Interference from Nearby Transmitters

An Application Note from Doppler Systems

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Introduction

A question frequently asked by our customers is "How close can I mount a transmit antenna to the direction finding antenna." Typically we respond by telling the customer to keep the DF antenna well separated from the transmit antenna. However, practically all our customers have limited options on siting the direction finder. The purpose of this application note is to give our customers some guidance on locating direction finders relative to transmitters to avoid damage to the direction finder as well as to avoid desensitizing the direction finder.

Our radio direction finders are designed to operate over a wide frequency band. The fixed site systems, for example, use biconical dipole elements that provide octave bandwidths (VHF = 115 to 250 MHz, UHF = 250 to 500 MHz, and THF = 500 to 1000 MHz). Mobile systems used at VHF and UHF use quarter wave wire whips that are cut to the frequency of operation, but even here, the bandwidth is at least +/-10%. THF mobile antennas are a quarter wave stub element that is very broad banded.

The RF Summers which combine the 4 or 8 antenna elements are also very broadband. While this means that the same DF system can operate over a wide range of frequencies, it also means it is susceptible to interfering signals. For that reason, care must be taken when siting the DF system in order to avoid damaging the DF circuitry and to avoid reducing its sensitivity as a result of the interfering signal saturating the RF circuitry.

This application note contains graphs and tables to allow simple calculation of the interference levels reaching the DF and a means to predict the change in sensitivity as a results of that interference.

Isolation Calculations

The power received by the DF system is calculated by subtracting the isolation in dB from the transmitted power in dBm:

Received Signal Power (dBm) = Transmitted Signal Power (dBm) –Isolation (dB)

Isolation as defined this way includes the gains and efficiencies of the transmitter and DF antenna (including matching networks) as well as the propagation path loss. The propagation path loss is calculated using the EZNEC program for both fixed site and mobile DF antennas and a variety of interfering transmitter geometries.

For a mobile DF, a medium loss ground is assumed while for fixed sites, the ground is ignored and free space propagation is assumed. As shown in Figure 1, ground reflections cause +/- 10 dB variations from free space path loss up to about 1000 ft at 300 MHz. At distances greater than 1000 ft, free space loss is lower, and it increases at a lower rate (20 dB/decade vs 40 dB/decade over an average ground).

In mobile DFs, the range is generally less, the height is limited to car roof, so it makes sense to include the effect of an average ground. Fixed site DFs are typically mounted between 30 and 100 ft high, and the isolation calculations use free space (no ground) to be conservative. (Lower isolation causes stronger DF interference).

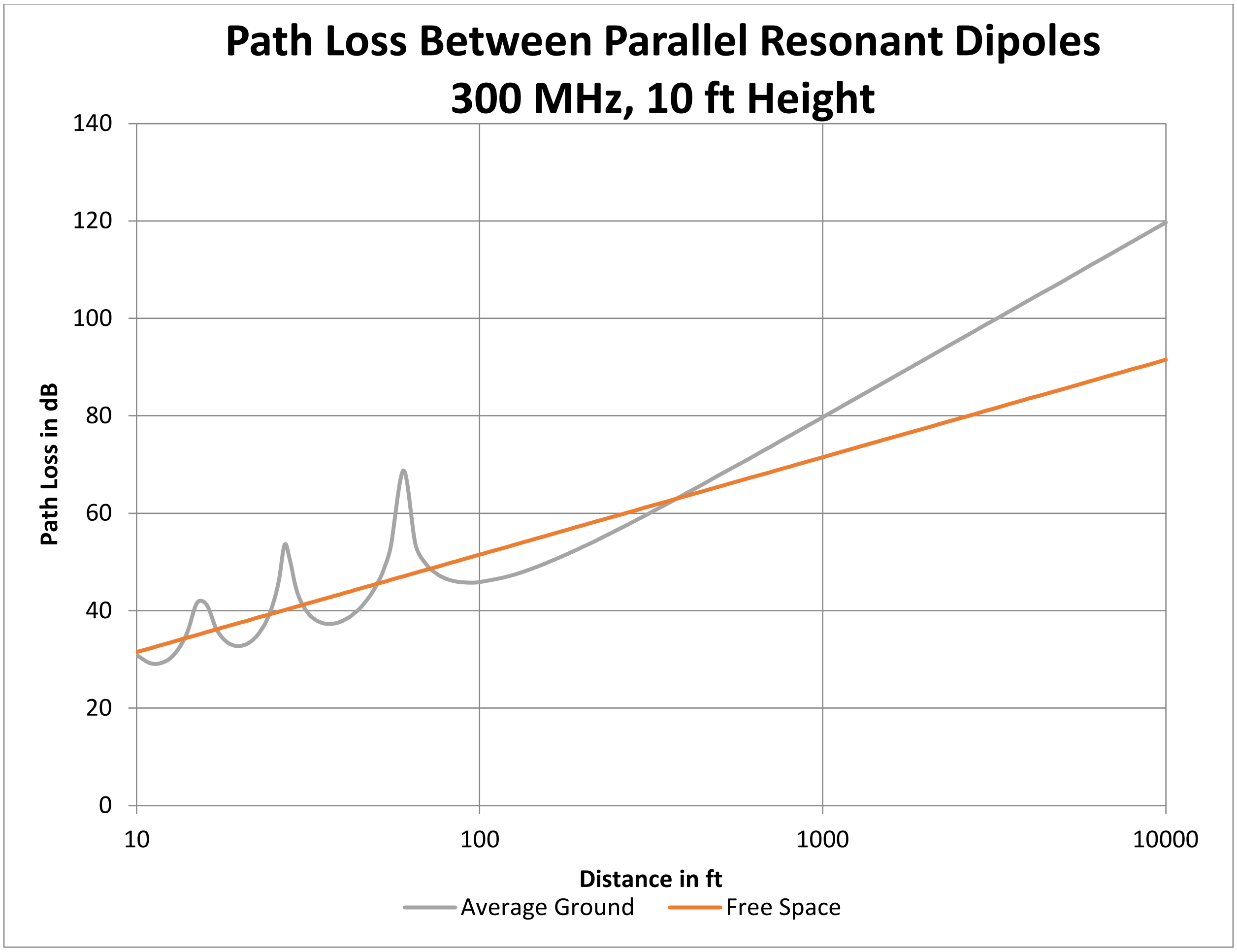

Figure 1 Comparison of Path Loss of Free Space and with Average Ground

Mobile DF antennas consist of a set of four monopoles on a ground plane – car roof for VHF and UHF, square plate for THF. Fixed site DF antennas are a circular array of 8 biconical dipoles

The transmit antenna is assumed to be a dipole resonant at the transmit frequency located in the XY plane with its center a distance *D* from the center of the DF array and at an elevation angle *E* of 0, 30, 60 or 90 degrees.

Interfering frequencies *F* chosen represent the FM broadcast band (96 MHz), the VHF band (150 MHz), the UHF band (450 MHz) and the THF band (900 MHz).

The DF antennas are always vertically polarized, but the interfering transmitter can be either vertically, horizontally or circularly polarized. To be conservative, however, the interfering transmitter is assumed to be vertically polarized (VP). This causes the lowest isolation (maximum interference).

Four VHF Monopoles on Car Roof, Transmitter Antenna Vertically Polarized

The car roof is assumed to be 3.5 ft wide by 5.5 ft long, typical of a medium size SUV. It is 5.5 ft high. The antennas are four 18 inch whips arranged in a 18 inch square and centered on the car's roof. The car roof is connected to the earth ground (XY plane) through the car body and tires. The interfering transmit antenna is in the YZ plane.

