MOTOROLA SOLUTIONS

Ulster County Emergency Communications Saugerties, NY – EME assessment

2 November 2020

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Executive Summary

A computational assessment was carried out to provide an estimation of the EME exposure at the Saugerties, NY site of the Ulster County Emergency Communications system, as described in the following. This assessment demonstrates that the Motorola Solutions system described in this report complies with the FCC requirements concerning radio-frequency (RF) exposure of trained workers and the general public.

The compliance is established with respect to the US FCC regulations [1]. The assessment was carried out using the methodologies specified in [1]-[2]. The following table provides the compliance distances for *general public* and *occupational-type* exposure:

Exposure Category	Locations Facing the Antennas*	At Street Level
General Public Exposure	9.2 m (30 ft)	All locations compliant
Occupational Exposure	3.6 m (12 ft)	All locations compliant

* These distances are extremely conservative as they are calculated presuming that all antenna emissions are oriented towards the same direction and that all the transmitting antennas are placed at the same height on the site communication tower.

The stated compliance distances are typically much larger than those that would be predicted to be calculated on the basis of an actual measurement taken under an SAR (specific absorption rate) analysis. SAR is a more accurate measure of exposure and is the basic measure for exposure under the US FCC regulations [3]. However SAR is much more complicated to estimate (measurements or electromagnetic simulations) than free-space fields or the equivalent power density. Thus in this case the simpler, practical approach to compute the compliance distance based on the analytical estimation of the free-space equivalent power density is used.

Antenna site information

The information illustrated in the following describes the Motorola Solutions system. Because Motorola Solutions does not have any information related to other products located at the site, the report does not include information about co-located pre-existing systems and antennas, if any.

Key technical information

The Motorola Solutions Land Mobile Radio (LMR) system features several transmitters and antennas operating across several frequency bands, whose key parameters are summarized in Table 1.

1	Sub-System	VHF_1	VHF_2	UHF	7-800	Dish
TRANSMITTERS	Number of Transmitters	2	2	2	4	1
	Frequencies (MHz)	156.12 - 156.18	151.14 - 155.8	453.4 – 453.7	769.2 – 851.5	6175
	Transmitter RF Power (W)	100	100	100	100	0.25
	Cable/Combiner Loss (dB)	4.5	4.5	5	6	3
ANTENNAS	Model	CSA10-41-DIN	CSA10-41-DIN	DS4D06P36D-D	DS7C09P36D-D	PAR6-59W-PXA/A
	Peak Gain (dBi)	9.15	9.15	8.05	11.15	37.8
	Elevation Beamwidth	68^0	68^0	15^0	6^0	1.8^0
	Azimuth Beamwidth	64^0	64^0	omni	omni	1.8^0
	Downtilt	0^0	0^0	1^0	0^0	0^0
	Polarization	Vertical	Vertical	Vertical	Vertical	Horizontal
	Physical Length	51"	51"	21'	24'	6' Ø
	Height AGL	180'	150'	100'	100'	100'
	Distance to Buildings	> 500'	> 500'	> 500'	> 500'	> 500'

Applicable RF exposure limits

The FCC exposure limits [1], when expressed in terms of equivalent power density, are frequency dependent. Table 2 reports the strictest applicable limits for general public and occupational exposures within each subsystem operating band:

2	Sub-System	VHF_1	VHF_2	UHF	7-800	Dish
$W\,m^{-2}$	General Public	2	2	3.02	5.13	10
	Occupational	10	10	15.1	25.63	50

Because the overall exposure is due to the combined emissions from each system over different frequency channels, the compliance distances are established by the sum of the respective exposure quotients, given by the ratio of the power density and the applicable limit, not exceeding unity.

Exposure prediction models

Three different models are employed to perform the exposure assessment. One is relative to exposures around sector antennas; another is for exposure at ground level. The last one is for exposures in front of a dish antenna.

