite condition, if the antenna is already at a reduced speed but does not stop at the target and passes it, then we are in the overshooting condition. When the overshooting is greater than 1 LSB (I already explained what 1 LSB is at the beginning), an overshooting---undershooting---overshooting oscillation can occur. In this case, the antenna never stops at the target, and for this, we will have to reduce the PWM value until we find the best operating point.

Normal PWM values:

- for AZ and EL are 165 but if you run in an undershooting/overshooting problem and/or using 12VDC motors you must adapt the PWM value.

The PWM value plays a granular configuration point together with the “Antenna window”. The antenna window is an area where the centre is defined by the target and its limits are +/- 1 LSB. This means that for AZ using a 12-bit encoder (1 LSB = 0.087 deg), the antenna window will have a size equal to +/- 1 LSB plus the additional value we assign according to the quality of our mechanical system.

This antenna window can have a value of ZERO; in this case, the size will be defined only by +/- 1 LSB. When the antenna, moving towards the target, enters the antenna window, it stops immediately, since, as we have explained, there is no value between 1 LSB and 2 LSB. The antenna stops until that condition changes due to the natural displacement of the target.

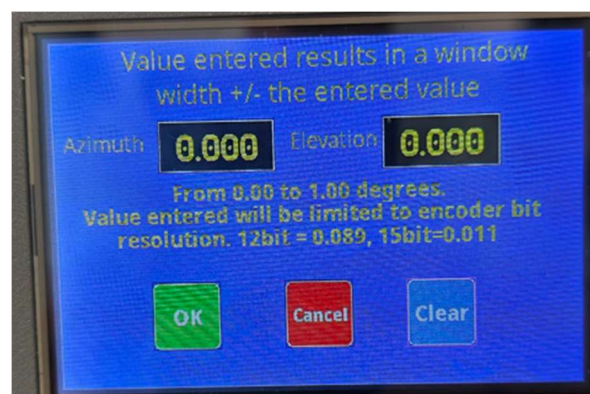
At 12 bits, this window will have a width of +/- 1 LSB =  $0.087 \times 2 = 0.17$  deg. If this value is too small, overshooting/undershooting oscillation may occur. If we use an antenna window = ZERO we will be at the mercy of the resolution of our encoder; more bits mean better resolution, but not necessarily better accuracy.

For a 12bit encoder with good mechanics we can place the antenna window at any value from 0 to 1 degree, use ZERO ONLY if your mechanics are good, considering a backlash not bigger than 0.1 degrees otherwise a good normal value is 0.1 degrees for yagui arrays and 0.05 degrees for parabolic dishes.

## SETTING THE ANTENNA WINDOW

In the main screen press "ANT"

You will see:



Enter the appropriated values for the Antenna window, when this value is ZERO or near demands much more precise mechanics, when you use, Yagi's don't make sense to place the Antenna Window too small due to the 3dB beamwidth the antenna exhibits.

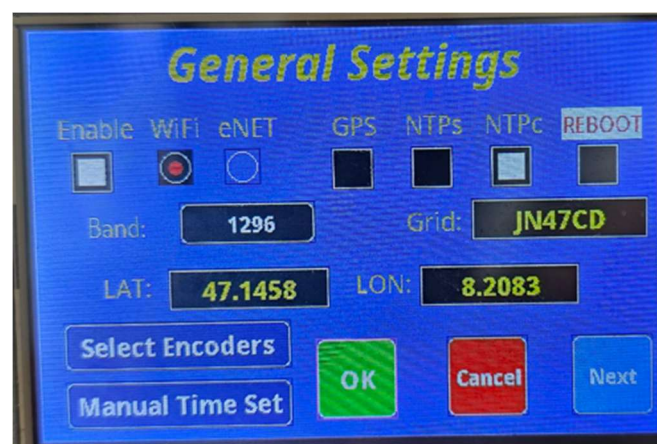
The value is directly related with bit depth or your encoder and mechanics.

For a 12bit encoder in AZ and 15bit SOLAR360 inclinometer in EL an SDD3 Slew drive or SDD7 can use ZERO in AZ and EL but demand a perfect PWM calibration, if you don't

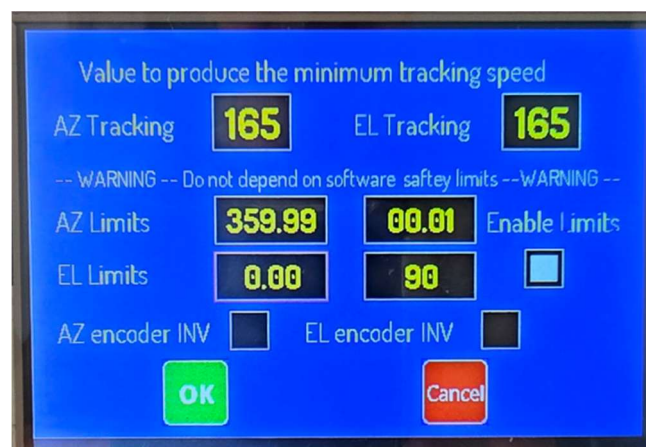
want to run in troubles and don't miss the moon at all use an Antenna window equivalent to 0.1 deg for 12bits in AZ and 0.04 for EL when using a 15bit inclinometer, if your inclinometer is HH12 then the value is 0.1 deg.

