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WN-003

Web Note

QUESTIONS & ANSWERS: A USER'S GUIDE TO RADIO DIRECTION FINDING RECEIVERS AND BEARING PROCESSORS

This Web Note discusses the basics of DF receivers and bearing processors in easy-to-read Question & Answer format. It is especially intended for users who are new to the field, and specifically addresses frequently asked questions.

Rev B01/12-06/wn003_apl_01

Original Writing: December, 1998

About RDF Products Application Notes...

In keeping with RDF Products' business philosophy that the best customer is well informed, RDF Products publishes Application Notes from time to time in an effort to illuminate various aspects of DF technology, provide important insights how to interpret manufacturers' product specifications, and how to avoid "specsmanship" traps. In general, these Application Notes are written for the benefit of the more technical user.

RDF Products also publishes Web Notes, which are short papers covering topics of general interest to DF users. These Web Notes are written in an easy-to-read format for users more focused on the practical (rather than theoretical) aspects of radio direction finding technology. Where more technical discussion is required, it is presented in plain language with an absolute minimum of supporting mathematics. Web Notes and Application Notes are distributed on the RDF Products Publications CD and can also be conveniently downloaded from the RDF Products website at www.rdfproducts.com.

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Question: What does a DF receiving system do?

Answer: Fundamentally, a DF receiving system accepts the signal from the DF antenna, provides the standard signal processing features common to all receivers (input preselection, frequency conversion, IF filtering, demodulation, etc.), recovers the DF bearing information imbedded in the signal, processes this information, and then uses this processed information to compute and display the bearing. In a fully self-contained system, the DF receiver, DF bearing processor, and bearing display are both electrically and mechanically integrated into a single package. For more detailed information on this as well as other DF fundamentals, see RDF Products Web Notes WN-001 ("Questions & Answers: A User's Guide to DF Basics") and WN-002 ("Basics of the Watson-Watt DF Technique"). Both of these documents can be downloaded from our website.

Q: Is it necessary for all of these components to be integrated into a single package?

A: At one time, DF receiving systems were mostly 1-box packages. In recent years, however, there has been a growing trend to separate these components to varying degrees. A typical configuration employs a separate host receiver interfaced to a DF bearing processor having a built-in bearing display. In a growing number of installations, the DF bearing processor does not have this built-in bearing display, but instead interfaces to a computer which provides the display function.

Q: Why the separate receiver?

A: The most compelling reason is economy. The traditional self-contained DF receiving system required a specialized receiver that was very expensive to build due to low-volume production. This was especially true if the receiver was required to provide wide frequency coverage. During the 1980s, however, low-cost consumer-market communications receivers with wide frequency coverage began appearing. DF manufacturers eventually realized that a DF receiving system employing such receivers could result in a tremendous economy for the overall DF receiving system.

Q: Are these consumer-market receivers really good enough to be used as a key component of a professional-quality DF system?

A: The higher-end consumer-market receivers actually work very well and have been used quite successfully in a wide range of demanding DF applications. Although these do not match the performance of true electronics warfare surveillance receivers, they can be obtained at only a fraction of the cost. Even for high-end applications, most customers find the high-end consumer-market receivers to be quite cost-effective.

Q: Is there any reason that a low-cost consumer-market receiver cannot be mechanically integrated with the DF bearing processor and display to have a low-cost self-contained DF receiving system?

A: No, and some vendors do just that. There is a serious problem with this approach, however, that astute users should consider. In order for the overall DF receiving system to be compact, these vendors must select a consumer-market receiver that has likewise been specifically designed for compactness (i.e., a low-cost scanner receiver). This inevitably entails serious performance trade-offs, with the result that the selected receiver's performance is inadequate or marginal for the demanding requirements imposed by DF. The overall result is that the DF receiving system is not of professional-quality. Unless such compactness is the dominant requirement, it is better to employ a larger, better quality consumer-market receiver. With a larger receiver, it is usually less advantageous to mechanically integrate it with the rest of the DF receiving system.

Q: What are these performance trade-offs?

A: In comparison to true surveillance receivers, consumer-market receivers in general tend to have poorer signal-handling capability (the ability to receive weak signals in the presence of stronger off-frequency signals), worse adjacent channel rejection, and more birdies (internally generated spurious signals). For consumer-market receivers designed mainly for compactness (i.e., low-cost scanners), these problems tend to be much worse.

Q: Despite these scanner receiver shortcomings, I noticed that your DFR-1000B appears to employ such a receiver. Wouldn't this seem to be contrary to your recommendations?

