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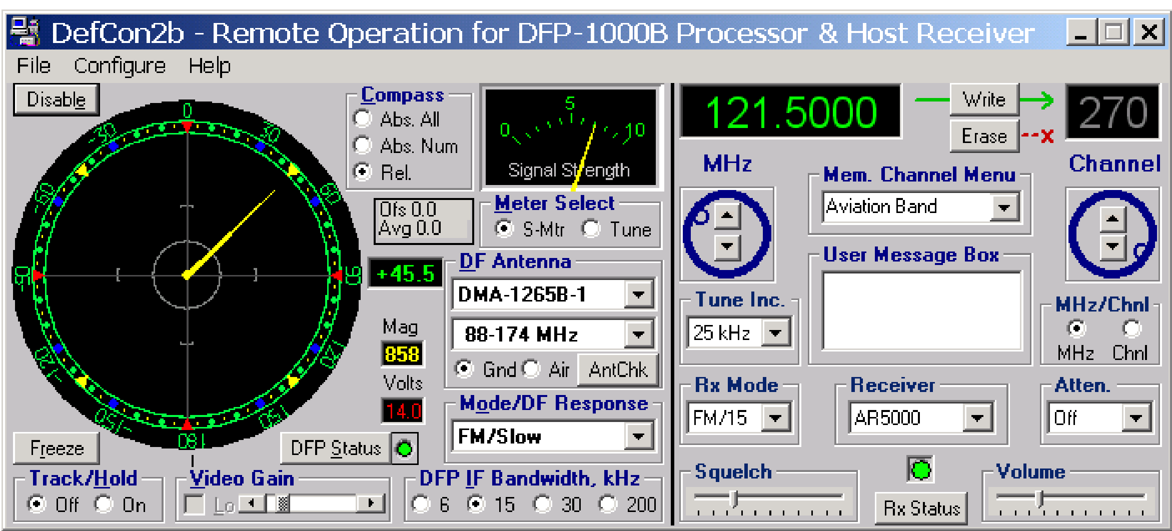
AN-001

Application Note

A USER'S GUIDE: HOW TO SHOP FOR A RADIO DIRECTION FINDING SYSTEM



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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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SECTION I - OVERVIEW

This Application Note addresses the various issues prospective users should consider when selecting and purchasing a radio direction finding system (and equally important, when selecting a radio direction finding system vendor). In large measure, this paper is based upon the many inquiries we receive from prospective customers, as well as on feedback from our existing customers.

Radio direction finding is an arcane technology that is a combination of science and art. Although DF technology offers many capabilities, it is also constrained by many limitations. It is therefore extremely important that the prospective buyer understand the issues and trade-offs so that informed purchasing decisions can be made. Although many of the issues associated with radio direction finding are highly technical in nature, most can be readily understood by a discerning and inquisitive user provided that the vendor is able and willing to present these issues in plain language.

Since procurement of a radio direction finding system is a major investment for most organizations, it is very important that the prospective customer embark on such a project advisedly and be armed with as much knowledge as possible. Prominent brand names alone do not guarantee that a particular radio direction finding system will be a good match for the prospective customer's requirements. It is equally true that weak performance can often be offset by strong salesmanship.

In the following Sections, we attempt to guide the prospective buyer through the DF system selection process to the extent possible in a brief paper. Where reference is made to other RDF Products publications (i.e., our Web Notes and Application Notes), we strongly urge the reader to obtain these documents (either from our website or Publications CD) as required for a more in-depth discussion of the topic at hand.

RDF Products also posts its major equipment Operator's Manuals on its website for convenient downloading. We strongly urge prospective buyers to download and carefully study these manuals to obtain the fullest understanding of equipment capabilities.

SECTION II - BUDGETARY CONSIDERATIONS

First and foremost, prospective buyers must establish their budgetary constraints, keeping in mind that with DF systems, as with most products, customers should expect to get what they pay for. Since radio direction finding products appeal to a somewhat narrow market niche, pricing tends to be high as a consequence of low-volume production.

The first issue that customers should confront is whether they want (and more importantly, are willing to pay for) a professional-quality DF system. Professional-quality DF systems are ones built to best commercial (as opposed to consumer) standards and characterized by the use of a proper DF technology, detailed specifications, precision, rugged hardware, and features appropriate for the intended application. RDF Products DF systems meet all these criteria, with pricing starting at approximately $12,000 (the low-end of the professional-quality pricing spectrum). At this pricing level, professional-quality DF equipment is usually out of the budgetary range of amateur radio operators, hobbyists, consumers, and most casual users.

Sub-professional-quality DF systems are available for such customers at much lower pricing. Typical of these systems are pseudo-Doppler designs with azimuth ring displays that require the user to provide a host receiver that must usually be modified for good performance. These systems also frequently require that the user construct the antenna array, or at least purchase an array of mobile whip antennas and accept responsibility for their uniformity and phase matching. These systems are furthermore prone to severe bearing errors if the host receiver is not precisely tuned to the received signal. System sensitivity is likely to be poor due to inherent limitations in the pseudo-Doppler DF technique. Furthermore, these systems all badly underperform in the face of multi-path signal reception in mobile DF applications due to the severe limitations of the non-polar bearing display format employed and due to poor hardware dynamics. Additionally, they have poor listen-through capability, in most cases requiring that the DF capability be disabled in order to monitor signal audio. Finally, most of these systems are unable to acquire bearings on short-duration signals. These are all serious performance limitations that must be accepted in sub-professional-quality DF systems. It is therefore important that users fully understand these compromises and carefully weigh this diminished performance against the lower pricing. See Web Note WN-004 ("A Comparison Of The Watson-Watt And Pseudo-Doppler DF Techniques") for a more detailed discussion of the shortcomings of the pseudo-Doppler DF technique.

At the extreme low-end of the sub-professional-quality spectrum, the DF systems are often non-automatic in that they require the DF antenna to be manually rotated to establish the bearing of the received signal. In other cases, such systems are nothing more than crude "right-left" indicators that are capable of resolving the bearing of a received signal only to the correct bi-quadrant. See Web Note WN-001 ("Questions & Answers: A User's Guide To Radio Direction Finding Basics") for additional information regarding sub-professional-quality DF systems.

Unfortunately, customers unfamiliar with these issues are often unable to resist the temptation to spend $4,000 instead of $12,000. Only later do they discover that the sub-professional-quality DF system is marginal or inadequate (especially for mobile DF applications) and that their purchase was "penny-wise and pound-foolish". In large measure then, the purpose of this paper is to advise customers of the advantages of professional-quality DF systems and how to identify these systems.

In cases where budgetary constraints dictate the purchase of a sub-professional-quality DF system, customers will have no choice but to accept their serious performance limitations. In fact, the best of the sub-professional-quality DF systems will work no better than one a technically skilled customer could build as a construction project found from time to time in the amateur radio magazines. (In fact, we are happy to offer specific recommendations regarding such articles for customers inclined to go this route.)

A good analogy to this professional-quality issue can be found in the electronic test equipment industry. A prospective customer in the market for professional-quality signal generators, network analyzers, spectrum analyzers, and other big-ticket test instruments, for example, would do best to first consider products manufactured by Hewlett-Packard, Tektronix, Rohde & Schwarz, Marconi, and other world-class vendors. Although such equipment is pricey, the fact that these companies are very successful and have been in business for so long is strong testament to the fact that professional-quality products are required for serious applications. While sub-professional electronic test equipment is available at much lower pricing, its performance, features, precision, and quality are usually inadequate for the demanding requirements of the electronics industry.

It is no less true that for serious DF applications such as search-and-rescue, law enforcement, signal intelligence, interference location, frequency management, and tactical military DF missions, users should carefully weigh the sub-professional-quality DF system's benefit of lower pricing against the detriment of increased risk to property and personnel that are likely to result as a consequence of using a marginal or inadequate DF system for critical DF missions affecting public safety, law enforcement, and national security. The various attributes of professional-quality DF systems are discussed in Section V.

Lest the reader think that the above claims are self-serving, RDF Products can support these claims with hard anecdotal evidence. In the early 1990s, the U.S. Government purchased a large quantity of RDF Products DFP-1000 DF Bearing Processors and DMA-1315 Mobile Adcock DF Antennas. A substantial number of these systems were transferred to a foreign government for tactical military use in a counter-insurgency application where they were used quite effectively. More recently, this foreign government wanted to purchase additional systems, but did not know how to contact RDF Products. As a result, it purchased a large quantity of less expensive sub-professional-quality pseudo-Doppler DF systems from a different vendor.

Unfortunately, these substitute systems failed to match the performance of their existing RDF Products DFP-1000/DMA-1315 radio direction finding systems and were not at all suitable for the demanding requirements of tactical military applications. After returning these systems to the vendor, this foreign government was subsequently able to find RDF Products on the Internet and has since ordered new systems. In addition, this foreign government has also contracted with RDF Products to provide maintenance and support for its older systems.

Here at RDF Products, we believe that the above anecdote is exceptionally strong testimony to the benefits of the performance and capabilities of professional-quality radio direction finding systems. We further hope that prospective customers will carefully consider this when attempting to determine the level of quality needed to match their performance requirements.

SECTION III - FUNDAMENTAL DF SYSTEM CONFIGURATIONS

A. DF SYSTEM COMPONENTS

The fundamental components of a DF system are illustrated in block diagrammatic form in Figure 1. Referring to that figure, a DF system fundamentally comprises a DF antenna, DF receiver, DF bearing processor, and DF bearing display. There are several different DF system configurations that are commonly employed, all with certain advantages and disadvantages. These system configurations are discussed in the following paragraphs. Also see Web Note WN-003 ("Questions & Answers: A User's Guide To DF Receivers And Bearing Processors") for additional information.