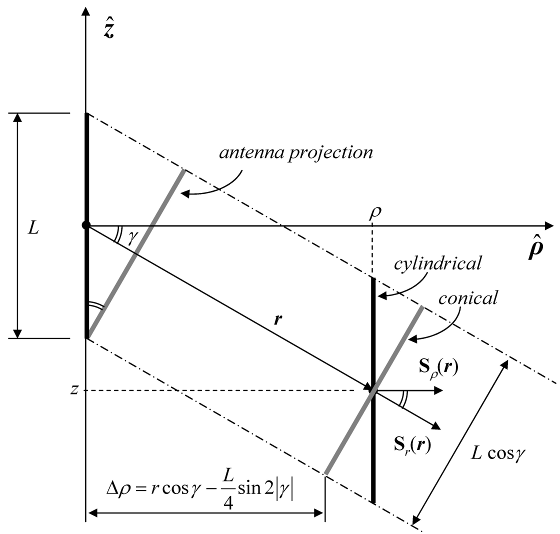


Fig. 1. Reference frame and notations employed to describe the cylindrical model.

A. Exposure to sector or omni-directional antennas

The behavior of the spatially averaged equivalent power density in the radiating near field of typical base station array antennas (omni-directional or sector coverage) can be predicted using simple algebraic formulas that depend on a few, readily available antenna parameters, such as directivity, beamwidth, physical length, and the radiated power [2]. The reference frame relative to an array antenna axis and the relevant analytical notations employed in the analytical prediction formulas for the spatially-averaged power density are illustrated in Fig. 1. The parameters required to apply the formulas are the following:

- W_{rad} : Antenna radiated power;
- L : Equivalent electrical antenna length (meters);
- D_A : Antenna peak directivity (unitless); using the peak gain G_A is acceptable;
- γ : Electrical down-tilt angle of the antenna main beam (radians);
- $\bar{\phi}_{3dB}$: Azimuth semi-beamwidth of the antenna pattern (radians).

For *sector* arrays, the prediction formula for the spatial-peak equivalent power density is:

$$\hat{S}_r(r,\phi;\gamma) = \frac{W_{rad}\, 2^{-\left(\frac{\phi}{\bar{\phi}_{3dB}}\right)^2}}{\bar{\phi}_{3dB} \cdot r \cdot L \cdot \cos^2\gamma \sqrt{1+\left(2\frac{r}{r_0}\right)^2}}, \quad r_0 = \frac{\bar{\phi}_{3dB}}{6} D_A L \cos^2\gamma \qquad (1)$$

For *omni-directional* arrays, the prediction formula for the spatial-peak equivalent power density is obtained by setting the azimuth semi-beamwidth equal to π and neglecting the exponential factor.

The above prediction formula does not take into account the formation of grating lobes near endfire, whose power content typically becomes significant for tilt angles greater than 10^0. Hence, we delimit conventionally the validity of this formula to the range $|\gamma| \leq 10^0$.

Equation (1) provides a conservative estimate of the RF exposure since it does not rely on ant spatial averaging over the projected area [1] of the exposed subject. It is particularly suitable for determining exposures within the antenna main lobe.

For exposures behind the antenna, which are much lower due to the antenna backplane shielding effect, it is possible to employ Eq. (1) with $\phi = 0$, but reducing the radiated power by the antenna front-to-back gain ratio, when this figure is available. This is preferable to sampling Eq. (1) at $\phi = \pi$, since the azimuthal gain tapering by the exponential factor may produce an excessive front-to-back ratio, thereby making the estimate less conservative.

Because near-field coupling between antenna and exposed body is not considered in the present treatment, the exposure estimates based on it should be trusted only for distances larger than a wavelength from the antenna.

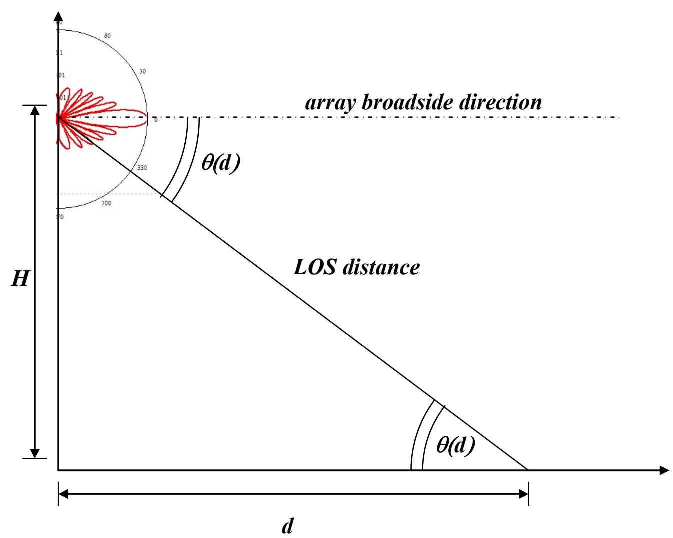


Fig. 2. Schematic of the ground-level exposure model adopted for the assessment.

