DATONG
ELECTRONICS LIMITED

R.F. DIRECTION INDICATOR

Direction finding attachment for use with existing narrow band FM receivers and transceivers.

MODEL DF

DISPLAY UNIT PLUS SPECIAL ANTENNA COMBINER CONVERTS ANY NBFM TRANSCEIVER INTO A RADIO DIRECTION FINDER. BUILT-IN R.F. ACTIVATED ANTENNA RELAY DIVERTS TRANSCEIVER OUTPUT TO NORMAL ANTENNA DURING TRANSMIT OR WHEN D.F. ATTACHMENT IS SWITCHED OFF.

FEATURES

- Works with any existing narrow-band FM receiver or transceiver. No modifications are needed. The only connections required are to the external speaker and antenna jacks.
- Gives a clear directional readout on a circular array of sixteen bright green LEDs.
- Display holds last reading when signal drops out.
- Very easy to use and install.
- Only a single coaxial cable needed between display unit and antenna combiner.
- Antenna combiner unit connects to four omnidirectional antennas to simulate a spinning antenna. Depending on the choice of antennas, operation is possible from 20 to 200 MHz.
- Professional quality at remarkably low cost. Display unit is based on two P.T.H. circuit boards. Gasket sealed combiner unit houses two conventional double sided PCBs.

SYSTEM DESCRIPTION

Model DF is a Radio Direction Finding (RDF) system which is designed as an add-on accessory for any existing narrow band FM communications receiver or transceiver. The only connections required to the receiver are to the antenna input and the external loudspeaker jack.

The system comprises two separate units. One contains control and display electronics and is located at the receiver; the other is a special antenna combining unit containing its own drive electronics and requiring only a single coaxial cable to connect to the control unit.

Directional read out is via sixteen green LEDs arranged in a circle at 22½° intervals.

When a signal is received its bearing relative to the antenna is indicated by whichever of the sixteen LEDs illuminates. In mobile applications this permits "homing" onto the signal, and at fixed stations when the antenna has been correctly aligned the compass bearing of the signal is directly indicated.

When used with transceivers an RF activated relay built into the control unit allows 'talk through' by diverting the transmitter signal to the normal antenna.

Model DF will work with FM receivers ranging from pocket scanners to mobile or marine radio telephones and including VHF amateur radio and CB transceivers.

In addition to the display unit and the antenna combiner unit, a complete system needs four omnidirectional antennas (e.g. conventional quarter wave whips or half wave dipoles) mounted in a square array (see later sections).

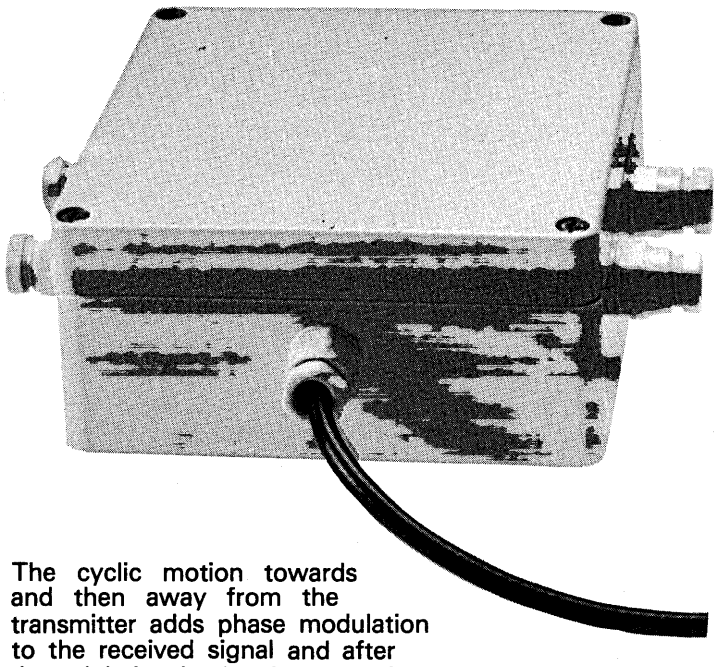
APPLICATIONS

Model DF costs between ten and a hundred times less than conventional RDF systems, and therefore opens up new application areas for both professional and hobby users.