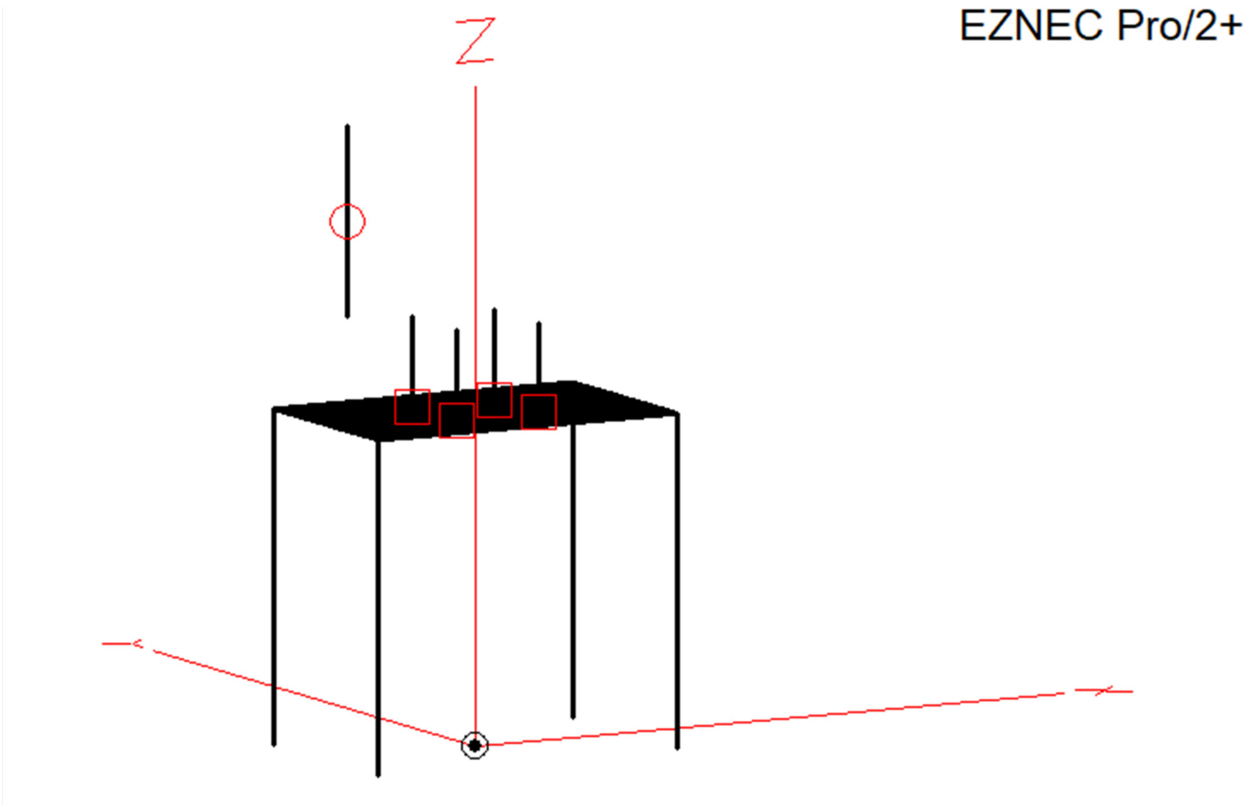

Figure 2 Geometry of 4 VHF Monopoles, VP TX Antenna

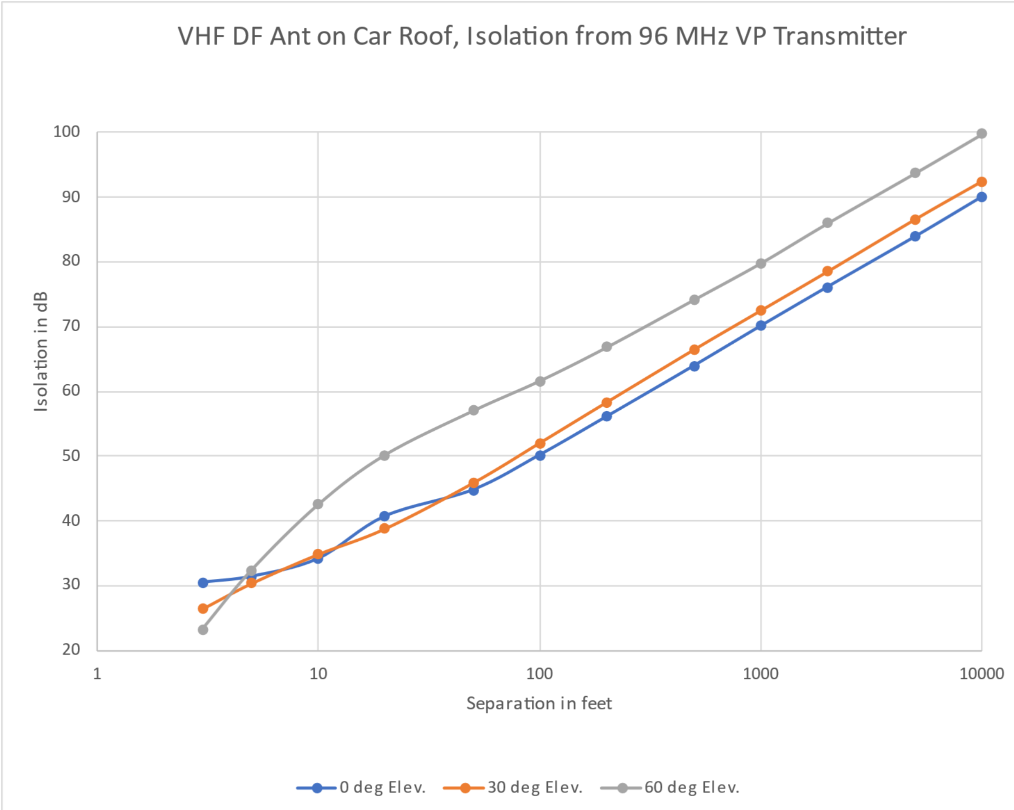

Figure 3 4VHF Monopole DF, 96 MHz VP TX Antenna Isolation

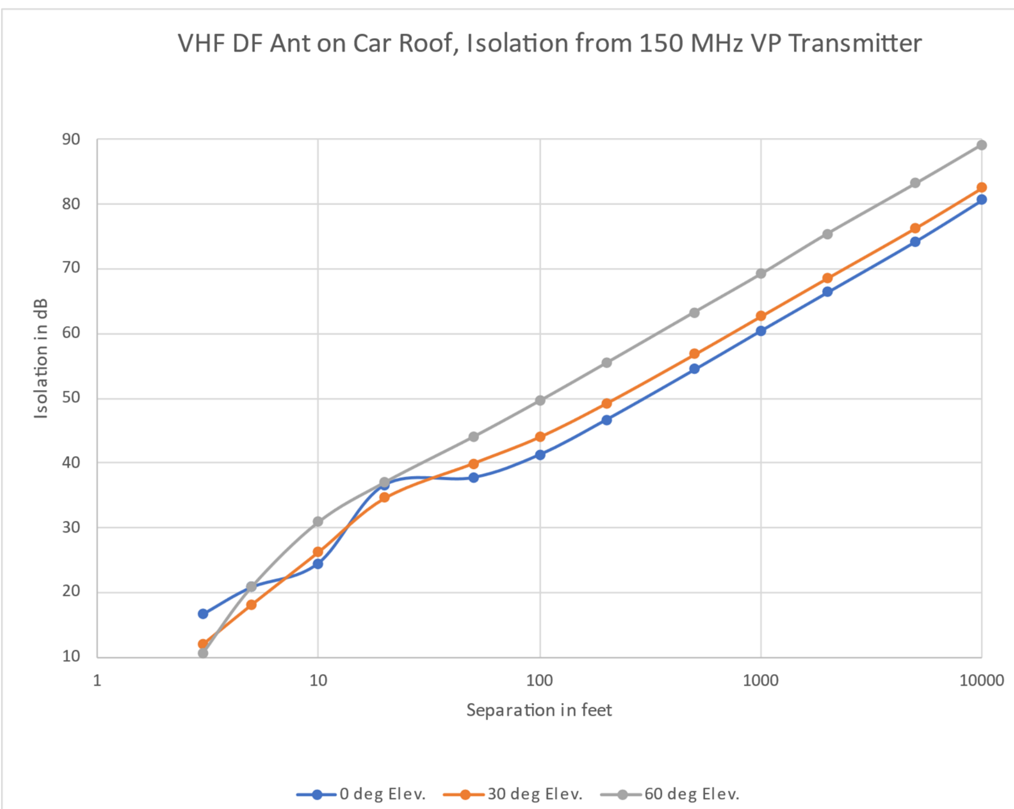

Figure 4 4VHF Monopole DF, 150 MHZ VP TX Antenna Isolation

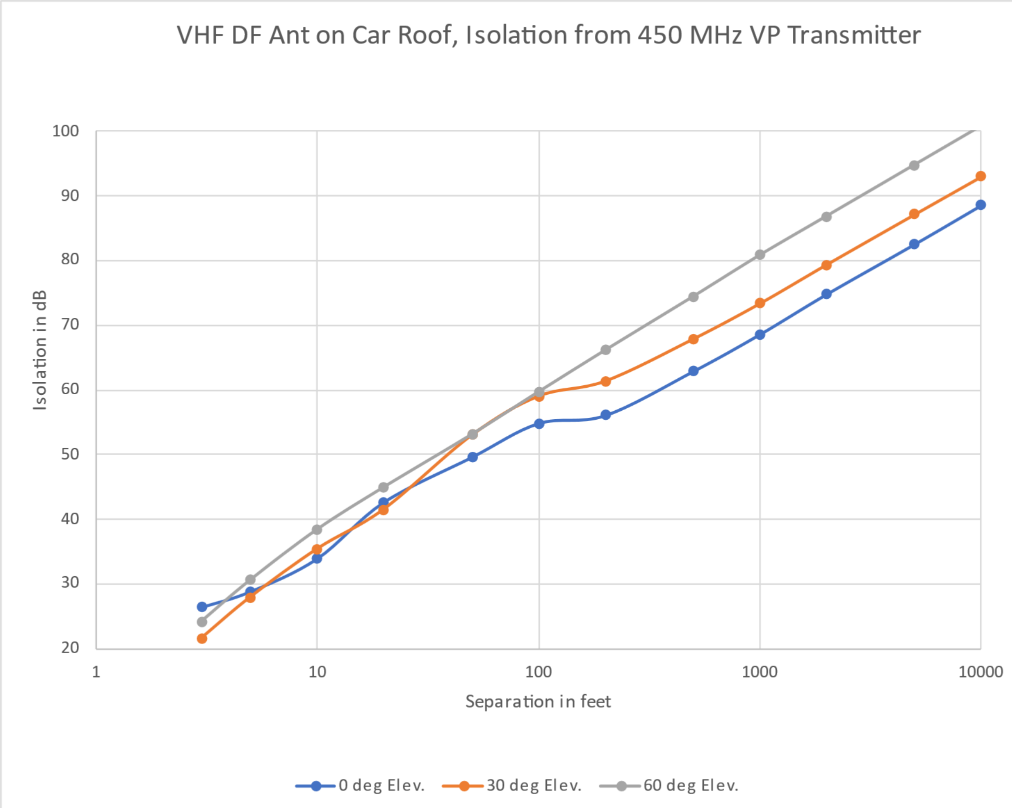

Figure 5 4VHF Monopole DF, 450 MHZ VP TX Antenna Isolation

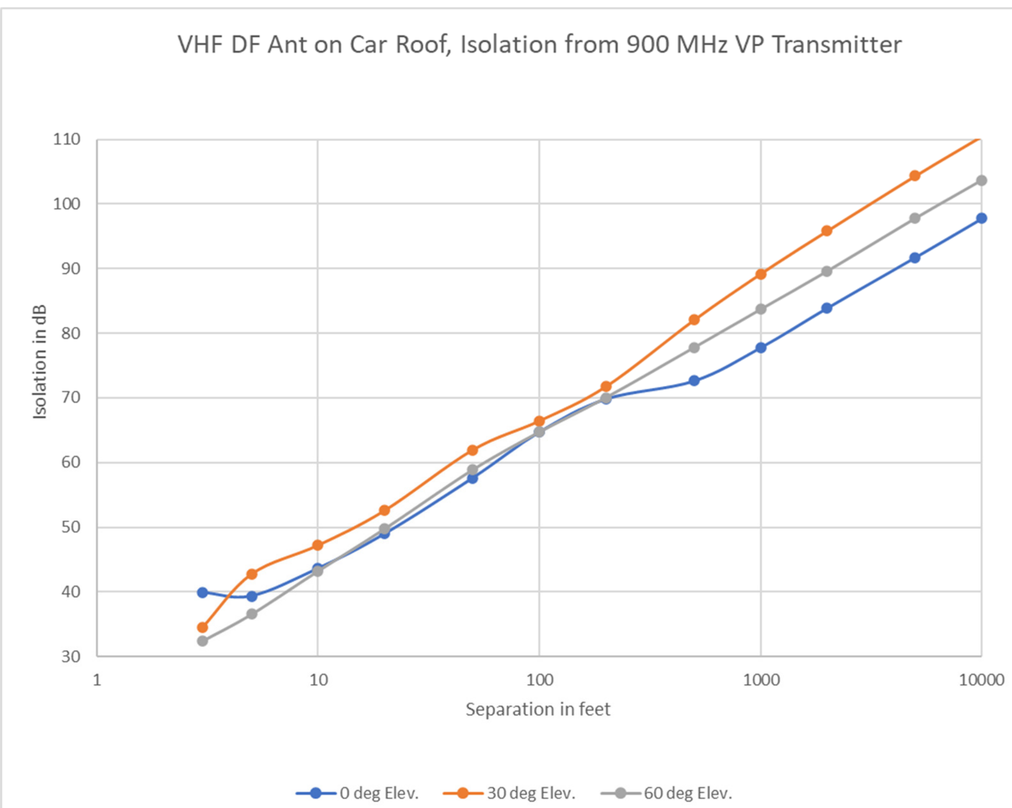

Figure 6 4VHF Monopole DF, 900 MHZ VP TX Antenna Isolation

Four UHF Monopoles on Car Roof, Transmitter Antenna Vertically Polarized

The car roof is assumed to be 3.5 ft wide by 5.5 ft long, typical of a medium size SUV. It is 5.5 ft high. The antennas are four 6 inch whips arranged in a 6 inch square and centered on the car's roof. The car roof is connected to the earth ground (XY plane) through the car body and tires. The interfering transmit antenna is in the YZ plane.

