



Trimble GCS900 Dual Antenna System

**Why Trimble uses a Dual Antenna Solution
and why it is the better solution?**

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Blade Control Single or Dual?

Available System configurations:

- a) Single antenna**
- b) Dual antenna**

Questions:

- What do we need to take in consideration for blade control?**
- Which configuration is the better choice?**



Problem Analysis

We want to

- **accurately know the location of the blade in 3 dimensions**
 - primary interest is the location of the cutting edge
- **know the location of the whole blade**
- **understand where the blade is relative to the machine**
 - Accuracy of the machine location is less important than accuracy of the blade location
 - the blade is what we guide the operator to control



Problem Analysis

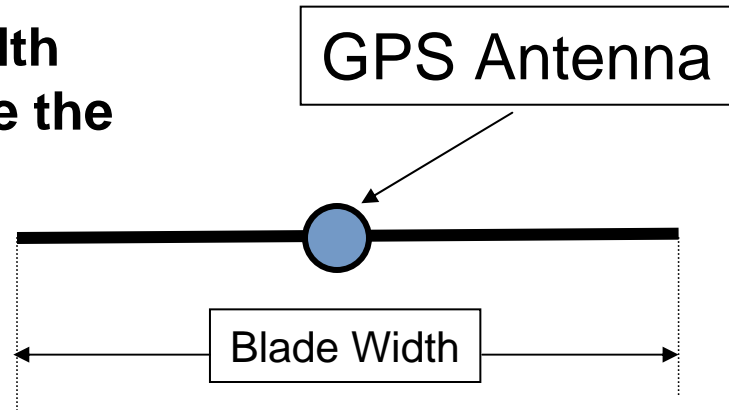
- Analysis began by evaluating a single antenna solution
- Benefits
 - appears to be simple
 - can use existing technology





Single antenna solution

- **Appears to be simple**
 - measure at the center of the blade
 - apply the blade width and we know where the blade is



**But do we really know
where the blade is??**



Problem Analysis

- the problem in our interest is not in the center position of the blade
- we are interested in the position of the whole blade
 - to be able to follow a brake line f.e.





We need to know

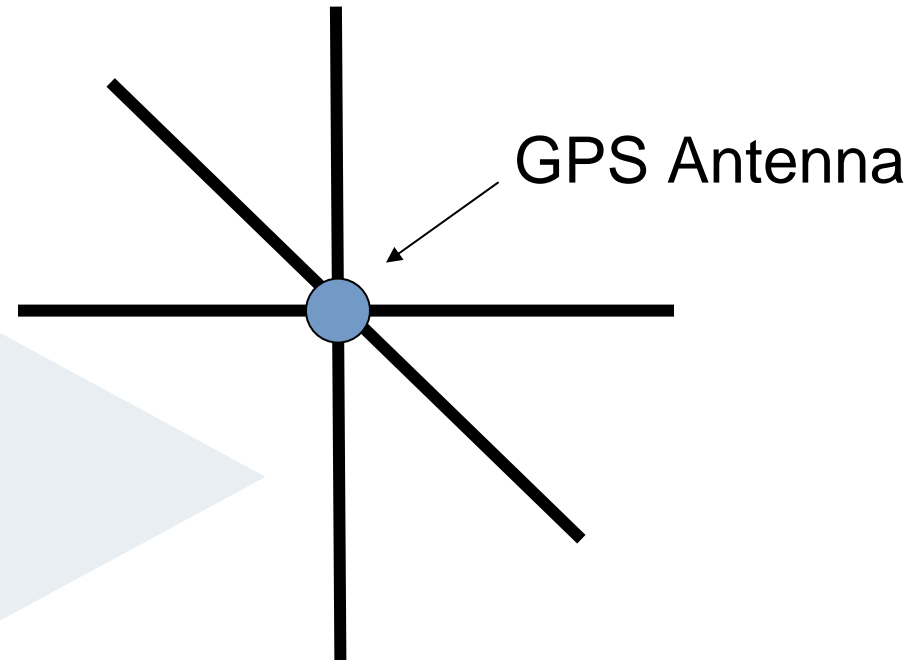
- at least one 3D position on blade
- blade orientation
- blade tilt
- blade heading





Consider Blade Orientation

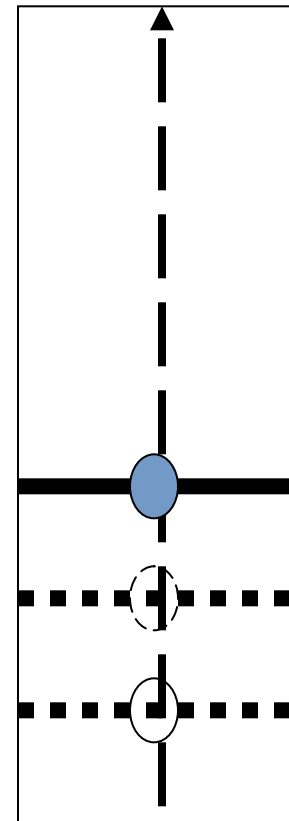
- **Where is the blade in a Single Antenna solution?**
 - is it here?
 - or here?
 - or here?
 - or where??