Applications include: VHF amateur radio, Citizen's Band radio, aircraft spotting, tracking gliders and light aircraft, locating lost model aircraft, private mobile radio systems, coastal and marine radio, tracking and locating anti-social radio operators, locating 'tagged' animals in the wild, helping to identify or trace unknown transmissions, law enforcement.

HOW IT WORKS

Model DF uses the so called Doppler principle in which a single antenna moves rapidly in a horizontal circular path.



The cyclic motion towards and then away from the transmitter adds phase modulation to the received signal and after demodulation in the detector of an FM receiver followed by filtering, a sinusoidal signal is obtained. The frequency of this signal is equal to the rotation rate of the antenna, and its phase relative to the antenna rotation is related to the direction of arrival of the radio signal.

To avoid the obvious drawbacks of mechanical rotation, Model DF simulates a rotating antenna electronically. Four quarter wave whip or half wave dipole antennas are mounted at the corners of a square, the separation being between about 0.05 and 0.3 of a wavelength. A special electronically controlled attenuator using PIN diodes smoothly transfers the receiver connection from one antenna to another. The resulting signal is then similar to that obtained from an antenna actually moving in a circle yet without any mechanical complications.

TECHNICAL DETAILS

The Model DF system has been designed using the latest technology to give excellent performance at remarkably low cost.

Installation is greatly simplified by the fact that only a single coaxial cable is needed to connect the display unit to the antenna combining unit. The normal control cables associated with Doppler D.F. systems have been eliminated by placing a phase locked loop system plus drive electronics at the antenna. This reduces installation costs, especially where the antenna is remotely located, and also means that existing coaxial cable runs can be used if desired.

It also means that alternative special purpose antenna systems can be easily used with the system as and when they become available.

A major technical feature of Model DF is the smooth switching technique used in the head unit. This avoids one of the problems associated with conventional non-mechanical Doppler DF systems. Typically these use abrupt switching techniques to step from one antenna to the next in the circular array of antennas. With this technique the phase modulation waveform is stepped instead of smooth, and therefore all incoming signals have sidebands added corresponding to harmonics of the switching frequency. High order sidebands from a strong adjacent channel signal can often be sufficiently strong to cause serious interference to the desired signal. The PIN diode smooth–switching technique used in the Datong system was optimised using computer simulation methods and reduces such effects to a very low level.

Two commutated capacitor filters are used in the signal processing circuits. One of them extracts the modulation signal from speech and noise prior to the digital phase

comparison circuits. The bandwidth of this filter is controlled by the knob labelled "RESPONSE" and determines the speed of response of the display to a changing bearing. The second filter notches out the superimposed modulation signal so that it does not disturb normal reception. After notching, the signal passes via the "VOLUME" control to a 2 watt audio power amplifier (LM380) which then drives an external loudspeaker.

INSTALLATION AND OPERATION

A complete RDF system requires the following items of equipment.

1. A narrow band FM receiver for the desired frequencies.
2. Model DF control and display unit.
3. Model DFA1 or DFA2 antenna combiner unit. (These are identical except that Model DFA2 is fitted with a magnetic base for car roof installations and with a four metre output lead - see below).
4. Four identical antennas with coaxial cables to connect to item 3.
5. An external loudspeaker to plug into the display unit.

In addition a coaxial cable jumper lead (e.g. Datong LEAD D) will be required to connect between the receiver and the control unit. The control unit requires an external power source of 12 volts DC (from the car electrical system in mobile applications or from a mains power supply such as the Datong Model MPU).

The nature of the antennas mentioned in item 4 will depend on the application. For mobile use four magnetically mounted quarter wave whip antennas are ideal, and in this case Model DFA2 combiner unit would be appropriate since it can be conveniently mounted between the antennas on the car roof. For fixed station use, four ground plane antennas or four vertical dipoles should be mounted symmetically on a vertical mast together with Model DFA1 combiner unit.

In either case the distance between adjacent antennas should be between about 0.05 and 0.3 wavelengths.

The connectors fitted to the Display Unit are as follows: Audio input (Phono), Loudspeaker output (Phono), R.F. output to receiver (SO239 coaxial), R.F. input from D.F. antenna (SO239 coaxial), R.F. input from normal antenna (SO239 coaxial). Power supply (3.5mm jack, and concentric type DC connector wired in parallel).

