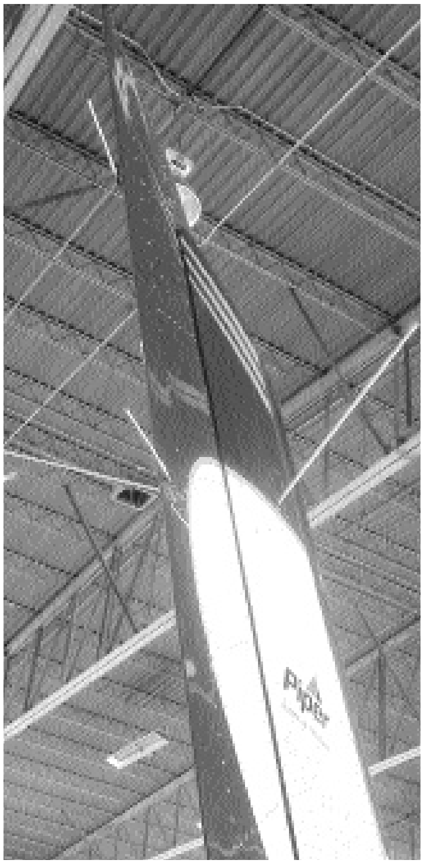
TROUBLESHOOTING

VHF NAV/ILS Problems

BY BRAD PRIMM



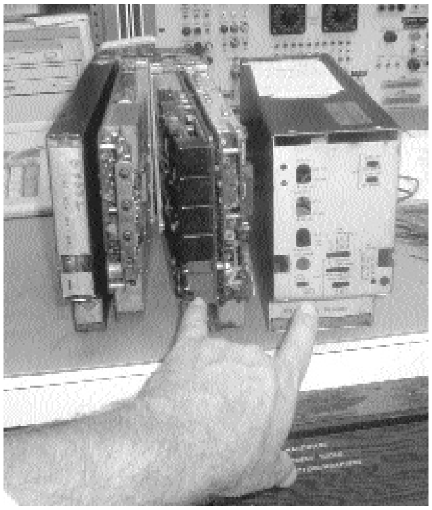
Nav dipole antenna, affectionately known as cat whiskers.

The VHF nav, or VOR (Very high frequency OmniRange), has been the mainstay of the en route navigation system in the United States since the 1950s with its development rooted in World War II. The VHF ILS (Instrument Landing System) was also pioneered in World War II and adopted in the United States during the 1950s. Obviously this was before my time and I have no direct knowledge of how someone could have thought of such a wonderful system.

The VHF nav has filled the needs of our national airspace system for many decades since and is projected to be the mainstay until the end of this decade. Yes, folks, the VHF navigation system we know and love will soon be history as GPS and other space-based technologies replace even the ILS. Call me old-fashioned, but I can't imagine avionics shops having no .5 volt RMS composite signal to check.

Until digital signals from outer space replace that composite signal, you will have to troubleshoot the VHF nav system found in virtually every IFR aircraft just like I have for the past 30 years. So where does one begin? Is it an instrumentation problem, reception problem, receiver problem, converter problem or a channeling problem? …or ground station problem? …or the interconnecting wiring? If it were easy, they wouldn't need you, would they?

Let's dissect the basic VHF nav or ILS system. The antenna is the same for both and is horizontally polarized. In almost all cases, the nav antenna will be on the vertical stabilizer and will either be the "V" or cat whisker type antenna at the top of the stabilizer or the balanced loop type with a horizontal blade or "towel bar" on either side of the stabilizer. If there is no stabilizer, the antenna will be on the belly in the rear or built into a "rams horn" antenna on top of the cabin. A balun transformer is used in the "V" antenna to match the dipole antenna elements up to the 50 ohm



The converter adjustments are conveniently located on the front of the 51RV2 ARINC nav receiver.

coax going forward to the nav receiver. In the case of a balanced loop type, a diplexer will be used to match the two antenna elements to the 50-ohm coax going forward. In some balanced loop antenna systems, the diplexer will have two outputs, one for each nav. This will allow each nav receiver to have a separate coax running forward from the tail to the input of each receiver. This gives greater independence to the nav systems and eliminates the possibility of one coax failure affecting both systems.

