Mihail Mateescu, TCS Inc

AM vs. AGC Auto-Tracking

The mechanism used by any system to Auto-Track a target is based on the same principle. When the target is slightly off from the main RF axis of the antenna, the RF signal gets modulated in amplitude by the feed which steers the antenna main beam in a certain sequence. The modulation signal is then extracted by the receiver and passed to the ACU. The ACU compares the AM signal and the feed scanning sequence to extract the error signals to drive the antenna on the target.

The AGC signal is a DC voltage that is correlated to the gain of all RF stages in the receiver such that the level arriving at its demodulator is at a fixed level. If the signal drops, the gain is increased (AGC voltage goes higher) and if the signal is increased, the gain is lowered (AGC voltage goes lower). The rate of gain change is limited by the AGC time constant (AGC TC), so essentially the gain does not change faster than the time constant setting. Therefore, the AGC time constant will dictate how "aggressive" the auto gain circuit in the receiver will behave in trying to hold the IF signal at a constant level. At the same time, the AM output is always generated from the envelope of the same IF signal (with some filtering). These two facts create a link between the two signals: AM and AGC.

If the AGC TC is too long, then the receiver reacts slowly to dropouts of signal due to various reasons including the AM modulation created by the feed scanning. In this case the AM output contains the tracking error, but when the RF level changes drastically it will take some time for the receiver AGC loop to stabilize itself for the new level. During this stabilization time the receiver demodulators will either be "saturated" when the RF level increases, or will be "starving" when the RF level decreases. In either case the data will have a dropout and the AM signal will be erroneous until the AGC loop stabilizes after a time dictated by its time constant setting.

If the AGC is very fast, then the receiver circuit will completely remove the AM signal (so no AM Auto-Tracking is possible) because the gain is allowed to change fast enough to track even the modulation of feed scanning. In exchange, the AGC itself will now include the scanning AM component. So the AGC signal will contain not only the DC level representing the signal strength, but also a small AC component representing the AM tracking signal (this is the fact that makes possible the AGC Auto-Tracking feature).

When set in AGC mode, the ACU card separates these two components (DC and AC), and process them differently (gains and filters before digitizing). Since any receiver filtering is basically out of the loop when the AGC is set to fastest setting, we do not need to worry about the tracking error signal being phase shifted in an unknown fashion by the receiver.

AM AUTOTRACKING

For the classic AM Auto-Tracking, the receiver AM output is used to get the tracking error signal to extract the AZ and EL errors. For a conical scan feed, the AGC TC of the receiver would be set at 100 msec. Because the receiver filter will introduce a phase shift if the cutoff is too close to the scanner frequency, the receiver AM filter cutoff frequency should be set anywhere above 1 kHz (additional filtering is done in the ACU).

This method works as long as the AGC TC set at 100msec can be tolerated. However, for targets with high dynamics, or cases where multipath creates fast changes in RF signal level, the demodulators may get either "saturated" or "starved" as mentioned above. This is one reason that "tracking" receivers exist: the tracking receiver is set to a high AGC TC for Auto-Tracking purposes, while the data receivers are set to low AGC TC to better track the RF level and provide data without dropouts.

The AM filter in the receiver has a pass-band response: does not pass lower frequencies toward DC and does not pass frequencies above its cutoff point that is set in the receiver. When the scan frequency is

changed, the AM modulation signal is affected differently in phase by this filter. The phase of the AM must be controlled precisely or otherwise crosstalk will occur (for example: AZ error component will be rotated and add to the EL error component). This is one reason you need to recalibrate the AutoTrack loop when you change receivers, because the filters are not identical or obscure settings are not the same between receivers.

AGC AUTOTRACKING

The new method of AGC Auto-Tracking works on a different principle than AM Auto-Tracking. In this method the AGC is set to the minimum time constant. In this case, the receiver AGC tracks instantly the RF signal received, and therefore it contains the AM scan component (with no phase shift). The ACU will simply extract the DC component for the regular signal strength usage, and the AM component for the Auto-Tracking function.

The AM component goes through an 8^{th} order Bessel low pass switched capacitor filter that has its cutoff frequency synchronized with the scan frequency so the phase shift is constant no matter what the scan frequency is. A constant phase shift is easily corrected during an AutoTrack calibration. Once that is done, it doesn't matter if the frequency of the scanner is changed afterward. The filter cutoff frequency will change accordingly in such a relationship that the phase correction will stay the same as the one found during the first calibration.

