Airway Operations

Flying VOR airways is a seamless operation, but there are a few quirks you need to know about.

By Wally Roberts

TODAY'S DOMESTIC AIRWAYS AND off-airway route requirements have evolved from the lighted airways used in the early days of DC-3 airline operations. It all began with statute miles, then World War Two resulted in a push towards knots and nautical miles as the preferred references for horizontal velocity and distances, at least for airline operations.

For many years, the domestic airway was 10 statute miles wide (5 miles from centerline to edge). During most of that time, en route navigation facilities were low-frequency (L/F) aids, which were either four-course range stations or ADF (NDB today) facilities. Early range stations could not support ADF operations, so the pilot had no choice but to listen to the drone of the combined "A" and "N" on-course aural signal. Eventually, range stations supported either the four aural on-course range legs, or ADF courses.

The limited L/F airways in use in the United States today are still 5 statute miles (4.34 nm) centerline-to-edge.

Evolution to VOR airways

When it came time to establish criteria for what is known today as "VHF Airways," it was decided that four nautical miles, centerline-to-edge, would be sufficient. There was absolutely no scientific basis for this decision whatsoever, other than empirical operational experience.

VHF Airways are based on VOR navaids, but in the beginning of the transition from L/F airways, there was briefly a VHF four-course replacement for the old L/F range stations: the Visual-Aural Range. The VAR was a localizer-like en route aid. Obviously, the omni-directional nature of VOR doomed VAR, almost from its beginning.

By the time the development of the VOR system got into high-gear, the FAA standards development folks of the era decided that some scientific basis was necessary to establish aeronautical navigation criteria. So, unlike L/F range stations and ADF, the VOR system was subjected to a fairly good study of probable system errors. By this time, radar surveillance technology had developed to the point where such studies were feasible.

Error considerations

For purposes of this discussion, the components of system error are: ground station error, receiver error, display error, and flight technical error (FTE). FTE is a polite way of expressing the pilot's, or the autopilot's, inability to keep the CD1 perfectly centered while tracking a course. These errors were determined using accepted statistical samples and analyses.

The error components were determined to be independent, so they were mathematically combined by the root-sum-square (RSS) method to arrive at a total error budget. The resulting error numbers were extended to probabilities deemed acceptable to the FAA. The along-track value was determined to be 4.5 degrees, and the crossing-radial value was determined to be 3.6 degrees. The statistical confidence of these values is 95 percent.

Because a VOR low-altitude airway (below 18,000 feet in most of the U.S.) is four nautical miles centerline-to-edge, a lot more than 4.5 degrees of lateral protection is provided from the VOR out to nominal distances. At 20 miles from the VOR, for example, the edge of the airway represents over 11 degrees from the centerline's course. This is the result of using an angular navigation system in rectangular protected areas.

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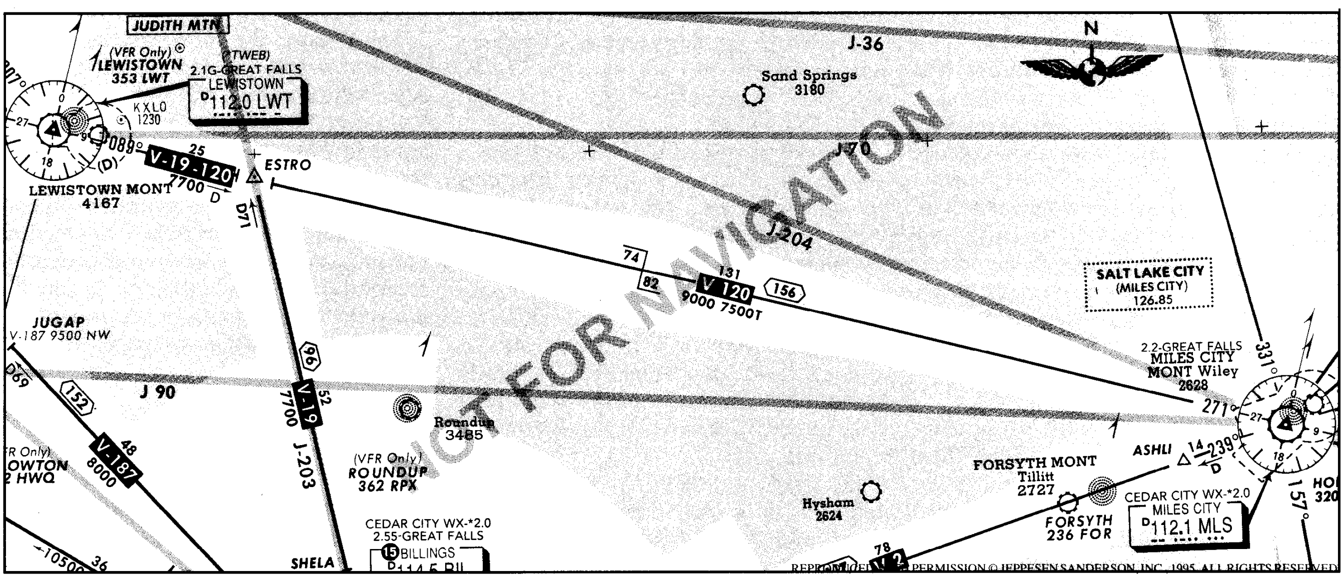