Why the two types? The "V" dipole antenna is simple, low cost and has a figure eight radiation pattern. As long as the aircraft is traveling to or from the station, the reception will be great. If the aircraft is perpendicular to the station, reception will be poor. Obviously, you do not want a cat whisker antenna hooked up to an RNAV. Also, if the aircraft is used for hard "IFR" where a radial cross check is needed, a "V" dipole is not the antenna of choice. Balanced loops are more expensive and have a more desirable circular antenna radiation pattern. Also, they are more resistant to ice buildup and can be made to withstand higher aircraft speeds.

Once the antenna receives the signal, it is sent on its merry way toward the nav receiver. Before it gets there, it will most likely be "split" into two signals and fed into each receiver. This splitter will be mounted near the receivers and may also provide one or two glide slope signals as well. Glide slopes are always collocated with VHF localizer stations and provide the vertical guidance on the precision approach. They utilize different receivers and their UHF channels are paired with the VHF localizer channels. The splitter will typically induce a 3-db loss into the signal by the time it reaches its respective receiver input. Without the splitter, the loss would be much greater because of an impedance mismatch, i.e. four unmatched 50-ohm receiver loads connected in parallel to one 50-ohm antenna output.

Now the signal has reached the receiver. The receiver tunes to the correct frequency and provides a composite signal to the converter circuits and a nav audio signal to the aircraft audio system. The pilot is required to use the audio signal to verify that he has tuned to the right facility for navigation. The composite signal is utilized by the nav converter to "convert" the information contained in the composite signal to needle, to-from, and flag information on the pilot's navigation display. In addition to the composite signal, the receiver sends an ILS energize discreet to the converter to switch the converter circuits from VOR mode to LOC mode. In ARINC nav systems, there will be an automatic converter that is utilized to drive RMI systems. The channeling scheme for VHF nav covers the 108.00 to 117.95 Mhz frequency spectrum in 50 Khz increments, providing 200 individual channels. Localizer channels are the odd tenths from 108.10 (including the .05 frequencies, i.e. 108.15) to 111.95 Mhz, providing 40 channels. The glide slope receiver is paired to these 40 channels. The VOR channels consist of the even tenths from 108.00 (including the .05 frequencies, i.e. 108.05) to 111.95 and all frequencies from 112.00 Mhz and above to 117.95 Mhz.

Make sure these controls are fully clockwise when using the NAV-401L

A remote glide slope

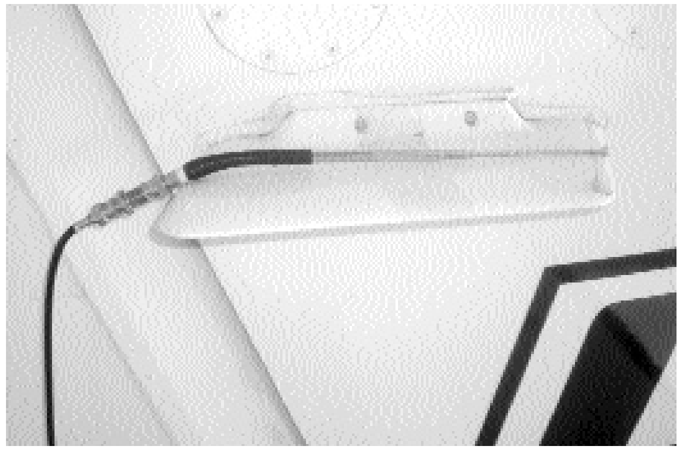
Once the signal is "converted," standard flag and needle voltages or currents are applied to the CDI or HSI. The pilot selects the VOR course he wishes to fly by utilizing an Omni Bearing Selector (OBS) in the display instrument. The output of the OBS is fed back to the converter for proper signal processing.