When the PWM optimal value is found the antenna window can be re adapted to a better number but keep in mind if the Antenna window is too big the antenna will start moving not before the target move away from the window.

After the Antenna window is selected let's change the PWM, in main window press "SET"



then in "General Settings" window press "Select Encoders"



As you see later in this same window, we will configure AZ and EL limits, for now do not enable limits, in the upper window you see the areas for AZ Tracking and EL Tracking, there you can place any value from 0 to 255 BUT considering 255 is the maximum PWM speed a good starting point is 165 for antenna Tracking speed. I translate that values and test your tracking, modify in this way:

**1.- IF ALL WORKS OK:** then I recommend finding the optimal minimum value, reduce in steps of 5 or 10 the numbers until you have an undershooting condition.

Means the antenna didn't arrive to target. From that value add in steps of 2 until the antenna arrives to target and from there add 5 more as a security gap. This test must be done with fully loaded antennas if you run just with the rotors with no antennas you will need to run again when setup is finished.

Do separate for each movement, don't do both at the same time.

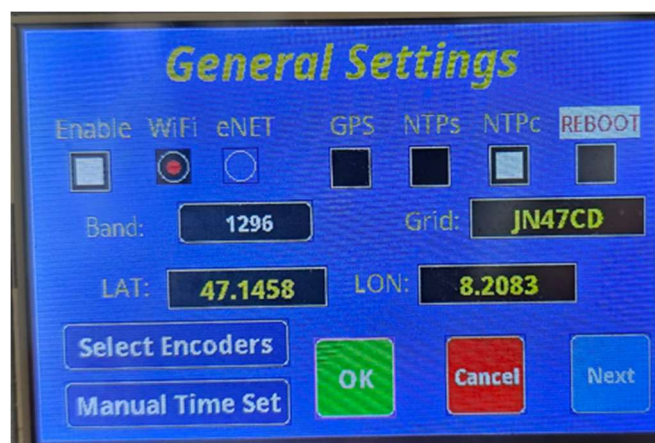
**2.-IF YOU RUN IN UNDERSHOOTING CONDITION,** means motor doesn't have enough power, just increase the number until you arrive to target and give 5 to 10 more from that value as a security window.

**3.- IF YOU RUN IN OVERTHOOTING CONDITION:** The value is too high then reduce until you are in target and see if reducing 5 to 10 steps more you still are in target, if not add values until you satisfy the condition of stop.

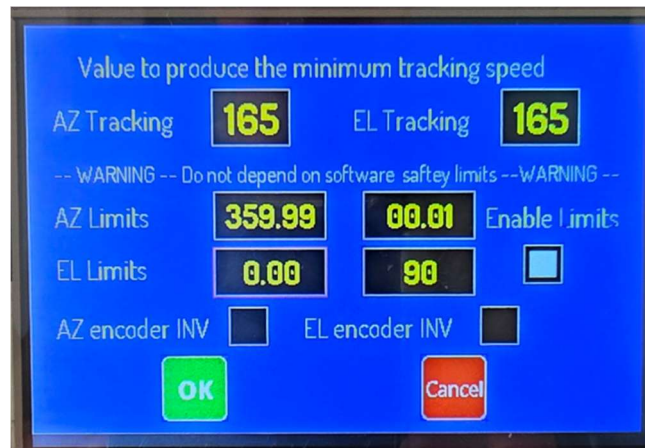
In combination with the antenna window, you can create a very smooth transition within the target window, but all is related with the quality of your mechanics and the bit depth and accuracy of your encoder.