How could we solve this?

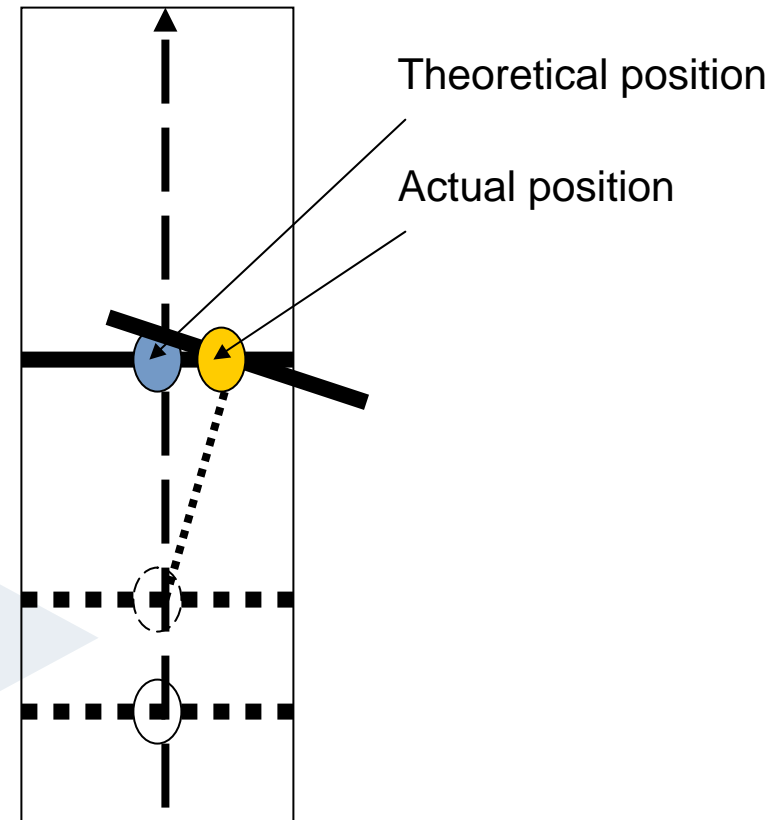
- Look at the direction of travel of the machine
- Use the heading to calculate blade orientation





Any position error gets added into the blade orientation

This effect can be minimized by increasing the spacing between the positions used for heading, but this reduces the responsiveness of the system to actual changes in heading

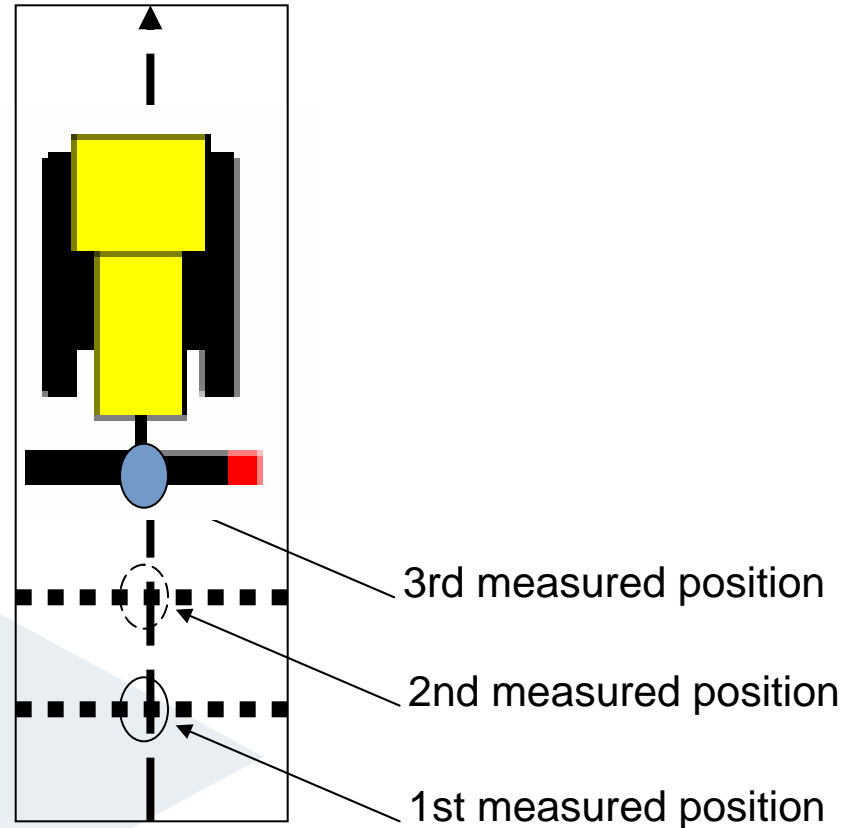




But there is another problem?