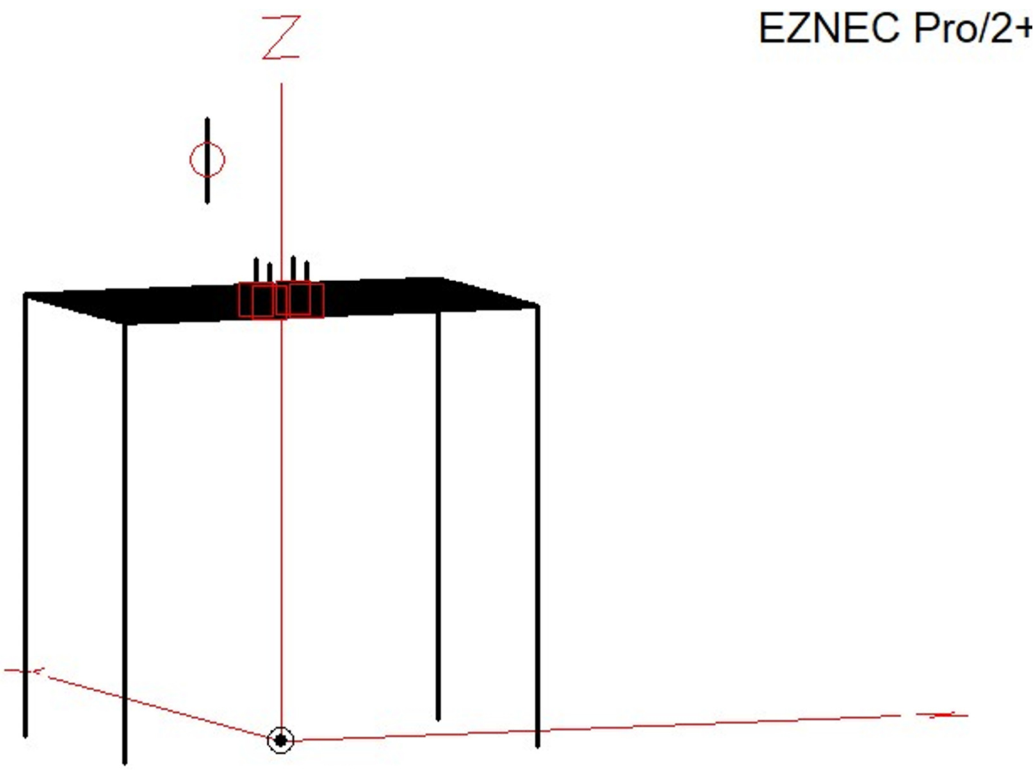

Figure 7 Geometry of 4 UHF Monopoles, VP TX Antenna

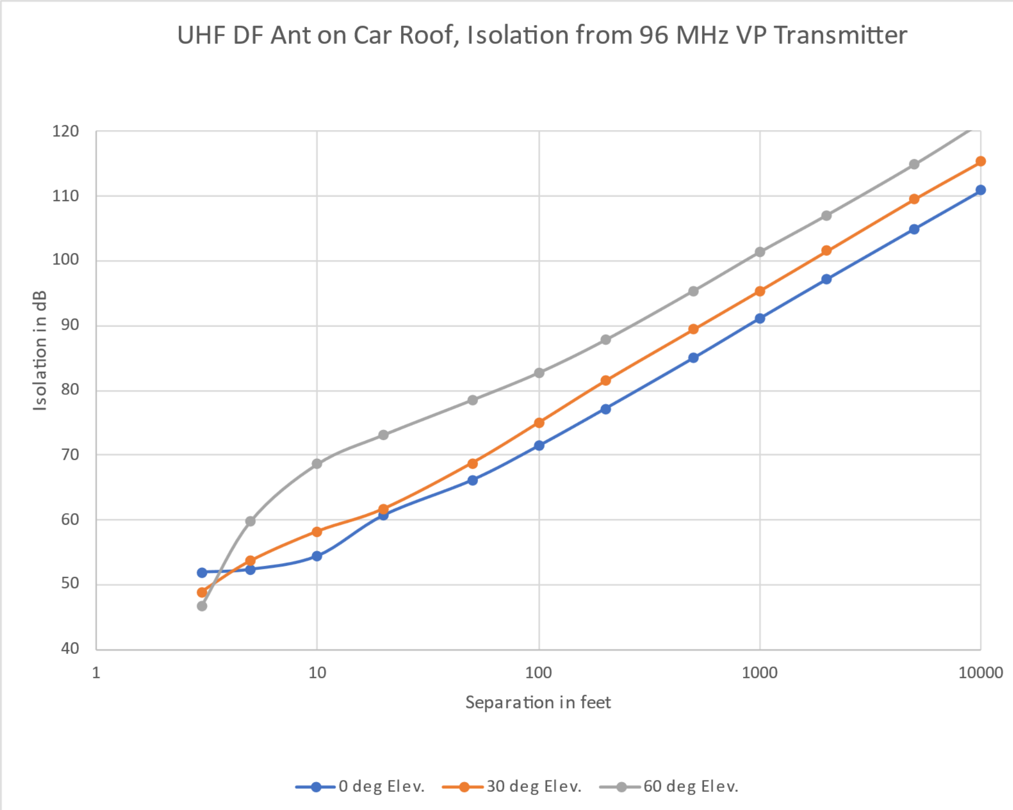

Figure 8 4UHF Monopole DF, 96 MHZ VP TX Antenna Isolation

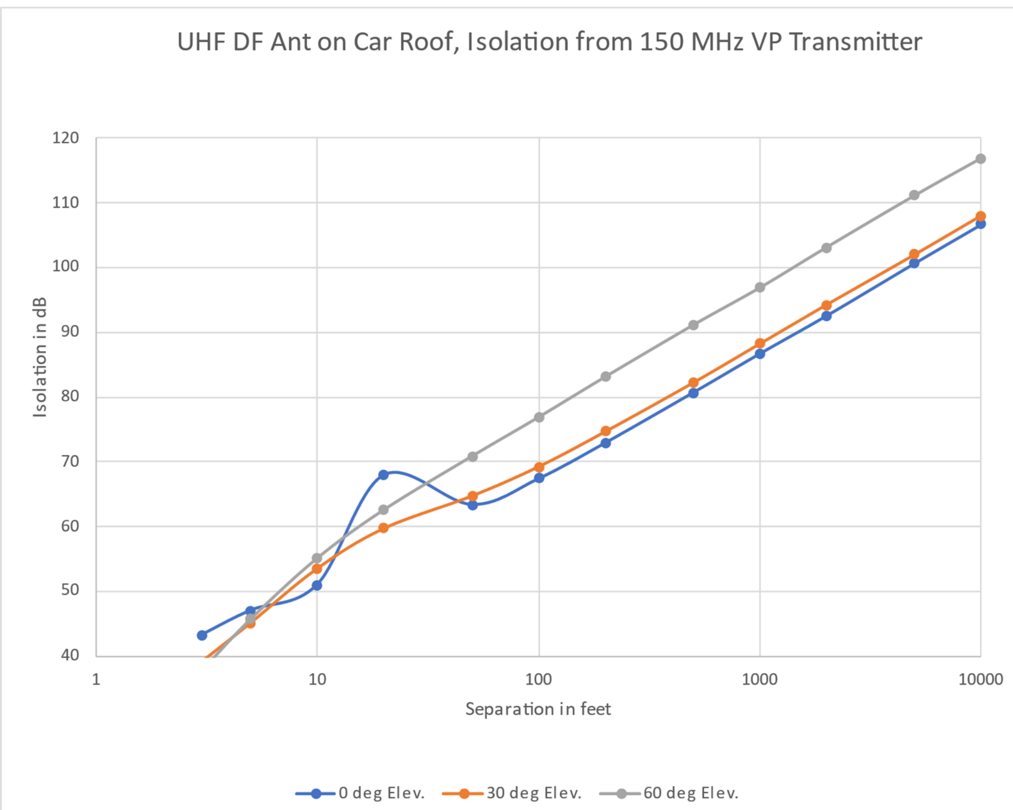

Figure 9 4UHF Monopole DF, 150 MHZ VP TX Antenna Isolation

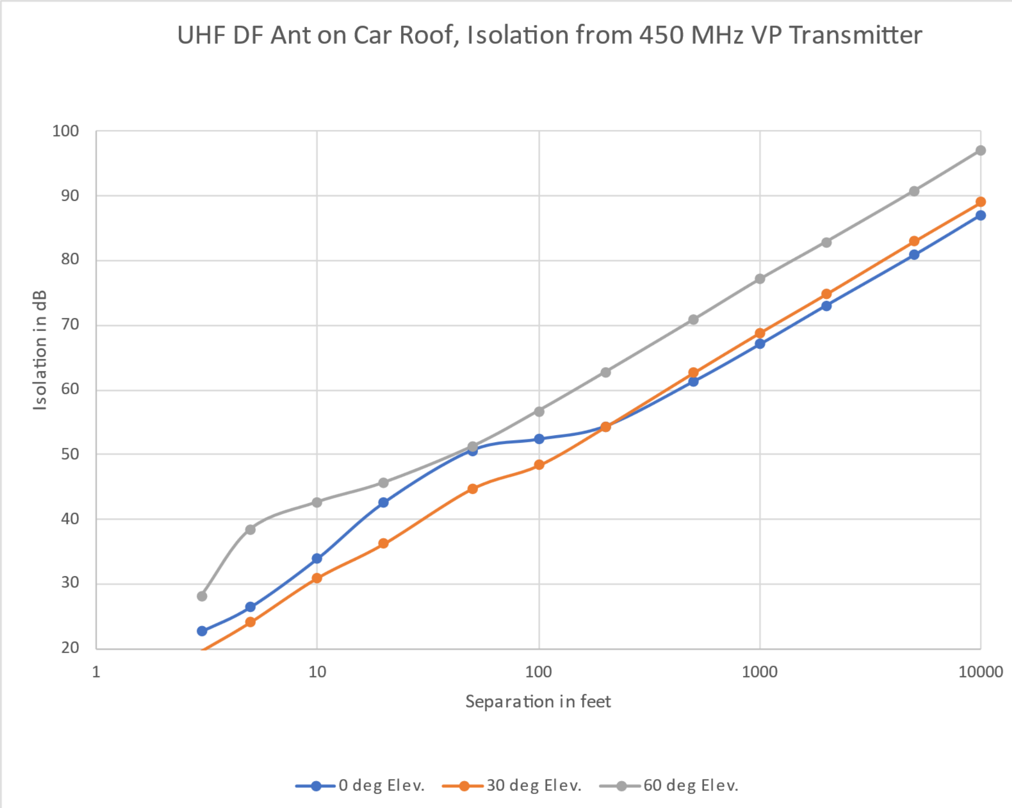

Figure 10 4UHF Monopole DF, 450 MHZ VP TX Antenna Isolation

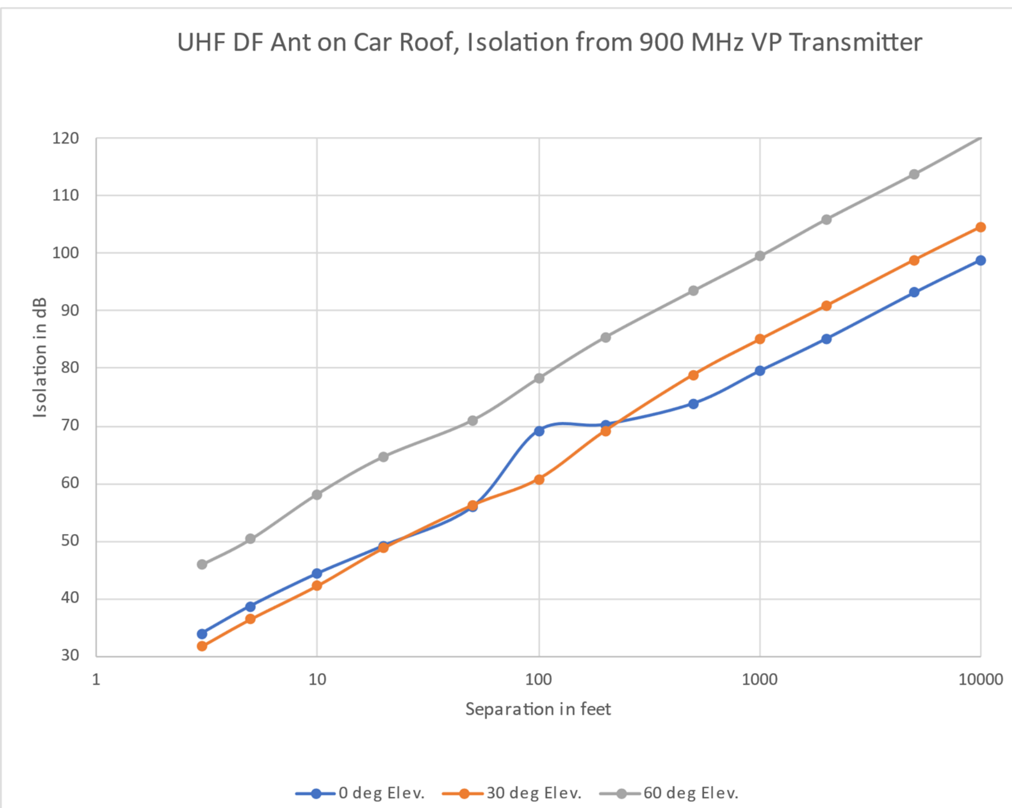

Figure 11 4UHF Monopole DF, 900 MHZ VP TX Antenna Isolation

Four THF Monopoles on Car Roof, Transmitter Antenna Vertically Polarized

The ground plane is a 3.5 ft wide 4.9 ft long car roof that is 5.5 ft above the ground. The four monopoles are 3 inches high and spaced in a 3 inch square centered on the ground plane. The ground plane is connected to the earth ground (XY plane) through the car body and tires. The interfering transmit antenna is in the YZ plane.

