ATDI

Navigational Aid Clearance Criteria per FAA Order 6820.10

February 2011

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Software Solutions in Radio Communications

What Are Navigational Aids?

Navigational information is provided to airplanes by more than one radio frequency system. Though recent innovations in satellite navigational technology have led to an increase in Global Positioning System (GPS) usage, navigational systems (also known as navigational aids) like non-directional beacons, civilian VOR and DME and the military TACAN are the backbones of air navigation and will continue to be in use for many years to come.

A VOR, or VHF omnidirectional radio, is a radio navigation system that broadcasts a navigational signal as well as voice and identifying information. Commercial aircraft use the VOR signal to determine magnetic bearing to a VOR beacon and to obtain any important broadcast information. The bearing information is obtained from the manner in which the VOR signal is modulated.

A DME, or distance measuring equipment, is another VHF radio system that is used to measure the slant range distance between an aircraft and a DME beacon. It works on radar ranging techniques. A DME station receives and decodes the RF pulse emitted by an airborne transponder and provides a reply after a 50-microsecond delay. Based on the time difference between transmission and arrival at the airborne transponder, the aircraft systems are able to calculate the distance to a DME beacon.

TACAN, or tactical air navigation, is the military combination of the civilian VOR and DME systems. Operating between 960 and 1215 MHz, it is a polar coordinate type radio air navigation system. TACAN is three to nine times as accurate as VOR. When a VOR and a TACAN are co-mounted, the installation is called a VORTAC; in this case, the distance measuring portion of the TACAN is available to both civil and military users while the bearing system is not shared.

Whether an aircraft is civilian or military, the bearing and distance information provided is displayed as two dials to the aircrew, one for each function. The aircrew uses the information provided by the two dials to fly towards a beacon or to establish geographic location with respect to a beacon. The information may also be used to intersect radials and flight paths. The two most common uses of the systems are to navigate along a certain flight path that is defined beacon-to-beacon or to perform an instrument-based approach to an airport.

Interference Caused to Navigational Aids

Much like other radio frequency systems, navigational aids are also subject to interference that may negatively impact the system, causing errors and potentially disabling the system entirely. For air navigation, where precision is important, it is vital to minimize the chances of error or system outage. For that reason, mandates such as the Federal Aviation Authority's Order 6820.10 exist. Entitled VOR, VOR/DME, and VORTAC Siting Criteria, Order 6820.10 establishes important siting criteria for buildings, vegetation, and other structures in the operational volumes of navigational aids. The interference effects of interest are shadowing, reflections, and Fresnel zone clearance.

Shadowing, caused by a tree, a fence, a building, or any tall structure, occurs when electromagnetic energy impacts upon an object and is scattered in various directions, preventing the energy in continuing in its forward path at undiminished power. Thus, a volume is created behind the obstruction where the electromagnetic energy penetrates partially or not at all. If aircraft are to be located in this volume of little to no signal, the communications with navigational aids may become unreliable or be lost completely.

Reflection is a phenomenon directly related to shadowing. When electromagnetic energy is incident upon an obstruction, it is scattered in many directions if the surface is not smooth and in one general direction if the surface is smooth. A single scattered ray or a group of rays scattered in one direction are also known as a reflection, or reflected rays. The reflected rays might impact other communications systems that operate on similar frequencies, causing interference. The reflected rays may also be reflected in such a way that they arrive at a receiver along with direct rays. Called multipath, the reflected rays may sum constructively or destructively at the receiver, depending on whether the reflected rays arrive in or out of phase with the direct signal. Multipath is directly related to Fresnel zones.

Fresnel zones are concentric elliptical volumes found around a direct signal path line that alternately add or subtract energy from the total amount of energy received. While odd numbered Fresnel zones add energy, even numbered Fresnel zones subtract energy. The closer a Fresnel zone is to the direct path line of the signal, the more energy it contains. For this reason, it is desirable to maintain an unobstructed first Fresnel zone so that all the energy contained within it reaches the receiver. Obstructions within the second Fresnel zone can cause reflections that may sum negatively at the receiver, ultimately lowering the amount of power received or even creating a null in the signal.