Is this the left side of the blade?

No, because the machine started by moving backwards



3rd measured position

2nd measured position

1st measured position

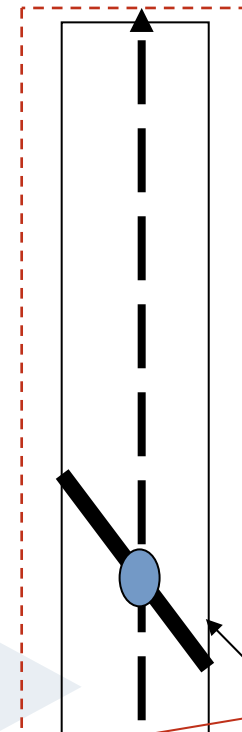


Also consider the effects when used with angle blade dozers and motor graders

Fixed blade



Angled blade



When used with an angled blade a single antenna system cannot accurately determine where the end of the blade is

Indicated blade path

Actual blade path

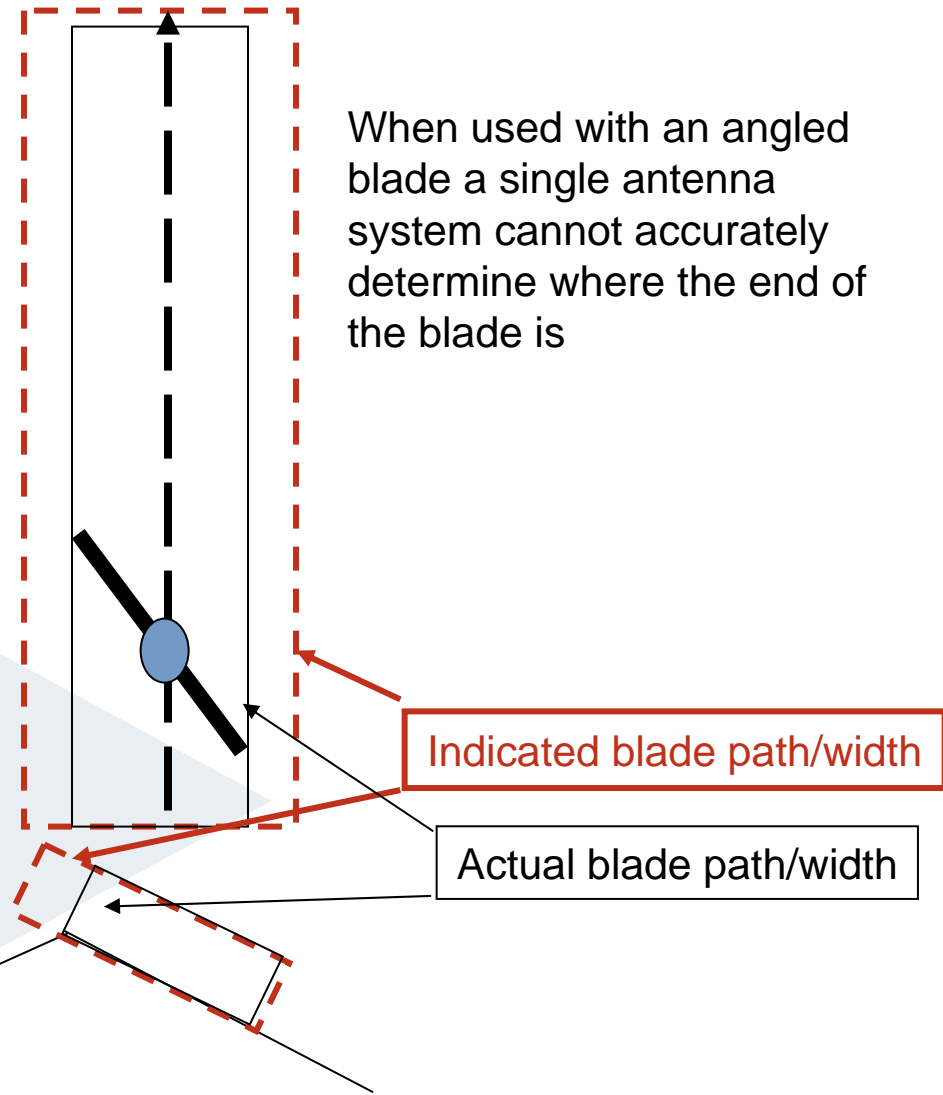


Can this problem be addressed?

Angled blade

Simple – add a rotation sensor
Is it that simple?

