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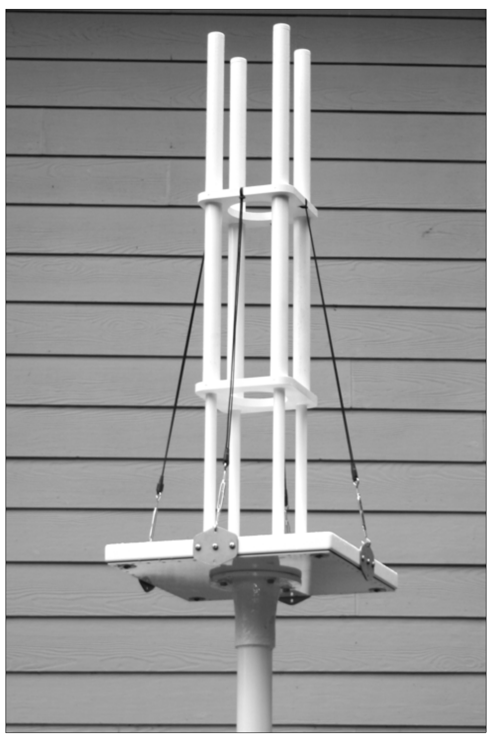
OPERATOR'S MANUAL
DFA-1333B1 108-520 MHz FIXED-SITE SLEEVE-DIPOLE ADCOCK DF ANTENNA



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Original Writing: November 2012

WARNING

Please comply with the following basic rules of safety and common sense to ensure safe installation and operation:

1. **LIGHTNING PROTECTION** - *Lightning strikes can cause death or serious injury to operating personnel and destruction of equipment if appropriate precautions are not taken.* It is *essential* that the DFA-1333B1 be installed with the lightning protection precautions discussed in Section V-G and Appendix C.

2. **ELECTRICAL POWER LINES** - *Never install the DFA-1333B1 in the immediate vicinity of electrical power lines. If the antenna comes in contact with power lines, death or serious injury to operating personnel is likely to result.* See Section V-H.

3. **INSTALLATION ISSUES** - The user must provide a mast mount for the DFA-1333B1 as discussed in Section V. In addition, the user must securely guy the unit for maximum safety. Please study Section V carefully and take all necessary steps to ensure that the DFA-1333B1 is safely mounted. *If there is any doubt regarding the safety of the installation, obtain professional help as required as per Section V-A.*

4. **ELECTROSTATIC DISCHARGE (ESD) ISSUES** - Although all RDF Products DF antennas and DF processors are designed to minimize vulnerability to electrostatic discharge (ESD) induced damage, fixed-site DF systems are especially prone to this hazard. *Do not connect the DFA-1333B1 to the DF receiver/processor before studying and complying with the necessary system grounding and procedural precautions discussed in Section V-I.*

5. **EXTERIOR WEATHER-SEALING** - Sealants have been applied to the DFA-1333B1 exterior to enhance weather-sealing and prevent water intrusion. For longest product service life, *do not break the integrity of these exterior weather-seals.*

Check the RDF Products website at www.rdfproducts.com for updates and bulletins.
Can we improve this manual? Contact us at mail@rdfproducts.com to offer suggestions.

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SECTION I - GENERAL DESCRIPTION

The RDF Products Model DFA-1333B1 is a 4-aerial V/UHF sleeve-dipole Adcock single-channel radio direction finding antenna covering 108-520 MHz in a single-band. This rugged, weather-sealed unit is specifically designed for permanent or transportable fixed-site DF applications and is readily mast- or tower-mounted.

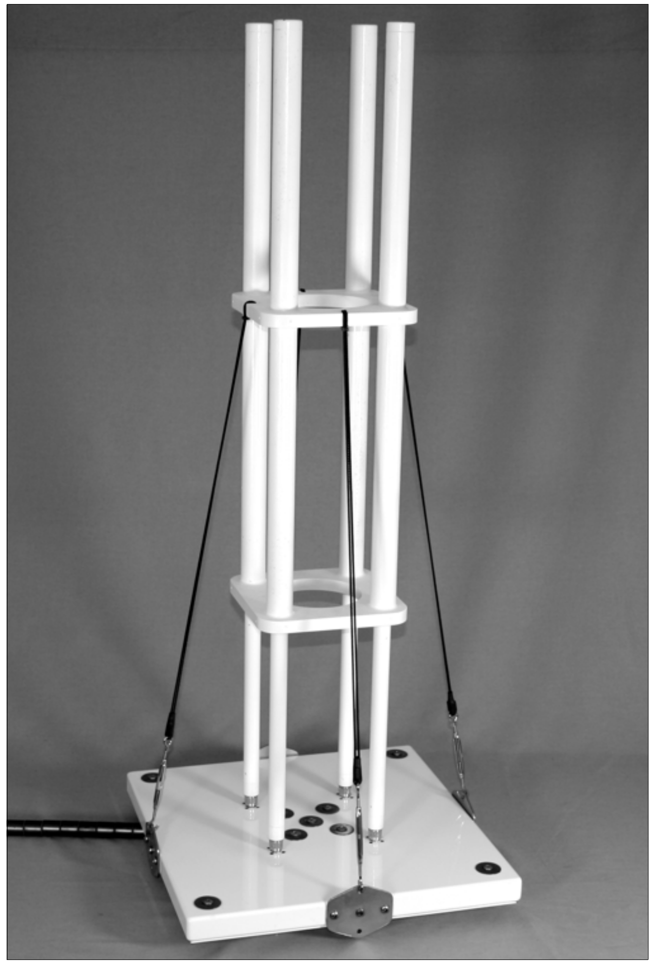


Figure 1 - DFA-1333B1 108-520 MHz Sleeve-Dipole Adcock DF Antenna

The DFA-1333B1 has been specifically designed so that its performance is independent of its supporting mast or tower (this is accomplished with the supplied isolation mast). This is in sharp contrast to competing mast-mounted DF antenna designs where performance is adversely and unpredictably affected not only by the presence of the mast, but also by changes in mast height. The DFA-1333B1 is specifically designed for superb signal-handling capability for reliable performance in dense-signal environments. It also includes a personality module that reports antenna model and frequency coverage information.

The DFA-1333B1 directly interfaces with all RDF Products DF receivers and bearing processors via a captive 8-meter long interface cable set (comprising a multi-conductor power/control cable and an RG-223 double-shielded RF output cable). For applications requiring longer cables, extensions may be added (see Appendix B). The mast and sleeve-dipoles are removable to facilitate storage, transport, and user-testing.