## **HOW TO CONFIGURE SOFT LIMITS**

To configure soft limits in the main page press "SET":



then in "General Settings" window press "Select Encoders"



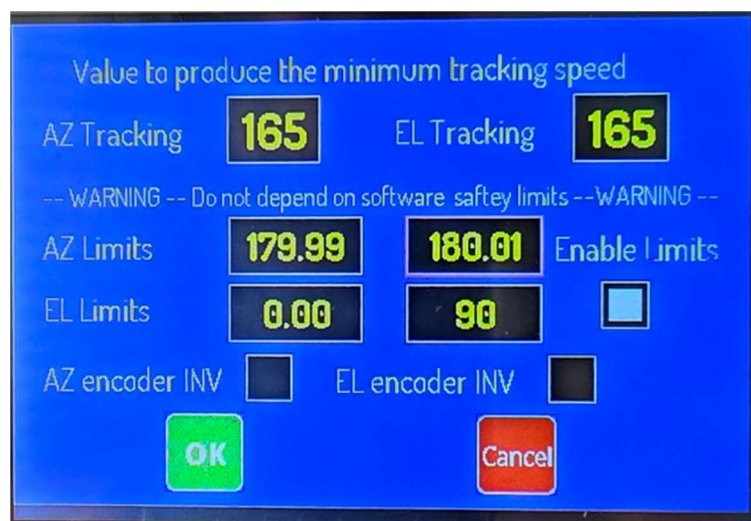
Now forget the AZ Tracking configuration and concentrate in AZ Limits and EL Limits, the previous screen corresponds to a station located in the Northern hemisphere, in AZ Limits introduce 359.99 in the first box and 00.01 in the second one.

### **CONFIGURATION FOR STATIONS IN NORTHERN HEMISPHERE:**

The AZ Limit first box = 359.99 means this is the maximum CW (clockwise) value you can enter here, the AZ Limit second box= 00.01 means this is lowest CCW (counterclockwise) value you can enter here. These two preconditions preserve the forbidden condition to cross from East to West via the North (or 0 deg or 360 deg), If those numbers are inverted or improperly configured the antenna will not rotate following the natural rule for stations in the northern hemisphere = NEVER CROSS ZERO, THE EAST WEST CROSS IS VIA SOUTH OR 180 DEG.

### **CONFIGURATION FOR STATION IN SOUTHERN HEMISPHERE**

Now if you are in the Southern hemisphere configure your limits like the next figure:



The AZ Limit first box = 179.99 means this is the maximum CW (clockwise) value you can enter here, the AZ Limit second box= 180.01 means this is lowest CCW (counterclockwise) value you can enter here. These two preconditions preserve the forbidden condition to cross from East to West via the South (or 180 deg), If those numbers are inverted or improperly configured the antenna will not rotate following the natural rule for stations in Southern hemisphere = NEVER CROSS SOUTH (or 180deg), THE EAST WEST CROSS IS VIA NORTH OR 0/360 DEG.

In both cases (Stations in north and south) with those parameters the STOP limits are 360 for northern Stations and 180 for station in Southern hemisphere.

**How to set a limit from there?** Suppose you are in the Northern hemisphere and then the maximum Northwest allowed by your mechanics is 300 degrees then change AZ Limit = 359.99 by 300.00, even if the target passes the 300 degrees with this new limit you create a forbidden zone between 300.00 and 359.99 where the antenna will not enter, it will stop in 300.00 slowing down and will not move until the target has a AZ lower to 300.00 deg, same in the other direction: if you don't want the antenna move less than 90.00 degrees then in AZ Limit = 00.01 you will introduce 90.00 , with these two parameters you create a "operative window" from 90.00 to 300 degrees crossing the South

**If I'm in the southern hemisphere?** Well, the principle is the same, let's assume you don't want the antenna go more than 225 Southwest then in the AZ Limit = 180.01 , the second box (not the first one) you will introduce 225.00 and if you want to don't allow the antenna to go more than 100.00 Southeast then in the AZ Limit =179.99 , the first box you will introduce 100.00, with these two parameters you create a "operative window from 100.00 to 225 degrees crossing the North, keep in mind your antenna will move from 100 southeast to 225 southwest crossing north or ZERO due the fact you are in the southern hemisphere.

## **CONFIGURE LIMITS FOR ELEVATION**

It's very simple, in elevation you don't have the hemisphere problematic; is just like that: The EL limits first box represent the minimum elevation (normally 0.00) and the EL Limits second box represent the maximum (normally 90.00)

The Min elevation can be negative IF YOUR MECHANICS ALLOW FREE MOVEMENT BELOW ZERO, this is useful to down the feed of parabolic antennas to a certain elevation where is more easy to access BUT keep in mind a parabolic dish could approach the rim of the antenna very fast to the support, normally negative angle of up to -10 are possible but you must take care of that. Same for max EL, you can introduce more than 90 deg but

your mechanics must allow, especially cables and boxes behind the antenna with electronics, it's very rare to introduce more than 90 deg as a maximum.

This graphics resume how limits work depending on your antenna location:

## Antrack-Pro AZ Limits