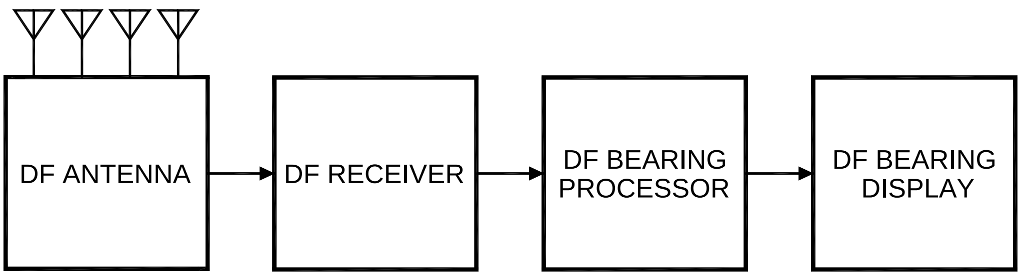

Figure 1 - DF System Functional Block Diagram

B. FULLY SELF-CONTAINED (HAND-HELD) DF SYSTEM

A fully self-contained DF system would be a hand-held unit with all DF components (including the DF antenna) contained in a single package. Hand-held DF systems are intended for mobile DF applications where the emitter location is inaccessible by vehicle and it becomes necessary for the DF operator to dismount and continue the mission on foot.

It is no exaggeration to state that the performance of hand-held DF systems ranges from very poor to useless. There are three primary reasons for this.

First, serious performance compromises must be accepted in the self-contained DF antenna in order to accommodate the extreme requirement for compactness. For example, it may be necessary to substitute poor-performing loops for Adcocks. Second, the close proximity of the operator to the DF antenna results in further diminished performance. Finally, mission requirements frequently require that hand-held units be deployed inside buildings or other structures where extreme multi-path conditions render DF technology ineffective. As often as not, the DF operator is ultimately forced to rely on the signal strength meter to find the emitter.

At the end of the day, most customers are inevitably dissatisfied with the performance of hand-held DF systems. Since the poor performance of such units is completely inconsistent with that of professional-quality products, RDF Products does not manufacture such systems.

C. SELF-CONTAINED DF RECEIVER/PROCESSOR/DISPLAY

A far more useful DF system configuration is the "traditional" one where the DF receiver is electrically and mechanically integrated with the DF bearing processor and bearing display and includes a separate DF antenna. A good example of such a unit is the early RDF Products Model DFR-1000A Dual-Band VHF/UHF DF Receiver (now discontinued in favor of the modernized DFR-1000B discussed below), illustrated in Figure 2.

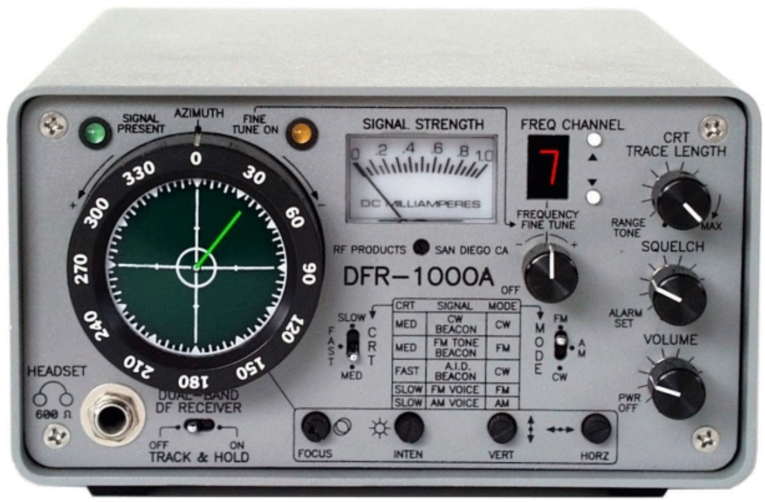

Figure 2 - **DFR-1000A VHF/UHF Dual-Band DF Receiver**

There are a number of advantages to this traditional configuration. In a well-designed unit, the receiver section can be optimized for best DF performance. (For truly professional-quality DF performance, certain attributes of the receiver design need to be optimized to accommodate the various subtleties and peculiarities associated with the selected DF technique). Since DF systems must often function in dense signal environments, the receiver can also be specifically designed for good adjacent-channel rejection and strong signal-handling capability (another characteristic of truly professional-quality DF systems). Finally, having the unit in a single, self-contained package allows for a compact, easy-to-operate system with a minimum of controls (especially important for mobile DF systems where space is at a premium, or in applications where the system must be operated by non-technical personnel). The DFR-1000A was particularly attractive in this regard due to its extreme compactness and simplicity of operation, and was an excellent choice for mobile DF applications where operating space was at a premium and for applications where the system had to be rapidly deployed.

While there was much to like about the DFR-1000A, certain features had to be traded-off in order to obtain its extreme compactness and simplicity. First, the receiver was crystal-controlled (although the companion DFS-1000 frequency synthesizer was available as an external top-mounted option). Second, its operating frequency range was restricted (typically 118-174/400-470 MHz). Finally, it offered only two IF bandwidths, was not capable of computer-controlled operation, and lacked a numeric bearing display. Although the DFR-1000A was the best DF receiver in its class for mobile DF tracking and homing, it lacked the wide frequency coverage and other features necessary for a full-featured general-purpose DF receiver capable of meeting the demands of a wide variety of DF applications.

Some vendors of self-contained DF receivers take the short-cut of purchasing an inexpensive compact consumer-market scanner receiver and then electrically and mechanically integrating it into their DF bearing processor/display unit. This expedient, however, compromises the professional-quality status of the overall DF system for two reasons. First, such scanner receivers have been optimized by their manufacturers primarily for compactness. As a result, serious performance compromises must be accepted with regard to the all-important receiver performance attributes of adjacent channel selectivity and strong signal-handling capability. Second, these scanner receivers are not designed to accommodate the various subtleties and peculiarities associated with DF, and therefore offer compromised performance.

Although there are often compelling reasons to employ a consumer-market receiver as a component of a DF system as discussed below, it is very important that the selected receiver be one that offers performance commensurate with a professional-quality DF system. While the high-end consumer-market receivers do offer professional-quality performance, such receivers are physically larger units that have been specifically designed primarily for good performance rather than compactness.

Given the importance of the receiver as a component of a DF system, DF systems that employ inexpensive compact scanner receivers (with their inherently compromised performance) cannot be considered as truly professional-quality systems. Vendors who employ such receivers as a component of their DF systems have done so to achieve wide frequency coverage in a compact package at the expense of diminished performance. Prospective buyers should avoid such systems unless these systems also have the uncompromised capability of working with external receivers of superior quality.

D. SEPARATE RECEIVER AND BEARING PROCESSOR/DISPLAY

In recent years, there has been an emerging trend by DF vendors to offer DF bearing processor/display units designed to work with existing communication and surveillance receivers. The dominant market force driving this trend has been the emergence in the past 20 years of modestly priced consumer-market receivers capable of covering very wide frequency ranges. These receivers evolved from amateur radio equipment (which for many years has had a reputation for very good quality and performance despite its low pricing), and first appeared on the market for HF coverage (up to 30 MHz). These wide-coverage HF receivers were soon followed by wide-coverage VHF/UHF versions, with units now available covering up to 3,000 MHz.

To digress for a moment, the major cost-driver of wide frequency coverage DF systems has traditionally been the receiver. With the low-volume production that is characteristic of the DF market, wide-frequency-coverage DF systems have been prohibitively expensive.

With the appearance of low-cost wide-frequency-coverage consumer-market receivers (which are relatively inexpensive due to high-volume production), however, a whole new DF system configuration paradigm has emerged whereby DF vendors supply *stand-alone DF bearing processor/display units that are specifically designed to add DF capability to low-cost consumer-market receivers*. By substituting the low-cost consumer market receiver for the high-cost DF vendor-built receiver, enormous DF system cost reductions have been achieved.

Even the best of these consumer-market receivers typically sell for under $3,000, and offer very wide frequency coverage (typically 0.1-3,000 MHz) with very good performance. To add DF capability to such receivers, customers purchase the DF bearing processor/display and a DF antenna suitable for the desired frequency range. If customers subsequently require additional frequency coverage, it is necessary only to purchase additional DF antennas. It is no exaggeration at all to say that the advent of stand-alone DF bearing processors and wide-frequency-coverage low-cost consumer-market receivers has resulted in a major cost breakthrough in DF system technology, allowing for professional-quality DF systems with unprecedented economy.

There are, however, some caveats. First, the stand-alone DF bearing processor concept is not compatible with all DF techniques (in fact, it works well with but a few). Second, the resulting DF system is not self-contained and is therefore less compact than the traditional self-contained DF receiver/bearing processor/display discussed above. (This is particularly true when a full-sized good-quality communication receiver is used rather than an inferior quality inexpensive compact scanner receiver.) Finally, the resulting system invariably has more operator controls (primarily as a result of the additional controls introduced by the external receiver), making the system somewhat more difficult to operate.

These disadvantages are most formidable when the DF system must be installed in a confined operating space (e.g., a compact car or small aircraft) and operated by non-technical personnel. In such cases, it is a distinct disadvantage to have two separate boxes with their associated interconnecting cables, and to have to deal with the large number of controls on the receiver.

For most other applications, however, these drawbacks impose no significant operational disadvantage. For land-mobile, airborne, and shipboard DF missions where there is sufficient space for a small work-station (e.g., on a small table set up in the back of a mini-van), most of the disadvantages of the 2-piece DF system evaporate. For such missions, it is not at all atypical for audio recorders, PCs, and other miscellaneous equipment to be present as part of the work station as well. In such an environment, then, it hardly matters that the DF system comprises two boxes rather than one.

Figure 3 - DFP-1000B DF Bearing Processor/Display

The RDF Products Model DFP-1000B DF Bearing Processor/Display is illustrated in Figure 3. Since the DFP-1000B is able to accept a 10.7MHz (or custom) IF or AM audio signal from the host receiver, it is capable of working with many communications or surveillance receivers without the need for receiver modifications. Best performance is usually achieved when the unit is driven by the low-level low-noise 10.7 MHz IF wideband signal monitor output from the host receiver. In this case, the host receiver serves strictly as a tuneable down-converter from the signal frequency to the 10.7 MHz IF output, with all the IF signal processing functions handled by the DFP-1000B IF interface module. This IF module is rather elaborate, being specifically designed to accommodate the various subtleties and peculiarities associated with the DF process. When the DFP-1000B is connected to a good-quality host receiver via its low-level low-noise 10.7 MHz signal monitor output, overall DF system performance is essentially the same as that obtainable with the more traditional self-contained DF receiver/bearing processor/display, but at far lower cost.