Connection to the antenna combiner unit is via five two-pole screw connector blocks mounted on an internal PCB. Each connector accepts a coaxial cable which enters the box via one of five waterproof compression glands. Model DFA1 is supplied without any cable, while the magnetic version, Model DFA2, is supplied fitted with a four metre coaxial output lead terminated in a PL259 plug to suit the Display Unit.

TECHNICAL INFORMATION

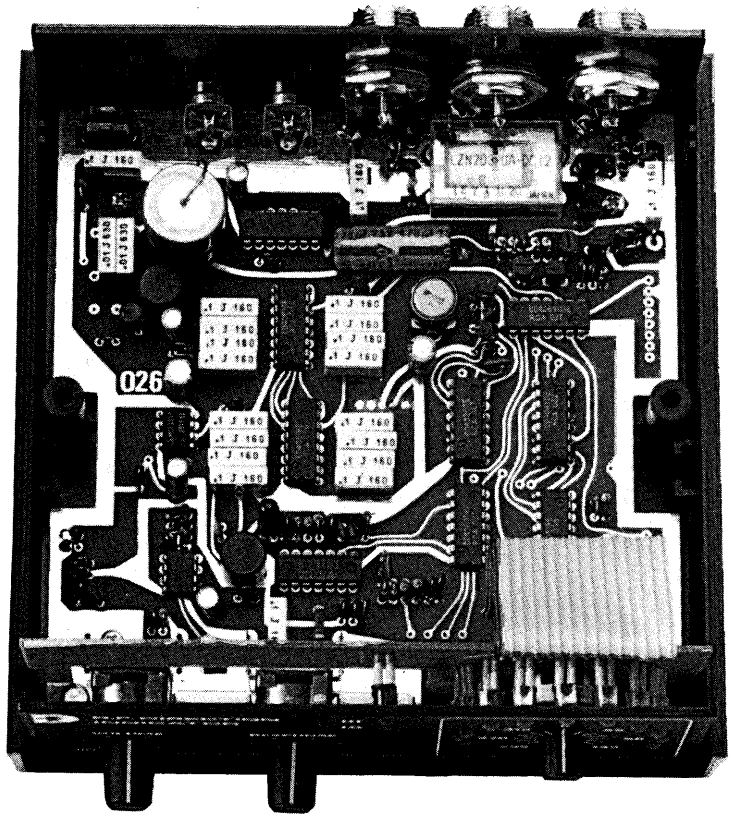
Supply voltage:	10 to 15 volts DC
Supply current for display unit only:	400 mA (full audio volume) 70 mA (quiescent)
Supply current for antenna combiner:	10 mA. The supply is automatically fed together with synchronising signals from the display unit via the coaxial antenna feeder.
Current limit:	the display unit is protected against damage due to short circuits in the coaxial cable feeding the combiner unit.
Frequency range:	20 to 200 MHz, depending on the chosen antennas.
System accuracy:	± 5 degrees. Initial zero trimming (via knob at centre of display) on a known signal is needed to compensate for any audio phase shifts in the receiver.
Readout:	16 bright green LED's at 22½ degree intervals, giving a resolution of + 11¼ degrees.
Audio power output:	1.2 watts into 8 ohms, 2 watts into 4 ohms (assuming 3% distortion and 12.5 volt supply).
Controls:	Audio volume, response time, phase trim, CONT/BLANK (display either stays on continuously or goes out approx 5 seconds after signal ceases), NML/INV (allows for odd or even number of stages in the receiver's audio system).
Antenna commutation frequency:	876Hz
Dimensions:	Model DF (Display Unit), width 153mm (6 inches), height 64mm (2.5 inches), depth 158mm (6.2 inches). Knob and connector projections add 18mm (0.7 inches) to depth. Model DFA1 and DFA2, 120 x 120 x 55 mm (4.7 x 4.7 x 2.2 inches) Cable glands protrude 20mm (0.75 inches). Magnet adds 15mm (0.6 inches) to height.
Approx. weights:	Model DF 500 gms (18 ounces) Model DFA1 340 gms (12 ounces) Model DFA2 700 gms (25 ounces)