A: That is a fair question that requires some elaboration. As you mention, the DFR-1000B employs a scanner receiver (the AOR AR8600 Mk2) that is electrically and mechanically integrated with our DFP-1000B DF Processor. There a number of factors driving the development of the DFR-1000B. First, we needed a replacement for our venerable DFR-1000A Dual-Band DF Receiver, which we finally had to discontinue as a result of unavailability of critical components. The DFR-1000B was therefore introduced for mobile DF applications where wide frequency coverage is necessary in a compact, self-contained, easy to install package. (The DFR-1000B is very similar in size to the earlier DFR-1000A with its companion DFS-1000 Frequency Synthesizer.)

Second, wide-coverage scanner receiver performance has greatly improved in recent years. In fact, the best of these scanners are now being referred to as "compact communications receivers". Although these units still do not match the performance of the larger high-end consumer-market communications receivers, they have greatly improved, and also have excellent sensitivity. We evaluated a number of compact scanners, and ultimately selected the AOR AR8600 Mk2. The Mk2 version of this receiver has major design improvements in its critical RF front-end that elevate its all-important RF performance to a level on a par with that of the high-end consumer-market receivers such as the AOR AR5000A and the ICOM R8500.

Third, all the IF signal processing, filtering, and demodulation is done in the DFP-1000B (which has a high-performance IF module.) This avoids the performance compromises inherent in the AR8600 Mk2 IF section.

Finally, we add modifications to the AR8600 Mk2 specifically intended to improve DF performance. The bottom line is that the DFR-1000B offers features and performance as good or better than that of the DFR-1000A/DFS-1000 it replaces with much wider frequency coverage in a similarly sized package.

Q: You mentioned that the DFR-1000B employs your DFP-1000B as its DF processor and display component. Is it possible to disconnect the AR8600 Mk2 from the DFP-1000B and employ an external receiver? We would like to use the DFR-1000B "as-is" for our mobile DF applications, but would also like to be able to substitute a higher-quality communications receiver for certain fixed-site applications where we don't have to worry about compactness. Can we do this?

A: Absolutely. The DFP-1000B employed in the DFR-1000B is completely unmodified and thus fully retains its capability to interface with external receivers. You would not even need to open the cabinet to do this. To even further facilitate this, the AR8600 Mk2 is configured so that it can be dismounted from the DFP-1000B in seconds.

Q: I noticed that only a very small number of DF equipment manufacturers make use of these consumer-market receivers. Why is that?

A: Most DF techniques do not easily lend themselves to the use of a receiver that has not been specifically designed for DF applications. The Watson-Watt DF technique employed by RDF Products, on the other hand, is far superior to other DF techniques when a general-purpose receiver must be employed as a component of a DF system. Furthermore, RDF Products has refined its implementation of the Watson-Watt DF technique to the point where almost any general-purpose receiver can be used.

Q: Are there any other drawbacks to using these consumer-market receivers?

A: The environmental specifications of consumer-market receivers tend not to be as good as those of true commercial-grade electronic equipment, with more restrictions on temperature and humidity. These receivers are best used in protected environments where they are not exposed to extremes of temperature and humidity. In most DF applications, however, this is not an unreasonable constraint.

Q: What DF bearing processors does RDF Products offer that will work with consumer-market receivers?

A: We supply two models. The DFP-1000B is a combination DF bearing processor and display unit that is designed to accommodate all DF applications, including those were computer-controlled operation is required. The DFP-1010B is functionally identical to the DFP-1000B but is designed exclusively for computer-controlled applications and therefore has no operational controls or indicators (and is somewhat lower in cost as a result).

Q: How do the DFP-1000B and DFP-1010B interface to the host receiver?

A: The DFP-1000B and DFP-1010B are designed to accept a 10.7 MHz IF output from the host receiver. Custom IF outputs are also available as options.

Q: Does RDF Products make any other DF receivers besides the DFR-1000B?

A: Yes. We also manufacture the DFR-1200B, which is similar to the DFR-1000B but employs the AOR AR5000A as the host receiver.

Q: What are the relevant advantages and disadvantages of these two DF receivers? I notice that their prices are very similar.

A: We hear this question quite frequently. The fundamental difference between these two systems is the quality of the host receiver (i.e., the AR5000A supplied with the DFR-1200B is a better receiver than the AR8600 Mk2 supplied with the DFR-1000B). Given that pricing is similar, we recommend the DFR-1200B in all applications where its larger size and heavier weight is acceptable since this system has a premium high-performance receiver. This would include all fixed-site DF applications and any mobile DF application that can comfortably handle the DFR-1200B footprint and bulk.