Figure 1. *When a VOR airway extends beyond 51 miles, the airway expands at 4.5 degrees to ensure a 95percentprobability of containment within the lateral confines of the airway. You can see this where controlled airspace is coincident with the airway boundaries.*

The crossover occurs where a 4.5 degree angle equals four nautical miles, or at almost 51 miles. When a VOR airway extends beyond 5 1 miles, the airway expands at 4.5 degrees to ensure a 95 percent probability of containment within the lateral confines of the airway of competently flown en route operations, over the long term. ("Competently flown" en route operations means that the pilot has the correct course set for the published VOR radial, and is making a diligent effort to keep the CD1 close to center, except during significant course changes, or overheading the facility.) You can indirectly see the result of this application on some low-altitude en route charts where controlled airspace is coincident with the airway boundaries (see Figure 1, page 5).

When the airway is less than 51 miles from the VOR, the probability of an aircraft remaining within the lateral confines of the airway becomes greater, the closer the aircraft is to the VOR facility. Also, a two-mile wide secondary area is located laterally to each side of the airway's primary area.

At 5 1 miles from the VOR, the combined six-mile width of the primary and secondary areas represents 6.7 degrees, which is the VOR along-track error limit, with a statistical probability of containment of 99 percent. Beyond 51 miles, the secondary area expands at 6.7 degrees, as the primary area expands at 4.5 degrees (see Figure 2 above).

Refer to the chart in Figure 1. If there was a vertical cement wall at the edge of each side of V- 120 extending above 9,000 feet msl, the 54-mile expanded area beyond 51 miles from both VORs would likely have an unacceptable accident rate over the long run. This assumes there are lots of IFR operations during instrument meteorological conditions at the MEA of 9,000 feet. What has saved the day is the lack of obstacle-rich environments right to the lateral limits of airways, and at distances where the VOR system error numbers become significant.

Vertical obstacle clearances

In non-mountainous areas, the primary area of the airway must have at least 1,000 feet of vertical obstacle clearance over the highest obstacle anywhere within a given airway segment. In designated mountainous areas (DMAs), the primary area vertical obstacle clearance is 2,000 feet, with some limited exceptions.

Primary Obstacle Clearance Area

Secondary Obstacle Clearance Areas

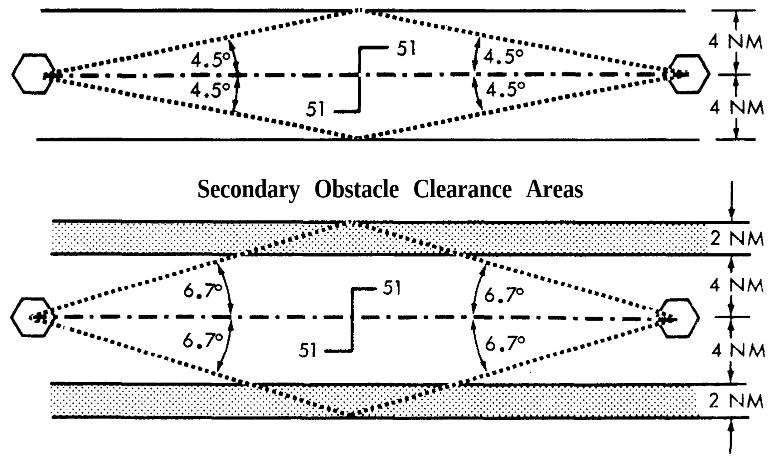

Figure 2. *At 51 miles from the VOR, the combined six-mile width of the primary and secondary areas represents 6.7 degrees, which is the VOR along-track error limit. Beyond 51 miles, the secondary area expands at 6.7 degrees, as the primary expands at 4.5 degrees.*