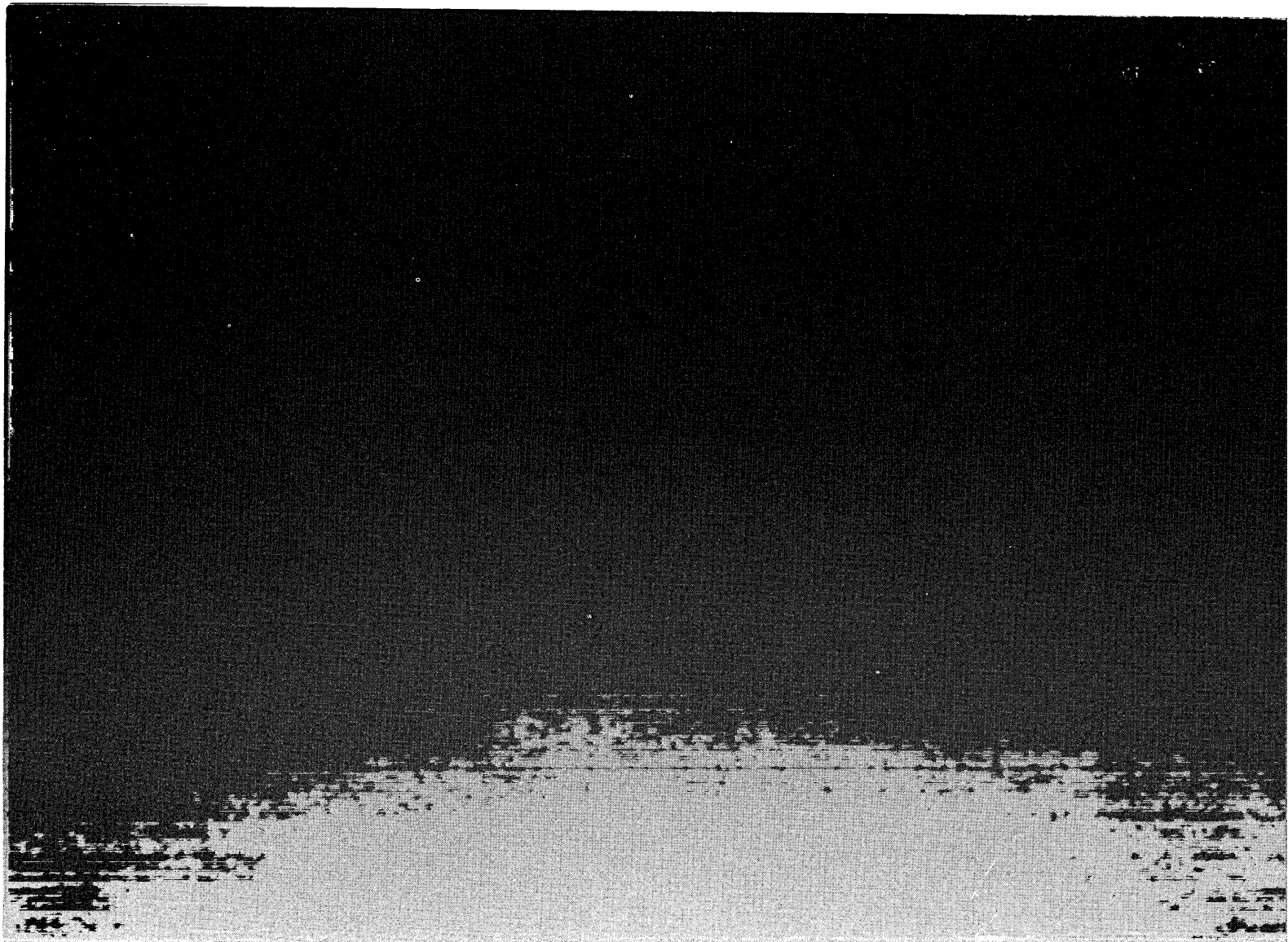
ACCESSORIES

Model DF (Display Unit) is supplied with two power supply connectors, and two 1 metre screened leads with phono plugs at one end, the other end being unterminated. The leads allow easy connection to receiver and loudspeaker.