NOTES

SECTION II - SPECIFICATIONS

DF Technique:	Single-channel 2-phase 4-aerial Adcock with derived sense.
Frequency Coverage:	108-520 MHz continuous (no bandswitching required).
Bearing Accuracy:	4.0° RMS maximum overall; 2.5° RMS typical (ideal siting conditions).
Polarization:	Vertical.
Output Impedance:	50 ohms nominal.
2nd Order Intercept:	+36/+25 dBm (V/UHF) typical (referred to derived sense input).
3rd Order Intercept:	+25/+15 dBm (V/UHF) typical (referred to derived sense input).
Required X & Y Axis Encoding Tone Voltages:	1.0 volts p-p, sinusoidal (100-2000 Hz).
Personality Module:	Reports antenna model and frequency coverage information as 300N81 RS-232 data string “DFA-1333B-1, 108-520 <CR><LF>”.
Power Requirements:	11-16 VDC @ 90 mA (negative ground).
Operating Temperature:	-40 to +60 degrees C.
Storage Temperature:	-40 to +70 degrees C.
Humidity:	0-100%.
Maximum Wind Velocity:	80 mph.
Dimensions:	121.5"x20.5"x20.5" (HxWxD, including 5' isolation mast, and 2' stainless-steel mast support pipe).
Weight:	66 lbs. (structural weight including main chassis, aerials, isolation mast, and 8-meter interface cable set; excluding 14 lbs. stainless-steel mast support pipe).

NOTES

SECTION III - PRE-ASSEMBLY INFORMATION

A. UNPACKING AND INSPECTION

Carefully examine the shipping carton for damage before it is opened. If damage is evident, have the carrier's agent present, if possible, when the equipment is unpacked. If the carrier's agent cannot be present, retain the cartons and packing material for the carrier's inspection if the equipment is subsequently found to be damaged after unpacking.

Do not use knives or other sharp instruments to remove packing material from individual items. To facilitate easy unpacking, the packing material protecting these individual items is secured with easy-to-remove tape where possible.

To ensure that the shipment has been received complete, inventory all items against the detailed shipping list. If a discrepancy is found, notify us immediately.

The equipment was thoroughly inspected and factory adjusted for optimum performance prior to shipment and is ready for immediate use. If evidence of damage during shipment is found, notify us immediately.

B. EQUIPMENT SUPPLIED

The following equipment is supplied:

1. Main chassis (P/N B333-6001; 1 ea., includes attached ferrite-loaded interface cable set).
2. 108-520 MHz sleeve-dipole array assembly (P/N S062-6101; 1 ea.).
3. 5' isolation mast (P/N S092-6005; 1 ea. - includes 3 ea. P/N 605-009 3/4" long 3/8" dia. 16 tpi stainless-steel anti-rotation bolts).
4. 1-1/2" long 3/8" dia. 16 tpi stainless-steel flange bolts (P/N 605-022; 4 ea.).
5. DFA-1333B1 spare hardware kit (P/N S092-6002; 1 bag).
6. 2' long 3" inside-diameter schedule 40 unthreaded stainless-steel mast support pipe (P/N S092-0002).
7. Silicone sealant (P/N 701-007; 1 tube).
8. DFA-1333B1 Operator's Manual (P/N B333-9001; 1 ea.).

All of the above components are illustrated in Figure 2 below. Refer to this photo as required to identify these components during the assembly procedure presented in Section IV.

Note: The tube of silicone sealant is no longer supplied. In current-production units, all sealing is done at the factory.

Figure 2 - DFA-1333B2 Components

C. EQUIPMENT REQUIRED BUT NOT SUPPLIED

The DFA-1333B1 must be used with an appropriate RDF Products DF receiver/bearing processor. In addition, a suitable user-supplied mast mount fitting may also be required to mount the DFA-1333B1 as discussed in Section V. The user must also supply non-conductive guy lines and associated hardware. Finally, an extension interface cable set may be required if the standard 8-meter interface cable is insufficiently long to reach the DF receiver/bearing processor.

SECTION IV - ASSEMBLY

A. INTRODUCTION

As mentioned, the DFA-1333B1 is shipped in disassembled form so that it can be stored and transported more compactly. It is therefore necessary for the user to assemble the unit prior to use. Although assembly is not difficult, it must be done carefully and in proper sequence to avoid damaging the unit.

*** CAUTION ***

1. Two-Man Assembly - At least two people are required to properly assemble and install this antenna.

2. Ferrite-Loaded Cable Set - The cable attached to the main housing (see Figure 2) is loaded with large ferrite cylinders. Since these ferrites are somewhat brittle, exercise caution when handling this cable set so as to prevent impact against hard surfaces or objects. Also, do not attempt to bend this cable set too tightly.

3. Main Housing Integrity - The main housing is a pre-assembled weather-sealed unit. *This housing contains no user-serviceable parts and should never be opened. Disassembling the main housing without written factory authorization voids the warranty.*

4. Flange Mounting Bolts - Four 3/8" diameter bolts are supplied to mount the chassis support flange to the main chassis. *Do not insert these bolts into the main chassis without the flange - if the flange is not installed, these bolts can protrude sufficiently far into the chassis to break the internal weather-seal gasket and damage circuit board components.*

5. Sleeve-Dipole Assembly - When tilting the assembled DFA-1333B1 up or down, use the antenna chassis or upper mast portion as the push point. *Do not apply pressure to the sleeve-dipole assembly as this may place excessive lateral stress on the sleeve-dipole connectors.*

B. STEP-BY-STEP ASSEMBLY INSTRUCTIONS

1. Locate the main chassis with its attached ferrite-loaded interface set and place it on the table. Using a #1 Phillips screwdriver, tighten down all *56 #6 flathead screws along the edge of the chassis bottom plate* as required, using no more that 10 inch-pounds of torque. (This is a precautionary step in the event that these screws have loosened if the main weather seal gasket has "cold-flowed".) *Do not attempt to tighten or loosen the 16 screws securing the corner hole covers. These screws have been dipped in silicone sealant to provide weather sealing and should not be disturbed (attempting to tighten or loosen these screws will break the silicone seal and thus make the chassis more susceptible to water intrusion).*

2. Set the main chassis on a flat horizontal surface so that the 4 type-N connectors are visible. Place supports underneath the chassis so that it does not rest on the ferrite-loaded cable set.