For mobile DF applications where there is a very high premium on compactness or light-weight, we recommend the DFR-1000B. Examples of such applications include installations in sub-compact vehicles and crowded aircraft cockpits.

Q: How can the pricing of these two systems be similar given that one uses a high-end communications receiver and the other a lower-cost scanner?

A: The AR8600 Mk2 scanner receiver used in the DFR-1000B requires expensive modifications that we have to install to make it truly “DF ready”. The AR5000A receiver used in the DFR-1200B, on the other hand, does not require any modifications.

Q: I noticed that RDF Products DF receivers and bearing processors are advertised as providing good “listen-through” capability. What does this means?

A: Listen-through capability refers to the ability of the DF receiver/bearing processor to simultaneously obtain bearings and monitor any audio modulation that might also be on the received signal. In many DF applications, this is important. As an example, if a DF system is being used to track a body-wire transmitter in an undercover drug sting operation, the law enforcement agents operating the DF system will want to be able to monitor the FM modulation on the body wire transmitter so that they will know when their undercover agent needs help. RDF Products DF systems are specifically designed to provide such listen-through capability, and are supplied with demodulators for FM, AM, and CW/SSB signals. In addition, the DFP-1000B is supplied with an internal speaker for maximum operator convenience. A line audio output jack is also

provided so that recorders or other audio monitoring devices can be conveniently connected.

Q: Do competing DF systems provide similar listen-through capability?

A: Most of them don't. Competitors' systems are mostly pseudo-Dopplers. These systems, unlike Watson-Watts, usually produce severe commutation noise that destroy listen-through capability. In fact, most of these systems require that system DF capability be disabled to permit audio monitoring.

Q: What is meant by "bearing integration time"?

A: DF bearing processors employ bearing integrators, which are actually noise filters that "smooth" (average) the bearings to reduce bearing jitter. These integrators also slow things down, thus limiting the ability of the bearing processor to respond to short-duration signals. It is therefore necessary that the DF bearing processor have user-selectable bearing integration times so that the integration time can be appropriately set.

Q: Do the DFP-1000B and DFP-1010B have selectable bearing integration times?

A: Yes. Selectable bearing integration times are provided from 35-400 milliseconds. For convenience of operation, these bearing integration times are selected concurrently with the reception mode. As an example, if the operator is monitoring a standard FM voice signal, he would select "FM/SLOW", which would select the FM demodulator and a 400 millisecond bearing integration time (suitable for FM voice signals). As an additional example, if the operator is monitoring a pulsed CW beacon, he would select "CW/MEDIUM" or "CW/FAST", depending upon the duration of the beacon pulse.

When operating the DFP-1000B/DFP-1010B remotely, bearing integration time can be software-extended up to 10 seconds (using our DefCon2b software program), although bearing integration times greater than one second are seldom useful in any practical application.

Q: You mentioned your software program DefCon2b. What does this do?

A: Defcon2b is our Windows-based user interface software package designed for remote operation of the DFP-1000B/DFP-1010B. It is actually a "virtual DF receiver", simultaneously controlling the DFP-1000B (or DFP-1010B) and the host receiver.

Q: Does DefCon2b require that the host computer have two serial ports to control both the DFP-1000B/DFP-1010B and the host receiver?

A: No - only a single computer serial port is required. For more detailed information on DefCon2b, you can download the operator's manual from our website.

Q: What is "Track & Hold"?

A: Track & Hold is a selectable feature included on both the DFP-1000B and DFP-1010B. When enabled, the displayed bearing is "frozen" for approximately 3 seconds or until updated by a new bearing. Track & Hold is used primarily when tracking a pulsed radio beacon transmitter, or in applications where the received signal appears infrequently and is of short duration. It is particularly useful under these circumstances when operators cannot continuously keep an eye on the bearing display and thus helps prevent bearings from being "lost".

Q: I noticed that the DFP-1000B has a feature called "Range Tone". What is this?

A: Range Tone is an audio relative ranging indicator that is useful in mobile DF applications. Normally, the DFP-1000B signal strength meter is used as the relative ranging indicator (i.e., a high S-meter reading warns operators that they are close to the transmitter). When Range Tone is enabled, a pulsed audio tone (i.e., a "beep" whose pitch is proportional to the received signal strength) is generated. Although this "beep" effectively audibly duplicates the relative ranging indication provided by the S-meter, the rising "beep" pitch more clearly and forcefully warns operators that caution is required on the final approach to the transmitter. Also, since operators very likely will be visually searching for the transmitter at this point, Range Tone relieves them from having to take their eyes off the road to look at the S-meter. Range Tone is particular effective when tracking radio beacons installed on vehicles.

