Technical Reference

Capstone C1000S/C800S/C600S Signature Series Acoustic Emissions

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1 Introduction

This document presents the acoustic emissions data for Capstone Models C1000S, C800S and C600S Series Microturbines operating on high-pressure natural gas fuel. These models are modular products, consisting of a number of 200 kW power modules installed into a common enclosure. The number of installed power modules determines the model of the Microturbine (i.e. a C600, C800 and C1000 utilize 3, 4 and 5 power modules, respectively). The individual 200 kW power modules share a common fuel header, control system, and electrical output bus. The system is controlled by a single controller with a single aggregate power rating.

Measurements were performed on the C1000S and C600S (3-bay enclosure) microturbine systems. For the C800S, sound pressure and sound power values were calculated using the C1000S/C600S measured values.

Two types of measurements were taken per test unit, sound power levels and sound pressure levels. The sound power levels were determined by following the ISO 3744 standard (relevant to EU requirements found in 2005/88/EC). The sound pressure measurements were acquired using directivity measurement technique similar to the ISO 3744 hemispherical test method. See Table 1 below for a summary of measured and calculated (for the C800S) sound levels.

Table 1. Summary of Measured Sound Levels

Configuration	Overall Sound Pressure Level at 10m (dBA)	Overall Sound Power (dBA ref 1pW)
C1000S	75.8	106.0
C800S	74.7*	105.0*
C600S	72.9	103.8

*These values are calculated, not measured. See sections 7.5 and 7.6 in Appendix A for calculation methods.

2 Applicable Documents

Table 2 lists the standards governing the test methods used in this Technical Reference.

Table 2. Testing Standards

Document Number	Document Title
2000/14/EC	Directive 2000/14/EC of the European Parliament and Council
2005/88/EC	Directive 2005/88/EC of the European Parliament and Council
ISO 3744	Determination of Sound Power Levels of Noise Sources Using Sound Pressure

3 Glossary

Table 3. Acoustical Glossary

Term	Definition
A-WEIGHTED SOUND LEVEL	The ear does not respond equally to frequencies. It is less efficient at low and high frequencies than it is at medium or speech range frequencies. Thus, to obtain a single number representing the sound level of a noise containing a wide range of frequencies in a manner representative of the ear's response, it is necessary to reduce the effects of the low and high frequencies, with respect to the medium frequencies. The resultant sound level is said to be A-weighted, and the units are decibels (dB). A popular method of indicating A-weighted decibels is dBA. The A-weighted sound level is also called the noise level.
ABSORPTION	Absorption is a property of materials that reduces the amount of sound reflected. Thus, the introduction of an "absorbent" onto the surfaces of a machine will reduce the sound pressure level by virtue of the fact that sound energy striking the machine surfaces will not be totally reflected.
ACOUSTICS	Acoustics is the science of sound; including the generation, transmission, and effects of sound waves, both audible and inaudible. It is also the physical qualities of an enclosure (such as size, shape, amount of noise) that determine the audibility and perception of sound.
AIRBORNE SOUND	Airborne sound is sound that reaches the point of interest by propagation through air.
ANALYSIS	The Analysis of a noise generally refers to the examination of the composition of noise in its various frequency bands, such as octaves or third-octave bands.
AUDIO FREQUENCY	Audio Frequency is the frequency of oscillation of an audible sine wave of sound. Typically, any frequency between 20 and 20,000 Hz. Refer to Frequency.
BACKGROUND NOISE	Background Noise is the noise from all sources other than the source under test. Background noise may include contributions from airborne sound, structure-borne vibration, and electrical noise in instrumentation.
DECIBEL	The Decibel (abbreviated "dB") is a unit of measure, on a logarithmic scale, of the magnitude of a particular quantity (e.g. sound pressure, sound power) with respect to a standard reference value (0.0002 microbars for sound pressure and 10^{-12} watts for sound power).
FREQUENCY	The number of times per second that the sine wave of sound repeats itself, or that the sine waves of a vibrating object repeats itself. Expressed in Hertz (Hz).
HERTZ	Unit of measurement of frequency, numerically equal to cycles per second.
LEVEL	The level of an acoustical quantity (sound pressure or sound power), in decibels, is 10 times the logarithm (base 10) of the ratio of the quantity to a reference quantity of the same physical kind.
MEDIUM	Medium is a substance carrying a sound wave.
MICROBAR	A Microbar is a unit of pressure, equal to 1 dyne per square centimeter.