Although a wide variety of low- to moderately-priced communications receivers can be employed, we strongly recommend top-of-the-line units if consumer-market receivers are to be considered. As mentioned, the receiver is an extremely important component of the DF system, and it is therefore essential that the quality and performance of the receiver be commensurate with that of the other DF system components if the overall DF system is to be of professional-quality. RDF Products customers have reported exceptionally good results with the AOR model AR5000A receiver covering up to 3,000 MHz and the ICOM model R8500 receiver covering up to 2,000 MHz. In addition to wide frequency coverage, these units offer very good performance, are modestly priced, require no modifications, and can be computer-controlled via RS-232 link. At the risk of belaboring this issue, it is important that inexpensive compact scanner receivers be avoided for this essential component if truly professional-quality DF system performance is to be obtained.

Figure 4 - **DFP-1010B RS-232 DF Bearing Processor**

Another RDF Products DF bearing processor is illustrated in Figure 4. The Model DFP-1010B RS-232 DF Bearing Processor is functionally very similar in to the DFP-1000B. Its major difference is that it has no operational controls or indicators, instead being fully computer-operated via RS-232 data link. The DFP-1010B was designed as a "DF engine" exclusively for the growing number of applications where the DF system is computer-operated. It is particularly well-suited for unmanned remotely-operated DF sites, and is especially cost-effective for such applications since it does not need (and does not include) an expensive bearing display or other features required for manual operation.

The DFP-1010B is supplied with the Windows software package "DefCon2b" (DefCon2b's main screen is illustrated on the cover page of this Application Note). In addition, its RS-232 protocol is published (in the Operator's Manual) so that users can write their own custom software if they prefer. DefCon2b will also operate the DFP-1000B.

E. DFR-1000B DF PROCESSOR/RECEIVER COMBO SYSTEM

Although the DFR-1000A DF receiver was ultimately discontinued as discussed above, the requirement for a very compact, easy-to-operate, self-contained DF receiver did not suddenly vanish. (Even despite its shortcomings and creeping obsolescence, the DFR-1000A remained in the product line and continued to be supplied until the unavailability of critical components ultimately forced it to be taken out of production.) In fact, the real market paradigm that ultimately emerged was that users wanted this compactness and ease-of-operation *in addition to* wide frequency coverage and modern features.

The design of a modernized and full-featured replacement for the DFR-1000A required careful thought. On the one hand, we recognized that the goal of economically obtaining wide frequency coverage could be achieved only by using a wide-coverage consumer-market receive. On the other hand, we did not want to ignore our own admonitions against the use of an inexpensive compact scanner receiver (which would result in a sub-professional-quality system).

This dilemma was ultimately resolved with the introduction of the AOR AR8600 Mk2 receiver. Although descended from a long line of compact scanner receivers that were completely unsuitable for use as a DF host receiver, the AR8600 Mk2 was an all-new design that employed a well-engineered RF front-end designed specifically for strong signal handling capability and other qualities that overcame the most serious deficiencies of compact consumer-market scanner receivers.

In fact, the performance of the AR8600 Mk2 is such that AOR designates this unit as a “compact communications receiver”. Although one might view this as marketing semantics, the fact is that the AR8600 Mk2 is a premium compact scanner receiver with RF front-end performance commensurate with that of consumer-market communications receivers.

As illustrated in Figure 5, the “DFR-1000B” is an integrated combo unit comprising the DFP-1000B DF processor with the AR8600 Mk2. The AR8600 Mk2 functions only as a tuneable down-converter, providing a 10.7 MHz IF output for the DFP-1000B. This arrangement offers the following two important benefits:

Figure 5 - **DFR-1000B Wideband VHF/UHF DF Receiver**

1. All IF filtering, processing, and demodulation are accomplished in the DFP-1000B, where these functions have been optimized for best DF performance.

2. Since the AR8600 Mk2 functions only as a tuneable down-converter, the only relevant receiver controls are those that set frequency. (As the reader will recall from the discussion above, one of the operational disadvantages of using consumer-market receivers is they have too many controls and features, thus compromising ease-of-operation. By requiring the operator to use only those receiver controls related to frequency selection, this disadvantage is overcome in the DFR-1000B.)

The DFR-1000B has proven itself to be a worthy successor to the venerable DFR-1000A. In addition to being a full-featured professional-quality unit, it occupies a physical footprint only modestly large than that of the DFR-1000A with its companion DFS-1000 frequency synthesizer.

F. DFR-1200B DF PROCESSOR/RECEIVER COMBO SYSTEM

The DFR-1200B combo system (see Figure 6) is very similar in concept to the DFR-1000B except that it employs the AOR AR5000A communications receiver in place of the AR8600 Mk2. The AR5000A is a premium-quality consumer-market communications receiver offering top-of-the-line features and performance surpassed only by the most expensive electronics warfare surveillance receivers.

Although the DFR-1200B table-top footprint is no larger than that of the DFR-1000B, the overall package is taller and heavier. As a result, the DFR-1200B may be somewhat less favorable in certain applications were a very high premium is placed on compactness and light weight. We strongly recommend the DFR-1200B, however, for fixed-site and all mobile DF applications suitable for its size and weight.

Figure 6 - DFR-1200B Wideband HF/VHF/UHF DF Receiver

SECTION IV - MOBILE VERSUS FIXED-SITE

A. OVERVIEW

The ultimate objective of a radio direction finding mission is to locate the geographical position of the radio emitter in question. In mobile DF applications, the emitter is located by means of *homing*, using a compact DF system mounted on a land vehicle, aircraft, or boat. In fixed-site DF applications, the emitter is located by *triangulation*, using two or more stationary DF systems to generate lines-of-bearing that are ultimately presented on a map display (the point of intersection being the nominal location of the emitter).

It is also possible to combine mobile and fixed-site DF systems to good effect. In such an application, the fixed-site DF systems are first employed to locate the emitter to within some area of uncertainty. The mobile system is then dispatched to that area and then precisely locates the emitter by physically homing in on it.

The requirements for mobile and fixed-site DF systems are quite different, and it is very important that prospective DF system customers understand these differences and how these differences pertain to specific user requirements. These issues are discussed in the paragraphs that follow.

B. MOBILE DF SYSTEMS

1. Mobile DF Receiver/Processors

Mobile DF systems are typically mounted in cars, vans, or aircraft. Since space is often at a premium, compactness is usually important. For this reason, we usually recommend the DFR-1000B (Figure 5) or DFR-1200B (Figure 6) DF Receivers for such applications.

The DFR-1000B and DFR-1200B have been specifically designed for excellent strong-signal handling capability and adjacent channel selectivity so that they will work well in high signal density urban environments. This is in sharp contrast to the aforementioned DF systems employing inexpensive scanner receivers that generally perform poorly in such environments.

Due to the compactness of the DFR-1000B and DFR-1200B and the fact that they are self-contained, they are very easy to deploy and knock-down. This is an especially important feature in applications where the DF system cannot be permanently installed, or must be frequently moved from one vehicle to another.

2. Mobile DF Antennas

Mobile DF antennas are specially designed units intended to be mounted on metal vehicle tops or on the underside of an aircraft. A typical RDF Products mobile DF antenna (the DMA-1315B1) is illustrated in Figure 7, with a typical car-top installation illustrated in Figure 8. Since the individual elements of mobile DF antennas are monopoles, it is necessary that these antennas be mounted atop sizeable metallic ground-planes for proper operation. RDF Products offers a wide variety of mobile DF antennas covering various frequency bands in the 20-1,000 MHz range. These antennas have been specifically designed for the necessary signal handling capability to function well in high signal density urban environments. Since these units are rugged and fully weather-sealed, they can be permanently installed outdoors.

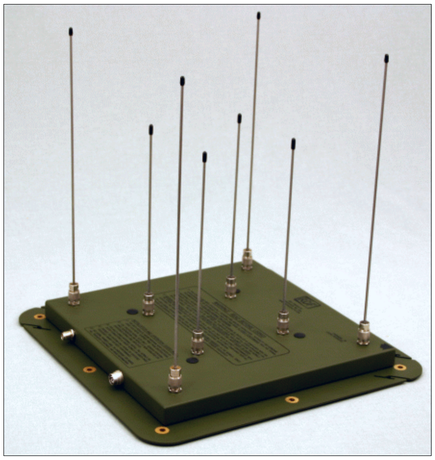

Figure 7 - DMA-1315B1 80-520 MHz Mobile Adcock DF Antenna

Figure 8 - Typical Mobile DF Installation

3. Homing Versus Triangulation

As mentioned, mobile radiolocation relies primarily upon homing as the means to find the emitter. This is an extremely important issue that requires some amplification, particularly in light of the fact that prospective customers often expect mobile DF systems to perform triangulation as well.

Homing offers the enormous advantage that large bearing errors can be tolerated without seriously degrading overall DF system effectiveness (at least if the DF system has an appropriate bearing display capable of providing the dynamic performance necessary for the demanding requirements of mobile DF operation). To illustrate this point, if the mobile DF system has a 20 degree bias error, as a hypothetical example, the operator would drive toward the emitter in an arc rather than a straight line, but would still find the emitter.

This tolerance of large bearing errors is very fortunate, since it is very difficult for mobile DF systems to provide good bearing accuracy. At first glance, this may seem inconsistent with RDF Products' mobile DF equipment bearing accuracy specifications, which are exceptionally good. This apparent inconsistency, however, is easily understood when the distinction is made between *instrument* accuracy and *site* accuracy.

