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Time-Distance-Speed-Angle Problem ©

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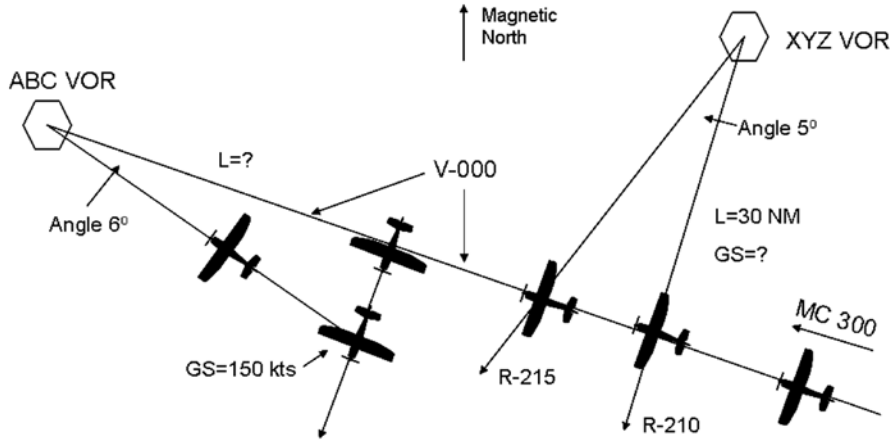
In this age of satellite navigation (GPS), Inertial Reference Systems (IRS), and Flight Management Systems (FMS), why would anyone bother with the fundamentals, right? Wrong! A well educated and trained pilot is still the best asset in any aircraft. Unfortunately, we see a trend in pilot training where the basic science and concepts are increasingly disregarded. Ignoring the best in human nature – intellectual curiosity and the quest for knowledge – and inviting the worst, boredom and the feeling of inferiority, will certainly take its toll sooner or later.

A simple method, rarely ever taught in practice, but found in some older IFR books and FAA materials, can be used to estimate distance and time to NAVAIDs. Why are we "wasting" time here learning this when FAA abandoned it? Well, for the same reasons why we practice stalls, Chandelles, Lazy 8s, and other "useless" maneuvers that never find place in daily flight operations. The understanding of the fundamental concepts in IFR navigation is the root for all other advanced applications.

In Fig. 1, the airplane on-course to ABC VOR, passing abeam XYZ VOR, is illustrated. Let's assume we are tracking toward the station and we don't have or can't use DME or GPS. Neither can we ask ATC *"Say distance and speed to ABC VOR…"*, because it is a non-radar environment, or the radar is out of service. How do we estimate the distance to the particular NAVAID if we don't know our exact position? What is even more useful – how can we estimate our groundspeed (GS), while IFR in a non-radar environment without using GPS or DME?



The time-distance-speed-angle problem in the basic IFR navigation.
(Not to scale)

The distance and the time-to-station can be calculated using elementary trigonometry. Employing the approximation that the tangent of a small angle (in radians) is the angle itself (in radians), we can derive the fundamental time-distance-speed-angle relationship for the right-angle triangle geometry. By measuring the time for a particular change in bearing, the distance L to the station, is simply:

$$L\,[NM] = \frac{GS\,[NM/h] * time\,[\text{min}]}{Angle\,[\text{degrees}]}$$

The equation is dimensionally correct. One knot is NM per hour, one radian has approximately 60°, while one hour has 60 minutes and that will cancel out, resulting in seemingly unreasonable units. Assuming the same GS in all directions, the time-to-station (TIME) is then:

$$TIME\,[\text{min}] = \frac{time\,[\text{min}] * 60}{Angle\,[\text{degrees}]} = \frac{time\,[\text{seconds}]}{Angle\,[\text{degrees}]}$$

So, we only need a working timepiece and the VOR/HIS/ADF/RMI panel instrument to measure the desired degrees of bearing change (should be less than 10° to minimize errors). FAA and other sources were making consistent error by using True Airspeed (TAS) instead of GS in Eq. (1). One note of caution here: be careful to distinguish between the time-to-station (TIME), and the time it takes for a desired bearing change (time). Let us work out a simple example!