OPTIONAL ACCESSORIES

Model MPU:	mains power unit.
LEAD D:	coaxial jumper lead 1 metre long with PL259 coaxial plug at each end.
Model MA1:	a good quality quarter wave whip antenna with magnetic mount and four metres of coaxial cable. (Four are needed for a DF system).





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MODEL DF - OPERATING INSTRUCTIONS

INSTALLATION

1. Power supply

A DC power source of between 11 and 15 volts should be connected to either of the two power connectors on the rear panel. In both cases the centre pin is positive and the outer negative. The negative terminal is connected internally to system ground.

Caution

It is recommended that normally the upper power supply socket is used. If the 3.5 mm jack socket is used the supply will be momentarily short-circuited when the jack is inserted or removed. This could damage an unprotected power supply, or blow a fuse in a car.

2. Interconnections

RF connections should be made using normal coaxial cables with PL259 connectors to suit the SO239 sockets on the rear panel of Model DF. Normally Model DF will be located close to the receiver or transceiver in which case a short coaxial jumper (such as the Datong accessory "LEAD D") should connect between the "RECEIVER" terminal on Model DF and the antenna terminal of the receiver. A longer coaxial cable should then be used to link the antenna combiner (Models DFA1 or DFA2) with the "DF ANTENNA" connector on Model DF. The receiver's original antenna can then be connected to the "NORMAL ANTENNA" terminal on Model DF. An internal relay connects the "RECEIVER" and "NORMAL ANTENNA" jacks together when the DF system is switched off or if the transceiver is switched to transmit.

The Phono leads supplied should be used to connect the "AUDIO IN" jack to the external loudspeaker jack on the receiver, and to connect the "AUDIO OUT" jack to a loudspeaker.

WARNING - do not transmit into Model DF with more than 20 watts otherwise damage may occur.

3. Antennas

Model DF is designed to operate with four identical omnidirectional antennas mounted in a square array. Circuitry in the combiner unit switches the feeder sequentially to the four antennas so as to simulate the effects of a single antenna moving around a circle at 876 Hz.

For the simulation to be effective it is important that the four antennas, and their feeder cables to the combiner unit, are identical. Any differences in feeder lengths or antenna characteristics will introduce asymmetrical phase shifts and cause bearing errors.

Best results will be obtained using simple quarter wave whip antennas or other relatively wide bandwidth antennas. Gain antennas or antennas using loading coils are not recommended because their high Q (narrow bandwidth) means that exact electrical matching is not likely to be achieved. It is also recommended that the four feeder cables to the combiner unit are kept reasonably short. Ideally they should be an electrical half-wave in length, which for normal coaxial cable means that their actual physical length should be 0.33 times the operating wavelength.

If L is the actual length of cable in metres, L can be calculated from:

$$L = 0.33 \times W$$

or

$$L = 0.33 \times \frac{300}{f}$$

Where W is the operating wavelength in metres and f is the operating frequency in MHz.

For best accuracy take care to put the antennas accurately at the four corners of a square. The important thing is to maintain a high degree of symmetry.

In mobile applications four magnetically mounted quarter-wave whip antennas are recommended, with Model DFA2 combiner unit placed at the centre of the square between them.

For fixed use four dipoles could be mounted symmetrically about a vertical mast.

In all cases the separation between antennas (i.e. the length of the side of the square) should be between 0.05 and 0.3 of a wavelength. Generally large spacings will give steadier readings than smaller spacings because of the increased depth of modulation given to the incoming signal by the antenna commutation. When the incoming signal is modulated by speech this improvement can be quite beneficial. If however the signal does not carry its own frequency or phase modulation smaller spacings will still give good results.

4. Connecting the antennas

Models DFA1 and DFA2 combiner units are identical inside. Connection to the main feeder and to the four antenna feeders is by five pairs of screw terminals. Access to the terminals is obtained by first removing the lid of the box by loosening the four captive screws in its lid. Two printed circuit boards will then be visible. Remove the four screws holding the top board and lift the board carefully to one side to expose the five terminal blocks on the lower board. Take care not to bend the flat jumper cable at points close to where it enters the PCB otherwise the wires will ultimately fatigue and break.