When used with an angled blade a single antenna system cannot accurately determine where the end of the blade is

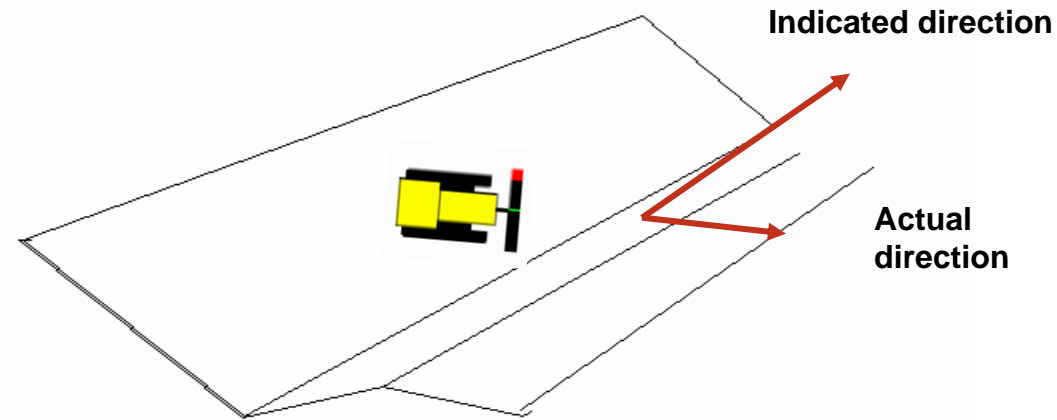
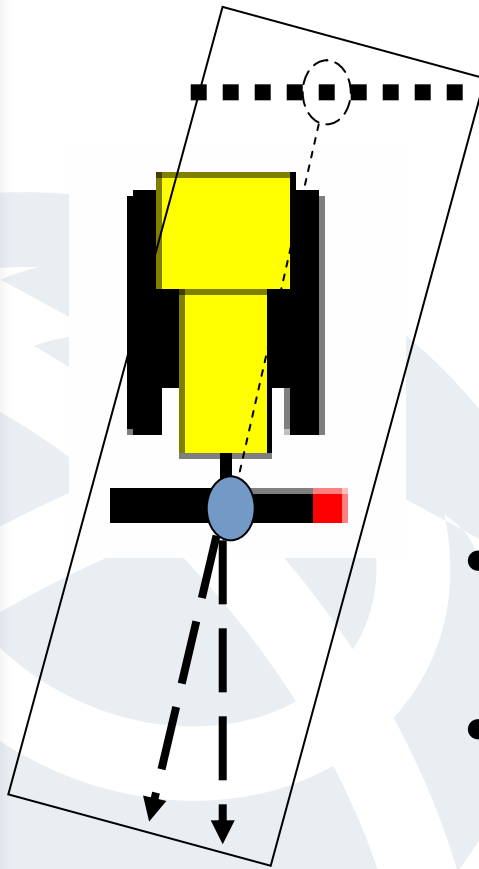


Indicated blade path/width

Actual blade path/width



The problem is more complex



- machines do not always move in the direction they are facing
- slippage occurs on slopes and under load
- also dozers can rotate without forward movement



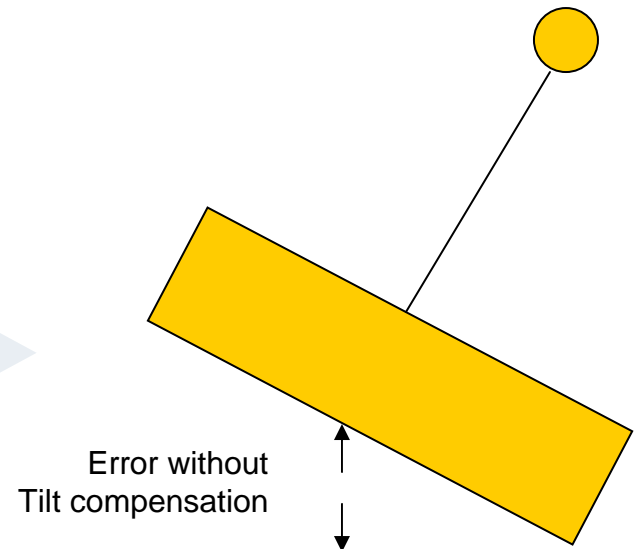
The Rotation Sensor

- **only tells how the blade moves with respect to the machine**
- **it does not tell you how the blade moves with respect to the terrain because the machine can rotate independently of the blade**
 - **these two rotations cannot be addressed by a single sensor**



Next look at blade cross slope

- we need to know the cross slope to be able to build anything other than a simple sloping plane
- a Single GPS antenna system is not sufficient
- one option
 - Add a tilt sensor to the blade