B. Exposure at ground level

This type of exposure occurs in the antenna far-field, and is very low compared to limits, thus simpler expressions can be employed. The antenna phase center is assumed to be the mounting height. The resulting predictive equation for the power density produced by each antenna at ground level is:

$$S(d) = (2.56) \cdot \frac{W_{rad} \cdot G(\theta(d))}{4\pi (H^2 + d^2)} \qquad (2)$$

where W_{rad} is the radiated power, and $G(\theta)$ is the elevation gain pattern, which is approximated by means of the following expression

$$G(\theta) = G_A \left[\left| \frac{\sin\left(\frac{k_0 L}{2}\sin\theta\right)}{\frac{k_0 L}{2}\sin\theta} \cos^X \theta \right|^2 (1-B) + B\cos^{1/X}\theta \right] \quad (3)$$

where G_A is the antenna gain, k_0 is the free space wavenumber and *L* is the effective antenna length yielding the appropriate vertical beamwidth, *X* and *B* are auxiliary parameters used to shape the elevation pattern, while *H* is the antenna height above ground and *d* is the field point distance from the base of the installation tower (see Fig. 2). The factor "2.56" is introduced to enforce near-perfect, in-phase ground reflection as recommended in [1].

C. Exposure to dish antennas

As illustrated in [1], the following expression allows estimating an upper bound of the RF exposure in the near field in front of dish antennas, expressed in terms of time-averaged power density:

$$S_{dish} = \frac{4W_{rad}}{A_{dish}} \quad (4)$$

where W_{rad} is the radiated power (conservatively assumed equal to the input RF power), and A_{dish} is the effective area of the dish antenna aperture, computed from the peak antenna gain (G_{dish}) according to the following expression:

$$A_{dish} = \frac{\lambda^2}{4\pi} G_{dish} \quad (5)$$

where λ is the electromagnetic free-space wavelength at the operating frequency. Therefore, antennas featuring larger apertures produce lower near-field exposure than antennas with smaller ones, for the same input RF power. Exposures outside the antenna aperture are typically negligible.

Equation (4) produces an overestimation in the antenna far field since it does not account for the eventual spherical field decay behavior. In order to account for this behavior, the formula is divided by the factor that grows weakly with distance at short distances and eventually grows with the square of the distance at large distances from the antenna:

$$S_{sph} = \frac{S_{dish}}{1+\left(\frac{r}{r_0}\right)^2}, \quad r_0 = \sqrt{\frac{G_{dish} A_{dish}}{16\pi}} \quad . \quad (6)$$

Exposure assessment

RF exposure assessments are carried out for the Motorola Solutions system for exposures close to the antennas or at ground level. No assessment is performed for pre-existing co-located systems and antennas, if any.

The ground level assessment is conducted extremely conservatively upon presuming that all antenna emissions are oriented towards the same direction. The assessment of exposure in front of the antennas is further exaggerated by assuming that the antennas are also physically collocated.