The feeder cables should be passed through the waterproof bushes in the case and connected as shown in the diagram. Finally tighten the bushes to clamp the five cables, and replace the box lid.

5. Description of controls

"Volume - on-off". This switches off power to Model DF when turned fully anti-clockwise, and is used as the main volume control when Model DF is in normal use.

"Response" This controls the bandwidth of the signal processing section of the system and therefore affects the response time of the display. When the control is fully anticlockwise the response is very rapid (widest bandwidth), while at the other extreme the display will take approximately one second to respond to a large change in bearing.

"LO" and "HI" lamps. These lamps are used as a guide to the correct input level of the unit. When the "LO" lamp is on, the input is too low to give a good bearing. Whenever the "LO" lamp is on, the display is frozen and holds its previous bearing. The "HI" lamp illuminates when the input signal is approaching

the maximum level for which a reliable bearing can be obtained. In normal operation the "HI" lamp should flicker on and off during speech.

"CONT/BLANK" In the "BLANK" mode a frozen display will blank off completely after about ten seconds. In the "CONT" mode it holds its last reading indefinitely.

"NML/INV" This switch adds an extra 180° shift to the display. It is used to compensate for receivers with either an odd or an even number of inversions in their audio amplifiers.

"PHASE TRIM" The unlabelled knob in the centre of the display is used to trim the displayed bearing to the correct reading on a known signal. It compensates for unavoidable phase shifts in the main receiver.

6. Initial Testing

Connect up the system as already described and set the controls on Model DF as follows:

"VOLUME" and "RESPONSE" to mid setting;
"PHASE TRIM" (knob at centre of display) fully anticlockwise;
Both slide switches fully left.

Tune in a strong steady signal on the receiver and set the receiver's volume control so that the "HI" lamp flickers on speech. If listening volume adjustments are needed they should be made using the volume control on Model DF and not the one on the receiver.

The display will indicate a bearing, but this will not be very meaningful until the system is calibrated (see later section). Check the effect of the "RESPONSE" control. Notice that when set to its anticlockwise position speech on the transmission causes flicker of the reading. As the control is moved more clockwise this effect reduces but the display takes longer to settle on to a new bearing.

7. Calibration

Calibration simply involves adjusting the phase trim control (and if necessary the NML/INV switch) until the DF system gives the correct reading for a signal whose direction is known.

It is important to carry out this adjustment while the antennas are well clear of any reflecting objects and with a clear and unobstructed path between the test signal and the DF antennas.

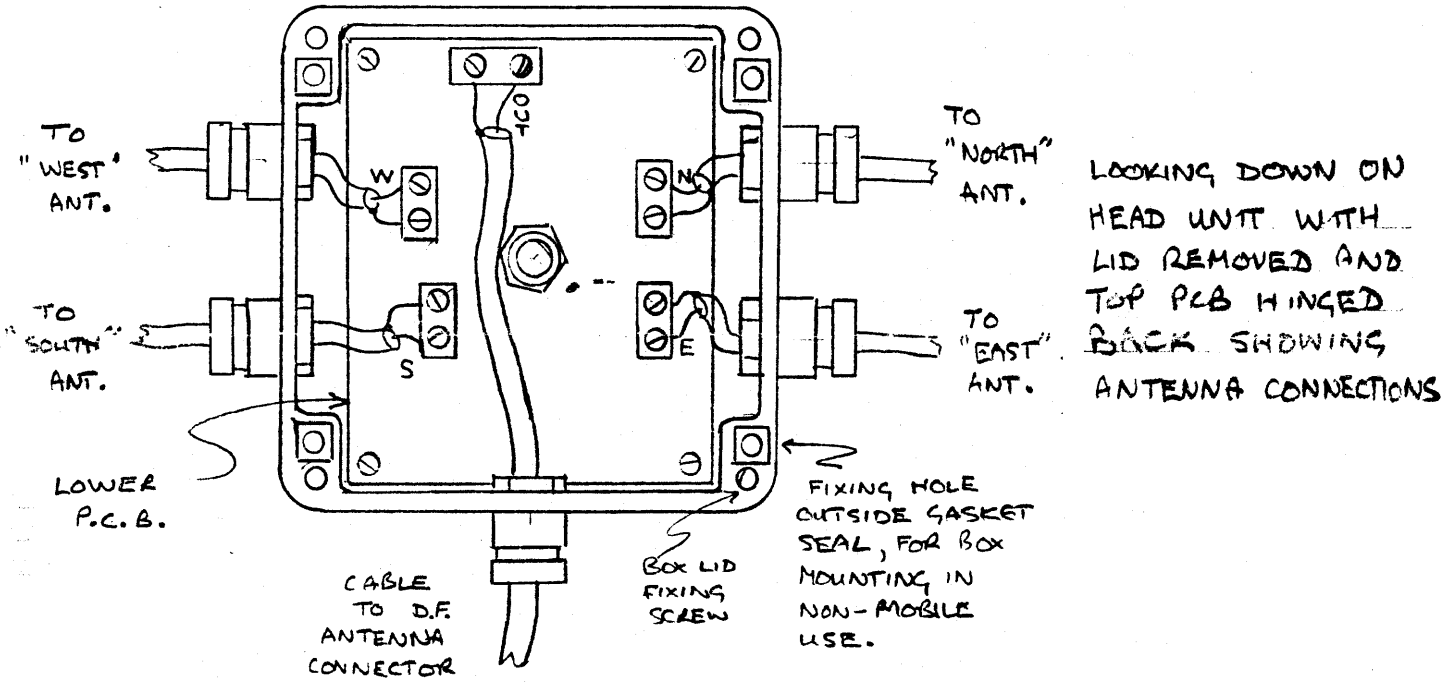
For a mobile system drive to a location on high ground which is as unobstructed as possible in all directions.