Tilt sensors

- **effected by vibration**
 - both fluid and solid state accelerometers
- **can be dampened**
 - at the expense of accuracy and/or update rate
- **require calibration, frequently**

so:

- **is there a better way?**



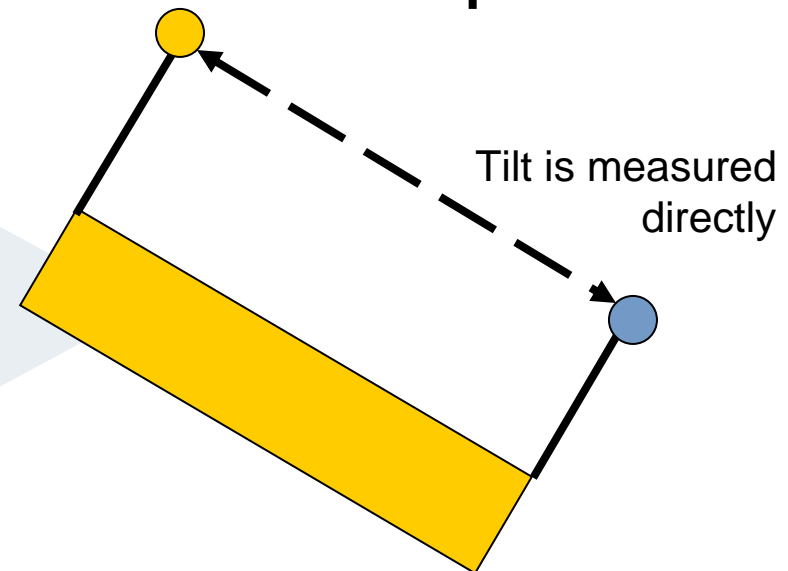
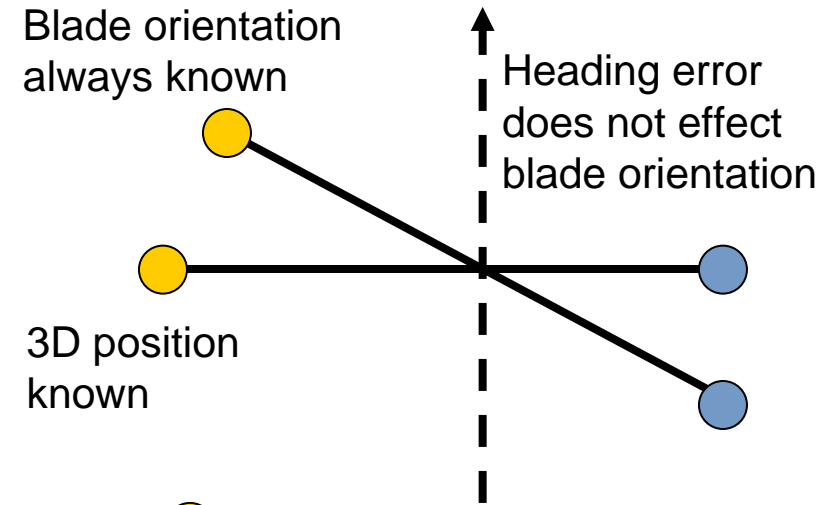
Summary so fare

- **With a single GPS antenna system we need**
 - tilt sensor
 - rotation sensor
 - mechanical devices that require calibration
- **There is better way**
 - replace two sensors and two cables with additional GPS technology