Table 3. Acoustical Glossary (Continued)

Term	Definition
MICROPHONE	An electro-acoustic transducer that responds to sound waves and delivers essentially equivalent electric waves.
NOISE	Noise is any sound that is undesirable because it interferes with speech and hearing, or is intense enough to damage hearing, or is otherwise annoying.
NOISE LEVEL	Refer to sound level.
OCTAVE	An Octave is the interval between two sounds having a basic frequency ratio of two.
OCTAVE BAND	Frequency ranges in which the upper limit of each band is twice the lower limit. Octave bands are identified by their geometric mean frequency, or center frequency.
PERIOD	The duration of time it takes for a periodic waveform (like a sine wave) to repeat itself.
PHASE	For a particular value of the independent variable, the fractional part of a period through which the independent variable has advanced, measured from an arbitrary reference.
PITCH	Pitch is a listener's perception of the frequency of a pure tone, wherein the higher the frequency, the higher the pitch.
PURE TONE	Pure Tone is a sound wave whose waveform is that of a sine wave. Irregular wave forms are not pure tones. Sound waves can have irregular shape, but when it is the same as a sine wave, it is said to be a pure tone.
SINE WAVE	A Sine Wave is a sound wave, audible as a pure tone, in which the sound pressure is a sinusoidal function of time.
SOUND	Refer to Acoustics.
SOUND LEVEL	The Sound Level is the A-weighted sound pressure level obtained by use of a sound level meter having a frequency filter for attenuating part of the sound spectrum.
SOUND POWER	Airborne sound energy per unit time that is radiated by a source. It is expressed in units of watts.
SOUND PRESSURE	Fluctuations in air pressure caused by the presence of sound waves.
SOUND POWER LEVEL (L_W)	The sound power radiated from a given sound source as related to a reference power level (typically 10^{-12} watts – hearing threshold). It is expressed in units of decibels (dB).
SOUND PRESSURE LEVEL (L_p)	The RMS value of the pressure fluctuations above and below atmospheric pressure, due to a sound wave. It is expressed in units of decibels (dB) or a reference pressure of 0.0002 microbars (2 x 10^{-5} N/m2).
SPECTRUM	Spectrum is the description a sound wave's resolution into components, each of different frequency and (usually) different amplitude and phase.

Table 3. Acoustical Glossary (Continued)

Term	Definition
TONE	Tone is a sound of a pitch. A pure tone has a sinusoidal waveform.
WAVEFORM	Waveform is a presentation of some feature of a sound wave, for example, the sound pressure level as a graph showing the variation of sound pressure level with time.

4 Test Setup

4.1 Environment

Measurements were performed on the outdoor concrete test pad at the Capstone Turbine facility. Figure 1 and Figure 2 respectively illustrate the layout of the test area and footprints of the C1000S and the C600S, showing also the Reference Box and Measurement Surface Box. The location of the test units was far enough away from the main building that the reflected sound did not affect the sound power measurements (with the exception of locations near 90° during polar measurements, requiring the minor corrections detailed in section 4.3). The test units were operated with high-pressure natural gas supplied by the facility gas mains through a single, stainless steel flexible hose. The C1000S unit was operated at the 1000kW and the C600S at 600kW power demand setting.

Sound power testing was recorded on level concrete. Polar sound pressure level measurements were made 10 meters (33 feet) from the measurement surface's center at the 15 degree increments shown in Figure 1 (C1000S) and Figure 2 (C600S). The concrete had a lip that went up to a fence before dropping to a level 0.9 meters (3 feet) below grade and running out to a drainage ditch. This lip reduced the ground effect for measurements made on the opposite side of the fence. As indicated in Section 4.3.3, corrections were made for the uneven surface.

The main building, east of the 180 degree point, did have an effect on the measured sound pressure levels at some of the measurement points nearest to it. Using spherical spreading and atmospheric absorption for the extra distance traveled by the reflected sound, a wall correction was used below to compensate for this. As indicated in Section 4.3.2, the correction does not exceed 1 dB.