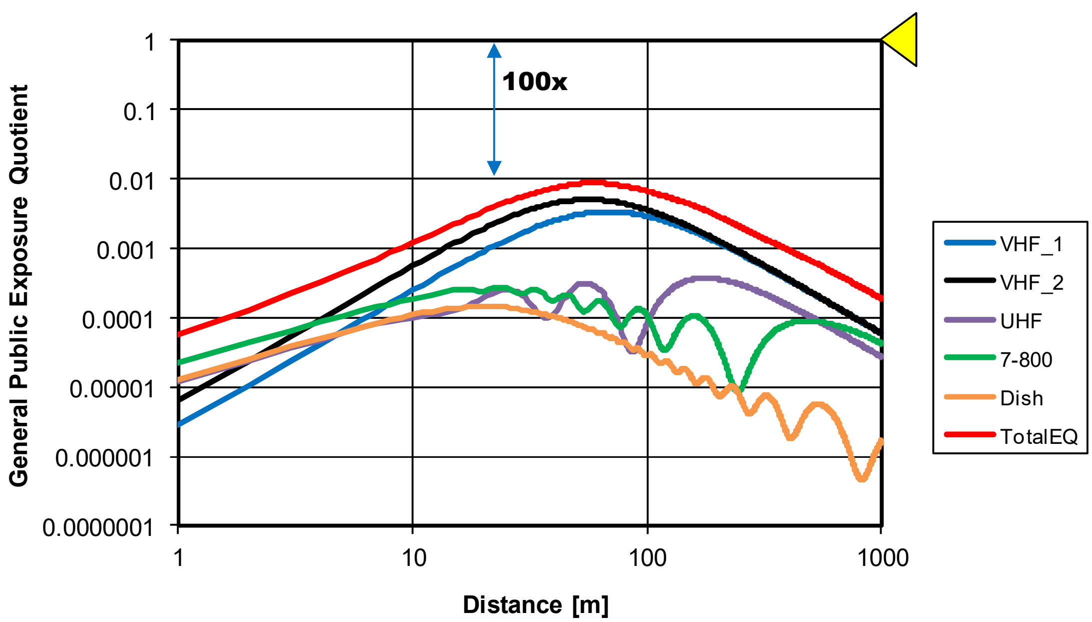
Furthermore, the assessment is carried out by assuming perfect antenna efficiency and spatial averaging across a person projection area is not performed, rather the peak exposure is computed for conservativeness.

Exposure at Ground Level

Table 3 reports the equivalent antenna length or area used in Equations (3) and (4):†

3	Sub-System	VHF_1	VHF_2	UHF	7-800	Dish
	Equivalent Length (m)	1.05	1.05	2.2	3.3	1.2
	Equivalent Area (m^2)	N/A	N/A	N/A	N/A	1.13

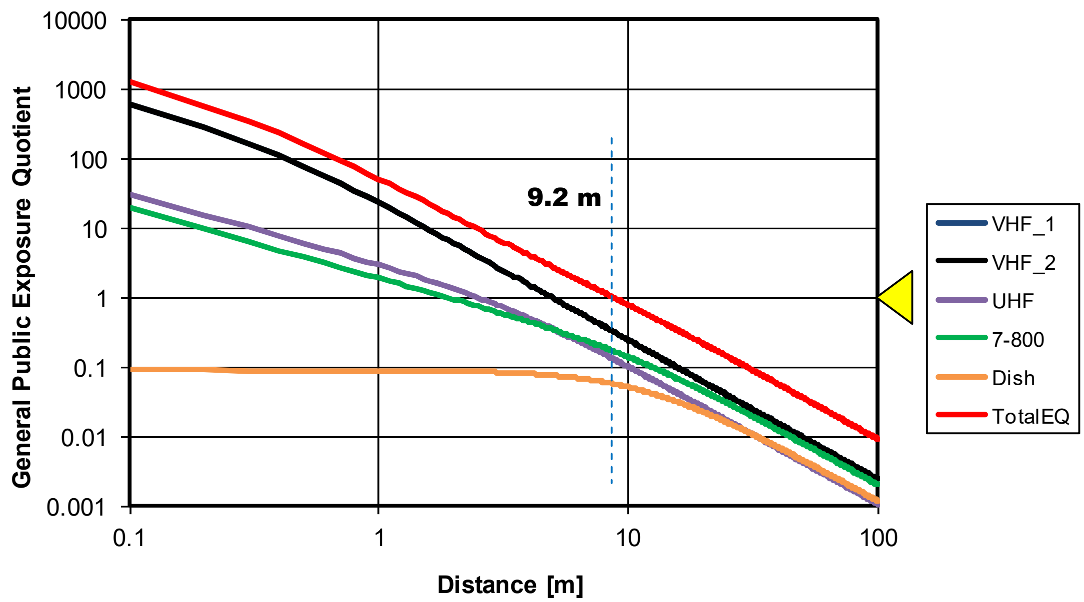
The following plot illustrates individual antenna and the total exposure quotients, at various distances from the site communication tower, showing that the combined exposure is always at least 100 times below the applicable general public limits (i.e., unity, highlighted by the yellow marker) even under the aforementioned conservative assumptions.