The typical flag current needed to pull the flag out of view is 220 micro amps. The typical current to deflect the needle to the edge of the display is 150 micro amps. The typical value of Left-Right meter resistance is 1,000 ohms. The typical flag meter is 1,000 ohms and the typical to-from meter is 250 ohms. It is OK to measure their resistance or stimulate these meters for troubleshooting using a digital multimeter on the 1K or higher scale. Lower scales will overdrive the meters.

Continued on following page

TROUBLESHOOTING VHF

Continued from page 57



Testing a nav blade antenna element.

Earlier designs of nav converters utilized high impedance outputs meaning that loading was extremely important. In order to provide installation flexibility, these designs were made to drive multiple loads. It was up to the installer to strap the system for the actual number of needle and flag loads utilized. Never assume that this has been done correctly when troubleshooting an older, high impedance design with needle or flag sensitivity problems. Newer converter designs utilizing low impedance op-amp outputs require no strapping.

Let's say a pilot pulls up to your shop in a puddle jumper and says, "My VOR doesn't work." Your response should be to pull out *AEA's Pilot's Avionics Troubleshooting Guide* and ask each question listed. Most pilots will respond with a glazed look and start stuttering. Just several of the questions need to be asked in order to get a good handle on the problem before walking out to the aircraft with test equipment.

First, ask if there was any indication on the CDI or HSI at all? On the *Pilot's Guide to Avionics Troubleshooting Guide* (downloadable from the AEA website at www.aea.net /Pilot), the question is phrased "Do the needles or flags move at all?" If the answer is no, the problem could be anywhere in the system. The correct follow-up question would be "Does it receive an ident?" This will effectively split the possibilities in half. If the answer is yes, most likely the system is good at the receiver output eliminating reception, antenna, channeling and receiver problems. This leaves the converter and display blocks as possible culprits.

If the answer is no, just the opposite applies. Let's assume the answer was "Yes, there was an ident." The next question to ask would be, "Is the Loran/GPS switched to the indicator?" In many nav/GPS switching systems, the ILS will override switch selection and display the localizer. When the pilot switches to a VOR with the GPS selected, his nav display will stop working or "freeze up" with unwanted GPS information. If the pilot is still insistent that something is wrong after this last question, then it is time to grab the trusty Nav-401L and do some first hand troubleshooting.

Before climbing into the cockpit, look at the nav antenna. Verify that both antenna elements are still on the aircraft. Once in the cockpit, turn on the Nav-401L and go to the crystal VOR frequency, usually 108.00 Mhz. With the telescoping antenna connected to the 401L output and the attenuator cranked up to maximum output (minimum attenuation), you should have no problem pulling the flags on both navs. If the problem is one of weak reception, i.e. poor range, tune both nav units to the 401L frequency and slowly decrease the attenuator output until the flags on the nav indicators come into view. If the split between the flag threshold of both nav systems is more than 10 db, you have a problem in the antenna system or in the sensitivity of one of the receivers. If the nav receivers are swappable, switch their positions and see if the weaker flag indication travels to the new position.

If you suspect an antenna or coax problem and the customer has blade antennas, do this trick. Take the antenna off of the NAV-401L output and tape it directly to the top of the blade antenna, parallel to the stabilizer and exactly one-half the distance from the blade base to the outside edge. Adjust the telescoping antenna so it is just as long as the blade. Perform a nav flag threshold check on No. 1 or No. 2 nav system. Jot down the result and then move the telescoping antenna to the other blade and repeat the set-up exactly. The flag threshold check for the other blade should yield the exact same result within 10 db. If the result is different by more than 10 db, something is wrong with the blades and they are unbalanced in their sensitivity. This test is very important if the customer is complaining of drifting needles on both navs.

On smaller aircraft with "V" antennas, look under the panel for the nav splitter and inject the 401L signal directly into the splitter output coax for each nav and compare flag thresholds. These results are almost as good as a bench check and if a split exists, you are looking at the actual receiver sensitivity plus the loss in the pigtail coax running from the receiver to the point of injection. If you identify either nav receiver as weak using any of the above methods, then a trip to the bench is in order for the offending box.