The secondary areas' vertical obstacle clearance for non-DMA areas is at 500 feet at the edge of the primary area and tapers to zero at the outer edge of the secondary area. Typically, the secondary area starts with 1,500 feet of vertical clearance in DMAs, tapering to zero at the secondary area's outer edge.

There is also a turning area obstacle clearance area for course changes at VOR intersections that are ambiguous because of their distance from the VOR facilities, or for significant course changes for jet aircraft above 10,000 feet msl, whether at distant VOR intersections, or at accurate fixes, such as a radial/DME fix. For those of you interested in the complexities of turning area protection, this is covered in TERPs Handbook Paragraphs 1713, 1714, and 1715.

The previous vertical obstacle clearance factors are all components that determine the minimum en route altitude (MEA). Also, both reception of the applicable VOR facilities and ATC communications requirements are considered when establishing MEAs. If, because of reception requirements, the MEA is driven significantly higher than that required for obstacle clearance, a minimum obstruction clearance altitude (MOCA) will sometimes be published.

Establishing a MOCA is usually the judgment of the FAA airspace and procedures folks. An MOCA is an operational altitude only within 22 miles of the VOR facility, unless ATC can see you on radar and is willing to accept responsibility for keeping you within the confines of the airway below the MEA and beyond 22 miles. Otherwise, any MOCA beyond 22 miles is strictly a "Mayday" altitude.

Airway gaps

On low-altitude airways, along-course gaps in VOR reception are permitted within very strict limitations in difficult mountainous areas, and there must be a genuine operational need for the gap. The gap will normally not exceed a distance which varies from zero nautical miles at sea level, to 65 nm at 45,000 feet msl. Also, there cannot be more than one gap per airway segment.

Since gaps are inherently hazardous where there's higher terrain close to the edges of the airway, the FAA has increasingly over the years generally limited their use to Jet Routes, where lateral error represents no terrain hazard. A kissing cousin of the gap is the minimum reception altitude (MRA) for some fixes, where the facility that provides the crossing radial cannot be received at the MEA of the airway. Any fix that receives this treatment has an optional purpose, such as a non-compulsory reporting point.

Change-over points

The change-over point (COP) from the preceding VOR to the next VOR is normally half-way between the two facilities along a straight airway. Where reception requirements dictate a COP at other than midpoint between the two facilities, a COP is

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published. Where no COP is published, but there is a dog-leg, change-over occurs at the intersection of the dog legs. Change-over at the COP is mandatory, whether published or not.

Minimum crossing altitudes

When no minimum crossing altitude (MCA) is specified, an airway segment with a higher MEA may be entered as low as the MEA of the preceding airway segment, with a climb to the higher MEA starting immediately upon entering the segment. This normally applies only during lost-corn procedures these days.

When airway climbing criteria cannot be met from the preceding segment's lower MEA to the next segment's higher MEA, an MCA is published. In mountainous areas, VOR facilities often have multiple MCAs, so it takes a good eye to pick out the right MCA.

One application of MCAs during normal operations is with some complex IFR departure procedures at non-radar, mountain airports, where climbing must be done in a holding pattern to meet specified MCA requirements (see Figure 3, above right).

The minimum climb gradient for an IFR departure procedure is 200 feet per nautical mile, unless a higher gradient is specified. For airway en route climbs from a lower to higher MEA, including any climb to MEA after just meeting an MCA requirement, the following climb gradients apply: sea level through 5,000 feet msl: 150 ft/nm; 5,000 through 10,000 feet msl: 120 ft/nm; 10,000 feet and over: 100 ft/nm.