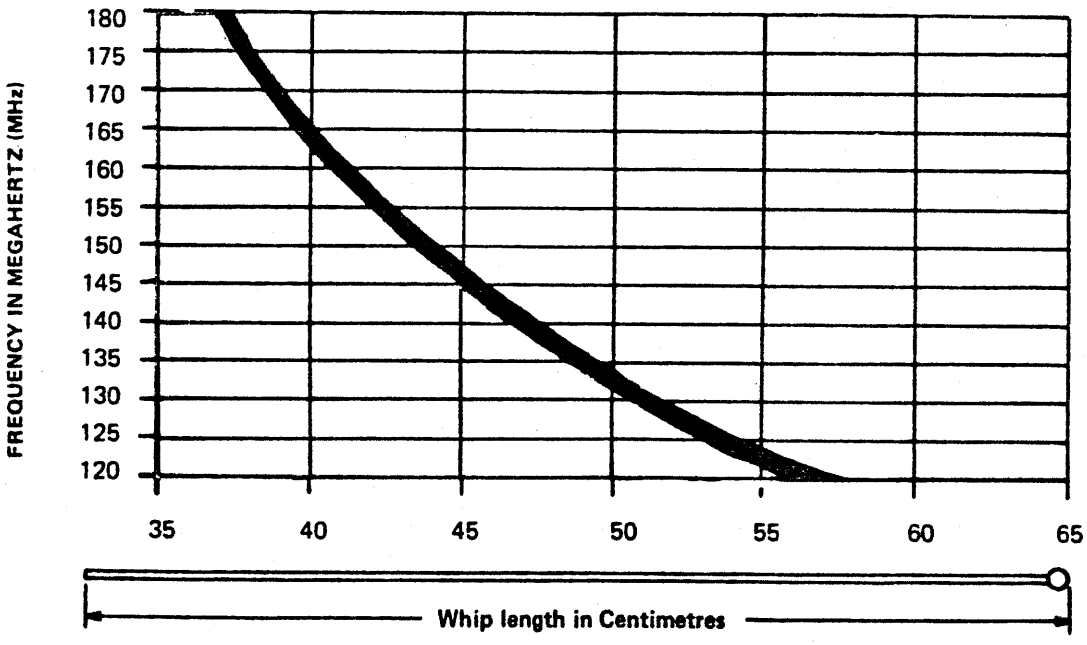
If no suitable test signal is already present a small self-contained test transmitter can be used. It should be placed at least 100 yards from the DF system.

Bear in mind that if the test transmitter is located near reflecting objects then its apparent direction may well be that of the reflecting object and not that of the transmitter.