Say we are on a certain radial (R-120) from the ABC VOR on a V-000 airway (Fig. 1). We want to know how far out we are in the absence of DME, GPS (RNAV), or ATC? In theory, the second VOR and the IFR charts can be used to estimate the position. But that takes time. So, turn 90° to the existing radial (left or right) and count the minutes it takes for the bearing change of 5° or 6o (6o is exactly three dots on the VOR display), once established on the tangential heading. Then estimate the aircraft GS from TAS and the existing wind reports. Let's say it took 2 minutes for the bearing change of 6° flying perpendicularly to the R-120 radial. We estimated GS to be 150 knots. How far are we from the ABC VOR? Simply multiply 150 knots by 2 minutes and divide by 6 to obtain 50 NM. We don't even need a calculator for this. Now, the time to

the VOR is simply distance divided by GS (50/150=1/3 hour=20 minutes), or using Eq. (2), 2 minutes times 60 divided by 6 which is, again, 20 minutes. This is assuming that the GS will remain unchanged while tracking the radial to the ABC VOR. One can estimate the GS for the desired course toward the VOR and the assumed winds and arrive to a more accurate time-to-station. This same technique can be used with the NDB as a desired station and the ADF delivering bearing change information. The Horizontal Situation Indicator (HSI) and/or Radio Magnetic Indicator (RMI) can be used instead of a traditional VOR needle and Omni-Bearing-Selector (OBS), in which case the tail of the needle shows the bearing change.

But there is more to this method! We can use the variation of Eq. (1) to estimate GS. This is more useful than the distance estimation, as the current position could be found using several VORs and/or NDBs and IFR/VFR charts. The difference here is that in Eq. (1), we had to assume GS, while this time we are solving for the unknown GS, while the distance L is known:

$$GS\,[KTS] = \frac{L\,[NM] * Angle\ [\text{degrees}]}{time\ [\text{min}]}$$

We just have to find a VOR and fly perpendicular to the current radial for about a 5° or 6° bearing change and use a clock to time that change. One can measure the total bearing change symmetrically around the center of the VOR's scale, or by using only one side of the VOR scale. The distance to the off-course VOR can be estimated from the IFR/VFR chart. Time can certainly be measured very accurately, while the bearing change can be measured with the accuracy of ± 0.25°. Incredibly, this simple technique was never mentioned or used in any flight training publication to the best of my knowledge.

Let's demonstrate this technique using another example. Say you are passing (Fig. 1) abeam the XYZ VOR on your route to ABC VOR on a magnetic course of 300°. You want to know what is the current GS and time to the ABC VOR. We find using the IFR/VFR chart distance to the, off-course, XYZ VOR to be 30 NM, when located on the perpendicular radial (R-210) on course to the ABC VOR. We then count time until there is a 5° bearing/radial change from the XYZ VOR. Say, you timed this and it took 1 minute and 15 seconds (75/60 seconds or 1.25 minutes). What is our current GS? Simply, from Eq. (3), multiply 30 times 5 and divide by 1.25 minutes, which is 120 knots exactly. The time to ABC VOR is distance to it (from the IFR chart) divided by a calculated GS of 120 knots. If the numbers are not round and easy, one can use a calculator. The uncertainty in GS estimation is equal to the uncertainty in distance-to-station estimation.

The next time you fly somewhere or practice in your local area, just do this simple exercise and you will be amazed how accurate it is. And you paid $3,000 for your GPS? This method will increase your confidence and give you a set of skills that can always be applied and particularly in an emergency situation when other systems fail. And there is even more to this method, but we will discuss this some other time.

EDITOR'S NOTE: Dr. Nihad E. Daidzic, Ph.D., is an Associate Professor of Aviation at Minnesota State University-Mankato. He is also an Adjunct Associate Professor of Mechanical Engineering; Airline Transport Pilot certified and "Gold Seal" CFI-IA, ME-I, CFI-G, AGI, IGI. (Nihad.Daidzic@mnsu.edu). Website: http://ed.mnsu.edu/aviation/faculty/daidzic.html.

ASK PETE

by Pete Schoeninger

Send questions to Pete.Harriet@gmail.com

Q: How do you see the current market?

A: Good news... if you are a buyer, or considering moving up! Most airplanes have depreciated in the last 2 years, and especially in the last months, but there are a few exceptions, Cessna 152s for one! It's too early to tell what the financial gyrations of the last couple of weeks have done to the airplane market, but probably prices will continue to soften. When will we hit bottom, I'm not that smart, but for the long haul, I think now would be a good time to be an airplane buyer.

Q: An old crop duster once told me NOT to head for a cornfield in the summer in the event of a forced landing…why?

A: Because a field crop of any height can cause you to flip nose down, causing major damage to the airplane and perhaps you as well. Also, be careful when operating from an airstrip with corn on the sides of the runway. If you accidentally brush the corn with your wing, it's like hitting small trees and your aircraft will likely turn into the corn and suffer damage to the wing and possibly the landing gear, as your takeoff momentum will no longer be directed forward, but rather sideways.

Q: I heard that a wing covered with fabric, or the new composites, may have less drag than a wing covered with aluminum?

A: Yes, certainly possible. Example: The first Cessna 170s had fabric wings, and in my experience flying them, were about 5 mph faster than the metal-winged version, which followed. ❑