3. Locate the sleeve-dipole main assembly (see Figure 2) and *gently* set it atop the type-N connectors as illustrated in Figure 3. **Note:** The rotational alignment of the sleeve-dipole assembly with respect to the chassis connectors is unimportant so long as all the connectors match up.

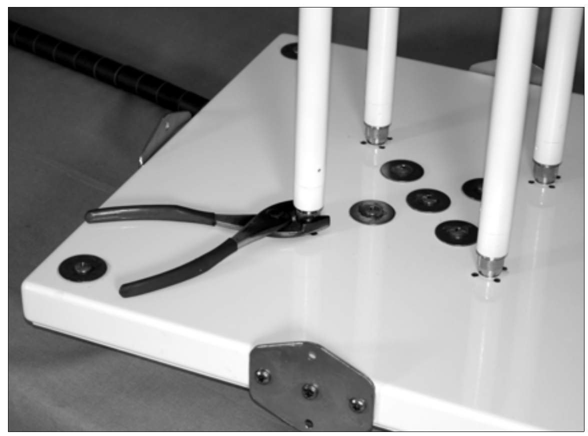


Figure 3 - Installing the Sleeve-Dipole Main Assembly on the Main Chassis

4. Slightly finger-tighten any two opposing connectors. Once the threads catch, slightly finger-tighten the other two opposing connectors. Once these threads catch, slightly finger tightening the center connector. *Do not use pliers to tighten the connectors at this time.*

5. Continue to progressively tighten the connectors in the above sequence until all connectors are fully finger-tightened.

6. To verify that all the connectors have been fully finger-tightened, grasp the sleeve-dipole assembly near the top with one hand and gently pressure (rock) it back and forth horizontally while attempting to continue to tighten the connectors with the other hand. (This will help relieve any thread binding or galling that might be preventing the connectors from fully tightening.)

7. When no further finger-tightening is possible, carefully inspect the assembly to verify that the sleeve-dipoles are perfectly vertical with respect to the chassis. If any tilt is visible, loosen all 4 connectors slightly and repeat the above steps. *Do not proceed to the next step until no tilt is visible.*

8. With the connectors fully finger-tightened and the sleeve-dipole assembly confirmed to have no tilt with respect to the chassis, continue progressively tightening the connectors in succession using pliers. *To prevent binding, tighten each connector only 1/4 turn at*

a time. Repeat this successive tightening process as many times as required until all 4 connectors are tight. *Do not use excessive force.*

9. When no further tightening is possible, again carefully inspect the assembly to verify that the sleeve-dipoles are perfectly vertical with respect to the chassis. If any tilt is visible, loosen all 4 connectors slightly and re-tighten so as to eliminate the tilt. *Do not proceed to the next step until the connectors are fully tightened and no tilt is visible.*

10. Slide the ferrites as far as possible along the cable set *toward the main chassis*.

11. Lay the isolation mast down on the table.

12. Insert the ferrite-loaded interface cable set through the mast end with the chassis support flange (see Figure 4). **Note:** There is an internal ferrite-support shoulder collar near the mast bottom that may obstruct the cable set ends and prevent them from pushing all the way through the mast. If the cable set ends catch on this shoulder, they can easily be freed by twisting and shaking the cable set or rolling the mast to a different position.

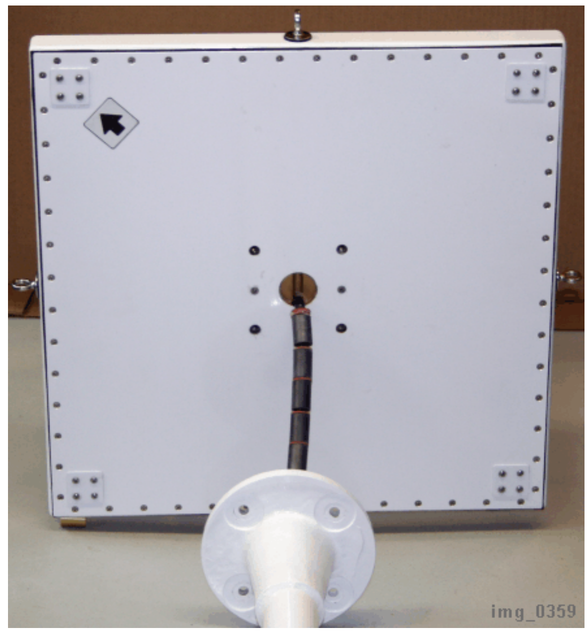


Figure 4 - Inserting the Ferrite-Loaded Interface Cable into the Mast

13. Wipe away any debris present on the top flat surface of the mast flange and the corresponding area on the chassis underside where the flange will be in contact.

14. Pull the cable set fully through the mast and then align the four chassis support flange holes with the corresponding four threaded holes on the underside of the main chassis. **Note:** The rotational alignment of the main chassis with respect to the chassis support flange is unimportant so long as all of the holes match up.

15. Install the four 1-1/4" long 3/8" dia. stainless-steel bolts into the chassis support flange holes as per Figure 5. Screw in each bolt until the threads catch. **Note:** Since this and the next step are very awkward to accomplish by one person alone, we strongly recommend that two people do this; one to support the chassis and the other to install the bolts.

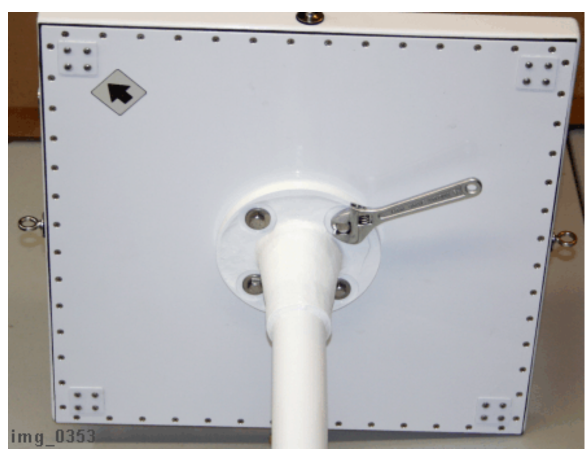


Figure 5 - Securing the Main Chassis to the Mast Flange

16. After all four bolts have been started, firmly finger-tighten each bolt as far as possible. Once done, fully tighten these bolts with a wrench as per Figure 5, *being sure that there is no cross-threading.* Inspect the junction between the chassis and flange to verify that there is no space in between (i.e., the

flange top should be fully flush with the chassis underside).