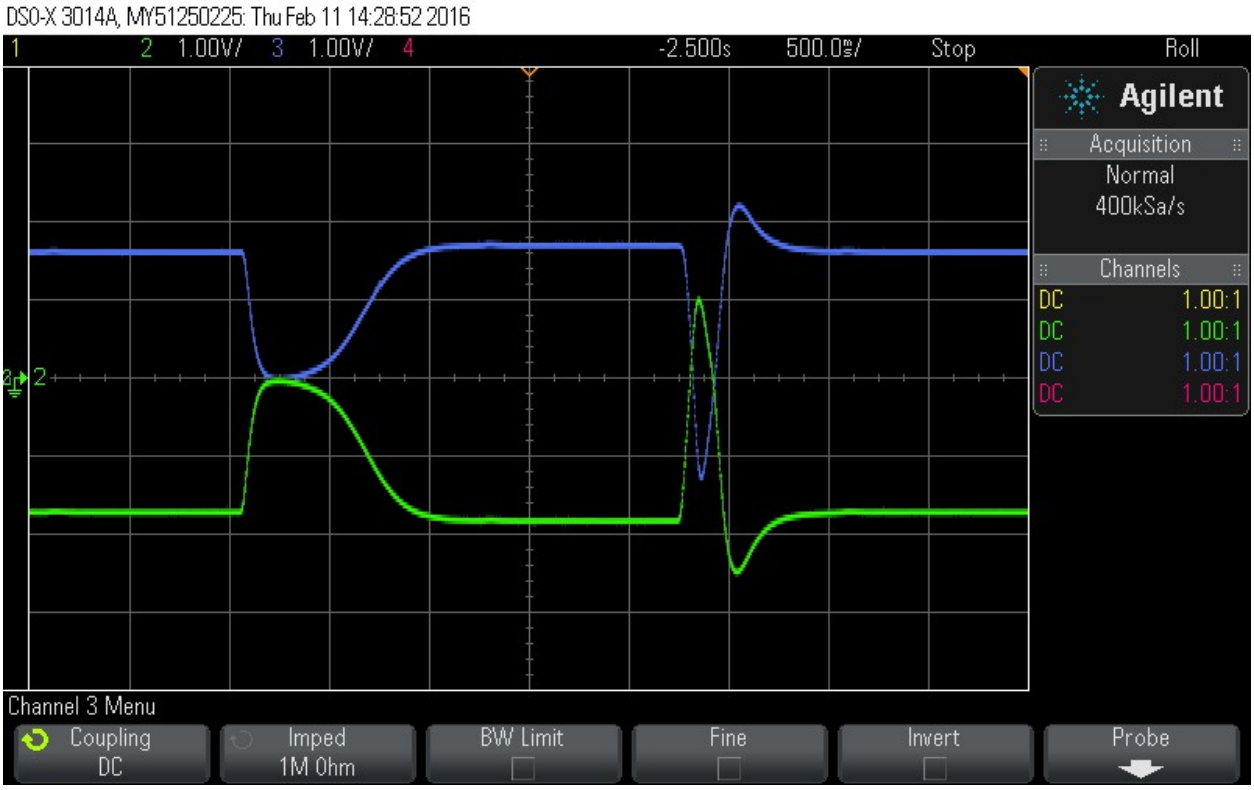
The advantages of using AGC Auto-Tracking are as follows:

- The small AGC time constant implies the receiver tracks better the signal during fast variations like multipath, spinning targets, rocket and missiles launches (smaller dropouts)
- The faster AGC will also allow the usage of the receiver for extracting the telemetry data because the IQ demods are not 'saturated' or 'starved' during the fading cycles
- All available receivers can be set to a specific AGC gain (like -20 dB/V) and AGC TC = 0.1 msec (or minimum available) which will make easier swapping receivers with spares
- The small AGC time constant will remove any AM phase shift (delay) introduced by the receiver since the AGC will instantly (within its time constant) track the RF level.
- Using the AGC Auto-Tracking, the ACU has full control over filtering of the AM signal so it can accurately correct the natural AM shift when the scan speed changes. The current design holds the AZ & EL phase crosstalk to nearly zero for possible scan rates starting from 18 Hz. Therefore once a calibration is done, the autotrack will be very accurate at any scan rate. AM output of the receiver will not be used and its filter settings therefore do not matter.