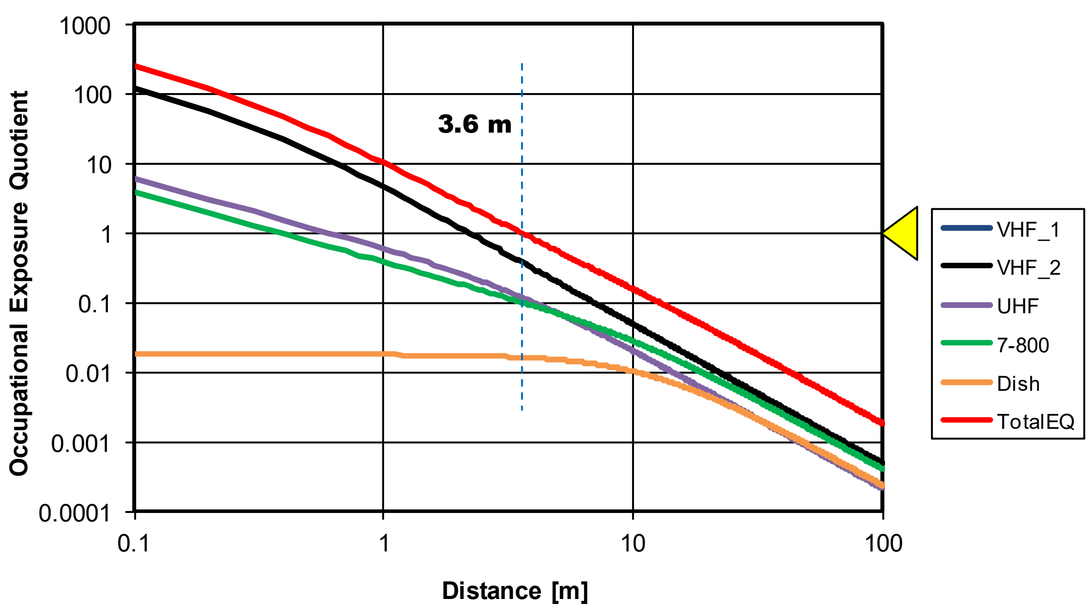


† The X, B factors used to shape the antenna elevation beam in Eq. (1) are B = 0.01, and X = 1 in all cases.

Exposure at Locations Facing the Antennas

Using the equivalent lengths and diameter in Table 3 in Equations (1) and (4)-(6), the exposure quotients are computed versus distance for the general public limits and for the occupational limits, as shown in the following diagrams:





This analysis indicates that, under the aforementioned conservative assumptions, the compliance distance for the general public is 9.2 m, while it is 3.6 m for occupational exposures.

Summary and conclusions

A computational assessment was carried out to provide an estimation of the RF exposure at the Saugerties, NY site communication tower, showing that the Motorola Solutions system described in the foregoing complies with the FCC requirements concerning RF exposure of trained workers and the general public. Because Motorola Solutions does not have any information related to other products located at the site, the report does not include information about co-located pre-existing systems and antennas, if any.

References

[1] United States Federal Communication Commission, "Evaluating compliance with FCC guidelines for human exposure to radiofrequency electromagnetic fields," OET Bulletin 65 (Ed. 97-01), August 1997.

[2] R. Cicchetti and A. Faraone, "Estimation of the Peak Power Density in the Vicinity of Cellular and Radio Base Station Antennas," *IEEE Transactions on Electromagnetic Compatibility*, Vol. 46, No. 2, pp. 275-290, May 2004.

[3] Federal Communications Commission Office of Engineering and Technology (Laboratory Division). RF Exposure Procedures and Equipment Authorization Policies for Mobile and Portable Devices. KDB 447498 D01 v06. October 23, 2015.

