Automatic Direction Finder

As simple to operate as an old AM radio

Back to Navigation

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Wouldn't it be great if there were an electronic aid to navigation that was as simple to operate as that old AM radio sitting on top of the fridge in the kitchen? And wouldn't it be even better if it could direct you to some places as easily as someone extending an arm and pointing in the desired direction?

Well, such a beauty exists, although it does have a few warts.

History and Theory of ADF

The airborne part of this system is generally referred to as the Automatic Direction Finder, or ADF—but that's only part of the story. The ground-based portion of the system is a simple AM transmitter that uses frequencies from 190 to 1,790 kilohertz (kHz).

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You probably recognize the frequencies from 540 to 1,710 kHz, which cover the commercial AM broadcast band where your favorite news, talk, or sports shows reside. The lower portion, below 535 kHz, is reserved for navigational aids called Non-Directional Beacons, or NDBs. They're non-directional since they broadcast the same signal equally in all directions, just like commercial broadcast stations. It's the ADF's job to figure out where the beacon or the broadcast station is.

Seems Like Old Times

The directional properties of a loop antenna were known at the time of World War I and were widely used by navies of that era. And, if you've ever looked at photos of 1930s-era airplanes, you may have noticed a loop about a foot or so in diameter mounted somewhere on the front of the airplane. You were looking at the ADF's ancestor, the Manual Direction Finder.

Out with the Old

Your Cessna Skyhawk SP Model 172 has this same antenna electronically reduced to a modest little bump on the belly of the aircraft, but the principal is the same.

To help you use them, NDBs are shown on your charts with a symbol that's often described as a circle and a dot with the measles around it. Note that just like the VOR, the NDB station is listed with its Morse code identifier, but for an NDB that could be one, two, or three letters.

Figure 1: McPherson airport has an NDB, shown by the dotted circle around the airport. A commercial broadcast station, KNGL, is also located near the airport.

Selected AM broadcast stations are depicted on aeronautical charts along with their call letters. Not every station is shown, only the more powerful ones—usually those that operate 24 hours.

AM transmitters are simple, relatively cheap and easy to maintain, and they still form a major part of the aerial navigation system in some areas of the world. Furthermore, they broadcast a signal that follows the earth's contours. Unlike the line-of-sight VOR, a powerful AM transmitter can often transmit a signal to the opposite side of a mountain range. That's the good news.

The bad news is that the signals in this band are subject to all sorts of bending and distortion, particularly in bad weather when you need them the most. Some older ADFs will cheerfully direct you to the ionized core of a thunderstorm without a hint of remorse.

So let's sample the hardware that organizes all these things, both good and bad.

Receiver Operation

Not surprisingly, you turn your ADF on with the switch labeled **OFF-VOL**. And, just like the VOR and comm radios, you see the active and standby frequencies.

By the way, the standby frequency will be replaced with a timing function if you press the button labeled **FLT/ET**—which stands for flight time and elapsed time. You can restore the standby frequency display by pressing the frequency—double arrow button in the middle.

Obviously then, the active—standby frequencies are transferred the same way as they are on nav/comm sets. Just press the button with the double-headed arrow, and they're transferred. Like the nav/comms, the ADF frequencies are set with the double knobs on the right. Pull the small knob out to set "1s," push it in to set "10s." The large knob sets "100s."

There are five buttons across the bottom of the faceplate. The two buttons on the right control the time. We've already talked about the center button, the "Frequency Transfer Button." Now let's skip the BFO button for a bit and move to the far left end of the row, where you'll find the ADF button.

The ADF actually has two functions combined in one antenna. One is used for direction finding and the other for regular AM radio reception. When the direction-finding antenna does its job, it's sometimes hard to hear the station identification signals—but if you push the button in to the **ANT** (antenna) position, you'll get a much clearer signal to confirm you station identification. To avoid confusion **ADF** or **ANT** appears just to the left of the active frequency on the panel, depending on the position of the button.

The other button we skipped is somewhat mysteriously labeled **BFO**. BFO stands for "beat frequency oscillator" and some transmitters require the use of this feature in order to hear the identification. Transmitters in the United States do not. However, if you hear an obnoxious noise when you're trying to listen for the NDB identifier, and the Automatic Direction Finder doesn't seem to find anything, let alone a direction, check the BFO button. It probably got bumped by mistake.

Pointing at the Station

Consider, if you will, the dial that looks like a cross between the VOR heads and the heading indicator. Don't leap to conclusions, though, because it doesn't quite work like either of them.