17. This completes preliminary assembly of the DFA-1333B1. If it becomes necessary to remove the sleeve-dipole main assembly, loosen the connectors in a successive and progressive manner similar to the procedure above by which they were tightened.

18. Note that the 4 Kevlar guy lines pre-attached to the sleeve-dipole array are terminated with hooked turnbuckle fasteners. Insert these hooks into the corresponding stainless-steel guy termination bracket ***upper holes*** on the main chassis sidewalls as illustrated in Figures 6 and 7 and then tighten the turnbuckles. ***Be sure to tighten these turnbuckles in pairs (opposing sides) by simultaneously tightening the opposing fasteners so that the sleeve-dipole array is not pulled to either side. (Rotate the turnbuckle fasteners clockwise to tighten.) To avoid damage to internal components, exercise caution not to allow the chassis topside to bend or bow while tightening these turnbuckles. Tighten to the point where moderate finger pressure on the center of the line results in approximately 1 cm of play.***

Figure 6 - Sleeve-Dipole Array Kevlar Guy Line Installation

Figure 7 - Turnbuckle Detail

NOTES

SECTION V - INSTALLATION

A. GENERAL

Once the DFA-1333B1 has been assembled as per Section IV, the remaining steps are to select a DF site, fabricate a suitable mast mount, secure the unit to the mount, and then properly orient the DF antenna. These steps are discussed in the paragraphs that follow.

The DFA-1333B1 installation should be done only by qualified personnel experienced in this field. Since most users are not likely to have these qualifications and experience, we strongly recommend that users have the installation done professionally by a reputable contractor proficient in this line of work with a full knowledge of all applicable rules, regulations, ordinances, and codes governing such installations.

B. SELECTING A DF SITE

The importance of a good DF site cannot be overstated. Although the DFA-1333B1 yields a typical *instrument accuracy* of better than 2.5° RMS, *system accuracy* can be many times worse than this if the DF antenna is installed at a poor site. Unlike mobile DF systems where poor bearing accuracy can often be forgiven due to the homing nature of typical mobile DF missions, mast-mounted fixed-site DF systems generally require a much higher degree of bearing accuracy. This is especially true where the fixed-site DF system is a component of a larger DF network used for triangulation.

The fundamental requirement for good DF antenna siting is that the DF antenna be mounted so that it is free of obstructions. (Obstructions tend to cause re-radiation that leads to multi-path reception at the DF antenna that in turn results in bearing errors.)

Although it is not strictly necessary that the DF antenna be mounted high off the ground, a high installation is more likely to raise the antenna above the various obstructions that are likely to be encountered (e.g., trees, buildings, utility poles, water towers, and even the operating console). A high installation is also advantageous in that bearing errors induced by non-uniform ground conductivity are likely to be reduced.

It is therefore important that a best effort be made to select a DF site that is as "clean" as possible. Although site calibration is often a useful procedure for improving the instrument accuracy of a DF system, it cannot compensate for bearing errors caused by poor siting (see discussion in paragraph V-F below).

C. MOUNTING THE MAST SUPPORT PIPE

The bottom of the DFA-1333B1 isolation mast is designed so that it can be directly inserted onto the supplied 2' long 3" inside-diameter schedule 40 stainless-steel mast support pipe. This mast support pipe in turn must be safely mounted to a user-supplied tower or other suitable support structure. Since the details of the mounting technique can vary widely depending upon user preferences and requirements, it is the user's responsibility to employ whatever construction techniques are necessary to safely secure the mast support pipe to the support structure. In this regard, it is also necessary that the user obtain or fabricate any custom fittings or adaptors that may be required to successfully complete the installation.

***** DANGER *****

> The support structure must be sufficiently strong to support the DFA-1333B1 under all conditions. In some installations, guy lines may be necessary. If the user is inexperienced in large antenna mounting or if there is any doubt regarding the ability of the support structure to support its own weight plus that of the DFA-1333B1 under conditions of maximum wind and ice loading, professional help should be obtained to guarantee a safe installation. *It is solely the user's responsibility to ensure a safe installation.*

There are a number of different mounting techniques available to the user. A common method is to weld or bolt the mast support pipe to a steel tower. Regardless of the method chosen to secure the mast support, it should be installed very carefully to ensure that it is nearly perfectly vertical with no measurable tilt.

**** WARNING ****

> *Do not attempt to directly side-mount the DFA-1333B1 isolation mast against a pipe, tower, chimney, or any other structure. Doing so will defeat its purpose and prevent the DFA-1333B1 from being isolated from its supporting structure, resulting in diminished performance.* Also, the fiberglass isolation mast is not designed for the stresses inherent in such a mounting scheme and may become damaged as a result. (This mounting scheme is unsafe as well.) Always construct a suitable mast mount as discussed above.

Regardless of the mounting technique selected, *be sure to leave a sufficient length of the upper portion of the mast support pipe unobstructed so that the DFA-1333B1 mast mounting base can be slid onto the pipe and fully seated.*

D. INSTALLING THE DFA-1333B1 ON THE MAST SUPPORT PIPE

Once the mast support pipe has been successfully installed, the DFA-1333B1 must be mounted, oriented, and secured. To accomplish this, proceed as follows:

1. Insert the free end of the interface cable set into the upper opening of the mast support pipe.

2. Retrieve this cable set end by bringing it out through the lower opening of the mast support pipe, pulling it all the way through.

3. Position the DFA-1333B1 mast mounting base (at the lower end of the mast) directly over the mast support pipe and *carefully* lower the DFA-1333B1 onto it. To prevent inadvertent pinching of (and possible damage to) the cable set, *have an assistant pull the cable set from below so as to always maintain sufficient tension to prevent it from bending* while the DFA-1333B1 is being lowered onto the pipe. If resistance is encountered, *do not use force* - lift the DFA-1333B1 off the mast support pipe and determine the source of the blockage before proceeding.

3. Rotate the DFA-1333B1 as required to establish the desired azimuthal orientation (the arrow or other marking on the chassis underside indicates the zero degree reference). Once the correct orientation is achieved, hand-tighten the three anti-rotation bolts at the base of the isolation mast. Once done, recheck the orientation and then firmly tighten the bolts with a wrench using moderate force. Again recheck the orientation to confirm that it is still correct. If the DFA-1333B1 is inadvertently rotationally misaligned during tightening, loosen the bolts and repeat this step as required. See Section V-E below for additional information regarding orientation.