L/F (NDB) airways

Today's L/F airways are mostly in Alaska. L/F airway construction principles are virtually identical to those for VOR airways, except the error assumptions are 5 degrees for the primary area and 7.5 degrees for the secondary areas. Unlike the VOR system error values, these numbers are quite subjective. ADF is inherently unreliable, except for homing and very short-distance tracking.

The FAA policy about L/F airways is: "The use of L/F navigation facilities will be considered a system deficiency and shall be limited to those cases where no other course of action is possible and where a definite operational requirement can be justified." The FAA Alaskan Region recently announced that it intends to proceed with replacement of the state's L/F route structure with en route GPS airways.

	TAKE-OFF & IFR DEPARTURE PROCEDURE									
	Rwys 10,15,20		Rwys 2, 33					Rwy 28		
			CAT A & B ACFT		CAT C & D ACFT			With Mim climb of 240'/NM to 7300'		Other
					With Mim climb of 330'/NM to 9000'		Other			
	Adequate Vis Ref	STD	Adequate Vis Ref	STD	Adequate Vis Ref	STD		Adequate Vis Ref	STD	
1 & 2 Eng	1/4	1	1/4	1	1/4	1	2900-3	1/4	1	1000-3
3 & 4 Eng		1/2		1/2		1/2			1/2	

IFR DEPARTURE PROCEDURE: Rwys 2, 10 & 33: Turn right; Rwys 20 & 28: Turn left; Rwy 15: Climb runway heading. All aircraft climb direct to SAF VOR. Continue climbing in SAF VOR holding pattern (Hold Southeast, right turns, 332° inbound) to cross SAF VOR at or above airway MEA/MCA for direction of flight.

	FOR FILING AS ALTERNATE — Authorized Only When Twr Operating		Authorized Only When Twr Operating or With Approved Weather Service
	ILS Rwy 2	LOC Rwy 2 NDB Rwy 2	VOR Rwy 33 VOR DME-A
A B C	600-2	800-2	800-2
D	700-2 1/4	800-2 1/4	800-2 1/4

Figure 3. *The IFR departure procedure for this airport requires a climb in a holding pattern to meet minimum crossing altitude (MCA) requirements.*

Operational considerations

The rationale for requiring 1,000 feet of vertical obstacle clearance in a non-DMA, and 2,000 feet in a DMA is lost to historical obscurity. Suffice it to say that containment within protected airspace is the most demanding on the worst-weather days. Turbulence, micro-pressure gradients, strong winds, and rapidly changing wind components with altitude, all contribute to increased difficulty to remaining within the vertical and lateral confines of the airway.

Add to this underlying precipitous terrain and/or very cold temperatures, and the potential for disaster in some of the more profound mountainous areas is significant. The FAA has failed to adequately address the issue of very cold temperatures, coupled with MEAs that are considerably higher than the elevation of the altimeter setting source. So, under adverse weather conditions, especially in mountainous areas, your personal MEA could very well be higher than the published MEA.

Like anything pertaining to serious instrument flying, there is no substitute for local knowledge of both terrain and significant weather conditions, especially where aircraft performance is limited.

GPS and other gee-whiz stuff

IFR-certified GPS holds great promise for taking away much of the ambiguities and uncertainties that exist with today's airways. When navigating with VOR, you can easily be one, two, or even three miles laterally offset from what is displayed on your CDI as the apparent center of a long airway segment.

Add to that a sudden change or increase in adverse crosswind component, and you have a real challenge to stay within the confines of the airway, without necessarily knowing how bad things are. Fortunately, when an aircraft leaves the protected airspace, there often is simply nothing to hit.

With GPS, the CDI will always faithfully show where the center of the "yellow brick road" is located. But, there are still the issues of controllability and strong, unexpected crosswinds. Because of the virtually unlimited ability to place GPS waypoints anywhere, there will be the inevitable tendency to find either published or random routes hugging the "canyon walls" far more than with the structured VOR system.

The FAA will be unrelenting in their attempts to tighten down the dimensions of GPS airways, based on accuracy assumptions alone. Unlike years ago, the FAA has neither the money nor the will to undertake meaningful scientific analysis of total system performance and safety risk targets. It will be up to pilots, through user groups, such as ALPA, AOPA, NBAA, etc. to keep these emerging technologies serving us, rather than doing us in.