Q: I noticed that your literature places a great deal of emphasis on the importance of the DF bearing display. Why is this such a major issue?

A: The highly dynamic nature of mobile DF applications is such that considerable judgement is often required to differentiate valid bearings from erroneous ones induced by noise and multi-path. Inexpensive bearing displays such as mechanical pointers and LED rings are extremely difficult to interpret under such conditions. Numeric bearing displays are almost useless. In contrast, the DFP-1000B employs a *real-time polar* bearing display that not only indicates the azimuth, but also indicates the *quality* of the bearing in a highly unified, intuitive format. To explain, bearings induced by noise and multi-path tend to be associated with *shorter* display vector lengths while valid bearings tend to be associated with *longer* display vector lengths. The real-time polar bearing display is thus an enormously powerful (and essential) tool for helping the operator deal with the demanding requirements of mobile DF.

Q: How is this accomplished with the DFP-1010B - it has no bearing display?

A: The DFP-1010B outputs bearings to the host computer in a format that contains both the necessary azimuth and magnitude information so that true polar bearings can be emulated on the host computer display using DefCon2b or other appropriate software. Since the DFP-1010B outputs these bearings at a rate of at 50 bearings/second, the computer-emulated polar bearing display has the same real-time appearance as the

TFT bearing display on the DFP-1000B. At 50 bearings/second, this computer-emulated display is faster than both standard motion pictures (shot at 24 frames/second), PAL-format TV (shot at 25 frames/second) and NTSC-format TV (shot at 30 frames/second).

Q: Do any of your competitors use real-time polar bearing displays?

A: To our knowledge, none of our competitors use real-time polar bearing displays. Of those few who did at one time, most are now out of business and those that remain have abandoned this display format in their current products.

Q: Why is that?

A: In many cases, they simply do not have sufficient experience in mobile DF to understand the enormous benefits of this display format. In other cases, they substitute non-polar azimuth ring displays on account of their lower cost (despite the severe performance trade-offs). In still other cases, their DF systems are not truly intended for operation in demanding mobile DF applications where the dynamic performance benefits of the real-time polar bearing display are necessary.

Q: I just want to make sure I fully understand something. I've noticed that even though some other vendors have advertised their DF systems as being "mobile", it is necessary to stop the vehicle in order to obtain good bearings. Are you saying that RDF Products DF systems can actually obtain good bearings even when the vehicle is in motion?

A: Absolutely. RDF Products DF systems were originally designed specifically to handle the demanding requirements imposed by mobile tracking of pulsed radio vehicle beacons in law enforcement applications where good bearings had to be obtained even if *both* the mobile DF vehicle and radio beacon were *simultaneously* in motion. This was the driving requirement not only for the real-time polar bearing display as previously discussed, but also for the enormous effort that was invested in all aspects of the equipment design to ensure that it met the dynamic performance requirements essential for mobile DF. Even though the scope of newer RDF Products DF equipment has been expanded to accommodate fixed-site DF applications as well, the dynamic performance requirements necessary for top-notch mobile DF operation have not been compromised.

Q: I noticed in a competitor's advertisement that a DF receiver sensitivity of 0.25 microvolts was claimed. Is this a good number?

A: A DF sensitivity specification of "0.25 microvolts" or "-120 dBm" is completely meaningless. For one thing, there are no qualifying attributes (i.e., the bearing integration time, IF bandwidth, and threshold bearing-to-noise ratio are not specified). Most importantly, however, the specification appears to be for the DF receiver only without regard for the intervening impact of the all-important DF antenna. A meaningful

DF sensitivity specification *must* be referenced in terms of the electric field strength in microvolts per meter of the signal illuminating the DF antenna as qualified by the above attributes. This issue is discussed in depth in RDF Products Application Note AN-004 ("Measuring Sensitivity of Mobile Adcock DF Antennas"). If a vendor specifies a DF system as having a DF sensitivity of "0.25 microvolts", the informed user should immediately suspect that either the vendor does not know how to measure DF sensitivity or the system is not of professional-quality.

Q: Is DF bearing accuracy also influenced mostly by the DF antenna?

A: Yes, this is almost always the case in a well-designed professional-quality DF system. To put some numbers on this, the specified bearing accuracy of most RDF Products DF antennas is 3° RMS versus 0.5° RMS for the DF receiver/bearing processor. Unless very careful DF antenna site calibration has been implemented, the 0.5° RMS error contribution of the DF receiver/bearing processor is unnoticeable. <>