4. Secure the DFA-1333B1 with non-conductive guy lines (attached to the stainless-steel guy termination bracket ***lower holes*** on the main chassis sidewalls on each side of the main chassis as illustrated in Figures 6 and 7). We recommend that these guy lines be made of a stretch resistant material such as UV-protected Kevlar. When installing these guy lines, be sure that the tension on each line is the same and that they not cause the iso-mast to bend.

5. If the DFA-1333B1 is to be permanently installed, we recommend that all mast mount openings (including the exit opening for the interface cable set) be sealed with an appropriate weather-resistant compound. To facilitate de-installation, however, we recommend that this compound be of a soft-cure removable variety (e.g., silicone sealant) rather than a hard-cure permanent type (e.g., epoxy).

6. *To prevent electrostatic discharge (ESD) damage, do not connect the DFA-1333B1 to the DF receiver/processor before studying and complying with the necessary system grounding and procedural precautions discussed in Section V-I.*

E. <u>ORIENTATION ISSUES</u>

A DF system provides bearings that are *relative* to the orientation of the DF antenna. In order for these bearings to be meaningful, it is necessary that the DF antenna be *oriented* in such a fashion that these relative bearings correspond to *absolute* bearings of some form or other.

A car-top mounted mobile DF antenna, for example, is usually oriented so that a zero degree bearing corresponds to the forward direction of the vehicle. Similarly, a mast-mounted shipboard DF antenna is usually oriented so that a zero degree bearing corresponds to the forward direction of the vessel. In contrast, a fixed-site mast-mounted DF antenna is usually oriented so as to be compatible with a geographical coordinate system. In typical fixed-site installations, the DF antenna is oriented so that a zero degree bearing corresponds to true, magnetic, or grid north.

For the DFA-1333B1 a zero degree bearing occurs when its “north-south” aerial axis is in-line with the signal source, with the “north” aerial closest to the signal source. The “north”, or zero degree reference aerial is indicated by an arrow or other marking on the chassis underside.

We strongly recommend that the desired orientation be established based on appropriate mechanical rotational alignment of the DFA-1333B1. That is, if a zero degree bearing is to indicate true north, for example, the antenna should be rotated so that the two diagonally-opposed aerials on the 0-180 degree (or “north-south”) axis are physically aligned with the true north-south axis based on careful visual siting.

This is preferable to attempting to establish orientation based on the actual bearing received by a test transmitter or other signal source of known location. This latter technique introduces potential errors as a consequence of possible multi-path reception and is therefore unreliable.

If for some reason it is difficult or inconvenient to rotate the DFA-1333B1 to obtain the precise orientation desired, or if the antenna must be used in a variety of DF missions requiring compatibility with different geographical coordinate systems, virtual orientation can be accomplished by the simple expedient offsetting the azimuth indication of the bearing display. In the more typical case where a computer will be used to display the bearings, this can be accomplished in software (most computer interface programs written for DF applications have a suitable azimuth offset feature). If an analog bearing display is used, an azimuth offset is normally accomplished by mechanically rotating the calibration bezel.

In either case, the procedure is reasonably straightforward. First, the actual orientation of the DF antenna (referenced to the zero degree orientation of the selected geographical coordinate system) is established by careful visual siting as discussed above. This observed angle is then entered into the bearing display program as an azimuth offset. As an example, suppose that it is desired that bearings be referenced to true north, and it is established by careful visual siting that the actual DF antenna orientation with respect to true north is +7 degrees. Without azimuth offset compensation, this would result in displayed bearings generally being *low* by 7 degrees. To correct this, an azimuth offset of +7 degrees would be entered into the bearing display program to compensated for this error. Note that this azimuth offset is frequency independent.

F. SITE CALIBRATION

Site calibration is a means by which bearing accuracy of a 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.

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

1. 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. More specifically, 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 it is ineffective in reducing *site error.*

2. Number Of Calibration Azimuths - In general, a substantial 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. Site calibrations conducted using 16 equally-spaced calibration points (i.e., at 22.5° azimuth increments) should be adequate in most cases.

3. 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.

4. 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 0° elevation, site calibrations are similarly performed at or near 0° elevation. Another mitigating factor is that DF antenna bearing accuracy does not change much over a modest range of elevations centered around 0°.

5. 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. Since the low-end band-edge frequency for the DFA-1333B1 is 108 MHz, the test transmitter should be located about 8' away and at the same elevation as the main housing.

6. 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 subtracted out 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 an involved topic and a more detailed discussion is beyond the scope of this manual. Users having additional questions about site calibration should contact RDF Products.

G. LIGHTNING PROTECTION

Although the DFA-1333B1 is sufficiently robust to survive the electromagnetic pulses generated by nearby lighting strikes, it cannot survive a direct hit. With regard to lightning protection, however, the far more overriding issue is that of operator safety.

***** DANGER *****

> *Lightning strikes can cause death or serious injury to operating personnel and destruction of equipment if appropriate precautions are not taken.* Proper lightning protection requires the use of specialized equipment to subdue the high voltages on the antenna feed-in cable set that can be induced by lightning. *Never install the DFA-1333B1 without the benefit of such protection.*

In general, such protection requires the use of appropriate high-voltage clamping devices combined with suitable grounding techniques. Due to the specialized nature of this equipment and technology, we strongly recommend that users procure the necessary protective devices directly from the various sources who manufacture them. One such source is PolyPhaser Corporation (P.O. Box 9000, Minden, NV, USA 89423). Polyphaser publishes a variety of application notes relevant to this topic that we strongly recommend users read. PolyPhaser can be reached at +1-800-325-7170, and has a website at www.smithspower.com/brands/polyphaser/.

H. ELECTRICAL POWER LINES

***** DANGER *****

Never install the DFA-1333B1 in the immediate vicinity of electrical power lines. If the antenna comes in contact with power lines, death or serious injury to operating personnel is likely to result.

In addition to the obvious safety issues, the presence of power lines and supporting utility poles in the immediate vicinity of the DFA-1333B1 are very likely to degrade bearing accuracy.