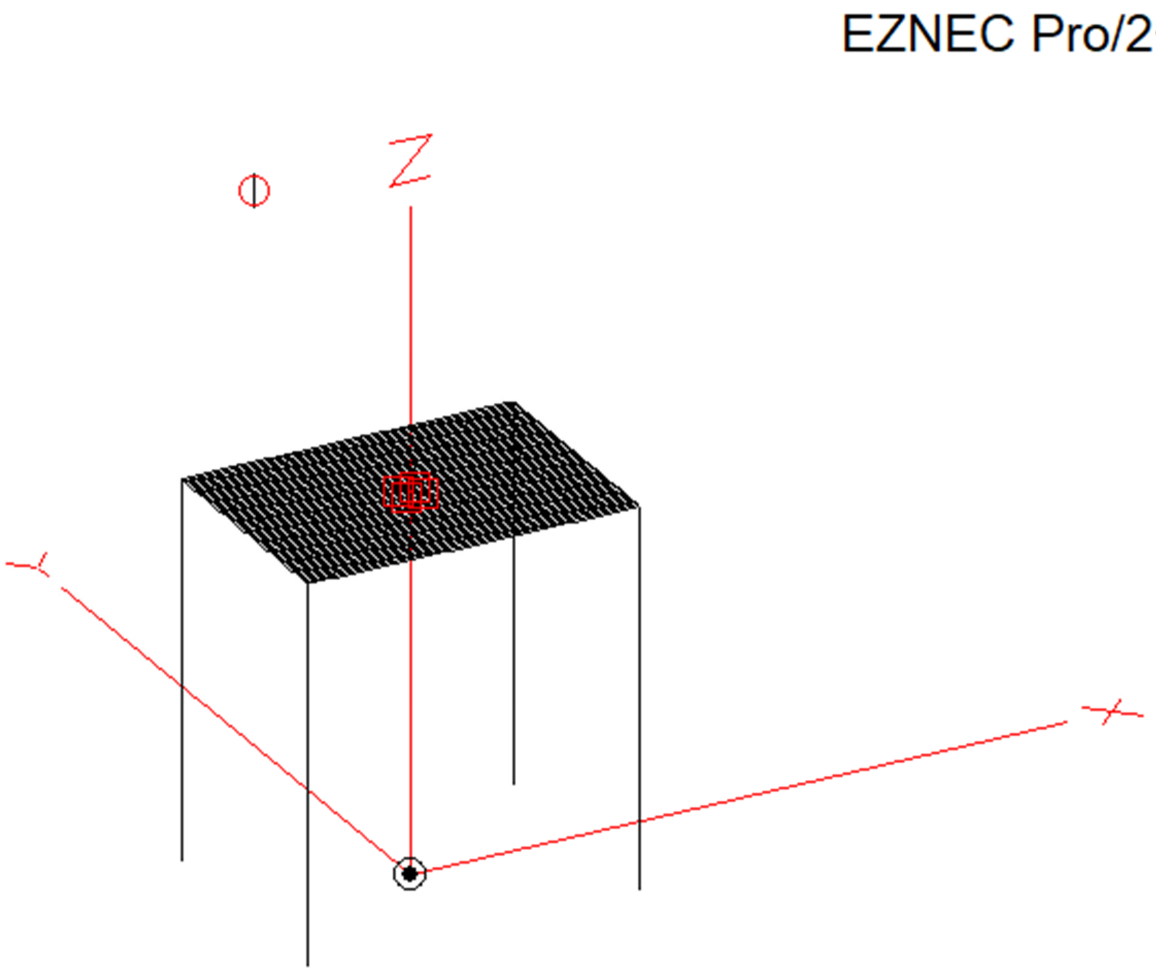

Figure 12 Geometry of 4 THF Monopoles, VP TX Antenna

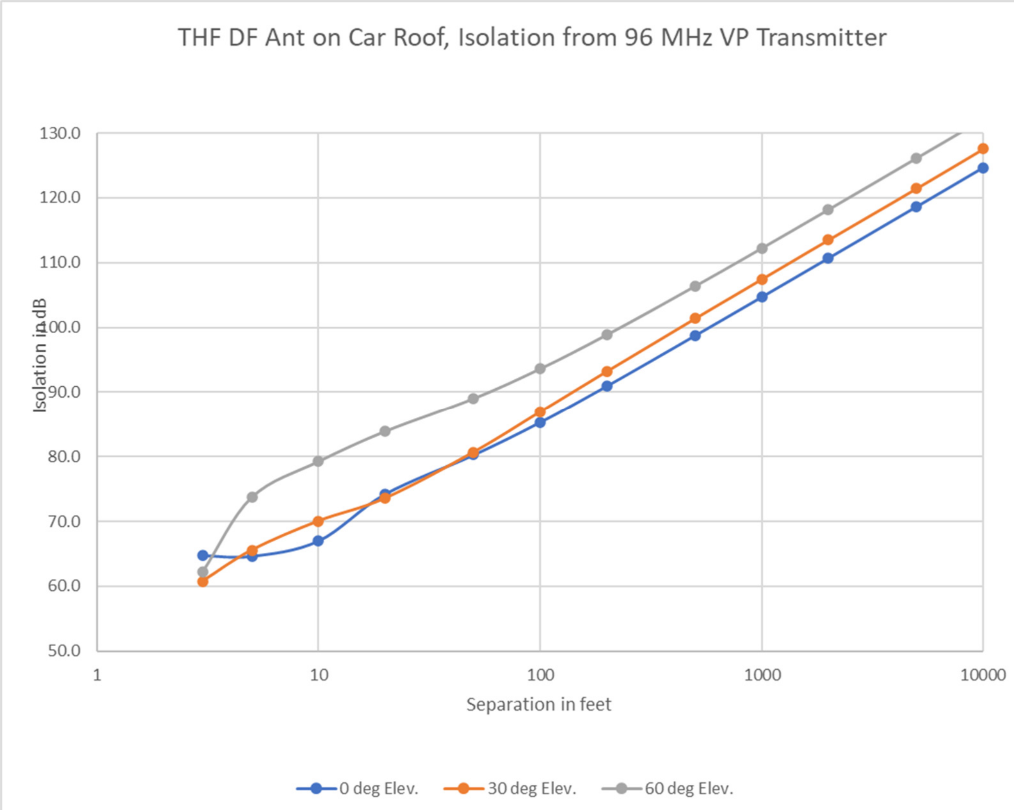

Figure 13 4THF Monopole DF, 96 MHZ VP TX Antenna Isolation

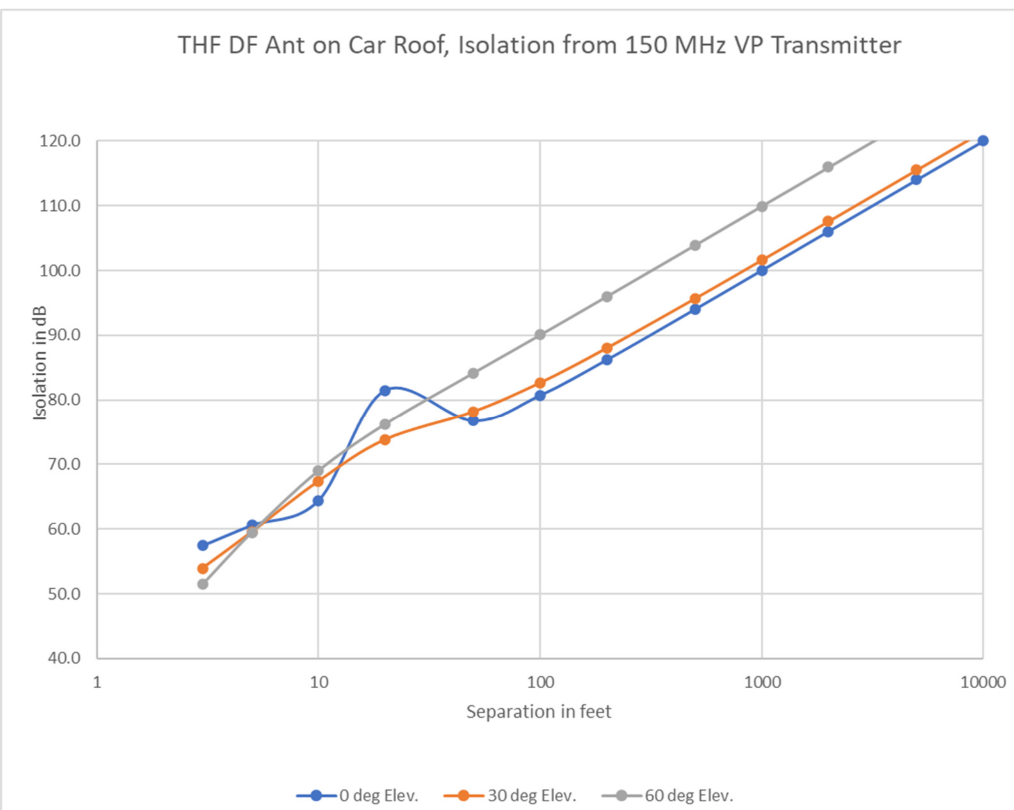

Figure 14 4THF Monopole DF, 150 MHZ VP TX Antenna Isolation

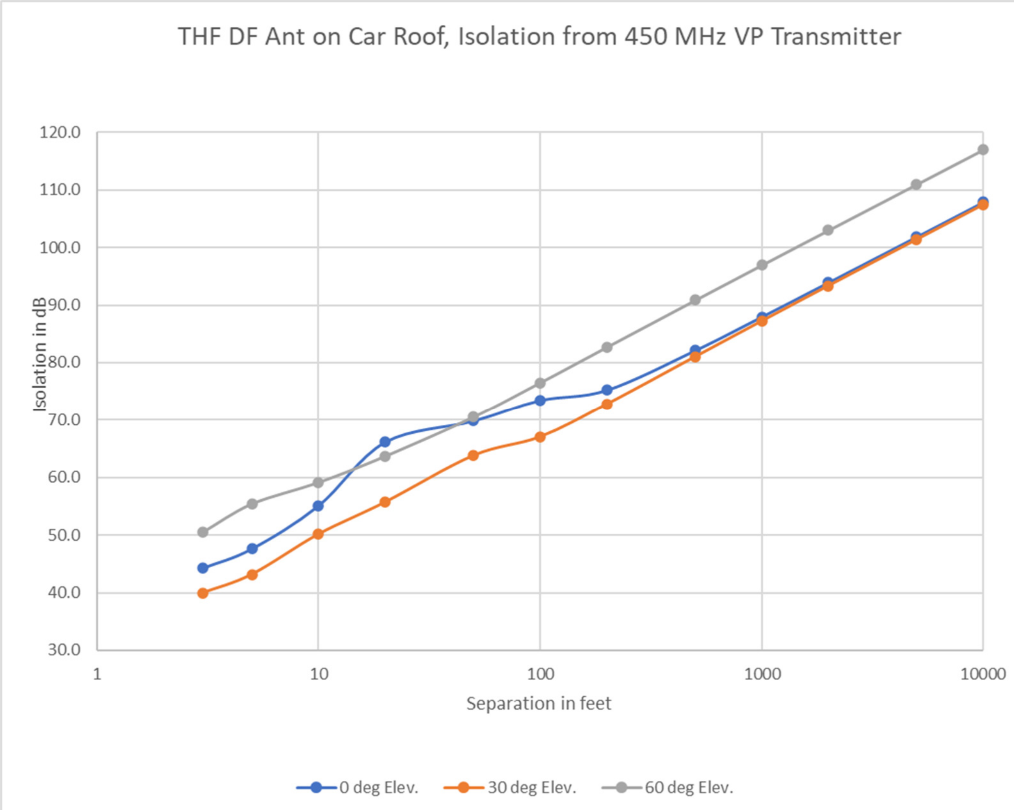

Figure 15 4THF Monopole DF, 450 MHZ VP TX Antenna Isolation

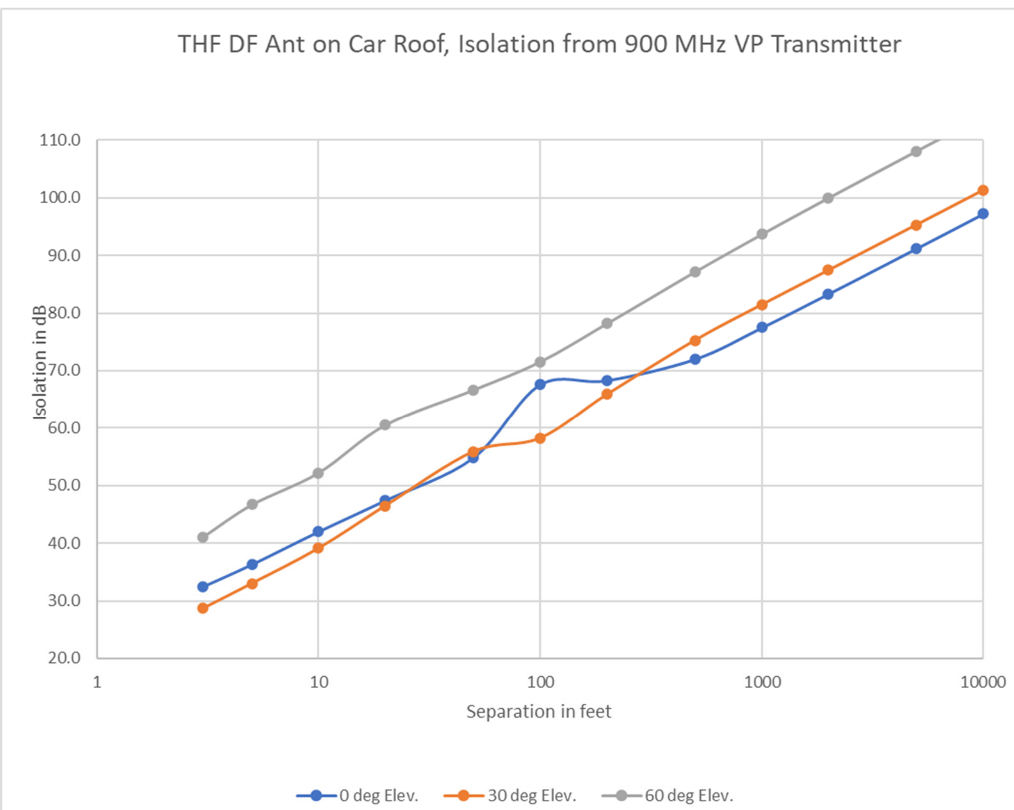

Figure 16 4THF Monopole DF, 900 MHZ VP TX Antenna Isolation

Eight Fixed Site VHF Biconical Dipoles, Transmitter Antenna Vertically Polarized

Each biconical dipole contains 3 flared wire elements 18 inches long. They are arranged in a circular pattern 15.7 inches in radius and matched using lattice baluns. There is no ground plane. The interfering transmit antenna is in the YZ plane.