Consider a dual receiver and dual antenna solution

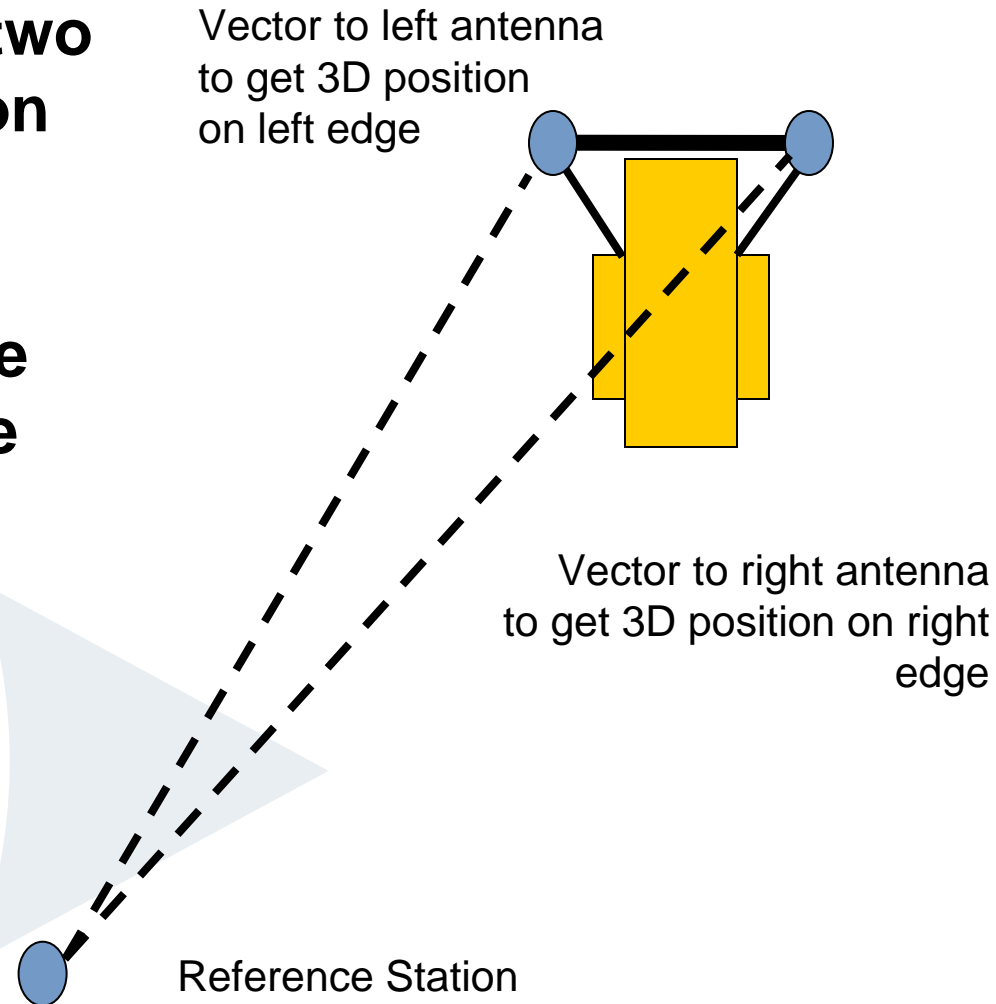
- available off the shelf GPS technology
- provides
 - tilt
 - blade orientation
- but
 - how accurate is the tilt ?





Accuracy when computing a position on each side of the blade

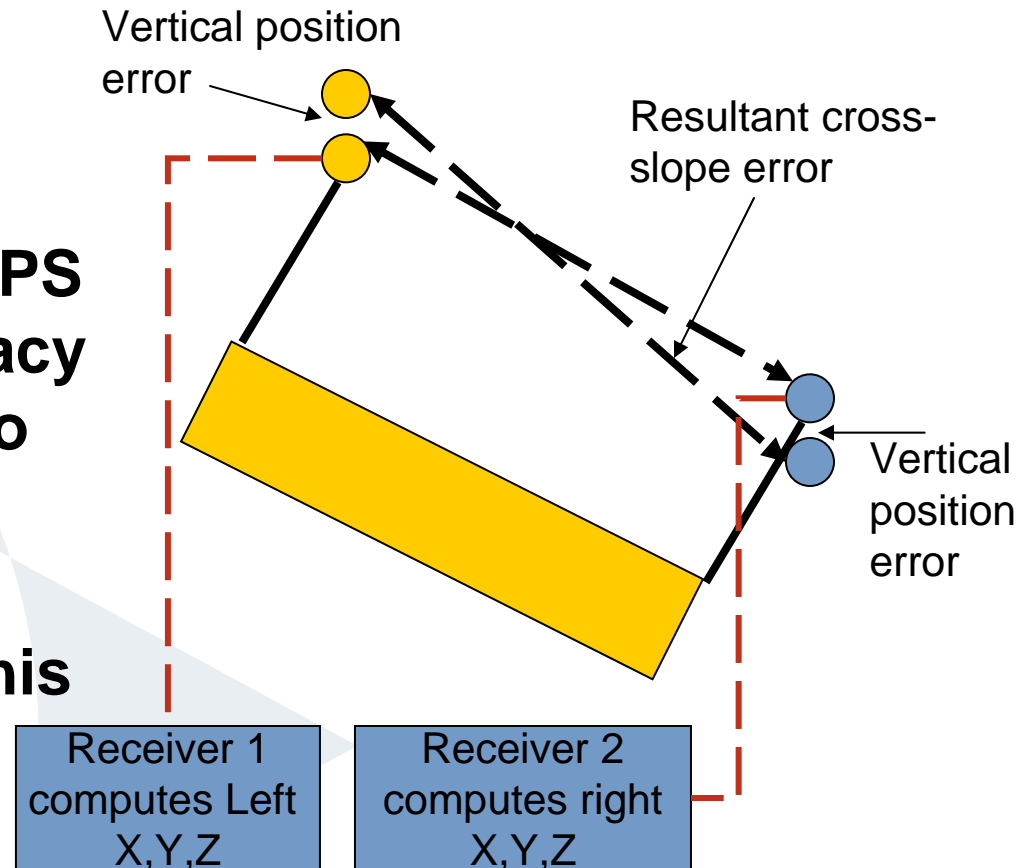
- a two receiver/two antenna solution
- each antenna computes a position relative to the reference station