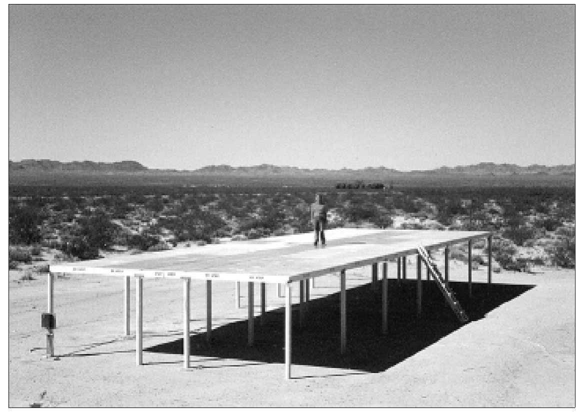

Figure 9 - RDF Products 20' x 60' Elevated DF Antenna Test Range

To explain, *instrument accuracy* is the accuracy of the DF system *as measured under ideal siting conditions*. Ideal (or, more accurately, *near-ideal*) siting conditions can be obtained only on a very elaborate and carefully-constructed antenna test range in an unobstructed area. The antenna test range constructed by RDF Products (located in the Arizona desert) is illustrated in Figure 9. This range comprises an elevated 20' x 60' platform covered with a fine wire mesh ground screen that has been carefully leveled. The range is elevated so that equipment and personnel can be placed underneath to avoid interference with the measurements. See Application Notes AN-003 ("Measuring Bearing Accuracy Of Mobile Adcock DF Antennas") and AN-004 ("Measuring Sensitivity Of Mobile Adcock DF Antennas") for additional information regarding the issues associated with constructing good antenna test ranges.

Of course, ideal siting conditions cannot be obtained for mobile DF applications. As a result, additional errors appear as a result of this non-ideal siting. There are two mechanisms by which this occurs. The first is that mobile DF antennas are placed atop vehicle roofs, which are small and non-symmetrical ground-planes. Such non-ideal ground-planes significantly degrade bearing accuracy.

The second mechanism is that of multi-path reception. Keeping in mind that a narrow-aperture DF antenna can be expected only to report the *apparent* angle-of-arrival of the incoming signal wavefront, a reflection (from a nearby building or utility pole, for example) that is received simultaneously with the direct (true) signal wavefront will distort that true wavefront. As a result, the DF antenna will report an apparent angle-of-arrival that can be significantly at variance with the true angle. This is an extremely serious issue when the DF system must be operated in areas where interfering objects are present (which is almost everywhere for mobile DF missions).

Consequently, even though the instrument accuracy of an RDF Products VHF mobile DF system is typically 1.5 degrees RMS, actual system accuracy under operational conditions can easily be an order of magnitude worse. Although the reader may wonder at this point how such a system could work at all, the redeeming factors that mitigate these errors are the inherently forgiving nature of DF homing (as discussed above), and operator judgment as aided by an appropriate DF bearing display (an extremely important issue that is discussed in more detail in subsequent paragraphs).

The inherent inaccuracy of mobile DF systems renders them largely ineffective when used for triangulation. As mentioned, DF triangulation establishes the location of the emitter to within some area of uncertainty. If the bearing errors of the DF stations are too large, this area of uncertainty similarly becomes too large to be useful in locating the emitter. For this reason, prospective customers should be wary of vendors' claims that their mobile DF systems are effective for triangulation.

Having stated this as the general rule, there are certain exceptions where operators can procedurally overcome (or at least mitigate) the bearing accuracy limitations of mobile DF systems. First, there may be circumstances under which the vehicle can be driven to a hilltop or other location that is relatively free from obstructions. By doing so, bearing errors caused by reflections can be greatly reduced.

Second, operators can take advantage of the fact that the best bearing accuracy for a mobile DF system is usually obtained when the vehicle is oriented so that the DF system reports a bearing near zero or 180 degrees (i.e., dead-ahead or directly behind). Where this procedural step can be taken, useful results can often be obtained with mobile triangulation.

Finally, effectiveness can be greatly increased by means of DF system proliferation. As the number of mobile DF sites increases (resulting in more bearing “cuts”), the DF triangulation area of uncertainty statistically diminishes. With a sufficiently large number of mobile DF sites, then, useful results can ultimately be obtained. This process can be greatly aided by appropriate data reduction techniques (ignoring atypical lines-of-bearing that are obviously incorrect, for example).

A corollary to improving effectiveness by proliferation is that if the target emitter is stationary and transmits frequently or for sufficiently long durations, even a small number of mobile DF stations can reduce the DF triangulation area of uncertainty by progressively taking bearing cuts at different locations. Aircraft are particularly good mobile platforms for this technique since they can rapidly change locations.

4. Bearing Displays

The importance of a good bearing display for mobile DF operation cannot be overemphasized. As the reader can ascertain from the previous paragraphs, the true test for a professional-quality mobile DF system is its ability to find the emitter in the face of severe signal reflections that are invariably present in any real-world operating environment. Unfortunately, uninformed prospective customers are usually unaware of the extreme importance of the bearing display and fail to factor this all-important issue into their evaluation of various DF systems.

As mentioned, operator judgment is necessary to overcome these reflection-induced bearing errors. Accordingly, a well-designed mobile DF system provides as much useful information as possible so that the operator can more easily exercise the necessary judgment. The bearing display is, by far, the most important source of this information. Unfortunately, few mobile DF systems provide a bearing display format that is suitable for the demanding requirements of mobile DF operation.

Most readers are probably familiar with the 3-digit numeric bearing displays that are used in many DF systems. Although numeric displays may look impressive and create an illusion of precision, they are almost totally ineffective for mobile DF applications. Prospective customers should not even consider a mobile DF system with a numeric bearing display unless it is augmented by an analog (or real-time emulated analog) display.

The most commonly-used analog display format is the azimuth ring. A typical azimuth ring display comprises 16 or more LEDs or LCDs arranged in a circular compass rose format, with the appropriate LED/LCD illuminating to indicate the bearing. The azimuth ring display is actually just a modern implementation of the old mechanical pointer bearing displays used in early 20th century DF systems.

Although azimuth rings are far more effective for mobile DF applications than numeric displays, they are marginal at best, providing the operator with very limited information with which to discriminate against noise and reflections. By far, the best bearing display for mobile DF operation is the real-time polar bearing display.

In contrast to the non-polar azimuth ring display, which provides *azimuthal* information only, the real-time polar bearing display provides both *azimuthal* and *magnitude* information as well in a highly unified, easy-to-interpret, user-friendly format (see Figures 2 and 3). The importance of this added magnitude information cannot be overemphasized. Fundamentally, it serves as a bearing *quality* indicator that can be effectively employed by the operator to discriminate valid bearings from noise and reflections.

To further amplify on this all-important point, reflections tend to be associated with bearings that produce a *shorter* vector length. Even inexperienced operators quickly learn to place best reliance on bearings producing *longer* vector lengths. The vector length is thus an extremely important criterion by which operators can exercise judgement to accept certain bearing indications and reject others. This is not possible with an azimuth ring display, where all bearings, regardless of quality, are equally prominent.

As another example, when the received signal is very weak and only intermittently detectable (a frequent occurrence in mobile DF), the polar bearing display is quite effective in discriminating valid bearings from noise. When the signal is detected, the operator can discern this as a result of the vector extending outward from the center of the display. When the signal is momentarily lost, the vector does not extend outward nearly as far, and the operator is therefore not fooled by spurious "noise bearings." In sharp contrast, valid signal and spurious noise bearings all look the same with an azimuth ring display, which makes it difficult for an operator to discriminate valid bearings from noise under such marginal receiving conditions.

A similar situation exists when the signal itself is inherently intermittent in nature (e.g., a pulsed radio beacon). Once again, the display vector becomes longer when the signal is present and falls back toward the center of the display when it is absent, thus allowing the operator to rely on bearings reported while the vector is long and ignoring those that occur when the vector is short. In sharp contrast, the azimuth ring display once again lacks this power of discrimination, reporting both legitimate and noise-induced bearings with equal prominence.

Note also that the vector length should not be confused with *signal strength.* To reiterate, the key point is that the vector length is primarily a *bearing quality* indication that is unavailable in inexpensive azimuth ring displays. Although a signal strength meter is also an important indicator for a mobile DF system, it does not aid in discriminating between valid bearings and reflections. (The primary purpose of the signal strength meter is to serve as a relative *ranging* indicator. The signal strength meter employed by RDF Products DF processors is driven by elaborate circuitry designed to provide a linear indication as a function of dB signal strength. This is in sharp contrast to most designs, in which signal strength indications are highly compressed for moderate to strong signals, thus greatly diminishing the usefulness of the signal strength meter as a relative ranging indicator.)

To meet the demanding requirements of mobile DF operation then, *there is simply no good* *substitute for a real-time polar bearing display.* A mobile DF system lacking this essential display format is not professional-quality, regardless of its price or brand name.

As mentioned, most mobile DF systems do not employ real-time polar bearing displays. There are three primary reasons for this. First, many DF vendors simply do not understand mobile DF well enough to be aware of the importance of the display format. Second, a real-time polar bearing display is an expense item that many vendors would prefer to avoid. Finally, a polar bearing display is not compatible with all DF techniques.

As a final note, it is important that the real-time polar bearing display have a response time sufficiently short to accommodate an update rate of at least 30 frames per second (i.e., as fast as NTSC television). In practice, this usually requires cathode ray tube (CRT) or TFT active-matrix LCD displays. Although slower STN or FSTN displays may appear presentable in a static DF environment, they are far too slow to provide the real-time polar bearing presentation required in the highly dynamic environment invariably encountered in mobile DF operation.

5. Listen-Through Capability

As mentioned, the inherently adverse nature of mobile DF is such that the operator is required to exercise judgment so as to be able to discriminate true bearings from reflections and noise. It is therefore necessary that the DF system provide as much useful information as possible to facilitate such judgment. Although the real-time polar bearing display is by far the best means available to accomplish this, another feature that can aid such judgment and thereby enhance mobile DF system performance is *simultaneous DF and listen-through capability*. What this means is that the DF system must be capable of allowing the operator to audibly monitor the received signal *without the need to disable DF operation*.

By being able to hear the signal, the operator gains another valuable input to help discriminate valid bearings from noise bearings under marginal receiving conditions. When the desired signal is very weak and accompanied by noise and interference, the polar bearing display vector length may not be adequate by itself to provide the operator with a sufficiently distinct indication. When the bearing display is observed in tandem with listening to the signal audio, however, the operator obtains the all-important added advantage of knowing *when* the signal is present and can mentally correlate this information with that received from the bearing display to good effect. This technique is particularly effective when tracking a pulsed radio beacon or any other signal that is intermittent in nature.

Listen-through capability is important in other respects as well. In many law enforcement and signal intelligence DF applications, voice modulation on the received signal should be clearly audible. In such cases, it is necessary that the signal processing technique employed by the DF system to facilitate the bearing acquisition process not disrupt the signal audio.