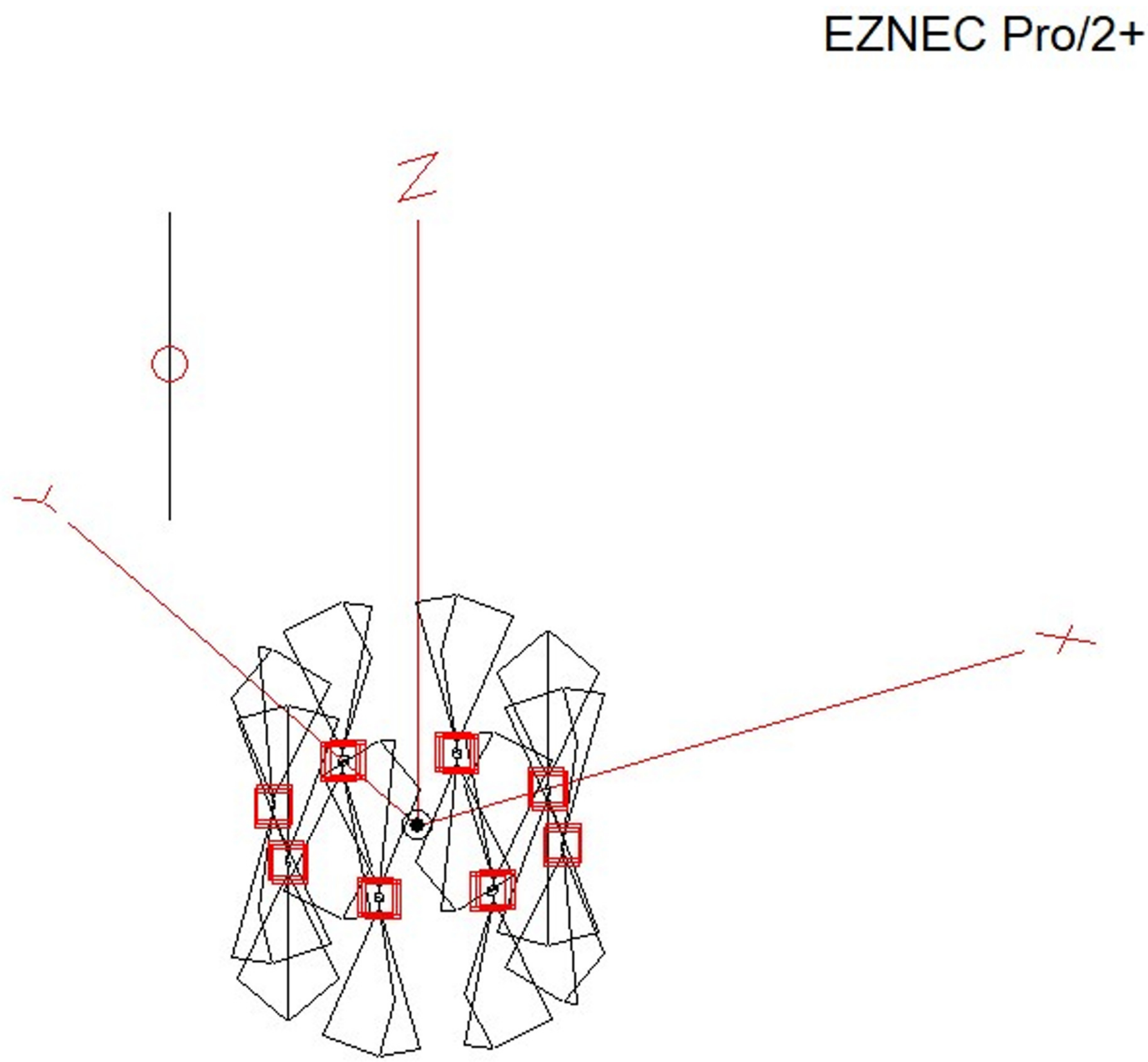

Figure 17 Geometry of 8 VHF Biconicals, VP TX Antenna

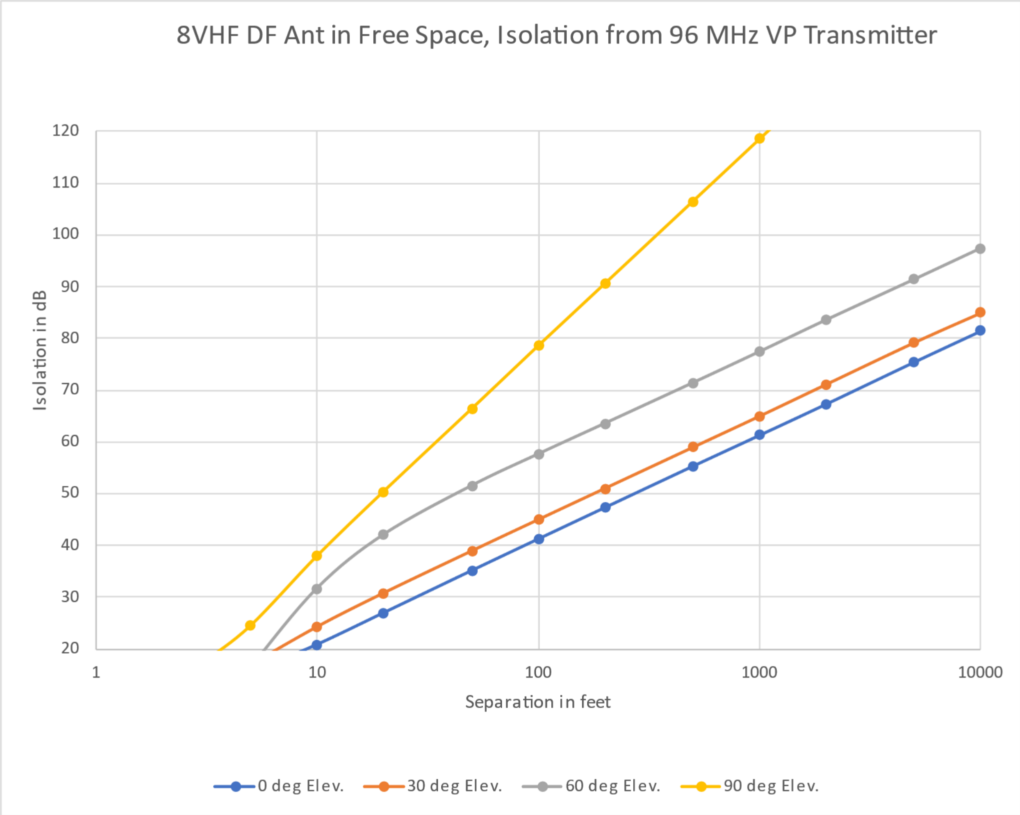

Figure 18 8VHF Biconical DF, 96 MHZ VP TX Antenna Isolation

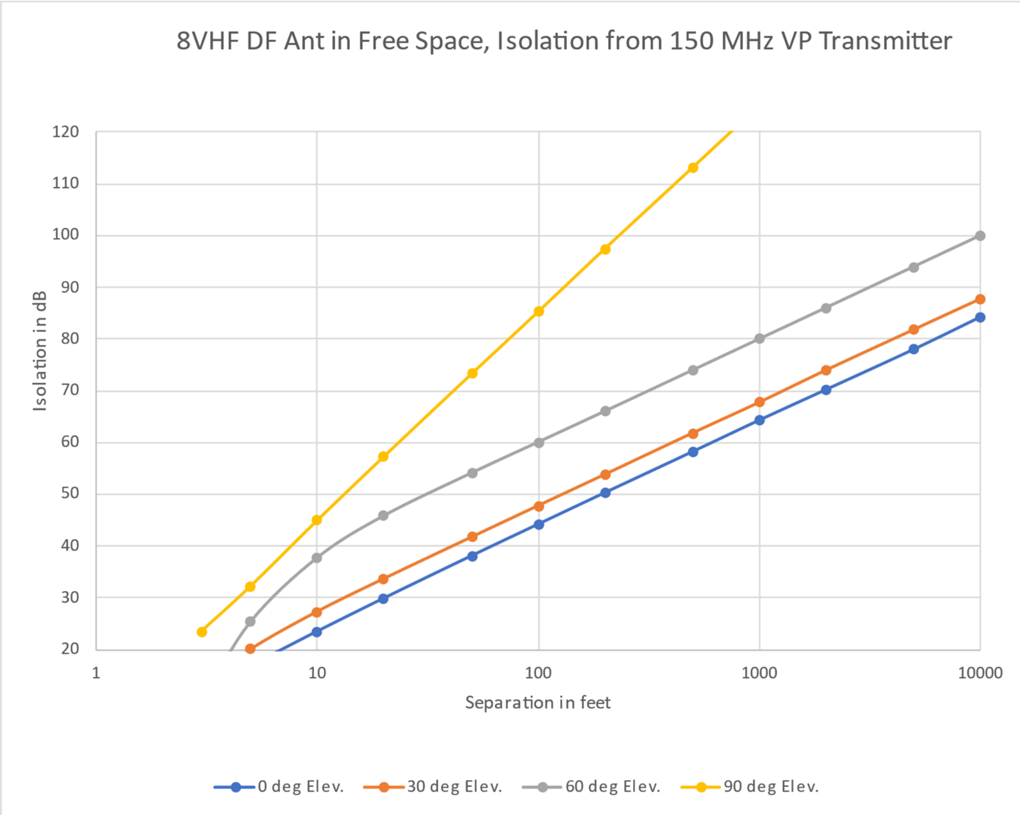

Figure 19 8VHF Biconical DF, 150 MHZ VP TX Antenna Isolation

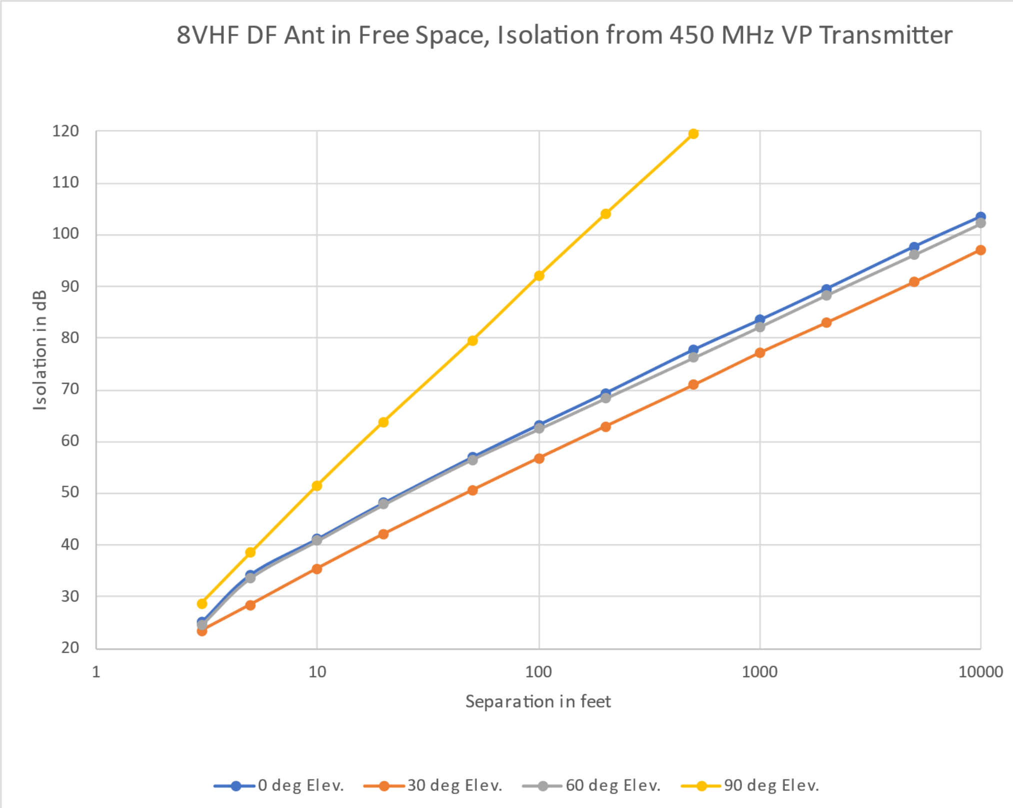

Figure 20 8VHF Biconical DF, 450 MHZ VP TX Antenna Isolation

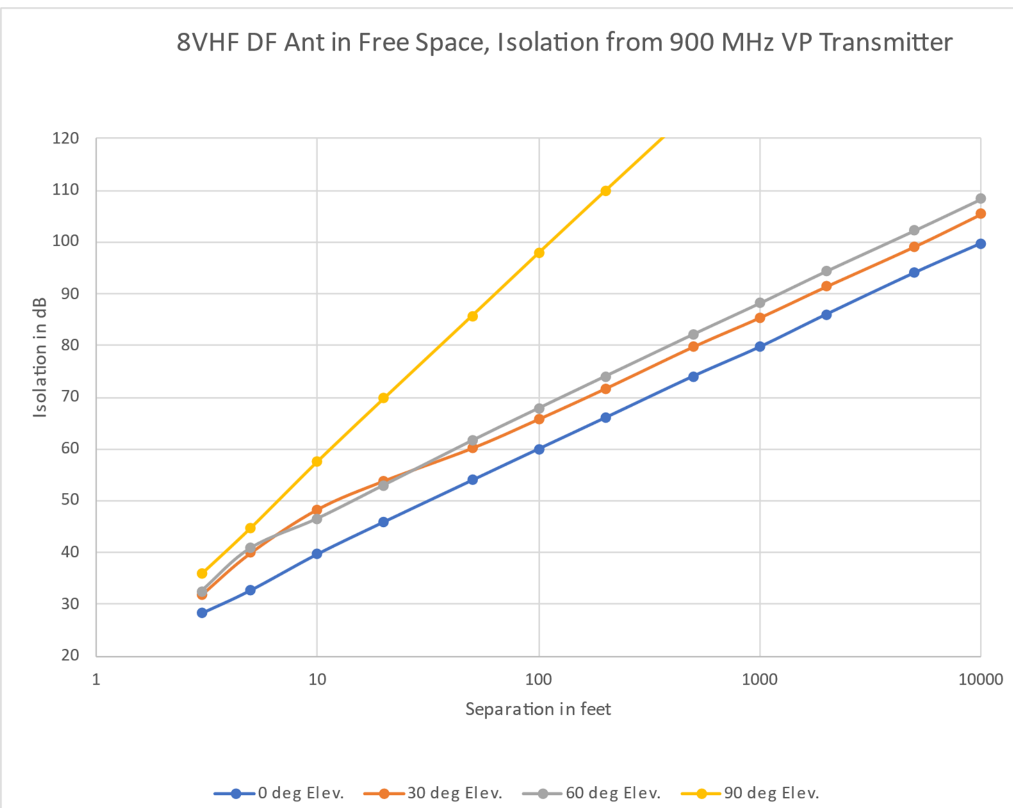

Figure 21 8VHF Biconical DF, 900 MHZ VP TX Antenna Isolation

Eight UHF Fixed Site Biconical Dipoles, Transmitter Antenna Vertically Polarized

Each biconical dipole contains 3 flared wire elements 6.8 inches long. They are arranged in a circular pattern 7.9 inches in radius and matched using lattice baluns. There is no ground plane. The interfering transmit antenna is in the YZ plane.

