Figure 1: VORTAC site

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2023-12-05 vhf omnidirectional range

The term "VHF omnidirectional range" can at first be confusing, because it includes "range"---a measurement that the technology does not provide. The answer to this conundrum is, as is so often the case, history. The "range" refers not to the radio equipment but to the space around it, the area in which the signal can be received. VOR is an inherently spatial technology; the signal is useless except as it relates to the physical world around it.

This use of the word "range" is about as old as instrument flying, dating back to the first radionavigation devices in the 1930s. We still use it today, in the somewhat abstract sense of an acronym that is rarely expanded: VOR.

This is Truth or Consequences VOR. Or, perhaps more accurately, the transmitter that defines the center of the Truth or Consequences VOR, which extends perhaps two hundred miles around this point. The range can be observed only by instruments, but it's there, a phase shift that varies like terrain.

The basic concept of VOR is reasonably simple: a signal is transmitted with two components, a 30Hz tone in amplitude modulation and a 30Hz in frequency modulation. The two tones are out of phase, by an amount that is determined by your position in the range, and more specifically by the radial from the VOR transmitter to your position. This apparent feat of magic, a radio signal that is different in different locations, is often described as "space modulation."

The first VOR transmitters achieved this effect the obvious way, by rapidly spinning a directional antenna in time with the electronically generated phase shift. Spinning anything quickly becomes a maintenance headache, and so VOR was quickly transitioned to solid-state techniques. Modern VOR transmitters are electronically rotated, by one of two techniques. They

Figure 2: Warning sign

rotate in the same sense as images on a screen, a set of discrete changes in a solid state system that produce the effect of rotation.

The Truth or Consequences VOR operates on 112.7 MHz, near the middle of the band assigned for this use. Patterned after the nearby Truth or Consequences Airport, KTCS, it identifies itself by transmitting "TCS" in Morse code. Modern charts give this identifier in dots and dashes, an affordance to the poor level of Morse literacy among contemporary pilots.

In the airspace, it defines the intersection of several airways. They all go generally north-south, unsurprising considering that the restricted airspace of White Sands Missile Range prevents nearly all flight to the east. Flights following the Rio Grande, most north-south traffic in this area, will pass directly overhead on their way to VOR transmitters at Socorro or Deming or El Paso, where complicated airspace leads to two such sites very nearby.

This is the function that VORs serve: for the most part, you fly to or from them. Because the radial from the VOR to you remains constant, they provide a reliable and easy to use indication that you are still on the right track. A warning sign, verbose by tradition, articulates the significance:

> This facility is used in FAA air traffic control. Loss of human life may result from service interruption. Any person who interferes with air traffic control or damages or trespasses on this property will be prosecuted under federal law.

The sign is backed up by a rustic wooden fence. Like most VOR transmitters, this one was built in the late 1950s or 1960s. The structure has seen only minimal changes since then, although the radio equipment has been improved and simplified.

The central, omnidirectional antenna of a VOR transmitter makes for a distinctive silhouette. You have likely noticed one before. I must admit that I have somewhat simplified; most of the volume of the central antenna housing is actually occupied by the TACAN antenna. Most VOR sites in the US are really VORTAC sites, combining the civilian VOR and military TACAN systems into one facility. TACAN has several minor advantages over VOR for military use, but one big advantage: it provides not only a radial but a distance. The same system used by TACAN for distance information, based on an unusual radio modulation technique called "squitter," can be used by civilian aircraft as well in the form of DME. VORTAC sites thus provide VOR, DME, and TACAN service.

Figure 3: Antennas

Figure 4: Central Antenna

True VOR sites, rare in the US but plentiful across the rest of the world, have smaller central antennas. If you are not used to observing the ring of radial antennas, you might not recognize them as the same system.

The radial antennas are placed in a circle some distance away, to open space between them. This reduces, but does not eliminate, the effect of each antenna's radiated power being absorbed by its neighbors. They are often on the roof of the equipment building, and may be surrounded by a metallic ground plane that extends still further. Most US VORTAC sites, originally built before modern RF technology, rely on careful positioning on suitable terrain rather than a ground plane.