Accuracy when computing a position on each side of the blade

- each antenna computes a position with normal RTK GPS vertical accuracy 0.5' to 1.2' (1 to 3cm)
- across a 12ft (3.6m) blade this equates to a grade error of 0.75% to 1.5 %

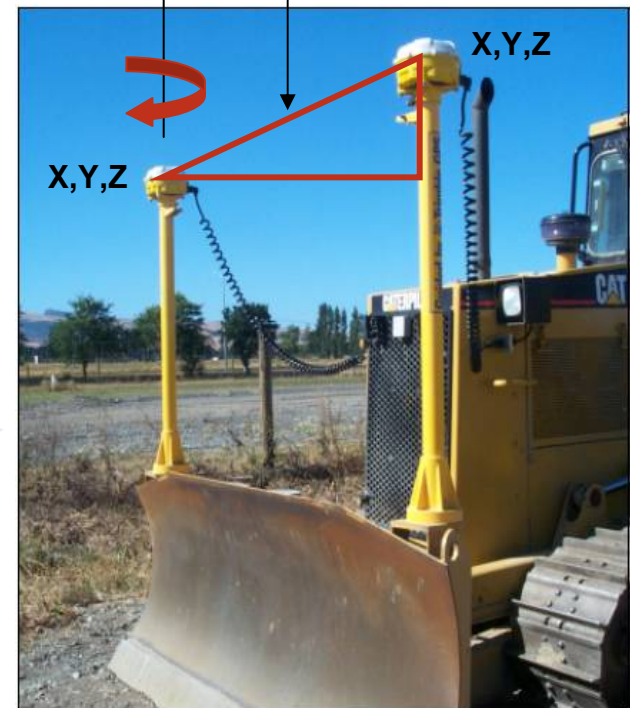




This accuracy problem can be solved!

- Innovation from the leader in GPS technology
- MS980 receiver
 - Smart antenna receiver
 - GPS & SBAS
- or
- MS990 receiver
 - Smart antenna receiver
 - GPS & GLONASS & SBAS
- GCS900 system
 - calculates position, orientation and cross slope
 - uses additional information about antenna separation for a more robust solution