Navigational Aid Clearance Analysis in ATDI RF Planning Software

ATDI's RF planning software allows a user to perform a navigational aid obstruction analysis quickly and efficiently. With precise cartography as the foundation for any RF study, the user can select an area and place a navigational aid and individual obstructions within minutes. In the figure below, a hypothetical navigational aid has been placed at Washington Reagan National Airport, located in Arlington County, Virginia.

Figure 1: Hypothetical navigational aid at Reagan National Airport

Now, two types of analysis may be performed. The first type refers to a rule in FAA Order 6820.10 and the second refers to minimum safe altitudes. FAA Order 6820.10 states that any structure that is wholly or partially metallic may not subtend a vertical angle greater than 1.2° with respect to the beacon and measured at ground level from the beacon site. It is important to include Earth dip into the calculation for the utmost accuracy. The figure below portrays the 1.2° criterion as well as the effect of Earth dip.

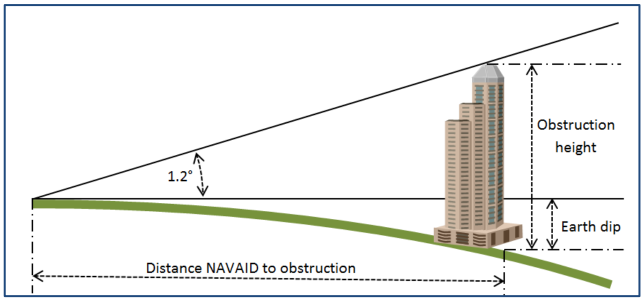

Figure 2: 1.2 degree vertical angle rule

The ATDI software takes into account not only Earth dip, but also any and all terrain features in the area of the navigational aid as well as the height of the obstruction. Once the 1.2 degree rule function is run in the software, the following images is the outcome. The inside of the red contour represents the area where construction of any obstruction that subtends more than 1.2° with respect to the navigational beacon would be in violation of FAA Order 6820.10.