Intriguingly, the radial antennas are not directional designs. In a modern VOR site, the radial antennas transmit an in-phase signal. The phase shift used for space modulation is created by rapidly changing the omnidirectional antenna in use. The space modulation is created not by rotating the antenna, but by moving the antenna through a circular path and allowing the Doppler effect to vary the apparent phase of the received signal.

The lower part of the central antenna, the more cone shaped part, is mostly empty. It encloses the structure that supports the cylindrical radome that houses the actual antenna elements. In newer installations it is often an exposed frame, but the original midcentury sites all

Figure 5: Monitor antennas

Figure 6: Rear of building

provide a conical enclosure. I suspect the circular metallic sheathing simplified calculation of the effective radiation pattern at the time.

An access door can be used to reach the interior to service the antennas; the rope holding this one closed is not standard equipment but is perhaps also not very unusual. These are old facilities. When this cone was installed, adjacent Interstate 25 wasn't an interstate yet.

Aviation engineers leave little to chance, and almost never leave a system without a spare. Ground-based infrastructure is no exception. Each VOR transmitter is continuously tested by a monitoring system. A pair of antennas mounted on a post near the fence line feed redundant monitoring systems that ensure the static antennas receive the correct radial. If failure or a bad fix are detected, it switches the transmit antennas over to a second, redundant set of radio equipment. The problem is reported to the FAA, and Tech Ops staff are dispatched to investigate the problem.

Occasionally, the telephone lines VOR stations use to report problems are, themselves, unreliable. When Tech Ops is unable to remotely monitor a VOR station, they issue a NOTAM that it should not be relied upon.

The rear of the building better shows its age. The wall is scarred where old electrical

Figure 7: Communications tower

service equipment has been removed; the weather-tight light fixture is a piece of incandescent history. It has probably been broken for longer than I have been alive.

A 1000 gallon propane tank to one side will supply the generator in the enclosure in case of a failure. Records of the Petroleum Storage Bureau of the New Mexico Environment Department show that an underground fuel tank was present at this site but has been removed. Propane is often selected for newer standby generator installations where an underground tank, no longer up to environmental safety standards, had to be removed.

It is indeed in its twilight years. The FAA has shut down about half of the VOR transmitters. TCS was spared this round, with all but one of the VOR transmitters in sparsely covered New Mexico. It is part of the "minimum operational network." It remains to be seen how long VOR's skeleton crew will carry on. A number of countries have now announced the end of VOR service. Another casualty to satellite PNT, joining LORAN wherever dead radio systems go.

The vastness and sparse population of southern New Mexico pose many challenges. One the FAA has long had to contend with is communications. Very near the Truth or Consequences VOR transmitter is an FAA microwave relay site. This tower is part of a chain that relays radar data from southern New Mexico to the air route traffic control center in Albuquerque.

When it was first built, the design of microwave communications equipment was much less advanced than it is today. Practical antennas were bulky and often pressurized for water tightness. Waveguides were expensive and cables were inefficient. To ease maintenance, shorten feedlines, and reduce tower loading, the actual antennas were installed on shelves near the bottom of the tower, pointing straight upwards. At the top of the tower, two passive reflectors acted like mirrors to redirect the signal into the distance. This "periscope" design was widely used by Western Union in the early days of microwave data networking.

Today, this system is partially retired, replaced by commercial fiber networks. This tower survives, maintained under contract by L3Harris. As the compound name suggests, half of this company used to Harris, a pioneer in microwave technology. The other half used to be L3, which split off from Lockheed Martin, which bought it when it was called Loral. Loral was a broad defense contractor, but had its history and focus in radar, another application of microwave RF engineering.

Two old radio sites, the remains of ambitious nationwide systems that helped create today's ubiquitous aviation. A town named after an old radio show. Some of the great achievements of

radio history are out there in Sierra County.