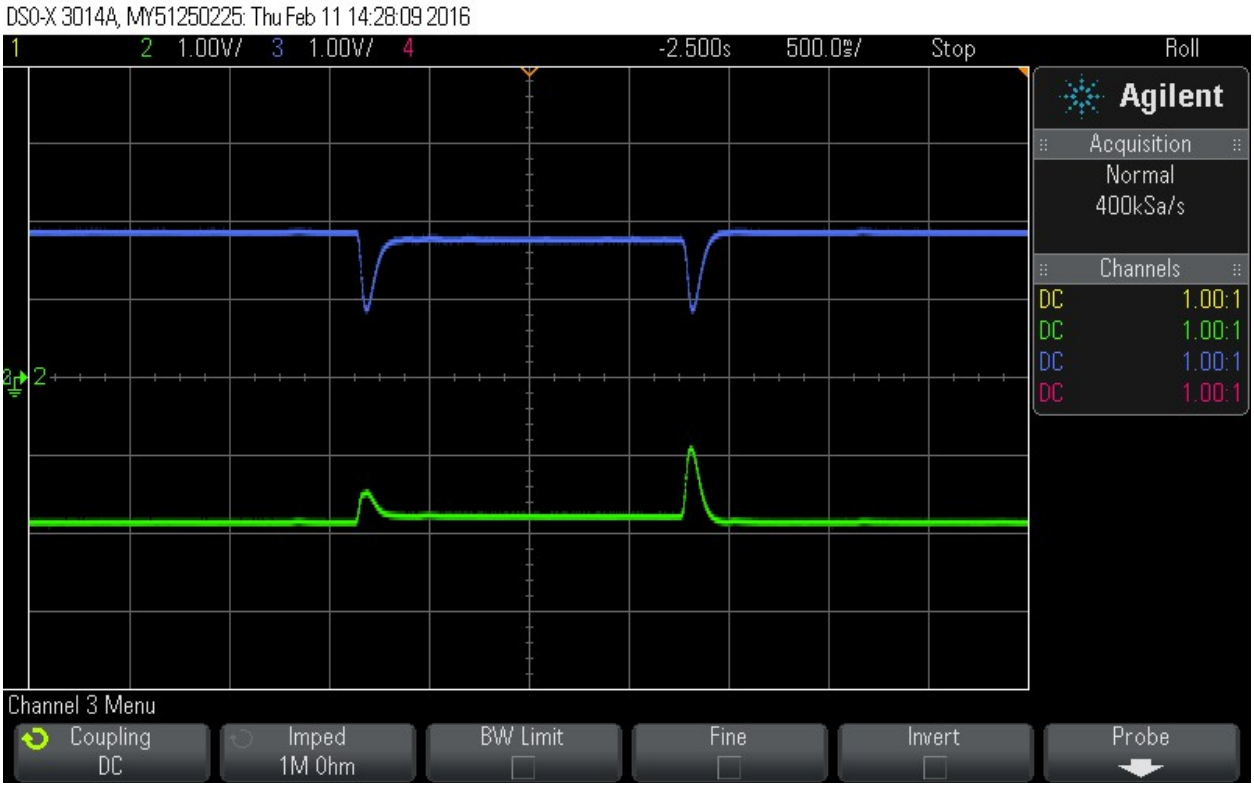
Since 2016, our TCS ACU cards implement both tracking methods: AM Auto-Tracking and AGC Auto-Tracking. Currently, we have many customers that use exclusively the AGC method for tracking since it provides a superior tracking performance. However, operators can choose their preferred Auto-Tracking method from the ACU front panel, but they must remember to set the receiver accordingly and use the correct ACU Calibration settings:

- AGC tracking: AGC TC = 0.1 msec (or minimum available)
- AM tracking: AGC TC = 100 msec and AM filter cutoff > 1kHz

Next two plots represent the behavior of Az and EL tracking errors when the RF signal has a drastic level decrease and then back to normal for the two methods. They clearly show that the AM tracking with a longer AGC time constant has longer dropouts in the error signal levels (AZ/EL tracking errors shown as Blue/Green) at the RF level transitions than the AGC tracking method. This is helpful in understanding the tracking behavior of the two methods when sudden changes occur in the RF level (multipath, spinning targets having non uniform antenna patterns, etc.).



AM TRACKING – longer dropouts



AGC TRACKING – shorter dropouts