In the center, there's a plain view of an airplane and the concept is the same as the tiny airplane etched on the heading indicator.

The heart of the whole system is the long needle in the middle—its arrowhead points to the station. Better, it points the station out in relation to the tiny airplane at the center of the dial.

If you're not sure that the needle is serious about pointing to something or whether it just happens to be resting in a particular spot, press the **ADF** button. When **ANT** is displayed, the needle automatically parks it in the 3 o'clock/9 o'clock position. Press **ADF** again and, if the needle returns to its original position, it wasn't joking around. If it has a good signal, it will snap over there rather briskly.

Since the ADF doesn't have a visual indicator for a lost signal like the VOR does, the only way you can be sure it's staying on the job is to listen to it. But this isn't quite as annoying as it sounds. After checking the identifier, turn down the volume until you can just hear it. You'll barely be aware of the background sound, but if it stops abruptly, you'll quickly be aware of the change.

Ignore the numbers around the edge for the moment. If the needle points halfway between the nose and right wing of the tiny airplane, then you can just bet the station is out there halfway between the nose and right wing of the Skyhawk you're sitting in. You could think of it as someone in the passenger seat telling you where things are by extending an arm and pointing to them.

Homing: The Easiest Way to Get There

Since you're still with us at this point, you've probably mastered the basic principles of ADF. So now let's build on those concepts.

If you turned your Skyhawk until the nose was pointed the same way the helpful passenger pointed, you'd be heading toward the station. But if there were a crosswind (and when isn't there?), it would blow you away from the direct path to the station. If, however, the helpful passenger kept pointing to the station, and you kept turning little by little so that the station stayed straight ahead, you'd get there—eventually.

Well, if you substituted your ADF needle for the helpful passenger, you'd call that process homing to a station. It lacks elegance, and adds time to your trip, but it gets the job done.

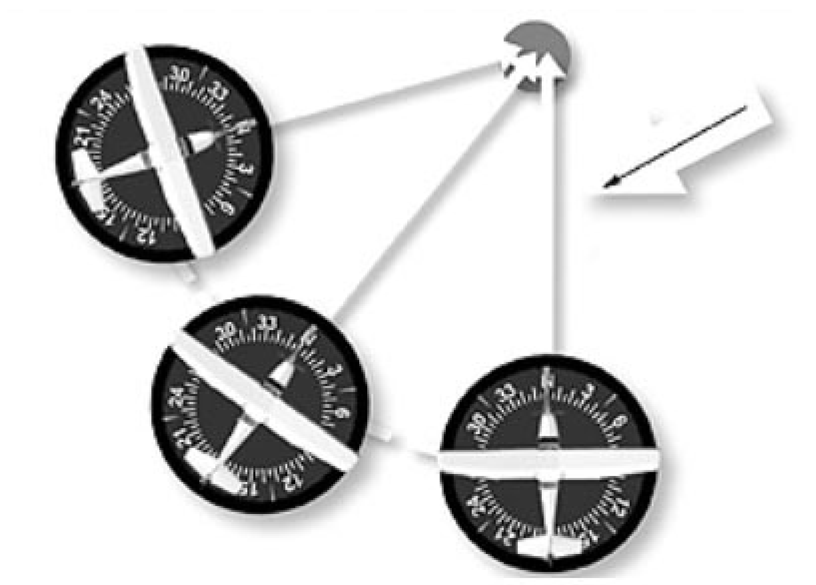

Figure 2: If you keep turning your aircraft to keep the ADF needle on the nose, you'll be "homing" toward the station. Not an elegant solution, but you'll get there.

That's the "no brainer" solution to ADF navigation. If you want to be more precise, then you'll have to give your pointer, whether it's the passenger or the ADF, a more precise way of describing direction than "head over there".

With that in mind, the solution is obvious. Let's borrow the dial we've been using for navigation and anchor **0º** or **360º** on the nose. The right wing, then, is 090, the tail 180, and the left wing 270. We call that a relative bearing system. Relative to what? Relative to the nose of the airplane. And here's an alternate and valuable definition for relative bearing: it's the number of degrees you'd have to turn to the right in order to point the nose of the airplane at the station. Of course that's awkward for things on the left side of the airplane—in practice you wouldn't really do it that way.

But if you always remember that relative bearing is the number of degrees you have to turn to the right in order to point the airplane at the station, you'll avoid all the messy negative numbers when you're working out ADF bearing problems.