I. ELECTROSTATIC DISCHARGE (ESD) ISSUES

Although all RDF Products DF antennas and DF receivers/processors are designed to minimize vulnerability to electrostatic discharge (ESD) induced damage, fixed-site DF systems are especially prone to this hazard. This is particularly true in installations where a long interface cable set is employed as would be the case where the DF antenna is mounted atop a tall tower or mast.

With a significant distance between the DF antenna and DF receiver/processor, a significant electrostatic charge can accumulate on the antenna relative to the receiver/processor. This relative charge can become especially large if wind is blowing on the antenna. As a result, *connecting the antenna control cable to the DF processor under such circumstances can result in a severe electrostatic discharge that can damage both the DF processor and antenna if reasonable precautions are not taken.*

We therefore recommend that the following steps be taken prior to connecting the DFA-1333B1 to the DF receiver/processor.

1. Tower Grounding - Be sure to earth-ground the tower or supporting mast upon which the DFA-1333B1 is mounted. This earth-ground should be low resistance. Typical earth grounding techniques include the use of metal ground stakes and buried wires.

2. RF Cable Shield Grounding - Since the DFA-1333B1 mast is non-conductive, grounding the tower does not ground the antenna chassis or RF cable shield. In installations where an extension cable is used (i.e., when there is a large physical separation between the DFA-1333B1 and the operator), this is most conveniently done at the junction point where the DFA-1333B1 RF output cable is connected to the RF extension cable. To obtain a good earth ground at this point, use a bulk-head cable junction connector or adaptor and directly mount it to the metal frame of the tower for good electrical contact.
3. Operator Console Grounding - Be sure that the DF processor and receiver are also connected to earth ground. *Although the AC safety ground is usually adequate for this purpose, do not automatically assume that the DF processor and receiver chassis are connected to AC safety ground. Since these units will likely be run from DC power sources that may be electrically isolated from the AC safety ground, effective earth grounding may not exist.* It is therefore necessary to verify first-hand that the DF

processor and receiver chassis are both firmly electrically bonded to AC safety ground. If they are not, then it will be necessary to add a safety ground wire for this purpose. Also be sure that the DF processor and receiver are firmly electrically bonded to each other.

Once the above earth grounding requirements have been met, we also recommend that the following procedure be followed when connecting the DFA-1333B1 to the DF processor and receiver:

1. First connect the RF cable to the DF receiver. The BNC connector is designed so that the ground contact is made before the inner conductor when the BNC plug is inserted into the BNC socket. This will help equalize static charges between the DF antenna and the DF processor/receiver.

2. Once the RF cable has been connected to the receiver (and the static charges equalized as discussed above), the DF antenna control cable plug can then be safely inserted into its mating socket on the DF processor.

SECTION VI - SIMPLIFIED THEORY OF OPERATION

In the most general sense, all non-rotating radio direction finding systems employ a DF antenna having an array of spatially-displaced aerials (three or more are required for unambiguous operation) that are illuminated by the received signal wavefront. The resulting voltages produced by these aerials exhibit attributes (phase, amplitude, or both) that are then measured. Since these characteristics are unique for every received azimuth in a properly designed DF antenna, the wavefront angle-of-arrival (bearing) can be ascertained by appropriately processing and analyzing these aerial output voltages.

The specific DF technique employed by RDF Products DF bearing processors and associated antennas is known as the *single-channel Watson-Watt DF technique*. A single-channel Watson-Watt DF system can be broken down into the following four basic functional blocks:

1. DF Antenna
2. DF Receiver
3. DF Bearing Processor
4. DF Bearing Display

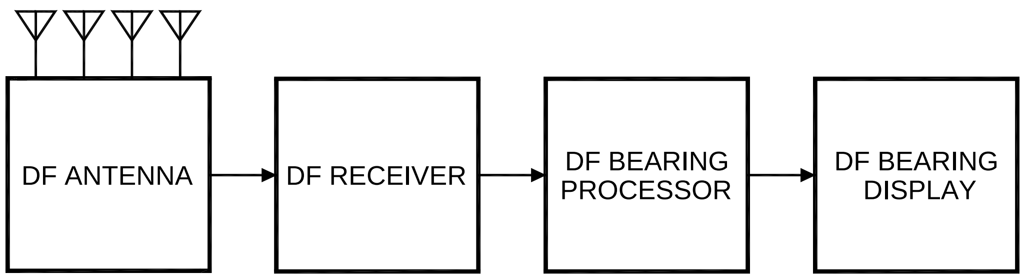


Figure 8 - Watson-Watt DF System Simplified Functional Block Diagram

As per Figure 8, the DF antenna receives the incoming wavefront, appropriately processes the signal and feeds it to the DF receiver. The DF receiver further processes the signal, demodulates it, and feeds it to the DF bearing processor. The DF bearing processor then provides additional signal processing and converts the signal into a format suitable for driving the DF bearing display.

A standard Watson-Watt DF system employs either Adcock or loop DF antennas, with Adcocks usually preferred because of their superior performance. Actually, the DF antenna is really an array of three separate but co-located antennas. Referring to a 4-aerial Adcock configuration, the first of these antennas is the N-S bi-directional array comprising the north and south aerials. As illustrated in Figure 9 below, the resulting figure-of-eight azimuthal gain pattern consists of circular lobes with maximum sensitivity to the north and south and nulls to the east and west. This figure-of-eight gain pattern is obtained by applying the N and S aerial voltages to a *differencing* network that vectorially subtracts them (N-S).

The second of these antennas is the E-W bi-directional array comprising the east and west aerials. Again as illustrated in Figure 9, its azimuthal gain pattern is identical to that of the N-S bi-directional array, but orthogonally oriented (as a consequence of the fact that the two arrays are physically at right angles to each other). This pattern is again obtained by applying the

E and W aerial voltages to a differencing network that vectorially subtracts them (E-W).