ANTENNA DATA SHEETS

(KEY SPECS)

CSA Series

VHF Screened Dipole Array Antennas

148 - 174 MHz

The CSA Series arrays are based on the popular OA Series dipole array antennas. Supplied in "kit" form the these antennas are delivered in flatpack packaging to minimise freight and warehousing issues and allow for simplified assembly at time of installation.

The CSA Series arrays have approximately 60 degrees horizontal beamwidth and offer 7 or 9dBd in gain. The use of the corner screen reflector boosts the front to back ratio considerably allowing for tailoring antenna patterns for frequency re-use in extended networks.

CSA Series Arrays feature the same solid construction as the standard array series. The folded dipoles utilise an internal phasing harness in PTFE based double screened coaxial cable with a polyethylene jacket. The screens themselves are also made of fully welded aluminum to assist in minimising PIM.

With all welded construction and superior internal harness construction the antennas provide not only excellent radiation characteristics but also defined, high levels of intermodulation and noise suppression. IM performance is -140dBc based on a two carrier test. The entire array rests at ground potential and offers the ultimate in lightning resistant antennas.

- Offset (cardioid) pattern with 60 Degree nominal Horizontal Beamwidth
- High front to back ratio to allow frequency re-use by tailoring coverage areas
- Hermetically sealed internal PTFE based phasing harness capable of 750W continuous operation.
- Shipped unassembled for ease of handling, easily assembled on site
- Direct DC grounded for lightning protection and reduction of precipitation static noise
- Industry leading dual sectioned antenna PIM ratings (-140dBc) providing low IM and low noise characteristics for optimum performance
- The screen can be purchased to retrofit to an existing OA series array. See table below;

Kitted components available for individual sale

Complete Array Part Number	CSA10-41-DIN	CSA20-41-DIN
Antenna Only Part Number	M-8648	OA20-41-DIN
Screen Only Part Number	M-8569	M-8567

RFI
2023 Case Parkway North
Twinsburg, OH 44087
Phone: 330 486 0706
Fax: 330 486 0705

CSA Series

VHF Screened Dipole Array Antennas

148 - 174 MHz

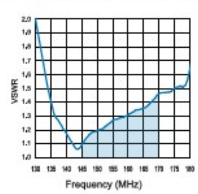
Electrical Specifications

Model Number	CSA10-41-DIN	CSA20-41-DIN
Nominal Gain *dBd (dBi)*	7 (9.1)	9 (11.1)
Frequency *MHz*	148-174	148 - 170
Tuned Bandwidth *MHz*	26	22
VSWR (Return Loss)	<1.5 :1 (14)	<1.7 :1 (11.7dB)
Nominal Impedance Ω	50	
Vertical Beamwidth°	66	35
Horizontal Beamwidth°	64	62
Front / Back Ratio *dB*	23	24
Input Power *Watts*	750	
Passive IM 3rd order (2x20W) *dBc*	-140	

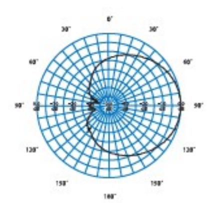
Mechanical Specifications

Model Number		CSA10-41-DIN	CSA20-41-DIN
Construction & Configuration		Welded aluminum, corrosion protection plating	
Screen Length *inches*		51	102
Screen Width *inches*		82	82
Weight lbs		47	172
Shipping Weight *lbs*		57	Screen = 92 + Array = 88 (Total=180)
Shipping Dimensions *inches*	H	17	Screen = 17 Array = 21
	W	38	Screen = 38 Array = 8
	L	59	Screen = 110 Array = 146
Termination		7/16 DIN female on a 20" cable tail	
Mounting Area *inches*		Clamps included to suit pole diameter 3.5 to 4.5	
Projected area *ft²*	No ice	11.4	47.5
	with ice	18.6	64.5
Lateral (Thrust) @ 100mph *lbs*	No ice	281	1175
	with ice	461	1597
Wind Gust Rating *mph*	No ice	>150	>150
	with ice	>150	>150
Torque @ 100mph *ft-lbs*	No ice	449	1100
	with ice	737	1495

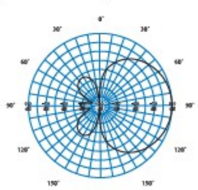
Typical VSWR response (CSA20-41-DIN)