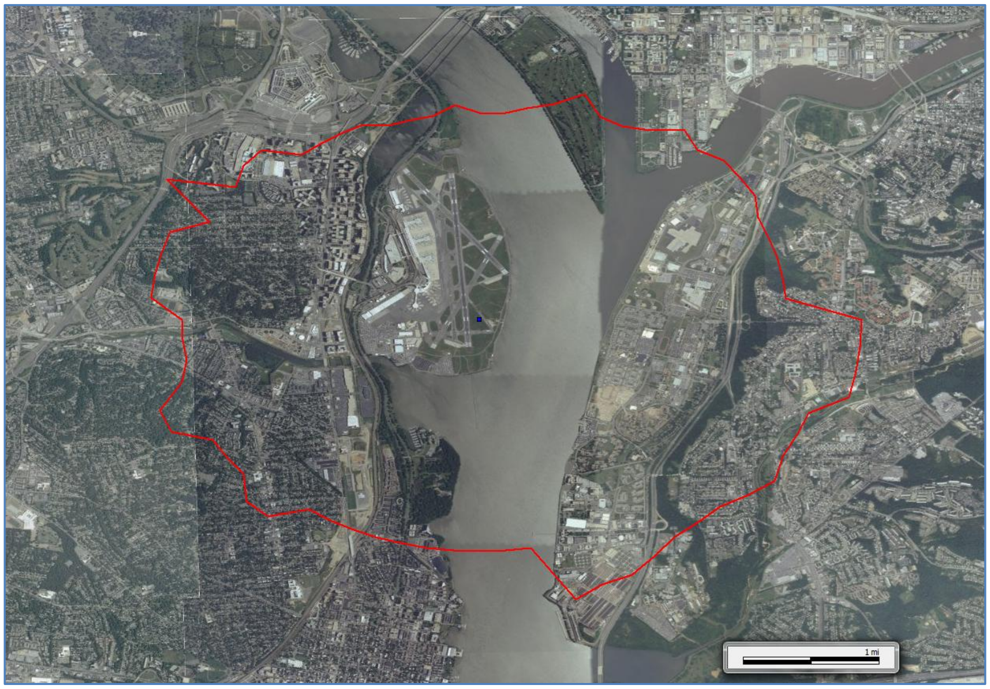

Figure 3: Exclusion zone based on FAA 1.2 degree rule

In this case, the hypothetical exclusion zone affects the entire area of the airport as well as a portion of Arlington County and the Southeast quadrant of the District of Columbia.

The second type of analysis performed by a separate function in the ATDI RF planning tool creates contours based on expected flight altitudes near the navigational aid. The user enters a minimum safe flight altitude and a distance between the navigational beacon and an aircraft for that altitude at which he requires communication unaffected by obstructions. Shadowing and null creation are the two major concerns behind this analysis. The software provides a 360 degree contour based on the flight altitude, distance to the expected obstruction, obstruction height, and variations in the elevation in the area.

The contour that is calculated (shown in red in the figure below) provides for first Fresnel zone clearance of the direct signal from the navigational aid to aircraft. This is provided according to FAA Order 6820.10 in order to minimize the risk of reflections that may negatively sum at the receiver site, potentially creating a null signal.

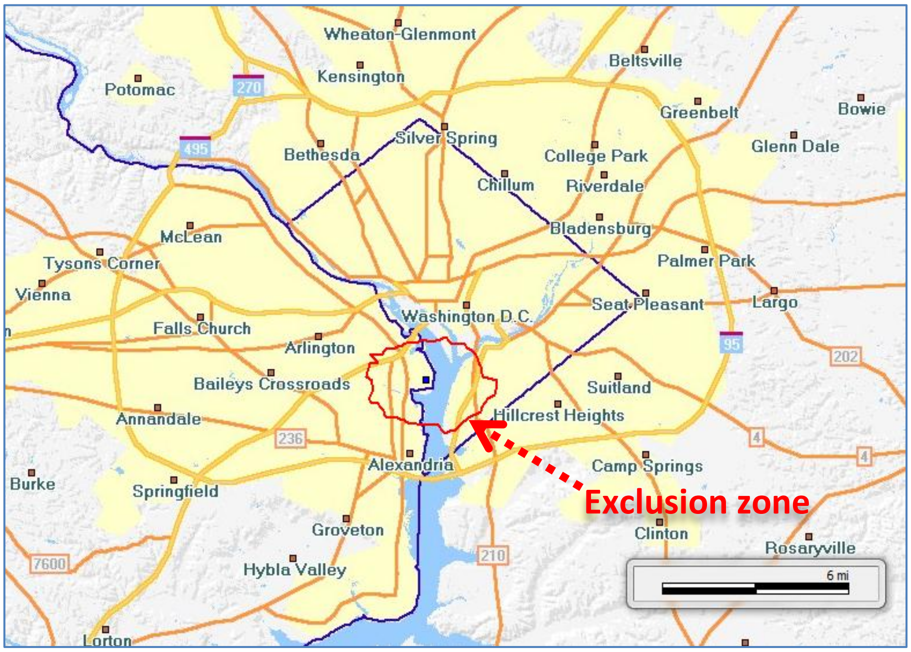

Figure 4: Flight altitude requirement

Conclusion

Though GPS-based navigation is gaining in popularity, navigational aids such as VOR and DME are and will continue to serve as the navigational backbones for worldwide air travel. Protection of the airspace around them is crucial to maintaining safety in the skies. The implementation of functions based on FAA rules into ATDI RF planning software allows for detailed analysis of potential obstruction issues.

For further information visit:
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