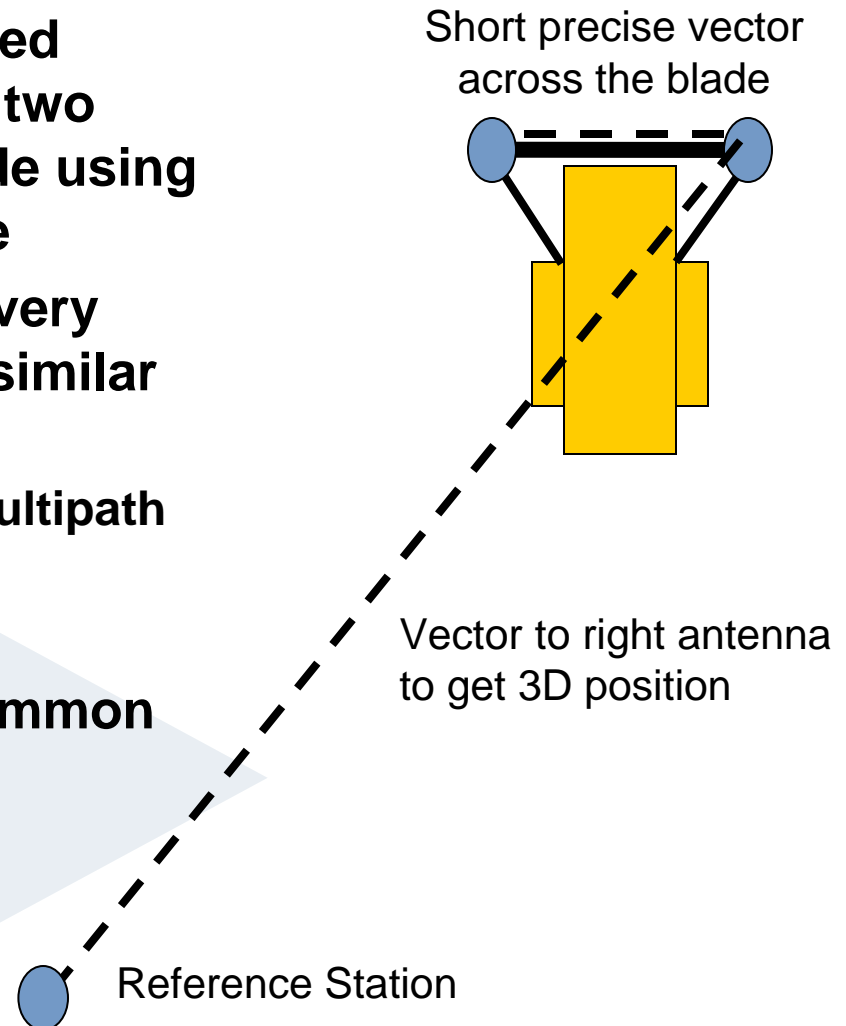
Cross slope & Separation
Orientation





Accuracy when computing the vector across the blade

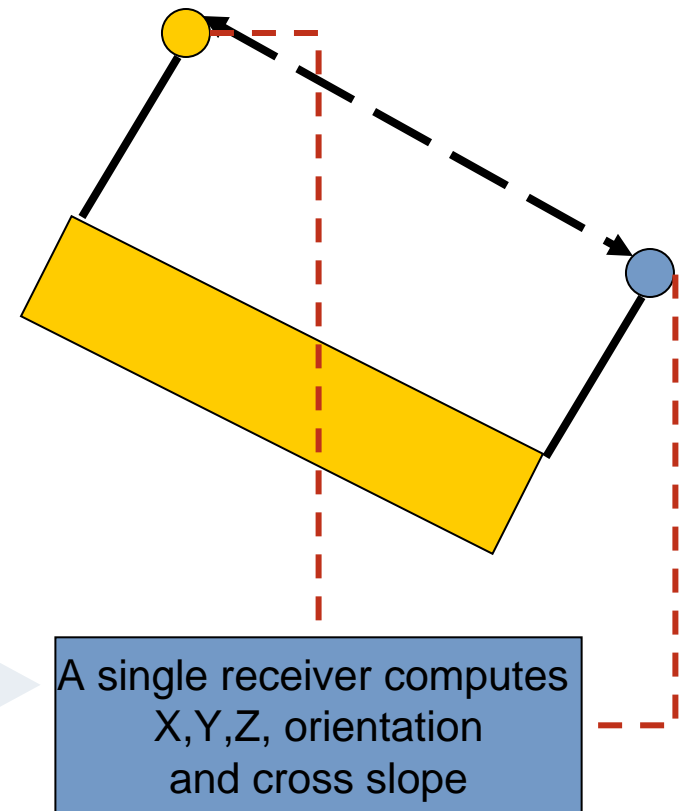
- the vector is computed directly between the two antennas on the blade using a patented technique
- as the antennas are very close they both see similar error sources
 - atmospheric and multipath
- when the satellite measurements are differenced these common errors are removed
- a patented Trimble technology!





Accuracy when computing the vector across the blade

- the single short vector is computed
- the known length between the antennas provides additional information for a more robust solution
- this results in a very accurate cross-slope
 - twice as accurate as a tilt sensor
 - provides cross-slope updates twice as fast





Summary – GCS900 dual antenna system

- most accurate solution
- all measurements on the blade – the place of interest
- accurate orientation under all conditions
- most accurate cross-slope tilt in the industry
- fastest system update for responsive guidance





Summary – GCS900 dual antenna system

- easier installation
- fewer components and cables for a complete solution
- universal solution
 - Dozer & Grader & Excavator & Scraper
- easier to move from machine to machine
- lower maintenance
 - no on-going calibration of components
- not effected by vibration
- higher reliability
 - no moving parts





Summary – GCS900 dual antenna system

- **Dozer – why dual antenna?**
 - **measures both corner tips of the blade**
 - without dual antenna = un-measured errors
 - also provides orientation (no user input)
 - **important when accuracy is required during:**
 - powered turns while pushing
 - sharp turns in tight spaces
 - any time the blade is angled
 - working on slopes ('crabbing')
- **In summary:**
high accurate and versatile





Summary – GCS900 dual antenna system

- **Grader – why dual antenna?**
 - allows you to use these grader features
 - circle side-shift
 - front wheel lean
 - frame articulation
 - these are used to: (CAT MG app. Guide)
 - to keep the front wheels from sliding
 - increase side-slope capability
 - reduce turn radius (cul-de-sacs or corners)
 - keep entire machine on smooth surface
- as a result they:
- broaden the graders application range
 - permit faster operation





Summary – GCS900 dual antenna system

- **Excavator – why dual antenna?**
 - provides accurate machine orientation
 - not affected by machine or environment
 - unlike magnetic sensors and using machine movement
- **results in increased accuracy**





Why do we still have single antenna systems available?

Aimed at those who...

- require the conventional support
- upgrade from GCS300 & GCS400 for dozers or GCS500 & GCS600 for graders
- work with a GPS/GLONASS based fleet
- who also want to use also ATS total station & Laser based conventional configuration
- work mostly in flat applications





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