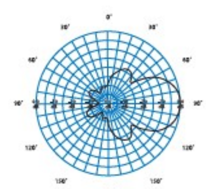
Typical H Plane (CSA20-41-DIN)



Typical E Plane (CSA10-41-DIN)



Typical E Plane (CSA20-41-DIN)



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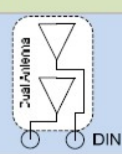
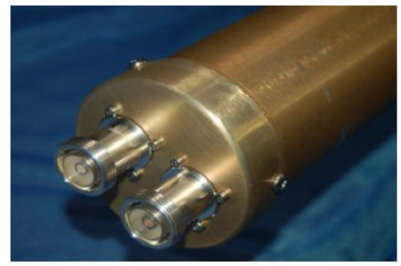
dbSpectra
Always a Better Value

UHF Dual Antenna, Low-PIM, Hi-PIP, 5.9 dBd
Model DS4D06P36D-D, DS4D06P36D6D and DS4D06P3ID-D

Specifications	
Design Type	True Corporate Feed Dual
Frequency Range	480-512 MHz
Passive Intermodulation – PIM (2 x 20W sources)	-150 dBc
Bandwidth	20 MHz
Gain - dBd (average over BW)	5.7 dBd Top 5.9 dBd Bottom
Isolation (typical)	45 dB
Beam Tilt**	1° and 6°
Vertical Beamwidth (E-Plane)	15°
Null fill and upper sidelobe supp.	Yes
Impedance -- Ohms	50
VSWR / Return Loss -- dB	1.5 : 1 / 14 dB (min.)
Average Power Rating	500 W (each antenna)
Peak Instantaneous Power	25 kW (each antenna)
Polarization	Vertical
Lightning Protection	Direct Ground
Connector	7/16 DIN female (2)
Equivalent Flat-Plate Area	3.5 sq. ft.
Lateral Windload Thrust @100mph	147 lbf.
Rated Wind Speed	>125 mph (without ice)
Total Length	21 feet
Mounting Mast Length	35 inches
Mounting Hardware (included)	DSH3V4N
Mast O.D.	3.5 inches
Radome color	Horizon Blue
Weight	65 lbs.
Shipping Weight	95 lbs.
Configuration: Dual, "Two antennas in one"	



Features and Benefits

Dual antenna configuration saves overall cost – allows two antennas in one tower slot.

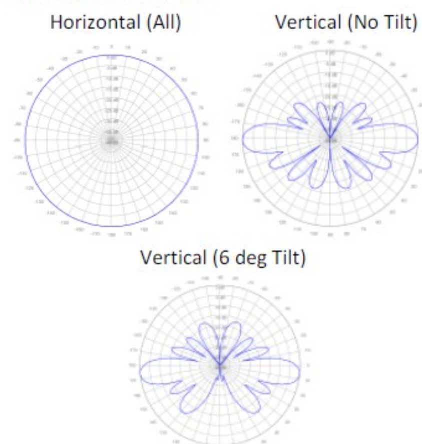
High RF isolation between the independent antennas provides greater system performance and interference protection!

Tested to stringent Peak Instantaneous Power (PIP) levels of 25 KW using dbSpectra's 12-channel P25 PIP test bed. High PIP level is demanded by today's digital systems.

Sturdy Construction – Heavy-wall fiberglass radome minimizes tip deflection.

Excellent Lightning Protection – heavy internal conductor DC ground.

Radiation Patterns:



***Pattern is optimized for "upright" mounting only. Order DS4D06P3ID-D for inverted mounting applications.*

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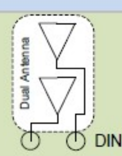
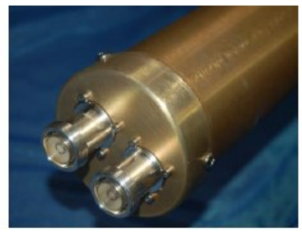
700/800 MHz DUAL Antenna, Low-PIM, Hi-PIP, 9 dBd
Models DS7C09P36D-D, DS7C09P36D2D, and DS7C09P36D6D