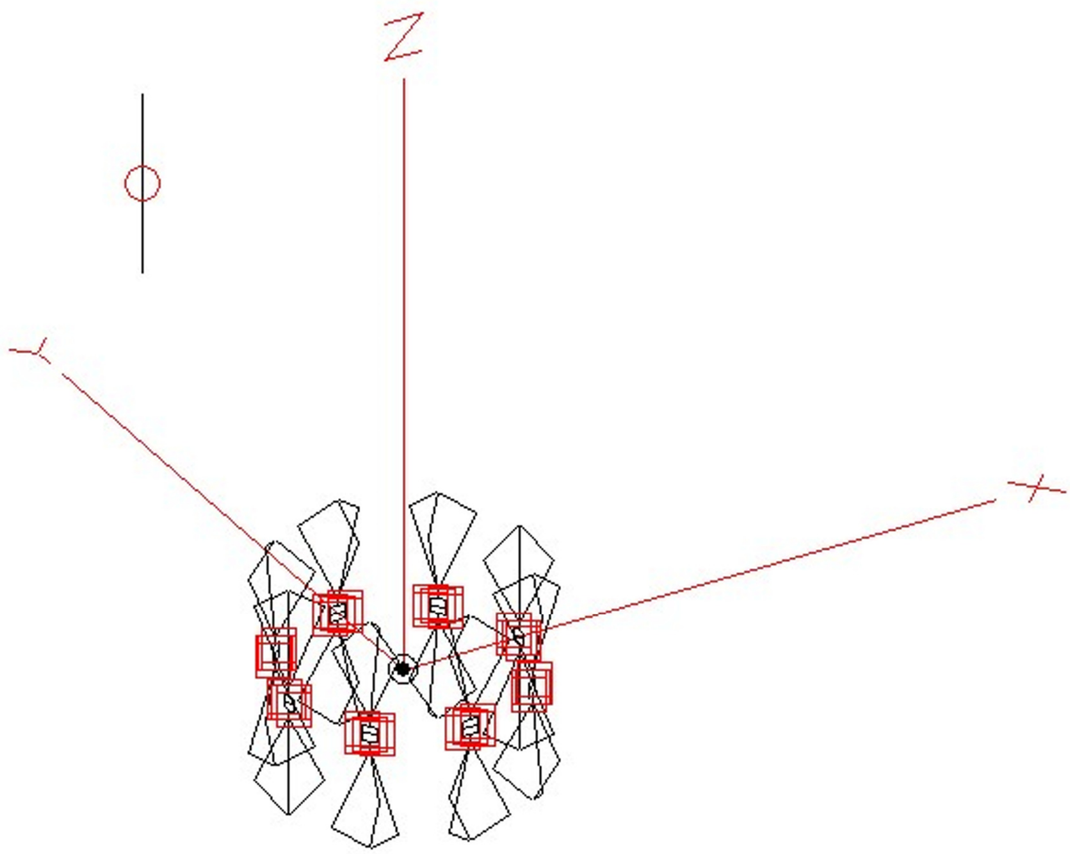

Figure 22 Geometry of 8 UHF Biconicals, VP TX Antenna

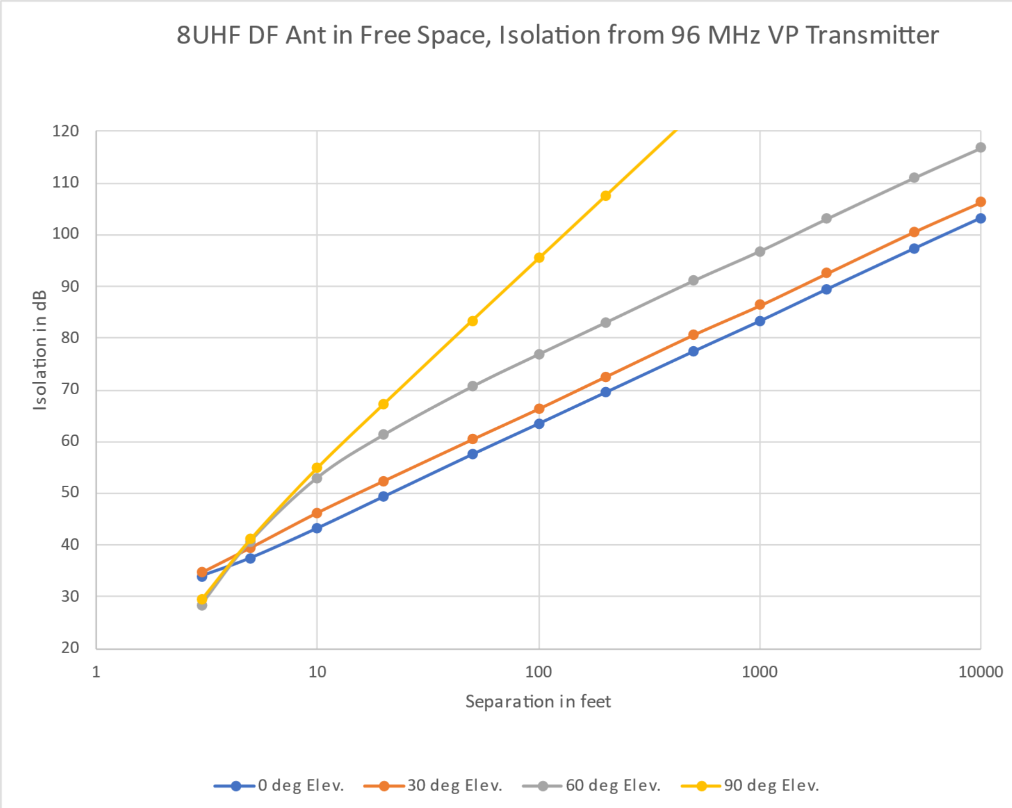

Figure 23 8UHF Biconical DF, 96 MHZ VP TX Antenna Isolation

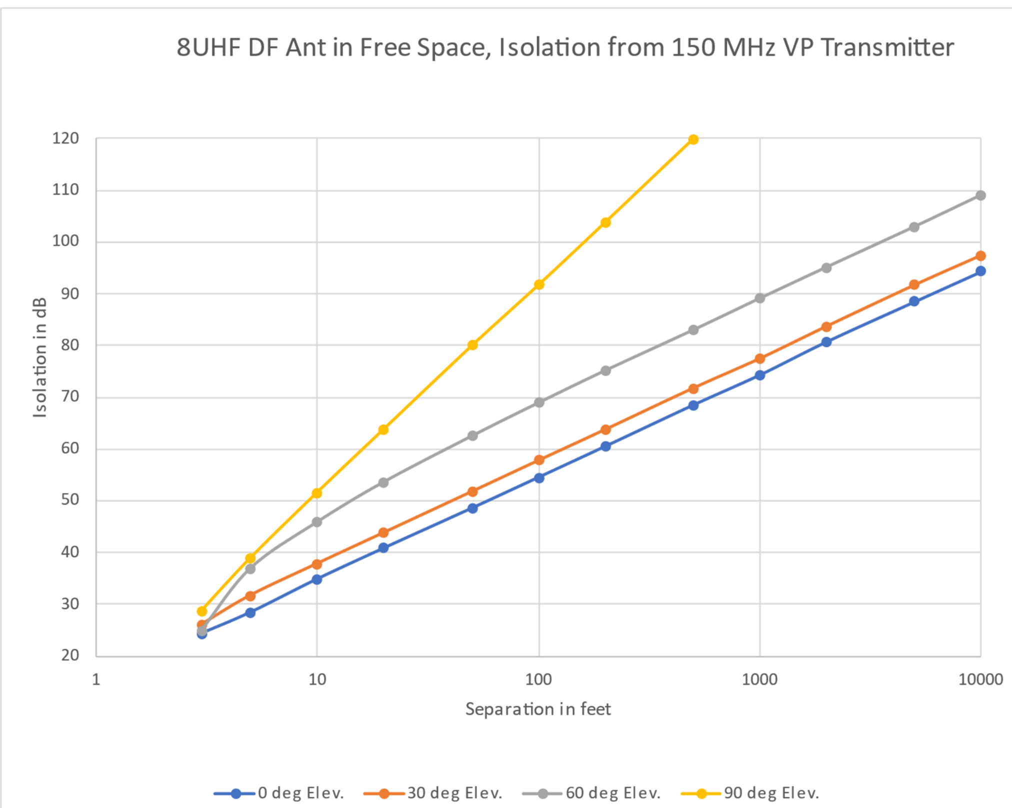

Figure 24 8UHF Biconical DF, 150 MHZ VP TX Antenna Isolation

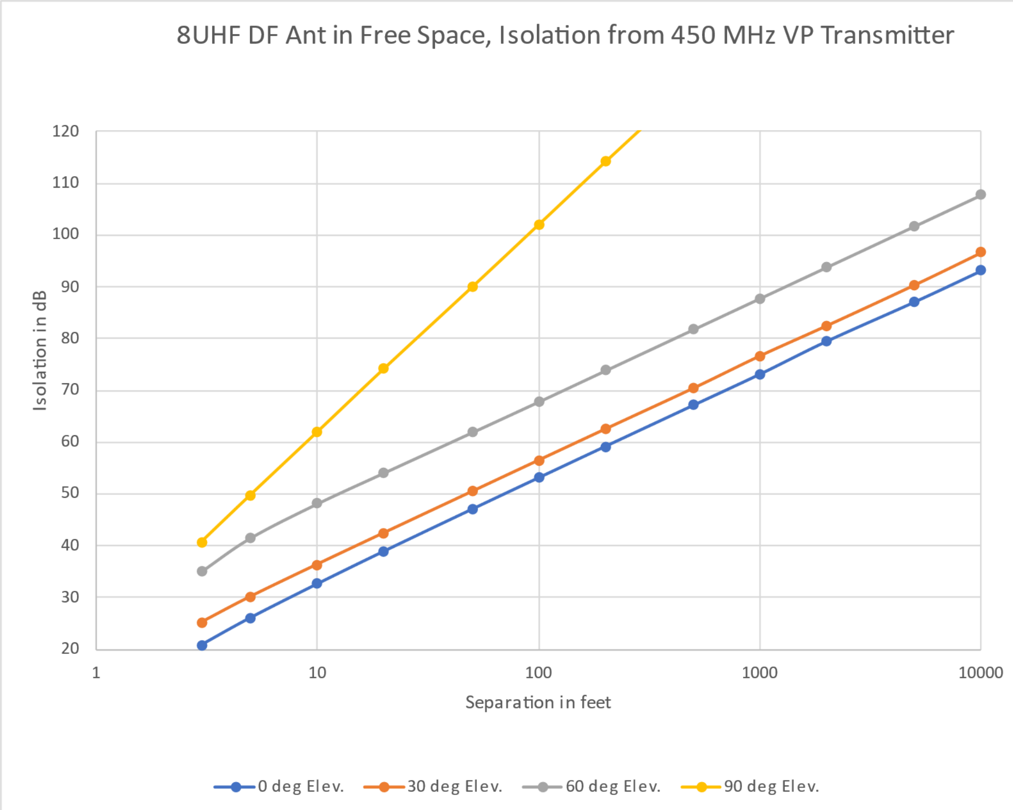

Figure 25 8UHF Biconical DF, 450 MHZ VP TX Antenna Isolation

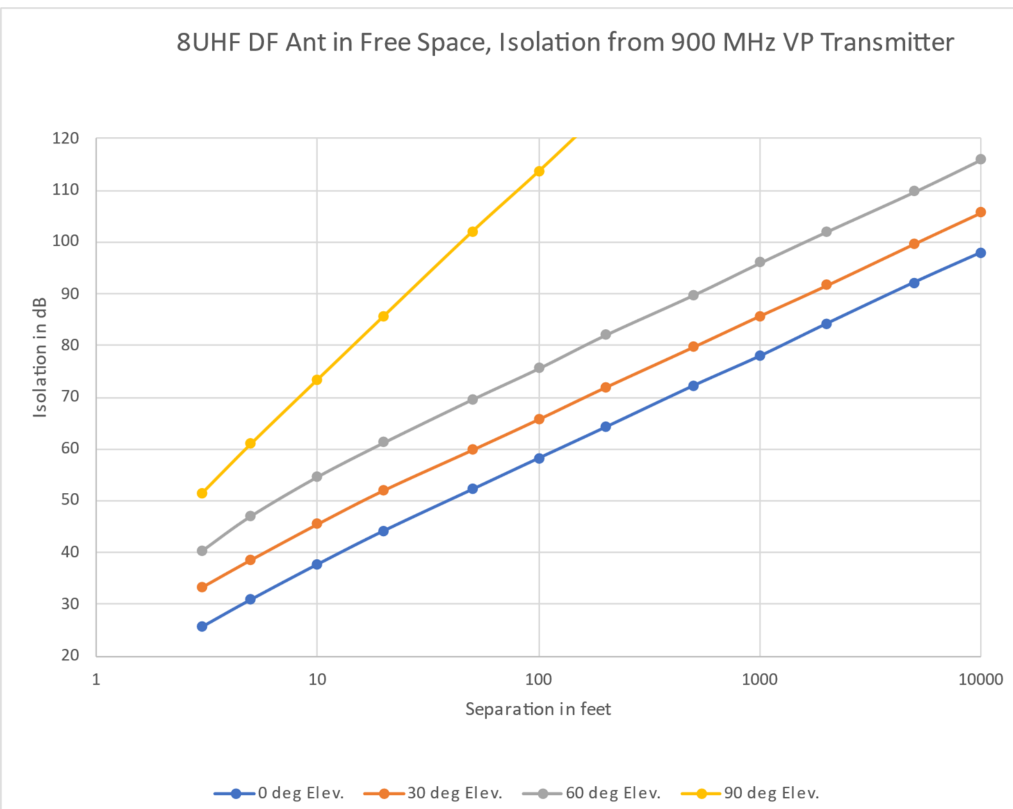

Figure 26 8UHF Biconical DF, 900 MHZ VP TX Antenna Isolation

Eight THF Fixed Site Biconical Dipoles, Transmitter Antenna Vertically Polarized

Each biconical dipole contains 3 flared wire elements 2.3 inches long. They are arranged in a circular pattern 4 inches in radius and matched using lattice baluns. There is no ground plane. The interfering transmit antenna is in the YZ plane.