To amplify on this point, single-channel DF systems (i.e., those employing a single receiver) all employ some form of an encoding (i.e., modulation) technique in the DF antenna to facilitate the bearing acquisition process as discussed in Web Notes WN-002 ("Basics of the Watson-Watt DF Technique") and WN-004 ("A Comparison of the Watson-Watt And Pseudo-Doppler DF Techniques"). Since this process usually causes an audio tone to be impressed upon the incoming signal, serious disruption to the received signal audio often results. Pseudo-Doppler DF systems are particularly notorious for their "commutation noise," and most require that the DF capability be disabled to monitor signal audio.

RDF Products DF systems, in contrast, employ the Adcock/Watson-Watt DF technique. Although axis encoding tones are impressed upon the received signal in the DF antenna, the nature of RDF Products' embodiment of the single-channel Adcock/Watson-Watt DF technique provides very good listen-through capability for both AM and FM signals. As a result, it is not necessary to disable DF capability in order to monitor signal audio.

6. Aircraft Operation

Mobile DF systems can be mounted on aircraft as well as land vehicles. Airborne DF systems provide a number of important advantages over land-based units.

First, the tracking range of an airborne DF system is much greater as a result of the fact that the aircraft's height permits extended line-of-sight. Tracking range in excess of 50 miles is easily possible for well-designed airborne DF systems, even when tracking low-power emitters.

Second, the aircraft's height also raises it above towers, buildings, and other obstructions that can cause severe bearing errors for land-based mobile DF systems as a consequence of multi-path reception. This results in a substantial improvement in bearing accuracy.

Finally, the aircraft, with its excellent mobility, can search a large area in a short period of time. Aircraft DF systems are especially effective for search-and-rescue missions.

On the downside, aircraft can be difficult platforms for successful installation of the DF antenna. Best results are usually obtained using low-wing aircraft with retractable landing gears. In these cases, the best location for the DF antenna is usually on the aircraft underside between the wings. For best results, the underside of the aircraft should have as few protrusions as possible (nav/com antennas located near the DF antenna can cause significant bearing errors). From a procedural standpoint, best DF bearing accuracy is usually achieved by flying the aircraft level and directly toward the target emitter.

Figure 10 - VHF DF Antenna Mounted On Search-And-Rescue Helicopter

Helicopters are particularly troublesome for good DF antenna installations. Part of the difficulty is that helicopter undersides are often made of fiberglass rather than aluminum, resulting in a poor ground plane for the DF antenna. These undersides are also typically cluttered with skids, nav/com antennas, searchlights, loudspeakers, and various other protrusions that degrade DF antenna performance. In spite of this, successful operation is possible, particularly if the DF system employs a real-time polar bearing display to assist the operator in judging bearing quality.

C. FIXED-SITE DF SYSTEMS

1. General Considerations

The requirements for fixed-site DF systems are much different than those for mobile units. In most instances, fixed-site DF systems are employed to locate radio emitters by means of triangulation rather than homing, and are usually networked to one or more other fixed-site DF stations for this purpose. Unlike mobile DF systems in which bearing accuracy requirements can be greatly relaxed due to the inherent nature of mobile homing as discussed above, fixed-site DF stations require good bearing accuracy to locate the emitter to within a reasonably small area of uncertainty. This places much greater emphasis on good DF antenna siting. Since fixed-site DF systems must usually be networked for coordinated operation from a single master station, it is important that these systems be capable of remote operation. These and other issues are discussed in greater detail in the paragraphs that follow.

Figure 11 - DFA-1310B1 75-300 MHz Fixed-Site H-Dipole Adcock DF Antenna

2. Fixed-Site DF Antennas

Fixed-site DF antennas in the VHF/UHF range are nearly always mounted atop masts (which in turn are mounted atop high towers or buildings). Height is very important for fixed-site DF antennas to avoid bearing errors induced by reflections from local obstructions.

Rather than the ground-plane monopoles that are employed for vehicle-top mobile applications, fixed-site DF antennas usually employ arrays of vertical dipoles so that no ground-plane is necessary (which in turn allows the antenna to be mounted atop a tall mast). A typical RDF Products VHF/UHF fixed-site dipole Adcock DF antenna is illustrated in Figure 11.

Some vendors attempt to employ their mobile DF antennas in fixed-site DF applications by adding elevated ground-planes or horizontal radials. As discussed in detail in Application Note AN-005 ("An Introduction to Dipole Adcock Fixed-Site DF Antennas"), this is very bad practice that invariably leads to poor DF antenna performance. Vendors who resort to this inferior expedient do so only to avoid the effort and expense inherent in the development of a properly designed fixed-site DF antenna. Prospective buyers should always avoid mast-mounted DF antennas that are simply elevated adaptations of mobile DF antennas.

Another important issue associated with fixed-site DF antennas is that of the interaction between the DF antenna and its supporting mast. Since this mast is in the immediate proximity of the vertical dipoles, interaction results that can cause pattern distortion and poor performance. If this issue of mast interaction is not properly addressed in the antenna design, frequency "holes" (frequency bands where performance is erratic) will result. Furthermore, the frequency bands where these holes occur will change with mast height. In general, DF antenna performance will tend to be mast dependent. Unfortunately, non-technical users may not recognize such performance anomalies, attributing any irregular performance to the vagaries of DF in general. This issue is also addressed in detail in Application Note AN-005.

RDF Products has addressed this issue in all of its dipole Adcock DF antenna designs by supplying a special isolation mast that is specifically designed to decouple the DF antenna from the supporting tower or mast. The inclusion of this iso-mast avoids these afore-mentioned anomalous effects and guarantees that dipole Adcock performance is independent of the height of the supporting tower or mast with no frequency holes.

Surprisingly, most vendors ignore this problem, either due to lack of understanding or the desire to avoid the effort and expense of designing the necessary isolation mast. Prospective buyers should question vendors closely on this point, and should be very suspicious if vendors seem to be unaware of the problem, offer some glib explanation as to why an isolation mast is not really necessary, or claim that the problem is not real.

3. Fixed-Site DF Receivers/Processors

Since space is not ordinarily at a premium for fixed-site DF systems, performance need not be traded off for compactness. This is fortunate from the standpoint that fixed-site DF systems require high levels of performance, particularly with regard to their ability to operate in high signal density environments.

It is especially important that fixed-site DF systems employ good quality receivers. If a consumer-market receiver is to be used, it should be a top-of-the-line model with good signal handling capability and adjacent channel rejection such as the AOR AR5000A or ICOM R8500. It should definitely *not* be one of the inexpensive compact scanner receivers that trades off performance for compactness.

In most instances, it will be necessary that both the receiver and DF bearing processor have the ability to be remotely operated via RS-232 or other format. In typical fixed-site DF networks, most of the sites are unmanned, with operation controlled and coordinated by the master site where the information from the various sites is processed and appropriately displayed.

The RDF Products Model DFP-1010B RS-232 DF Bearing Processor (see Figure 4) is especially well-suited for fixed-site DF applications, both for the master and remote sites. The DFP-1010B was designed as a "DF engine" exclusively for the growing number of applications where the DF system is computer-operated. It is particularly well-suited for unmanned remotely-operated DF sites, and is especially cost-effective for such applications since it does not need (and does not have) an expensive bearing display or other features required for manual operation. Since the DFP-1010B outputs 50 bearings per second, real-time computer emulations of polar bearing displays can be constructed in software (as is done in RDF Products' DefCon2b Windows user interface program).

4. Site Calibration

Site calibration is a means by which bearing accuracy of a fixed-site DF antenna can be improved by carefully positioning a test transmitter at various known azimuths around the DF antenna, recording the actual measured bearings, and then constructing a calibration "look-up" table that can be used to correct subsequent bearing readings. For a DF system employing a computer interface, this look-up table would normally be constructed in software and would employ automatic interpolation to allow corrections to be applied to bearing readings between calibration points. Site calibration is seldom useful for mobile DF systems.

Although site calibration can be a useful tool, it is subject to certain limitations. Some of the issues associated with site calibration are as follows:

Multi-Path Limitations - Site calibration is totally ineffective as a means of reducing bearing errors caused by multi-path reception (i.e., reflections). Generally speaking, a reflection has the effect of altering the apparent angle-of-arrival of the incoming wavefront, and the very best we can ask of a narrow-aperture DF antenna is to correctly report this *apparent* angle-of-arrival. The reason for this is that the amount of bearing error caused by a reflection is dependent not only upon the *magnitude* of the reflected ray, but also upon its *phase* relationship to the direct ray. Depending upon this phase relationship, the bearing error induced by a reflection can be either positive or negative (or even zero). Since there is no *a priori* knowledge of this phase relationship in the general case, site calibration cannot offset the error. A corollary to this point is that site calibration in general is ineffective if the DF site is poor and most of the bearing errors are caused by multi-path. When considering site calibration, then, always keep in mind the all-important point that only DF system *instrument error* can be reduced, and that site calibration is ineffective in reducing *site error.*

Number Of Calibration Azimuths - In general, a large number of calibration azimuths are necessary to construct an effective calibration look-up table, particularly if linear interpolation is employed to estimate and correct for errors between the calibration azimuths. Non-linear interpolation (if skillfully implemented) is somewhat more forgiving in this regard and in general demands fewer calibration azimuths for the same corrected bearing accuracy. Typical site calibrations are conducted using 36 calibration points (i.e., at 10E azimuth increments).

Frequency Dependency - A site calibration is theoretically valid only at the frequency at which it was conducted. It is therefore necessary to repeat the calibration procedure at a number of different frequencies throughout the antenna frequency range. Once again, interpolation can be used to compute corrections for intermediate frequencies.

Elevation Angle Dependency - A site calibration is theoretically valid only at the elevation angle at which it was conducted. In practice, however, since most signals intercepted by fixed-site DF antennas are received at or near 0E elevation angle, site calibrations are similarly performed at or near 0E elevation angle. Another mitigating factor is that DF antenna bearing accuracy does not change much over a modest range of elevation angles centered around 0E.