Specifications	
Design Type	True Corporate Feed/Dual
Frequency Range	764-869 MHz
Passive Intermodulation – PIM (2 x 20W)	-150 dBc, 3rd Order
Bandwidth	105 MHz
Gain - dBd (average over BW)	9.0 dBd (lower antenna) 8.7 dBd (top antenna)
Isolation (typical)	45 dB
Beam Tilt (electrical downtilt)	0° (none), 2°, or 6°
Vertical Beamwidth (E-Plane) typ.	6°
Impedance -- Ohms	50
VSWR / Return Loss -- dB	1.5:1 / 14 dB (min.)
Average Power Rating	500 W (each antenna)
Peak Instantaneous Power	25 kW (each antenna)
Polarization	Vertical
Lightning Protection	Direct Ground
Connector	7/16 DIN female (x2)
Equivalent Flat-Plate Area	4.8 sq. ft.
Lateral Windload Thrust @100mph	179 lbf.
Rated Wind Speed	125 mph (without ice)
Total Length	24 feet
Mounting Mast Length	35 inches
Mounting Hardware (included)	DSH-3V4N (No Torsion)
Mast O.D.	3.5 inches
Radome color	Horizon Blue
Weight (approx.)	82 lbs.
Shipping Weight (approx.)	105 lbs.
Configuration: Dual, "Two antennas in one"	



Features and Benefits

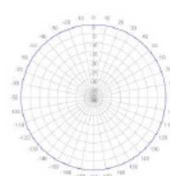
Dual-antenna configuration saves overall cost – allows two antennas in one tower slot!

High RF isolation between the independent antenna provides greater system performance and interference protection.

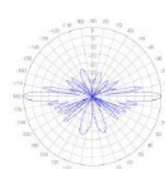
Tested to stringent Peak Instantaneous Power (PIP) levels of 25 KW using dbSpectra's 12-channel P25 PIP test bed. High PIP level is demanded by today's digital systems.

PIM Rated Design – better than -150 dBc.

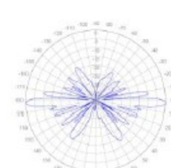
Horizontal (All)



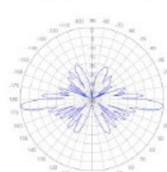
Vertical (no tilt)



Vertical w/ 2-deg Downtilt



Vertical w/ 6-deg Downtilt



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Product Specifications

COMMSCOPE®

on the go

PAR6-59W-PXA/A

1.8 m | 6 ft Parabolic Unshielded Antenna for Relocation-Category A, single-polarized, 5.925–7.125 GHz, CPR137G, gray antenna, molded gray radome with flash, standard pack—one-piece reflector

General Specifications

Packing	Standard pack
Radome Color	Gray
Radome Material	Molded
Reflector Construction	One-piece reflector
Antenna Input	CPR137G
Antenna Color	Gray
Antenna Type	PAR - Parabolic Unshielded Antenna for Relocation-Category A, single-polarized
Diameter, nominal	1.8 m | 6 ft
Flash Included	Yes
Polarization	Single

Electrical Specifications

Beamwidth, Horizontal	1.8 °
Beamwidth, Vertical	1.8 °
Cross Polarization Discrimination (XPD)	30 dB
Electrical Compliance	Canada SRSP 305.9 Part A | Canada SRSP 306.4 Part A | ETSI Class 1 | US FCC Part 101A | US FCC Part 74B
Front-to-Back Ratio	59 dB
Gain, Low Band	38.0 dBi
Gain, Mid Band	38.7 dBi
Gain, Top Band	39.0 dBi
Operating Frequency Band	5.925 – 7.125 GHz
Radiation Pattern Envelope Reference (RPE)	2480
Return Loss	28.3 dB
VSWR	1.08

Mechanical Specifications

Fine Azimuth Adjustment	±15°
Fine Elevation Adjustment	±20°
Mounting Pipe Diameter	115 mm | 4.5 in
Net Weight	98 kg | 216 lb
Side Struts, Included	1 inboard
Side Struts, Optional	1 inboard
Wind Velocity Operational	110 km/h | 68 mph
Wind Velocity Survival Rating	200 km/h | 124 mph

Wind Forces At Wind Velocity Survival Rating

Angle α for MT Max	-130 °