The third of these antennas is the omni-directional sense antenna. In early Adcock designs, a *central* sense antenna was implemented using a single aerial physically centered in the Adcock array. Most (but not all) modern Adcock antennas employ a *derived* sense antenna configuration whereby the omni-directional pattern is derived by vectorially *summing* the output voltages of all four aerials. This omni-directional sense azimuthal gain pattern is illustrated in Figure 9. The sense antenna is required to resolve a 180° bearing ambiguity that would otherwise result. Early Watson-Watt DF systems required three separate but very carefully matched receivers to process the three DF antenna outputs. Since this was expensive and it was operationally difficult to maintain the precise gain and phase matching among the three receivers necessary for good bearing accuracy, an antenna axis tone encoding (modulation) scheme was developed so that all three DF antenna outputs could be combined into a single composite signal that could be fed to a single receiver. Essentially, this is done by amplitude modulating the N-S bi-directional output with one tone and the E-W bi-directional output with another. The receiver then processes this composite signal in the standard fashion and recovers the two tones (whose respective amplitudes are now proportional to the two bi-directional antenna outputs) from its AM demodulator. These two tones are then fed to the DF bearing processor where they are separated and converted into proportional DC voltages, which in turn drive the bearing display.

Analog bearing displays are typically two-phase devices such as a CRT or magnetically controlled mechanical pointer. For a CRT display, these two DC voltages drive the CRT X and Y deflection amplifiers, resulting in a true real-time polar bearing display. For a mechanical pointer display, these two DC voltages drive the X and Y deflection coils.

Bearings can also be computed in software and then displayed in a variety of different formats. This is typically accomplished by first converting the X and Y DC voltages to a digital format using an analog-to-digital converter. The resulting digitized representation of the DC voltages is then fed to a microprocessor, which in turn computes the bearing in software using a 4-quadrant arc-tangent algorithm. Once the bearing has been computed, the microprocessor can then drive one or more of several different bearing displays, including azimuth rings, numeric displays, or even computer emulations of analog bearing displays.

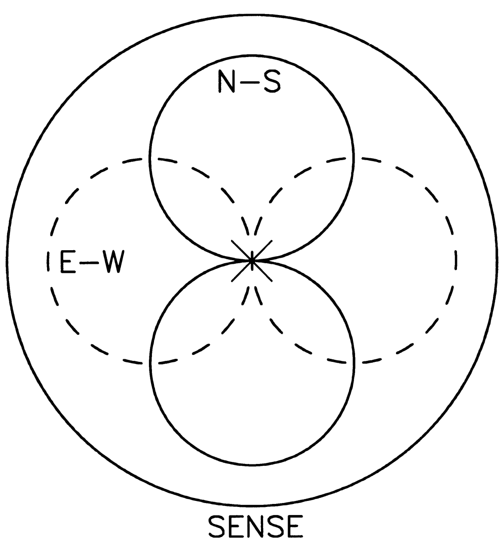


Figure 9 - Adcock DF Antenna Azimuthal Gain Patterns

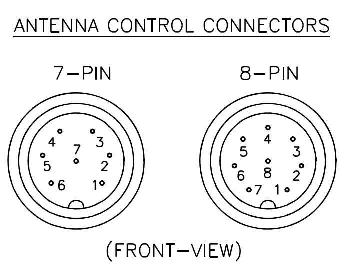
For a more detailed explanation of the Watson-Watt DF technique, see RDF Products Web Note WN-002 ("Basics Of The Watson-Watt DF Technique"). WN-002 can be downloaded from the RDF Products web site at www.rdfproducts.com, and is also included on the RDF Products publications CD.

APPENDIX A - MULTI-CONDUCTOR CABLE MATING CONNECTOR PIN-OUT

Refer to Figure 10 below for the pin-out of the *mating connector* for the female microphone (mobile radio) connector terminating the multi-conductor (antenna control) portion of the antenna interface cable set. This is the "Antenna Control" male chassis connector on the DF receiver/bearing processor.

Note that while the current "B-series" equipment employs an 8-pin connector for this purpose, earlier DF processors (e.g., the DFP-1000, DFP-1000A, DFP-1010, DFR-1000, and DFR-1000A) employ a 7-pin connector. Figure 10 illustrates both connector styles along with a pin-out list.

As can be seen from the illustration, the pin-outs are nearly identical, with the only difference being how the ground connection is implemented. With the 7-pin version, the connector metal shell (body) is relied upon to provide the ground connection. With the 8-pin version, the added 8th pin provides the ground connection. The standard microphone connector termination for the DFA-1333B1 control cable is the 8-pin version, although users with earlier DF processors can purchase the RDF Products DCA-087 Cable Adaptor.



PIN-OUT
PIN 1 – X-TONE
PIN 2 – Y-TONE
PIN 3 – BAND (BIT-1)
PIN 4 – BAND (BIT-2)
PIN 5 – BAND (BIT-4)
PIN 6 – +13.8 VOLTS OUT
PIN 7 – BAND (BIT-3)
PIN 8 – GROUND (8-PIN ONLY)
SHELL – GROUND (7-PIN ONLY)

Figure 10 - Control Cable Mating Connector Pin-Outs

The pin functions are explained below:

Pin 1 - X-axis encoding tone from DF receiver/bearing processor (1 volt p-p sinusoid).
Pin 2 - Y-axis encoding tone from DF receiver/bearing processor (1 volt p-p sinusoid).
Pin 3 - Antenna bandswitch line (Bit-1).
Pin 4 - Antenna bandswitch line (Bit-2).
Pin 5 - Antenna bandswitch line (Bit-4).
Pin 6 - 11-16 volt DC power from DF receiver/bearing processor.
Pin 7 - Antenna bandswitch line (Bit-3).
Pin 8 - Ground (8-pin version only)
Shell - Ground (7-pin version only). The connector shell must be connected to the DF receiver/bearing processor chassis ground.

Note that while the DFA-1333B1 is a single-band DF antenna requiring no bandswitching, setting all four bandswitch lines low signals the personality module to report the model and band information. This information is sent as a 300N81 RS-232 data string in TTL format, and is sent repeatedly as long as all four bandswitch lines are held low. The string format is as follows:

DFA-1333B-1, 108-250, 250-520<CR><LF>

APPENDIX B - INTERFACE CABLE EXTENSIONS

Although the supplied captive 8-meter interface cable set should be sufficiently long for most applications, there may be some applications where a longer cable is necessary (e.g., if the DFA-1333B1 is to be mounted atop a tall tower, or if the operator's console cannot be located close to the DF antenna). Although this can be done, there are certain issues that the user should keep in mind.

Addressing first the 8-conductor control cable, this cable can be extended out to 100 meters. This cable should employ #22 AWG wires with a weather-proof jacket. If the cable will be in direct sunlight, the jacket should have an appropriate UV rating. Alpha Wire & Cable P/N 1178C works well for this purpose (available from Mouser Electronics, Inc.; P/N 602-1178C-500 (the last three/four digits specify the cable length in feet, with standard lengths of 100/500/1000 feet).