Distance Between DF Antenna And Test Transmitter - For best results, the test transmitter should be located close to the DF antenna since this increases the magnitude of the desired direct ray in relationship to any reflected rays (thus minimizing any bearing errors due to multi-path reception). The test transmitter should not, however, be closer than a wavelength or so at the lowest test frequency.

Error Contribution Of Other DF Components - Although the DF antenna is usually the dominant DF system component with regard to bearing errors, the error contribution of the DF receiver/bearing processor may not be negligible (especially after a well-implemented site calibration). It is therefore good practice to first measure and record the bearing accuracy of the DF receiver/bearing processor so that these errors can be appropriately excised from the measured composite system bearing errors to determine the error contribution of the DF antenna alone. Using this procedure, the calibration look-up table constructed for the DF antenna is still valid if a different DF receiver/bearing processor is later substituted. Of course, the bearing accuracy of the new DF receiver/bearing processor will have to be measured and the calibration look-up table appropriately modified to accommodate these errors.

Site calibration is a very tedious and time-consuming undertaking that requires considerable technical resources as well as great care and patience to implement. In practice, very few users actually attempt it, so it is best that the DF antenna have good inherent bearing accuracy. For this reason, any attempt by DF vendors to excuse the poor bearing accuracy of their DF antennas by claiming improvements can be made via site calibration should be viewed with extreme skepticism.

5. Coordination With Mobile DF Units

As mentioned, the ultimate objective of most fixed-site DF systems is to geographically locate a target radio emitter by means of DF triangulation so that this emitter can ultimately be found. The scenarios associated with such a requirement can be quite varied. In some cases, the objective may be to locate the source of interference to a phone cell or public safety frequency. In others, the objective may be to locate a homing beacon in a stolen vehicle. In other cases still, the requirement may be to locate a distress signal so that a search-and-rescue operation can be launched, or even to coordinate artillery fire on an enemy position. Regardless of the scenario, the desired end result is that the emitter be located with sufficient accuracy so that it can be visually identified and appropriate follow-up action can be taken.

In the general case, however, radio direction finding technology does not offer the precision necessary to accomplish this without supplementary action to refine the emitter location. Interestingly, many prospective users labor under the misconception that fixed-site DF systems can triangulate a target transmitter with “James Bond-style” pin-point accuracy. Regrettably, James Bond-style DF systems exist only in the movies. Real-world DF systems locate the target emitter to within an area of uncertainty that is usually too large to directly ascertain its precise location.

The most direct method to reduce this area of uncertainty is to employ additional DF sites. As the number of DF sites increases (resulting in more bearing “cuts”), the DF triangulation area of uncertainty statistically diminishes. This process can be greatly aided by appropriate data reduction techniques (ignoring atypical lines-of-bearing that are obviously incorrect, for example). Of course, since DF sites are expensive, there is a practical limit as to the number of sites that can be employed. Even with a large number of DF sites and skillful processing, however, the area of uncertainty, though diminished, is still likely to be too large.

By far, the most effective supplementary action, where applicable, is to send a mobile DF unit into the area of uncertainty to locate the target emitter by mobile homing. Once the mobile unit is deployed to the area and acquires the signal, it can almost always find it (assuming the mobile DF unit is well designed). This arrangement is exceptionally effective in playing to the strengths and overcoming the weaknesses of both DF techniques.

To illustrate this symbiosis by example, assume that a DF system is to be deployed that is intended to locate radio distress signals from small boats. When the distress signal is heard, shore-based fixed-site DF units are first employed to triangulate the distress signal and locate it to within some area of uncertainty. Since the fixed-site DF antennas are mounted atop high towers along the coast, their long reception range and high bearing accuracy are used to great advantage.

Once the distress signal area of uncertainty has been established, a rescue vessel with a mobile DF system is then deployed to that area. Initially, the mobile DF system is unlikely to be able hear the signal (since its DF antenna lacks the height of the shore-based fixed-site DF antennas atop the high towers). As the rescue vessel approaches the area, however, it soon acquires the signal. Once that occurs, the rescue vessel can easily home in on it.

In sharp contrast, if the rescue vessel lacks such mobile DF capability, it must consume valuable time running search patterns until visual siting is finally established. Clearly, the ability of the DF-equipped rescue vessel to work in conjunction with the fixed-site DF station is an enormous advantage.

SECTION V - ATTRIBUTES OF PROFESSIONAL-QUALITY DF SYSTEMS

A. OVERVIEW

In Section II (Budgetary Considerations), certain attributes of sub-professional-quality DF systems were discussed. Unfortunately, it is not always apparent to uninformed prospective customers how to distinguish professional- from sub-professional-quality DF systems. (This problem is especially magnified in this age of Internet marketing where anyone with a personal computer and an Internet connection can publish a flashy website.) Similarly, serious system performance deficiencies can often be camouflaged with glitzy interface software. Since it is important that the prospective customer be able to separate the "steak" from the "sizzle," this Section has been written to provide guidance to aid in distinguishing professional- from sub-professional-quality DF systems.

B. DF TECHNIQUE

Most sub-professional-quality DF systems employ the pseudo-Doppler DF technique, despite the fact that this technique is poorly-matched in most cases to the performance requirements of compact, narrow-aperture DF systems intended for mobile and many fixed-site DF applications. As discussed in an early paper on this subject written in 1947 as per reference (12), the primary advantage of the pseudo-Doppler DF technique is its ability to reduce bearing errors induced by multi-path reception when implemented in its *wide-aperture* embodiment. As also discussed in Web Note WN-004 ("Comparison Of The Watson-Watt And Pseudo-Doppler DF Techniques"), the applications for which pseudo-Doppler DF systems are best suited are fixed-site DF requirements where multi-path rejection is the driving requirement. Such DF systems can be identified by their wide-aperture antenna arrays containing eight or more aerials.

Narrow-aperture pseudo-Doppler DF systems (those whose antenna arrays employ four aerials), in contrast, do not have any significant ability to reduce bearing errors induced by multi-path reception. Despite this reality, most pseudo-Doppler DF systems employ narrow-aperture designs, even though use of the pseudo-Doppler DF technique seriously compromises performance in comparison to Adcock/Watson-Watt DF systems with regard to sensitivity, bearing accuracy, listen-through capability, and adaptability to low-cost consumer market receivers, as discussed in WN-004.

Although this may seem to be a paradox, it is readily explained by the fact that a pseudo-Doppler DF antenna is very easy to design and build in comparison to the far more subtle and complicated Adcock DF antenna. In fact, there have even been a number of pseudo-Doppler DF system construction articles in the amateur radio magazines in recent years, which is very strong evidence that only a modest degree of technical skill and understanding is required to successfully design and construct such a system. (We hope this latter statement does not offend amateur radio operators, whom we have always greatly admired for their enthusiasm, energy, and creativity that has generated over the years a body of collective wisdom that open-minded engineers should never ignore.)

A prospective customer can therefore reasonably conclude that the driving force compelling vendors to design and manufacture narrow-aperture pseudo-Doppler DF systems is either cost or a limited understanding of DF technology. In either case, the customer should strongly suspect that such systems are of sub-professional-quality. The prospective customer should also be aware that all of the available low-priced pseudo-Doppler DF systems badly underperform in mobile DF applications as a result of their inability to effectively deal with multi-path reception (reflections) and short-duration signals.

C. PRODUCT DATA SHEETS

The qualities and features of professional-quality DF systems are communicated to customers via professionally-written product data sheets with detailed specifications. Poorly-written or incomplete product data sheets, on the other hand, are strong indications of sub-professional-quality. Radio direction finders are complicated instruments that require more than just perfunctory product data sheets to adequately inform customers of their capabilities.

Similarly, if the product data sheet lists meaningless specifications, or ones without the necessary qualifying factors, this is also a serious red flag. As an example from WN-006 ("Questions & Answers: A User's Guide to Radio Direction Finding System Sensitivity"), a DF sensitivity specification of "1.0 microvolt" or "-110 dBm" is completely meaningless.

The informed prospective customer, upon seeing such product data sheets, should immediately suspect that the vendor is either trying to conceal poor product specifications or lacks the technical means and understanding to conduct the necessary measurements. In either case, the prospective customer should strongly suspect that the DF system in question is sub-professional-quality.

D. AVAILABILITY OF APPLICATIONS LITERATURE

Vendors of professional-quality DF equipment should be expected to publish an extensive library of applications literature covering topics of interest to both technical and non-technical users alike. Even though many prospective customers may not be overly interested in the more technical applications literature, they should at least verify that it is available so as to gain a certain level of confidence that the vendor is truly expert in its core DF technology.

Vendors of sub-professional-quality DF equipment, on the other hand, are far less likely to publish applications literature, particularly of the more technical variety. This is a reflection of the fact that in general, most such vendors lack the technical expertise to publish such information, or would prefer not to make information available to users that might cast their products in a bad light and expose them as being of sub-professional-quality.

As a point of reference, RDF Products publishes an extensive library of applications literature.

Its Web Notes are short papers that are written primarily for the benefit of non-technical users. Its Application Notes are lengthier papers that are oriented primarily toward a more technical audience. All RDF Products Web Notes and Application Notes can be downloaded from RDF Products' website, and are also distributed on RDF Products' Publications CD.

E. OPERATOR'S MANUALS AND USER FUNCTIONAL TEST PROCEDURES

Another strong indication of DF system quality is the quality of its equipment operator's manuals. It stands to reason that professional-quality DF equipment should be accompanied by a professionally written operator's manual that is extensive, clear, and well illustrated. Manuals that are perfunctorily written or contain little useful information should convey a warning signal that the DF equipment itself may likewise be of sub-professional-quality. Given the complexity and subtleties of modern DF systems, it stands to reason that the operator's manuals need to be written with far more thought, care, and effort than, for example, manuals written for the assembly of a book shelf or a backyard swing set.

Prospective customers should *always* insist on seeing the operator's manual prior to purchasing the equipment. A DF vendor would refuse this legitimate request only if the manual might expose the equipment as being of sub-professional-quality, is poorly written, or does not exist. Furthermore, the vendor should not insult customers by charging them for these manuals since they can be conveniently sent via the Internet at negligible cost. As a final point before leaving this topic, like all expensive equipment, radio direction finding products should be accompanied by a *printed* operator's manual rather than just a CD.