Sticky flag or needle problems will usually show up on a hot cockpit check. With external ground power applied to the aircraft, there is no engine vibration to shake sticky meters loose. In many cases you will discover a sticky meter even though the pilot has not complained of one. It is a judgment call on whether you should recommend replacement. Obviously it isn't going to get better and usually indicates the beginning of the end for said meter.

The VHF nav system is not known for stable needles but certain things can aggravate the situation. An unbalanced nav antenna is one (see above). Excessive precipitation static and/or poor bonding of control surfaces is another. Since the antenna is usually mounted on the vertical stabilizer, the bonding of the rudder control surface and/or the elevators is most crucial. Another contributor to unstable needles is the course sensitivity of the needle itself. This is an adjustment in the converter and obviously if the adjustment is too high, then any instability will be magnified. To measure the sensitivity in VOR mode, center the needle using the OBS with a strong signal radiated by the 401L. Using the thumbwheel bearing selection switches, move the needle over the last deflection dot on the display without disturbing the OBS setting on the instrument. Ideally the bearing selection should be exactly 10 degrees different from the starting point. Another contributor to "jumpy needles" is an incorrectly mounted splitter. I have seen many installations where the splitter is just tied up into a bundle, not mounted. If this is the case, it must not touch any metal surface or strapping otherwise the intermittent touching of the splitter case to the nearby, grounded metal surface or strap will cause jumpy needles.

The course sensitivity of the localizer needs to be checked as well even if the VOR is OK. These are two different adjustments in the converter. Since the OBS is inactive in LOC, check the centering of the needle using the 0 ddm selection on the Nav-401L and then the deflection sensitivity using .155 ddm. The needle should center itself over the last dot before hitting the meter stops. For glide slope, the needle should center over the last dot on the .175 ddm setting of the Nav-401L. When checking the LOC or glide slope, I always go to the pure 150 or 90 hertz settings. These should ALWAYS produce a flag. If not, the flag threshold of the converter must be readjusted on the bench.

The Nav-401Lis a great tool but has some peculiarities. Many junior technicians have come back into the shop and told me that neither VOR will work with the Nav-401L but appear to work on the local VOR station or VOT. I ask two things, "Is the master mod control in detent?" and "Are the variable mod controls for the 9960 and the 30 hertz fully clockwise?" These last two controls are easily bumped and have no detent. Another problem is that the Nav-401L standard crystal frequencies are 108.0 for VOR and 108.1 for LOC. These frequencies may be less than desirable if you have a local commercial FM station on any of the 107 MHz channels. We have local FM interference and our crystals have been changed to 112.8 Mhz for VOR and 110.5 Mhz for LOC. Next time you send in your 401L for calibration, request that the crystal frequencies be changed if you are experiencing these same interference problems.

Lastly, the Nav-401L design has been around since the late 1970s and is a power hungry beast. My experience has been that the NiCad batteries are good for about two years. There is nothing more frustrating than getting halfway through a hot cockpit check and having the batteries die. I recommend getting the batteries switched out every other annual calibration.

Accuracy problems for VOR or centering problems for LOC/GS are almost always fixed by adjustment of the converter. FAR 91.171 requires that the VOR equipment must have been operationally checked within the preceding 30 days if the aircraft is to be used for IFR flight. The FAR provides several methods of doing this. The first is checking against a VOT test signal maintained by the FAA. The second is the use of a VOR checkpoint, also maintained by the FAA. The third is a signal radiated by an authorized FAA repair station. In any case, the VOR error cannot exceed four degrees. If no checkpoint or test signal is available, the FAR allows the pilot to perform an airborne accuracy test and the allowable error is six degrees. A final method allowable by the regulation applies to dual VOR installations and allows the pilot to compare one system against the other when tuned to the same VOR ground facility. If the split is less than four degrees, he is good to go. If a repair station test signal is used to comply with FAR 91.171, then the repair station certificate holder must make the logbook entry and that entry must specify the bearing transmitted and the date of the transmission.

Hopefully, the basics didn't bore you experienced technicians too much and you have picked up a trick or two. If so, then this article has been a success. One last thing, please don't call a "glide slope" a "glide scope." There is no such thing. If a customer does it I won't correct them, but if a technician does it, I jump all over them. Until next time… ❑