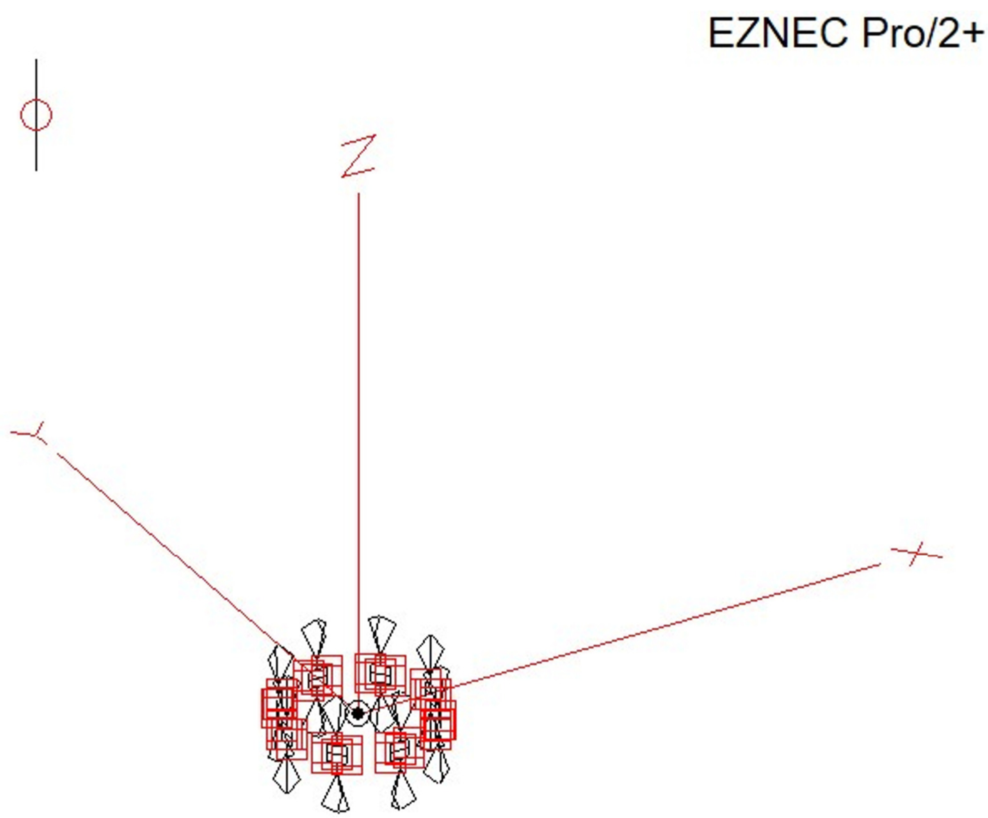

Figure 27 Geometry of 8 THF Biconicals, VP TX Antenna

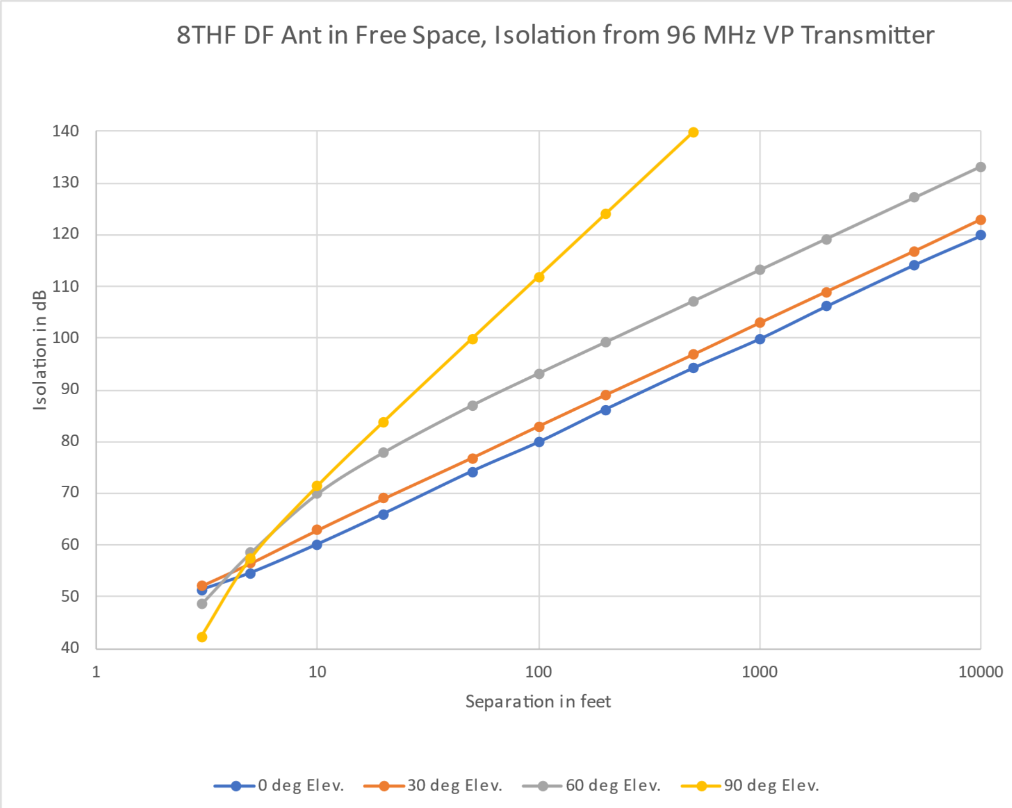

Figure 28 8THF Biconical DF, 96 MHZ VP TX Antenna Isolation

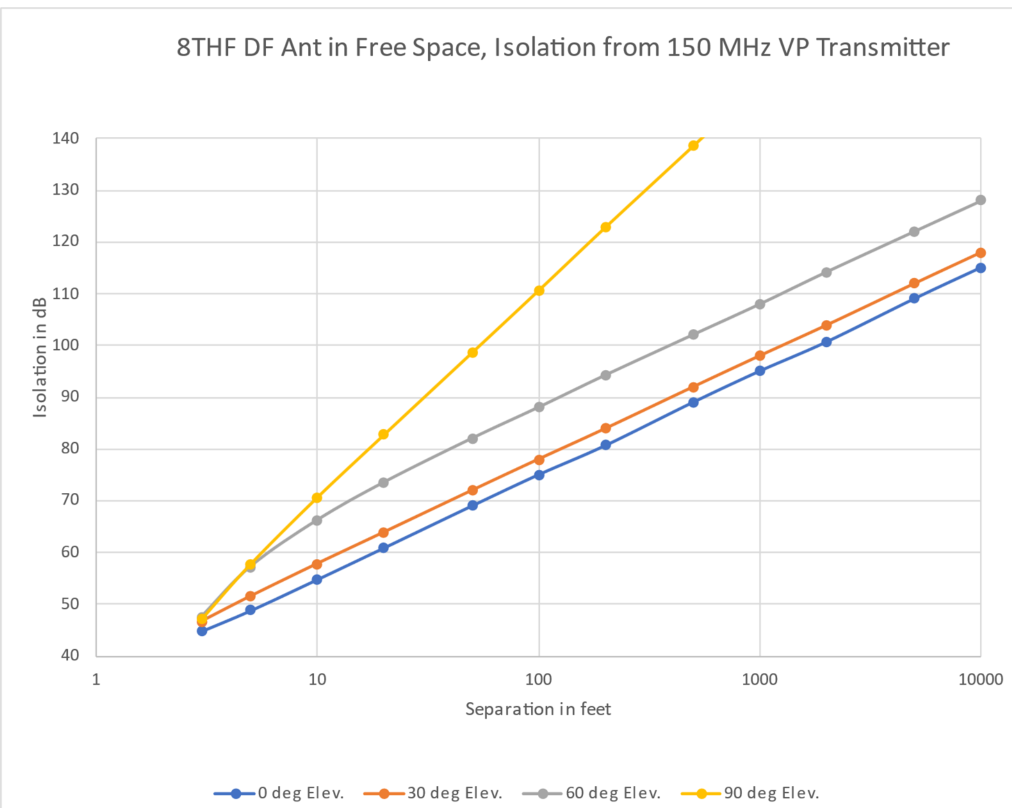

Figure 29 8THF Biconical DF, 150 MHZ VP TX Antenna Isolation

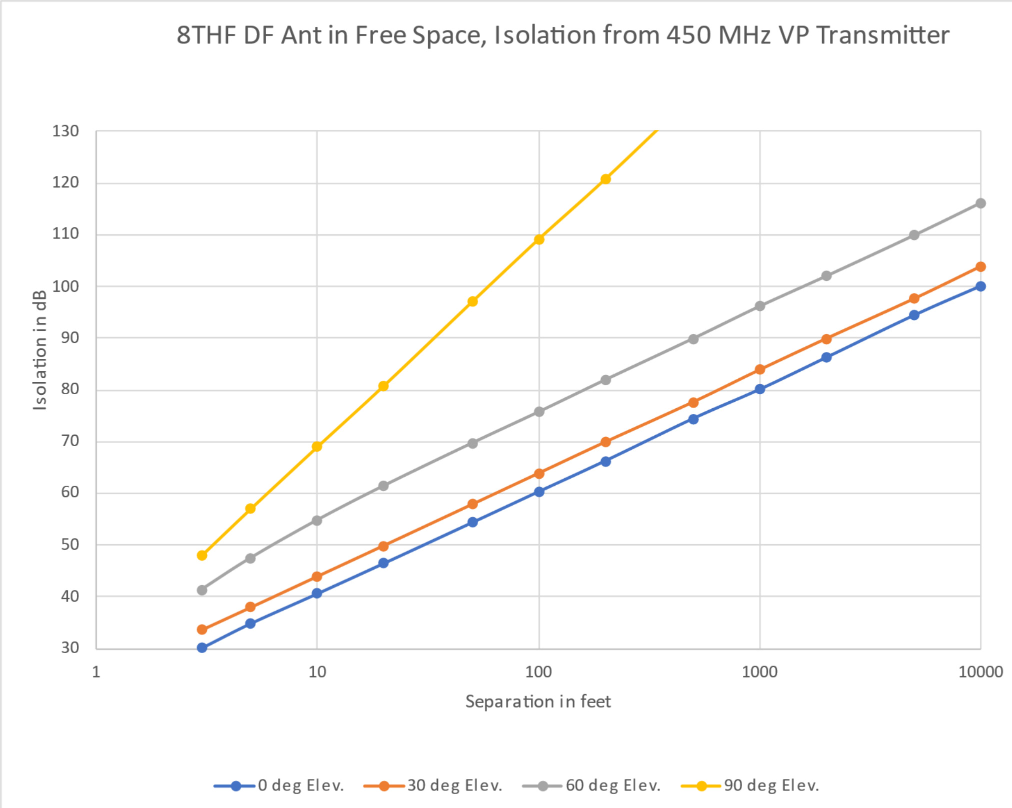

Figure 30 8THF Biconical DF, 450 MHZ VP TX Antenna Isolation

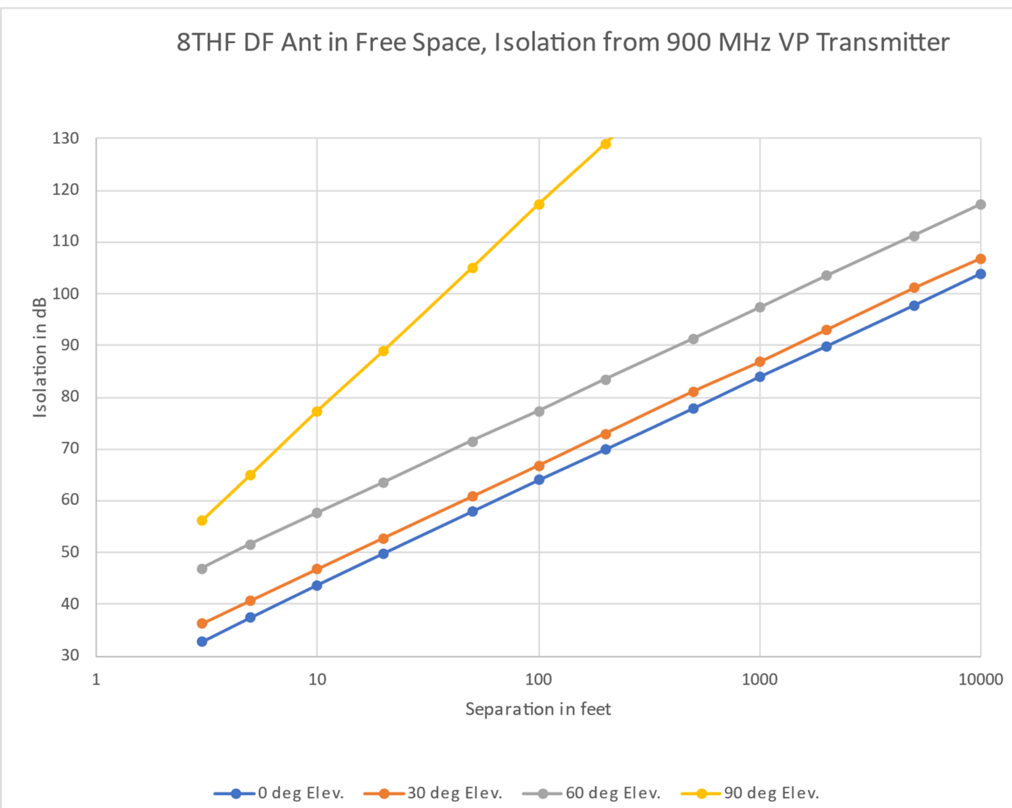

Figure 31 8THF Biconical DF, 900 MHZ VP TX Antenna Isolation

Interference Causing Damage to DF

The RF summers are rated to handle 100 mw maximum input (+20 dBm). Note that this limit applies whether or not the DF is turned on. The mobile summers contain a protective limiter than can handle up to 2 watts (+33dBm) but only on an intermittent basis. To calculate the levels that will be induced into the DF, convert the transmitted power to dBm, then subtract the Isolation in dB using the appropriate graph in the previous section. The table below provides some typical power conversions.

100 mW	1 W	5 W	10 W	25 W	100 W	500 W	1 KW	2.5 KW	10 KW
+20 dBm	+30 dBm	+37 dBm	+40 dBm	+44 dBm	+50 dBm	+57 dBm	+60 dBm	+67 dBm	+70 dBm

Example 1 - Mobile VHF DF close to 5 watt hand held VHF transmitter 3 feet from car at same height as car roof.

> 5 watts is +37 dBm. Isolation from Figure 4 is 17 dB. Received power is 37 – 17 = 20 dBm which is just at the 100 mW input limit. So because of the limiters, this level will be safe.

Example 2 - Same as above except the transmitter is at UHF.

> From Figure 5 the isolation is now 27 dB. Received power is 37 – 27 = 10 dBm. Examples 1 and 2 show the advantage of using a crossband frequency for communications while direction finding.

Example 3 - Mobile VHF DF 60 ft from 100 watt VHF base station antenna at height of 40 ft.

> This is an elevation angle of about 30 degrees and a distance of 72 ft. 100 watts is +50 dBm. From Figure 4 the isolation is about 40 dB, so the received power is 50 – 40 = +10 dBm. This should be a safe condition.

Example 4 - An 8 biconical VHF array is mounted on top of a mast and there is another mast mounted VHF transmit antenna at the same height 20 ft away with a power output of 1000 watts (+60 dBm);

> From Figure 19 the isolation is about 30 dB. So the received power is +60 – 30 = +30 dBm. The DF will be damaged at this power level.

Example 5 - Same as above but with the transmit antenna on the same mast as the DF, but 20 feet below it.

> From Figure 19, the isolation is now 58 dB, so the received power is only +60 – 58 = +2 dBm. This is a safer value and illustrates the fact that vertical separation is more effective than horizontal separation for vertically polarized antennas.

Example 6 - An 8 biconical VHF array is mast mounted at the same height as a nearby FM broadcast station running 2.5 KW (+67 dBm). The two antennas are about ¼ mile (1320 ft) apart.

> From Figure 18, the isolation is 64 dB, so the received signal is +67 – 64 = +3 dBm (safe).

These examples show that the DF will not be damaged by most practical interference transmitters. But in all of these examples, the DF will be seriously desensitized when the transmitter is on. There may, however, still be cases where the DF can be used while the transmitter is off, for example, when the transmitter is only occasionally used or is synchronized with the DF to be off when it is taking data.

Interference that Desensitizes the DF

The sensitivity of the DF is typically -124 dBm with no interference. With an interfering signal, it is less sensitive, and the degradation depends on the interfering signal strength and closeness in frequency to the signal that the DF is receiving. Measurements were made using two signal generators to determine the susceptibility to both in band and out of band interferences.