As a point of reference, RDF Products publishes detailed, well-illustrated operator's manuals for all of its major equipment. These manuals are included on RDF Products' Publications CD and can be downloaded from the RDF Products' website.

F. USER FUNCTIONAL TEST PROCEDURES AND SERVICE BULLETINS

User functional test procedures and service bulletins are also very important. User functional test procedures are "closed-box" test procedures that allow customers to independently verify equipment performance. Professional-quality DF equipment should always be accompanied by such a test procedure when feasible.

Service bulletins are advisory notices to customers regarding equipment modifications, bugs, patches, problem work-arounds, and related topics. Unfortunately for customers, since the attitude of many DF equipment vendors is to hide the existence of problems, they understandably are reluctant to publish solutions.

As a point of reference, RDF Products includes user functional test procedures in its equipment operator's manuals, and posts the most current revisions on its website along with service bulletins. These documents are also published on RDF Products' Publications CD.

Since user functional test procedures and service bulletins are a key component of a vendor's overall customer support program, their absence is a good predictor of poor customer support. Discerning customers should always verify that all candidate DF equipment vendors publish such documents. Vendors that do not provide user functional test procedures and service bulletins are almost certainly unlikely to provide proper customer post-sales support.

G. DF ANTENNA TEST RANGE

It is essential that a professional-quality DF equipment vendor have a DF antenna test range that can be used to objectively and precisely measure DF antenna performance (especially bearing accuracy). Since these tests clearly cannot be conducted in crowded urban or suburban environments or indoors, the prospective customer should ask to see a photograph of the vendor's test range. If the vendor refuses or cannot produce evidence that such a test range really exists, this is a very strong indication that the DF antenna accuracy specifications are based on wishful thinking rather than rigorous measurements and that the vendor's DF antennas are sub-professional-quality. Similarly, the prospective customer should immediately dismiss any vendor contention that DF antennas can be adequately tested via computer simulation since such a claim would be outright fraudulent. Along the same line, a vendor claim that DF antenna testing is subcontracted out to an EMI test facility or an antenna test consultant should also be summarily dismissed since no DF vendor could ever successfully out-source a task so central to its core technology.

The fact is that unless the vendor has direct and convenient access to an on-premises antenna test range meeting FCC standards for open area testing, all published specifications regarding its DF antennas should be considered suspect. Furthermore, it is certain in such cases that important tests and measurements that directly relate to DF antenna performance have been omitted as a concession to convenience and schedule, with the inevitable result that the vendor's DF antennas will suffer from various performance shortcomings.

Since antenna test ranges are difficult, expensive, and time-consuming to build, prospective customers should view them as a litmus test to determine the DF vendor's commitment to product performance and quality. Vendors who are willing to make this expensive and time-consuming investment are far more likely to embrace this commitment. Ones who are not are more likely to be dilettantes rather than true professionals. The RDF Products DF antenna test range is illustrated in Figure 9.

H. MISCELLANEOUS ISSUES

1. Mobile DF System Bearing Displays

As discussed at length in Section IV-B-4, professional-quality mobile DF systems require true real-time polar bearing displays if they are to well meet the demanding requirements of mobile DF operation (see Figure 3 as an example), particularly if either the emitter or DF station is in motion. Surprisingly, very few DF vendors employ such displays in their equipment, relying instead upon vastly inferior azimuth ring displays. Mobile DF systems lacking real-time polar bearing displays cannot be expected to yield performance consistent with professional-quality standards (even if they have professional-quality price tags).

2. Excessive Reliance On Software

The advent of low-cost microprocessors has greatly improved the utility and functionality of radio direction finding equipment. At the same time, however, prospective customers should understand that regardless of how elaborately DF system software is written, it cannot compensate for fundamental system ills caused by poor hardware design, the selection of an inappropriate DF technique, or a vendor's general lack of understanding of DF technology. Prospective customers should be very suspicious of DF vendors who overemphasize system software or fancy computer displays, keeping in mind that it is far easier to write software than to design good DF hardware. A good example of this would be a vendor's claim that software can compensate for the ills of relying on an azimuth ring rather than a real-time polar bearing display as discussed above.

SECTION VI - EVALUATING AND DEALING WITH THE DF EQUIPMENT VENDOR

A. OVERVIEW

Although this Section has been saved for last, it is probably the most important. Since radio direction finding is a niche technology that is well understood by but a small number of specialists, customers are forced place a great deal of reliance on the knowledge and integrity of the DF equipment vendor for guidance as to the best solution for their DF requirements. As a consequence, the progressive and conscientious DF vendor must be willing to be more attentive to and candid with customers than is traditional for most businesses. Some of the issues associated with this vendor-customer relationship are discussed in the paragraphs that follow.

B. DF VENDOR BUSINESS PHILOSOPHY

Fundamentally, there are two diametrically-opposed business philosophies that are embraced by DF equipment vendors. One of these is the large corporation trust-me-I-know-best "closed-door" philosophy where the sales strategy is to divulge as little information as possible. Under this paternalistic philosophy, the vendor relies heavily on its corporate name size, and prestige to win sales rather than customer education and quick, flexible response.

This philosophy requires some explanation. Large, successful (and even not-so-large and not-so-successful) corporations over time often tend to forget their modest roots, lose their entrepreneurial spirit, believe that the market owes them a living, and ultimately develop a certain sense of organizational ego that eventually evolves into corporate arrogance. Although this business philosophy is dangerous and self-defeating in the long term, such corporations can coast on their brand name recognition for quite a long time before their market position is ultimately eroded by smaller and more responsive, entrepreneurial competitors that can better adapt to changing market conditions and provide customers with better support and superior value.

At the other end of this continuum is the usually smaller DF vendor that relies on flexibility, fast response, credibility, and most importantly, customer education to win sales. This "open-door" vendor has confidence in its products and correctly recognizes that its most important sales function is *customer education* so that customers can make informed and cost-effective purchasing decisions.

Fortunately for customers, it is usually not difficult to ascertain a DF vendor's business philosophy. DF vendors with an open-door policy committed to customer education can be relied upon to maintain comprehensive, easy-to-navigate websites with large, clear product photos and informative, detailed product data sheets. Such vendors also publish informative and useful professionally-written applications literature that can either be directly downloaded from their websites or supplied on CD for a nominal charge or none at all. Service bulletins, user functional test procedures, and other helpful information intended to facilitate customer post-sales support are also available from their websites.

Open-door policy vendors are also willing to supply prospective customers with equipment operator's manuals so that they can gain better insight as to the capabilities and limitations of the equipment *prior* to making a purchasing commitment. Astute vendors correctly recognize that comprehensive, professionally-written operator's manuals are highly effective sales tools for good products, and thus make these manuals easily available to prospective customers. Astute customers should *always* demand to see these manuals prior to equipment purchase to better ascertain product features and capabilities as well as to gauge manual quality itself.

This latter issue requires some elaboration. Manual quality is an important predictor of product quality, vendor attention to detail, and post-sales support. If the operator's manual is professionally written, well illustrated, and comprehensive, the prospective customer can have much greater confidence that similar skill, effort, and thoroughness have been invested in the design and manufacture of the product itself. If, on the other hand, the manual appears to have been perfunctorily written as an afterthought, or is mostly "boiler plate" with little useful information, the astute customer should suspect that the vendor is not fully committed to post-sales customer support, and that the equipment itself may be sloppily designed and carelessly built.

Closed-door policy vendors, on the other hand, can easily be identified by their sparser websites, more abbreviated product data sheets, and lack of applications literature, service bulletins, and user functional test procedures. They are usually very reluctant to provide operator's manuals, often citing that these manuals contain "proprietary information" that is not intended for general publication. This, of course, is a spurious claim that is really intended to maintain their policy of minimal disclosure or to prevent the prospective customer from seeing a poorly-written manual (or one that is mostly boiler-plate with little substance)prior to the sale.

Some closed-door vendors may be willing to supply operator's manuals, but charge several hundred dollars, citing publication, shipping, and handling costs. This is an atrocious example of the vendor "dumping" on the customer, and should stand out as a red flag that should alert astute customers to the vendor's business philosophy. All vendors of professional-quality DF equipment have (or should have) their manuals on CD, and should be more than willing to supply their publications CD to prospective customers for a very nominal charge and to supply all publications to customers in PDF format via the Internet at no charge.

As a point of reference on this subject, RDF Products has a Publications CD that includes all available operator's manuals, instruction sheets, operator's guides, product data sheets, applications literature, user functional test procedures, service bulletins, equipment photographs, and user software. This CD is available at no charge to prospective customers who fax their request on company letterhead to RDF Products. Printed versions of operators manuals are also available for a nominal charge, and PDF files of all manuals and applications literature is available to customer via the Internet at no charge.

C. ACCESSIBILITY TO VENDOR TECHNICAL PERSONNEL

At the risk of belaboring the issue, radio direction finding is a niche technology characterized by many subtleties and nuances that are often not evident to the non-specialist. It is therefore essential that the prospective customer understand these issues so that informed purchasing decisions can be made.

As mentioned, the progressive and conscientious DF vendor attempts to illuminate these issues by publishing applications literature so that the customer can be better equipped to deal with these issues. In fairness, if the DF vendor is willing to invest the effort and expense to publish such literature, it is important that the prospective customer likewise be willing to make a commensurate effort to carefully study this literature.

At the end of the day, however, the prospective customer will probably have questions or need information that is not fully addressed in the vendor's applications literature. Since selling radio direction finders requires more finesse and attention to detail than selling used cars or washing machines, it is *essential* that the customer have easy and direct access to vendor application engineers or technical sales personnel who can respond to technical inquiries with authority.

Although the above statements may seem obvious to the reader, it is surprising how often customers encounter difficulty in connecting with vendor technical personnel. All too often, customers are forced instead to deal with administrators or non-technical sales people who cannot satisfactorily respond to technical inquiries. In addition, engineers or technical sales personnel often are slow to return calls or seem reluctant to provide the customer with their full attention.

It should go without saying that a proper vendor-customer relationship demands that the vendor have easy and direct access to the people who can answer the customer's questions, with all calls and inquiries promptly returned. Customers should regard inaccessibility and sluggish response as a red flag that the vendor does not take its responsibilities to its customers seriously. Furthermore, poor pre-sales support is *always* a very strong predictor of poor post-sales customer support.