Mating connectors are available to match the 8-pin mobile radio plug connected to the end of the 8-meter antenna control cable. Keep in mind, however, that these mobile radio connectors *are not waterproof, so it will be necessary to seal the junction to prevent water intrusion if this junction is outdoors.*

Alternatively, the 8-pin mobile radio plug can be cut off and the end directly spliced onto the extension cable. Again, this junction must be appropriately sealed against water intrusion.

For a long cable run, it is possible that there may be excessive voltage drop through the +13.8 VDC line. It is important that the user verify that the DC supply voltage presented to the DFA-1333B1 *be no less than 11.0 VDC under full load* (i.e., with the antenna connected) to guarantee that the internal voltage regulator will not drop out of regulation. If the voltage presented to the DFA-1333B1 is less than 11.0 VDC, the most expedient means to correct this is to "goose-up" the head-end DC power supply voltage (connected to the DFP-1000B/DFP-1010B DF processor) slightly.

Many DC power supplies have internal adjustments allowing the output voltage to be raised or lowered slightly. If this is the case, the output voltage can often be raised to offset the antenna control cable wire voltage drop. Since the DFP-1000B/DFP-1010B can accept up to +16 VDC, there is considerable latitude to raise the supply voltage as required to offset this voltage drop. (Be certain, however, that this voltage does not exceed the host receiver inputd DC voltage rating if this host receiver is powered from the same supply.)

For a fuller discussion of this DC voltage drop issue, see Section IV ("Extended Interface Cable Lengths") of the "DMA-Series Mobile Adcock Radio Direction Finding Antennas" Operator's Manual. This manual can be downloaded from the RDF Products website.

With regard to the RF output cable, an extension can be added using an appropriate coaxial cable adaptor as required. If this junction is outdoors, it will have to be weather-sealed if the junction is not inherently weather-proof.

The two major concerns with respect to the selection of a suitable RF extension cable are cable loss and cable shielding. Since coaxial cables have significant loss in the 108-520 MHz range covered by the DFA-1333B1, a premium low-loss cable must be used for a long extension. As a point of reference, matched cable loss per hundred feet for RG-223 (the RF output cable supplied with the DFA-1333B1 is approximately 4.8 dB at 108 MHz and 12.0 dB at 520 MHz (for 50 feet these dB loss figures would be halved). Since losses of this magnitude can noticeably degrade system sensitivity (especially at the higher frequencies), it is better to use a premium low-loss cable such as RG-214 (with corresponding 100 foot cable losses of 2.4 dB at 108 MHz and 5.8 dB at 520 MHz).

If extension cable losses cannot be kept within reasonable bounds, a cable line amplifier can be employed. Since this amplifier is likely to be exposed to a large number of strong signals over a wide frequency spectrum, it is important that it be a premium device having very wide dynamic range and good strong signal handling capability so as to minimize the generation of intermodulation products that can interfere with desired signals.

Cable shielding is also very important. If inexpensive coaxial cable is used, it is likely to suffer from signal pickup that will degrade DF antenna performance. To explain, it is very important that nearly all signal pickup be from the DF antenna itself rather than from the coaxial feedline. If significant feedline pickup occurs, bearing errors and reduced sensitivity are the likely result. This shielding issue becomes more of a problem at higher frequencies and for longer cable runs.

It is therefore very important that double-shielded coaxial cables (i.e., RG-223 and RG-214) be used for cable extensions. *Always avoid less expensive substitutes such as RG-58 and RG-213 - these cables do not have adequate shielding.*

APPENDIX C - MORE ON LIGHTNING PROTECTION

Addressing DF system lightning safety issues more fully, we advise users to prioritize these issues in the following order:

1. First and foremost, *protection of personnel must always be the highest priority*.

2. The next most important issue is the protection of all equipment at the operating console including the building housing this equipment.

3. The DF antenna and its associated cables are the final priority.

Issues #1 and #2 are best addressed using a special lightning protection interface panel for the DF antenna cables. This panel includes lightning arresters that are intended to protect personnel and equipment at the operator console. These panels are specialized products that can be obtained from various sources. One of these sources is PolyPhaser (www.smithspower.com/brands/polyphaser/). PolyPhaser also posts relevant literature on this website that is well worth the time to read.

Unfortunately, the DF antenna itself is very hard to protect from a lightning strike. Although one might think that a tall grounded lightning rod extending vertically through the center of the chassis would serve this purpose, this is not the case for the following two reasons.

First, keep in mind that any conductive object in the vicinity of the DF antenna is an *unintended parasitic re-radiator*. In effect then, *this conductive object becomes part of the DF antenna*. In the general case, this undesired parasitic re-radiation results in pattern distortions that can cause serious performance degradation.

For a fuller discussion of this issue, see our 1999 Application Note AN-005 ("An Introduction to Dipole Adcock Fixed-Site DF Antennas"). In particular see the discussion in Section V-D ("Dipole Adcock Performance Degradation Caused by the Vertical Support Mast") beginning on page 13. This discussion details the adverse effects of the central vertical support mast (which in effect is what a lightning rod would be) on DF antenna gain patterns. The paper goes on to discuss how this issue is resolved in RDF Products dipole Adcock DF antennas by means of a special "iso-mast" (a special mast isolation technique employing ferrites).

Replacing this iso-mast with a lightning rod would reverse all of the careful and timeconsuming engineering effort that was invested in its development and would undo one of the premier features of RDF Products dipole Adcock DF antennas that distinguish them from less capable competing designs.

The second issue is that even if such a lightning rod could be installed with no adverse performance repercussions, it would almost certainly be ineffective in protecting the DF antenna. To explain, the discharge voltage of a lightning strike on the lightning rod would typically be in excess of 1,000,000 volts with a resulting current pulse peaking at over 10,000 amperes. In addition to likely structural damage, this massive current pulse would result in a localized electro-magnetic pulse (EMP) that would almost certainly destroy any semiconductors inside the DF antenna. (Unlike passive FM broadcast, TV, and shortwave receiving antennas, DF antennas contain active electronics.)

With these issues in mind, we believe that the best course of action is to invest whatever is necessary to protect personnel, operating equipment, and the building housing this equipment from a lightning strike as discussed above, but to recognize that there is no practical or reliable way to protect an antenna containing active electronics from this same event. <>