More Definitions

Before we attack some of those problems, we need to drop a couple more definitions on you, and then we'll let it rest for a while.

Directions to and from NDBs are called bearings. They can be a bearing to—or an inbound bearing—and bearing from—or an outbound bearing—depending on whether you're going towards or away from the station. Quite simply, they are the courses you draw on your chart to or from the station.

For example, a line drawn directly eastward from the NDB is the bearing 090 degrees from the station, and if you were proceeding toward the station the same line is the bearing 270 degrees to the station. These terms could be expressed as either magnetic or true directions, but in practice, they are usually magnetic. We'll be using magnetic bearings.

Which Way Do We Go?

Suppose the ADF dial shows a 220-degree relative bearing and you've got the heading indicator nailed on 270 degrees magnetic. You might want to know the heading to get to the station—the magnetic bearing to the station.

Okay, you're headed 270 degrees and the relative bearing is the number of degrees you'd turn to the right of 270 degrees to point your Skyhawk directly at the station. If you turn to the right, the numbers get bigger. That boils down to this neat little equation: magnetic heading plus relative bearing equals magnetic bearing to the station.

Fitting action to the word, 270 degrees plus 220 degrees equals 490 degrees. Tilt! No way can you find that number on a compass. Panic not, friends. Instead, just subtract 360 degrees from 490 degrees and you'll find that the magnetic bearing to the station is 130 degrees.

"But isn't that cheating?" you ask. Heck no. If you made a 360-degree degree turn to the left, you'd end up headed exactly the same way, wouldn't you?

Remember the trick though: If you end up with a heading or bearing greater than 360 degrees, just subtract 360.

Another Heading Needed

The biggest blemish on the face of the ADF-NDB system is that compared to other systems, parts of it are not user friendly—you've gotta think.

But then, you wouldn't want to be roaming around up there in your Skyhawk if you weren't thinking, now would you? And with just the least bit of thinking, this little black box will show you how to get somewhere—and that sure beats being nowhere.

That being the case, let's see about having the ADF tell you when you are somewhere.

How to Know When You Cross a Magnetic Bearing

Suppose you're planning a cross-country flight. You've chosen a particular checkpoint along the course and you notice a commercial broadcast station is depicted on the chart several miles off to one side. "Ah ha!" you astutely cry. "I can use my ADF to help identify that checkpoint."

With the natural skill of a born navigator, you slap your Cessna plotter on the chart, lay in a line, apply variation, and swiftly deduce a magnetic direction from the checkpoint to the station of 010 degrees. By definition, you have just determined magnetic bearing to the station. Obviously, you would like to know when you are crossing that line. How to do that?

Easy! Just calculate what the relative bearing would be for that combination of magnetic heading and magnetic bearing to the station.

Let's say you're making good your course using a magnetic heading of 225 degrees and that you want to know when you'll cross the magnetic bearing 010 degrees to the station.

Just use your handy formula and solve it for relative bearing. That becomes magnetic bearing to minus magnetic heading equals relative bearing. Plug in the numbers and turn the crank, 010 degrees minus 225 degrees...uh, oh...we're headed for a negative. What will we do?

Figure 3: 010 degrees magnetic bearing to the station; 225 degrees on course magnetic heading. Relative bearing to the station shown on the ADF as 145 degrees when crossing 010 degrees magnetic bearing to the station.

No problem. Just add 360 to 010 and it becomes the larger number: 370. 370 minus 225 leaves 145. So when the ADF needle points to 145 degrees and your heading is exactly 225 degrees, you are crossing the 010 degrees magnetic bearing to the station.

What's The Heading?

All right, one final permutation. Suppose you want to intercept an inbound bearing of 270 degrees and you decide that a relative bearing of about 45 degrees will allow you to make the turn easily when you get to the intercept point. What heading should you fly?

Once more, tumble the equation around and you'll discover that magnetic bearing to minus relative bearing equals magnetic heading. That's 270 minus 45, so the magnetic heading you need is 225 degrees. You'd fly that as carefully as you could until you nearly had a relative bearing of 45 degrees and then you'd start your turn to 270 degrees.

With a situation like this, it's helpful to make a rough sketch of where you are and where you want to be. Then pick out a relative bearing.

I've Got a Secret

You've endured the challenge of using an ADF for navigation and survived the demanding requirement for thinking. So as a reward, we'll let you in on a secret feature of your Skyhawk's ADF. Well, maybe not really secret, but up until now, we haven't been in any rush to share it.