D. CUSTOMIZATION ISSUES

The nature of radio direction finding is such that in many cases, the vendor's standard products may not be completely suitable for the customer's requirements. In such cases, customized or special products are necessary. Progressive and responsive DF vendors exhibit the flexibility to accommodate such requirements where possible.

Unfortunately, many DF vendors lack this flexibility. All too often, vendors have a "one-size-fits-all" mentality and are unreceptive (or even outright hostile) to customers with special requirements. While such a policy might be more appropriate for a company selling a mass-market consumer product, it is entirely inappropriate for a niche-market product where annual sales volume is often less than 100 systems. The more appropriate policy is to regard customers as important people who are worthy of the extra effort that may need to be expended to provide them with the solution they really want to meet their requirements.

For their part, however, customers should not expect such customization to be done for free, or overnight. Given that the DF vendor is running a business rather than a charity, the vendor needs to be compensated for its time and effort, particularly in light of the fact that diversion of organizational resources for customization work inevitably slows down production of standard products.

For its part, RDF Products has always been receptive to requests for new or customized products. In cases where the new product or customization may have appeal to the general market, RDF Products is willing to absorb a significant portion of the development costs.

An issue closely related to that of customization is company size. In general, it is the smaller DF vendors that have the flexibility and interest to respond to customization requests. Larger companies tend to be less willing to do so on account of their enormous engineering and manufacturing overhead burdens and the general sluggishness inherent to large, bureaucratic organizations.

In fact, large companies tend to be ill-suited for niche-markets in general. With their large and hungry production floors, they need correspondingly large orders to remain profitable and thus tend to shun smaller orders. To do this, they have to increasingly rely on government contracts to stay in business and ultimately are forced to move away from the commercial market to survive.

E. <u>PARTIAL DF SYSTEM VENDORS</u>

Some DF vendors lack the technical capability or resources to supply complete DF systems. To provide a complete system, they are forced to procure one or more of the critical DF system components (e.g. the DF antenna) from some other DF vendor.

Prospective customers should be very careful in dealing with any DF vendor who lacks the core technology to design and produce a complete DF system, and who instead must rely upon a third-party source for critical components. Such vendors almost certainly do not have a DF systems engineer on staff, and are therefore poorly qualified to provide the all-important technical advice and counseling that customers will inevitably require from their DF vendor.

There are other hazards as well. Without a DF engineer on staff, there is a real probability that there may be unresolved DF hardware compatibility and system integration issues that can compromise DF performance. There is also the issue of added risk to the customer regarding long-term product support. In addition to absorbing the unavoidable risk of the primary vendor going out of business, the customer must also absorb the added risk of the third-party vendor going out of business.

A further issue that must be considered is the vendor's ability to produce new products to respond to new requirements. If the vendor lacks the core technology to design a complete DF system, then its ability to supply new DF products is likely to be very questionable at best, and more often than not will be contingent on the willingness and ability of the third-party DF vendor to cooperate.

To illustrate this latter issue using a hypothetical example, suppose that someone tries to enter the DF market by designing the simplest DF system component (e.g., the DF bearing processor) and procures DF antennas from some other DF vendor to supply a complete system for sale to a customer. If this customer then subsequently wants an additional DF antenna to cover a new frequency range, the primary vendor is hostage to the willingness and ability of the third-party vendor to design the new antenna. It is probably fair to say that the third-party vendor is likely to be more receptive to the idea of a DF antenna development effort that would result in orders for its own DF bearing processor rather than someone else's.

All in all, it is better for prospective customers to deal directly with DF vendors that possess the core technology to design and produce its own fundamental DF system components. By doing so, they are more likely to obtain a well-integrated, professional-quality DF system that can be upgraded to meet new requirements and that will be supported over the long term.

The astute reader may argue that the above statement appears inconsistent with the cost-effective concept of employing a consumer-market communications receiver as a DF system component discussed in Section III-D. Although this is a correct observation in the strictest sense, an important distinction can be made. In the hypothetical example presented above in which the DF antenna is procured from a third-party vendor, the hazards of this arrangement result from the fact that the DF antenna is a key (if not *the* key) component of the DF system, for which there is usually no second source.

Although the receiver is also an important element of any DF system, receivers are not inherently DF components, and are produced in large volume with many available sources. As a result, none of the risks cited above are applicable, with the possible exception of the system integration issues (which can be completely circumvented with the selection of an appropriate DF technique and a well-designed DF bearing processor).

As a final note, this discussion is not intended to discourage customers from dealing with qualified sales representatives who are also value-added resellers. Value-added resellers can serve a useful and important function by increasing the functionality and versatility of a DF system. This added value can take the form of something as simple as a customized carrying case or as complex as a customized software package that provides DF triangulation capability with digital mapping. Regardless, the important point is that value-added resellers can take advantage of their closer proximity to customers to better determine the details of their customers' requirements. See discussion below of additional issue regarding sales representatives.

F. VENDOR STABILITY

Finally, prospective customers should consider the issue of vendor stability. To put this matter very bluntly, a customer who makes a major investment in DF equipment wants assurance that the vendor will still be available in the following years to service and upgrade the equipment. Unfortunately, the market is littered with the corpses of failed DF companies.

Most prospective customers primarily associate the matter of vendor stability with vendor longevity. Although there is a certain logic in this assumption, longevity alone does not always correlate to stability.

An issue closely related to organizational stability is *management* stability. There are a number of DF companies that have been in existence for many years, but that have been through a large number of reorganizations and changes in management. Such turbulence inevitably results in major upheaval, confusion, and personnel turnover.

This latter issue is particularly devastating when key personnel leave. This results in a loss of *institutional memory* that in turn neutralizes much of the benefit of the company's longevity. All too often, such companies have a large product line, but have no one who really understands how these products work. The ultimate effect of this is to clamp new product development and create stagnation. The warning signs of such loss of institutional memory include poor quality control, escalated pricing, inability to reach key personnel, and poor pre- and post-sales support.

Since radio direction finding is a niche technology in a niche market, there are not very many engineers who are expert in this field. Furthermore, entry-level DF engineer candidates require many years of professional growth to gain the experience and professional maturity necessary to design DF systems competently. As a result, the loss of a DF engineer is a very serious setback to a DF vendor.

As a point of reference, RDF Products has been in business since 1979, has over 30 years of radio direction finding experience, and has never had a change in management during this entire period. A further testament to RDF Products' stability and commitment to customer support is the fact that it is called upon periodically to do repairs on older equipment produced by *competitors* who are unable or unwilling to support their customers in this regard.

G. SALES REPRESENTATIVES

Small to medium size manufacturing companies traditionally have relied upon third-party sales representatives as an important adjunct to their own (often limited) marketing resources to increase sales. This has been especially true for companies selling to a world-wide market.

The essence of this arrangement is that the sales representative buys the products from the manufacturer at discount and then sells to the end user at the higher list (or otherwise agreed-upon retail) price. The economics of this arrangement is that the manufacturer is willing to sell at discount since it does not have to absorb the marketing costs associate with the sale.

Although the sales representative can still play an important role in the marketing chain, the widespread use of the Internet as a marketing tool has created a completely new marketing paradigm that allows buyers and sellers to easily and directly communicate. This new paradigm has greatly diminished the need for traditional third-party sales representatives and usually results in better pricing for the buyer and faster response.

There are some caveats, however, particularly for international sales where the manufacturer will usually insist on prepayment or that the goods be shipped against an irrevocable letter of credit. In such cases, it is very important that the customer have complete confidence in the manufacturer's credibility and integrity since legal recourse is often very difficult to pursue in international transactions. For the same reason, the manufacturer must rely upon the customer's credibility and integrity not to cancel an order without appropriate compensation.

As a point of reference, most of RDF Products' sales, both domestic and international, are conducted by direct customer contact via the Internet. Customers typically find the RDF Products website using appropriate Internet search engines (or by referral), download and study the product data sheets and applications literature, make contact via telephone or e-mail to obtain technical advice, and then directly order the equipment.

Sales representatives can, however, still serve a useful purpose. A good sales representative can often add value to the product, either directly by supplying customized software or peripheral equipment as discussed above, or by performing services such as installation, training, and technical support (including repairs).

The sales representative can also provide valuable pre-sales services such as product demonstrations. In addition, customers may prefer to deal through a sales representative of known credibility to help insulate themselves from the risks of dealing with an unknown manufacturer.

Customers who choose to conduct business through sales representatives should, however, avoid certain pitfalls. It is essential that customers demand that the sales representative present a current and bona-fide certificate of representation that establishes the authority of that representative to deal directly with the manufacturer. This certificate is extremely important. Without it, warranty and other post-sales support may be difficult to obtain. This certificate also provides assurance to customers that the sales representative is dealing directly with the manufacturer, rather than through a chain of sales representatives that can result in excessive pricing mark-ups and sluggish communication. A sample certificate of representation is presented below.

Customers should also demand direct access to the manufacturer so that technical queries can be easily made. If the sales representative attempts to "hide" the manufacturer from the customer, this should be regarded as a serious "red flag" that the bond of trust between the sales representative and manufacturer is questionable (a situation that can only mean trouble for the customer).

RDF Products
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** Certificate Of Representation **

To whom it may concern:

We, RDF Products, located at 17706 NE 72nd Street, Vancouver, Washington, USA, designer and manufacturer of professional-quality radio direction finding and location equipment for law enforcement, public safety, national security, national defense, regulatory, interference location, and scientific research applications, on Dec 01 2000 hereby appoint:

Jerome & Francis Co. Ltd.
1869 Welch Street
North Vancouver, B.C. Canada V7P 1B7
Tel: (604) 986-1286
Fax: (604) 986-2216
E-Mail: info@jerome&francis.com
Web: www.jeromefrancis.com/jfrancis/

Represented by: **Mr. John Joyce**

As our sole and exclusive sales representative to the Canadian Coast Guard and authorize him to represent our company and introduce, offer, and sell our products with our full technical and warranty support. This designation covers the period Dec 01 2000 to Jun 01 2002, subject to renewal.

by:

Alex J. Burwasser, Proprietor
RDF Products

Figure 12 - Sample Certificate Of Sales Representation

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