The antennas should be mounted on the vehicle roof with the orientation shown in the diagram. The trim control should then be able to bring the bearing to a zero degree reading when the signal approaches from the front of the vehicle. (Note: try both settings of the "NML/INV" switch and choose the one which gives the smallest trim adjustment).

With a fixed installation the same comments apply. It is important that the antennas are mounted far from reflecting objects. In an urban area this means that a high mounting position is essential to clear neighbouring buildings. Indoor operation of the DF system will always be unsatisfactory due to multipath reflections and cannot be recommended under any circumstances.





CUTTING DETAILS FOR QUARTER-WAVE WHIPS (WHEN SUPPLIED)

OPERATIONAL NOTES

1. Effects of multipath reception

For best results with Model DF (or any other direction finder) the unit should be located far from any reflecting objects. Whenever the main signal is mixed with reflected signals the display will indicate some kind of average reading which generally will not correspond to the true direction of the transmitter.

When used mobile in non-hilly country areas the system will give steady readings most of the time. In cities on the other hand the operator will need to continously assess the quality of the bearing. Normally one finds while mobile that patches of steady readings are mixed with patches where the display fluctuates wildly. The experienced operator places more reliance on the former since if the display is steady it is likely that only a single signal path is being received. Remember however that this could still be a reflected signal if for example the DF is in a valley with the distant transmitter signal reaching the DF by reflection from the valley wall.

When the display is fluctuating rapidly some directional information is still obtainable since frequently the fluctuations will be centred on some average bearing. Naturally the wilder the fluctuation the less reliance should be placed on the indication In these circumstances it is a mistake to turn the RESPONSE control too far clockwise since this will tend to mask fluctuations and may give a false sense of confidence in the reading.

When tracking a transmitter it is best wherever possible to choose a route which keeps the DF system on relatively high ground. Also, given a choice choose wide roads among small buildings rather than narrow roads among high buildings.

2. Strong adjacent channel signals

Very strong signals nearby in frequency to a weak wanted signal may cause a spurious tone to appear on the weak signal. This effect is caused by deviations from true circular motion of the effective spinning antenna. In fact its motion approximates to movement in a square so that some higher order harmonics of the 876 Hz spinning frequency are present. Modulation sidebands produced from strong adjacent signals by these harmonics are the source of the interference.

3. Types of signal

The use of Model DF is not restricted only to narrow band FM signals. The only requirement is that the signals must be received using a narrow band FM receiver. Model DF will give good bearings on AM signals (especially because the directional modulation is then not contaminated by speech modulation) and also on SSB signals.

4. Receiver tuning accuracy

Mistuning of the receiver will have a significant effect on bearing accuracy only when the signal is tuned near to the edge of the receiver passband. Deliberate mistuning on a steady signal will easily show the magnitude of the effect. It depends on the selectivity characteristics of the particular receiver.

DATONG DF SYSTEM

The four aerials and combiner have magnetic mounts and are placed on the vehicles' roof with a North South East West orientation as indicated on the combiner. North being placed on the front left of vehicle.

The aerial spacing is dependant on the frequency required and is nominally 0.05λ to 0.3λ .In practice each side of the square is set at:

750mm for CB - 26 MHz
650mm for Police - 75 MHz

The aerial lead from the combiner is taken thru the door/window and connected to the "DF ANTENNA" on the Datong unit.

All connecting leads from the Datong to the receiver are made into one lead 2 metres long, and is connected as follows:

At the Datong DF unit:- Phono plug to AUDIO IN
Phono plug to AUDIO OUT
BNC Coaxialto RECEIVER
12v Centre pin connector to 12v POWER SUPPLY
The 'S' meter is permanently wired to the lead.

At the Kenwood receiver:- 7mm Audio plug to EXT METER Socket
BNC Coaxial to RX ANTENNA INPUT (50 or 500 ohms
3.5mm Audio socket to Speaker
3.5mm Audio plug to EX SPEAKER socket
Yellow din plug to VHF CONVERTER socket
Red/Green, 12v plug to power Converter (or other accessory)

The receiver is powered from the standard Rx power cord (fused) to bannana plugs.
The 50Ω Rx antenna input is the best match up to approximately 100 MHz

PTO for Opperation.