The Moveable Card

The reason some ADF dials have the cardinal compass points on them the way your Skyhawk's does is because the card is moveable.

If you were flying the Skyhawk, we'd have you turn the knob on your ADF card until your present heading was under the index. If you were to glance over at the center panel, you'd notice that your heading indicator and ADF dial form an identical pair.

What that tells you is that the ADF needle no longer shows relative bearing. It now shows the magnetic bearing to the station, and believe us, that will save some arithmetic. Not only that, but the blunt end of the needle shows the magnetic bearing from the station in case you are of a mind to plot your line of position.

Let's examine the possibilities. Suppose you know that you're somewhere inbound along the 220 degrees radial of a VOR, and you'd like to determine your position a tad more accurately than that.

Your ADF needle is pointing to the left, and when you match the moveable card with the heading indicator, 040 degrees, the ADF needle points to 300 degrees.

Figure 4: By setting the moveable card on the ADF to the aircraft heading, you can read your bearing to the selected NDB or AM station directly on the ADF without having to do the math.

By looking at the blunt end of the needle, you know that your MAGNETIC BEARING FROM the station is 120 degrees. You quickly sketch in a line about 120 degrees magnetic from the NDB, and where it crosses the VOR radial is your approximate position. Simple!

Inbound and Outbound

Let's set up a hypothetical scenario and say that you and another airplane both have had your transponders fail. Unlikely, but this is a what-if question.

So ATC is trying to sort you out using primary radar, and the controller says, "Which one of you is crossing the Mugwump NDB 025 degrees outbound bearing?"

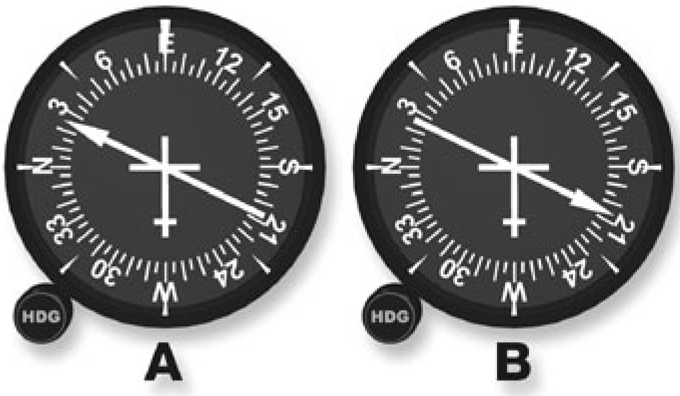

Figure 5: ADF "A" shows a position on the 025 degree bearing to a station. ADF "B" is on the 025 degree bearing from the station.

Your ADF looks like ADF "A" in Figure 5, and you're on an easterly heading. The other guy's ADF looks like the ADF "B" in Figure 5, and he's on an easterly heading too. Who's on the Mugwump NDB 025 degrees outbound bearing? If you could see the other guy's ADF, you'd know that the blunt end of his needle is on 025 degrees so he's crossing the 025-degree outbound bearing. You are crossing the Mugwump NDB 025-degree inbound bearing.

Tracking a Bearing

You can even use your ADF to fly a specific inbound bearing to the station, so long as you keep in mind the ever-present crosswind. You'd need to crab into the wind just as you would if you were following a course line you had drawn on your chart for dead reckoning.

For example, if you were tracking the 330-degree magnetic bearing to the station with a crosswind from the right, the needle would be on 330 degrees and you could think of it as representing the course line. The nose of the airplane on the dial face would be clearly to the right of course, slightly into the crosswind.

A word of warning, though: Information from the moveable card is only as good as the match between the setting of the moveable card and the heading indicator. Unless the moveable card exactly matches the heading indicator, the numbers on the moveable card are just that—numbers, without meaning.

And on the average, most pilots do a pretty good job if they can hold heading within plus or minus 2.5 degrees. That means a lot of fumbling with the moveable card setting or some careful reading when the heading is "passing through."

"Well, why don't they put the ADF needle on a dial that moves like the heading indicator?" you ask. Actually, such a thing exists. It's called a Radio Magnetic Indicator (RMI) and is considered the best thing that ever happened to ADF navigation.

But, an RMI installation is expensive and not cost effective for many smaller aircraft.

So that's it. You've seen the ADF with all its wrinkles, outwitted the most difficult things it could throw at you, had it lead you somewhere, and learned some of the tricks that will help you keep your thinking clear.

- top -