For the DF operating in the VHF band, the data is shown in Table 1. For these tests, the DF was tuned to a signal at the center of the VHF band, 177 MHz. So the in-band interference frequencies of 171, 176.4 and 176.94 represent interference frequencies offset 6 MHz, 600 KHz, and 60 KHz respectively from the DF frequency. The table shows, for example, that out of band signals as strong as -38 to -35 dBm have negligible effect on the DF sensitivity, while a signal that is only 60 KHz separated must be less than -85 dBm to have a similar negligible effect. If the same signal is -63 dBm, the DF sensitivity will degrade to -108 dBm.

Table 1 Sensitivity of VHF DF with Interfering Signal

	DF Sensitivity at VHF (dBm)			
	-124.3	-118.3	-108.3	-98.3
Interference Freq (MHz)	Interference Level (dBm)			
96	-38.3	-23.3	-14.3	-3.3
150	-35.3	-24.3	-15.3	-2.3
171 (6 MHz offset)	-45.3	-35.3	-31.3	-23.3
176.4 (600 KHz offset)	-63.3	-49.3	-38.3	-33.3
176.94 (60 KHz offset)	-85.3	-72.3	-63.3	-52.3
450	-35.9	-24.9	-14.9	1.1
900	-37.9	-26.9	-16.9	4.1

Similar data is shown in Table 2 and Table 3 for the UHF and THF bands.

Table 2 Sensitivity of UHF DF with Interfering Signal

	DF Sensitivity at UHF (dBm)			
	-118.4	-115.4	-105.4	-95.4
Interference Freq (MHz)	Interference Level (dBm)			
96	-14.3	-14.3	-2.3	-1.3
150	-24.3	-24.3	-14.3	1.7
348 (6 MHz offset)	-32.9	-32.9	-28.9	-26.9
353.4 (600 KHz offset)	-52.9	-48.9	-37.9	-30.9
353.94 (60 KHz offset)	-75.9	-71.9	-59.9	-49.9
450	-24.9	-24.9	-14.9	2.1
900	-26.9	-26.9	-16.9	4.1

Table 3 Sensitivity of THF DF with Interfering Signal

	DF Sensitivity at THF (dBm)			
	-118.7	-113.7	-103.7	-93.7
Interference Freq (MHz)	Interference Level (dBm)			

96	-3.3	-2.3	-1.3	2.7
150	-24.3	-18.3	0.7	5.7
450	-24.9	-14.9	3.1	6.1
701 (6 MHz offset)	-32.9	-28.9	-25.9	-19.9
706.4 (600 KHz offset)	-51.9	-45.9	-34.9	-26.9
706.94 (60 KHz offset)	-73.9	-66.9	-55.9	-45.9
900	-26.9	-16.9	1.1	4.1

If a spectrum analyzer is available, a potential DF site can be readily evaluated for interference by connecting the analyzer to a dipole antenna resonant in the band where the DF will be used and noting the amplitude and frequency of any interfering signals. Then refer to the appropriate table above to see the resultant DF sensitivity.

If direct measurement is not available, but an estimate of the power level, frequency and distance to the interfering signal is available, the signal strength can be estimated using the isolation curves provided in the previous sections. Then the tables can be used to predict the DF sensitivity.

Some examples are given below.

Example 1 – A UHF DF is intended to monitor the input of a repeater (600 KHz offset). If the repeater output is 25 watts (+44 dBm), what is the DF sensitivity if the DF antenna is located 1000 ft from the repeater antenna?

> From Figure 25, assuming the same antenna height (0 degrees elevation), the isolation will be 74 dB, so the received signal from the repeater output will be +44 – 74 = -30 dBm. From Table 2, a signal of this strength will cause the DF sensitivity to be about -94 dBm, limiting the DF to only strong signals.

Example 2 – A VHF DF is used in conjunction with a UHF telemetry transmitter at the same site. Both antennas are at the same height and 100 ft separated. What is the DF sensitivity when the UHF transmitter is on (10 watts).

> From Figure 20 the isolation is 64 dB, so the received interfering signal will be +40 – 64 = -24 dBm. From Table 1 the DF sensitivity will be -118 dBm which is sufficient for most applications.

Example 3 - An 8 biconical VHF array is mast mounted at the same height as a nearby FM broadcast station running 2.5 KW (+67 dBm). The two antennas are about ¼ mile (1320 ft) apart. (This is the same as example 6 in the previous section).

> From Figure 18, the isolation is 64 dB, so the received signal is +67 – 64 = +3 dBm. Extrapolating from Table 1, the DF sensitivity will be about -90 dBm – a very strong signal.

Summary

Achieving good sensitivity and protecting your radio direction finder requires adequate separation of the direction finding antenna from transmit antennas. Using the path loss charts and the sensitivity measurements in this application note will allow you to choose the location of your direction finder to achieve maximum performance.