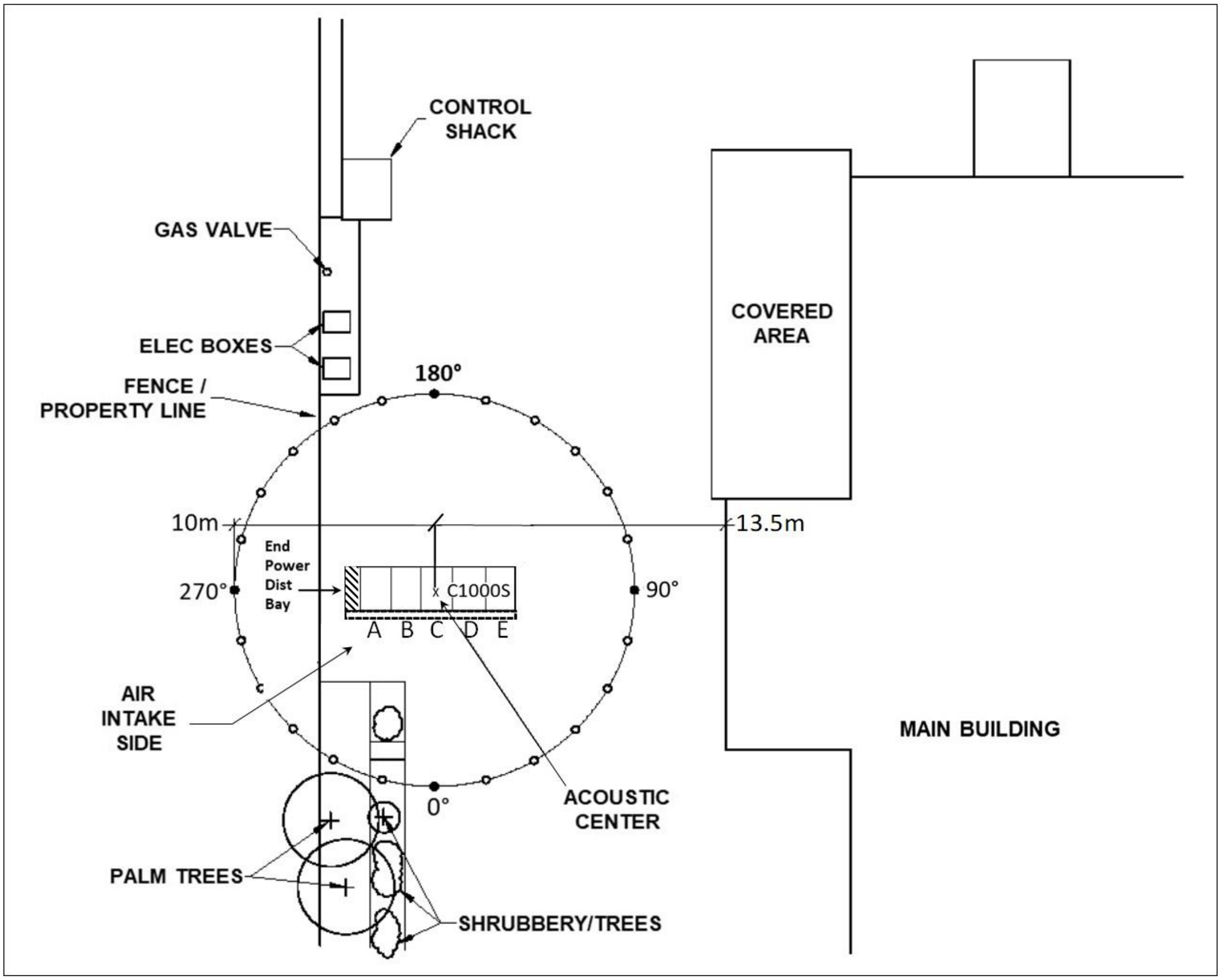

Figure 1. Plan View of C1000S Test Setup

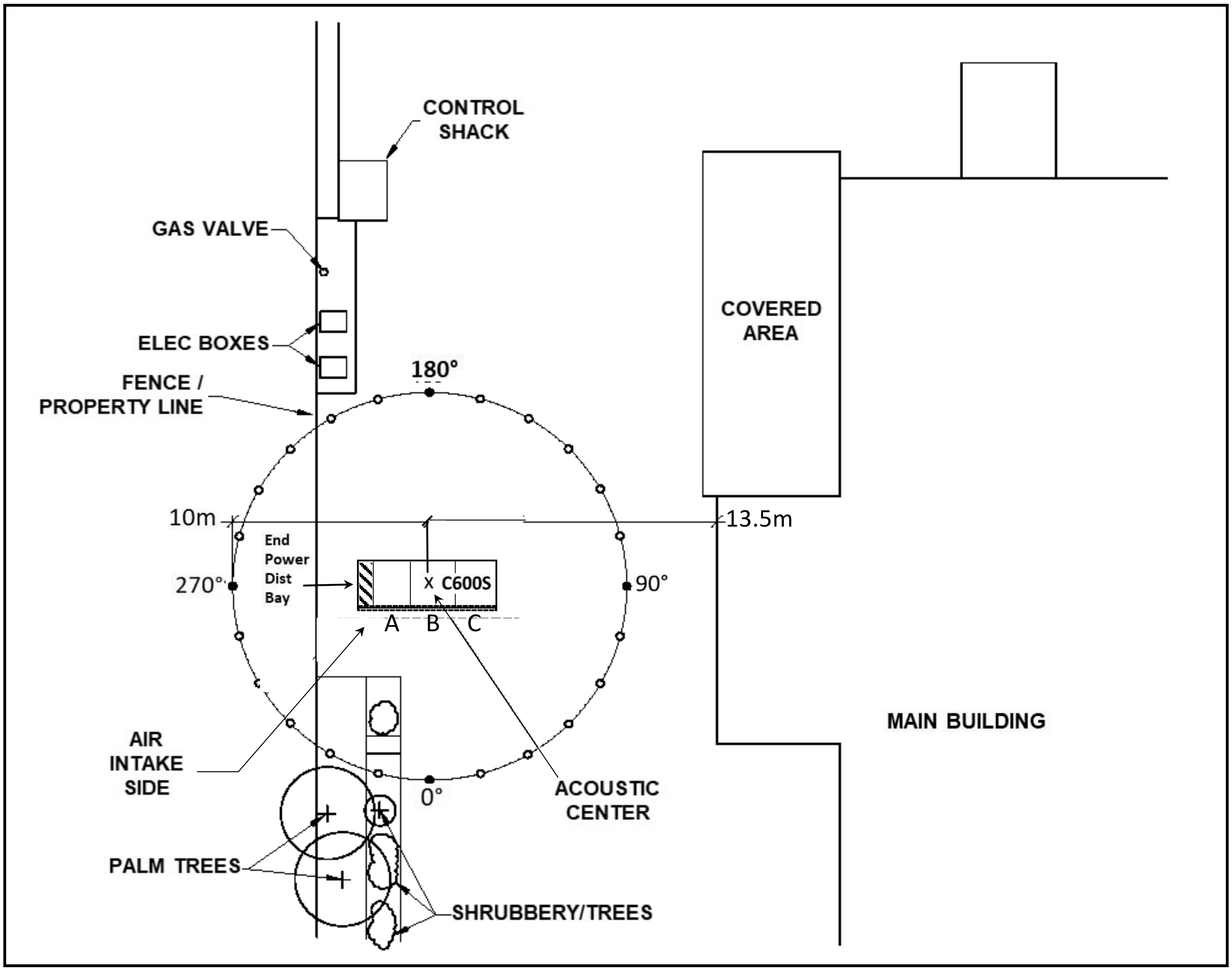

Figure 2. Plan View of C600S Test Setup

4.2 Sound Power Level Test Method

4.2.1 Reference Box and Measurement Surface Box

Prior to testing, a reference box was defined for the C1000S. As indicated in the standard, this reference box had to encompass all parts of the source to be measured. The height of the reference box defined for C1000S was the largest and for simplicity this height was used both for the C1000S and C600S testing.

After determining the reference box, a measurement surface was defined 1 meter from the surface of the reference box. Dimensions of the reference box and measurement surface are noted in Table 4.

Table 4. Dimensions of the Reference Box and Measurement Surface Box

		L	W	H
C1000S	Ref Box [m]	9.14	3.20	4.30
	Meas Box [m]	11.14	5.20	5.30
C600S	Ref Box [m]	5.84	3.20	4.30
	Meas Box [m]	7.84	5.20	5.30

The average sound level over the measurement surface was measured by moving the microphone along paths that met the standard's requirement of representing equal areas where each path was separated by no more than 1.5 meters. Figure 3 shows the layout of the paths around the measurement surface. The separation of the six traversing side paths was 0.88 m (dimension 'a' in Figure 3) around the C1000S unit. To measure the average sound level of the top of the measurement surface, straight paths were used in combination with the top path around the vertical sides.

To measure the top surface for the C1000S, seven straight paths were used, separated by 0.65 m (dimension 'b' in Figure 3). The straight paths stopped short of meeting the top perimeter traversing path. This was done to ensure the paths represented equal areas. The distance between the straight paths and the long side of the top traversing path were equal to the separation between the straight paths. Path numbers increase from ground up. Figure 4 illustrates the package, reference box, and measurement path dimensions used for the C1000S. Figure 5 illustrates the package, reference box, and measurement path dimensions used for the C600S.

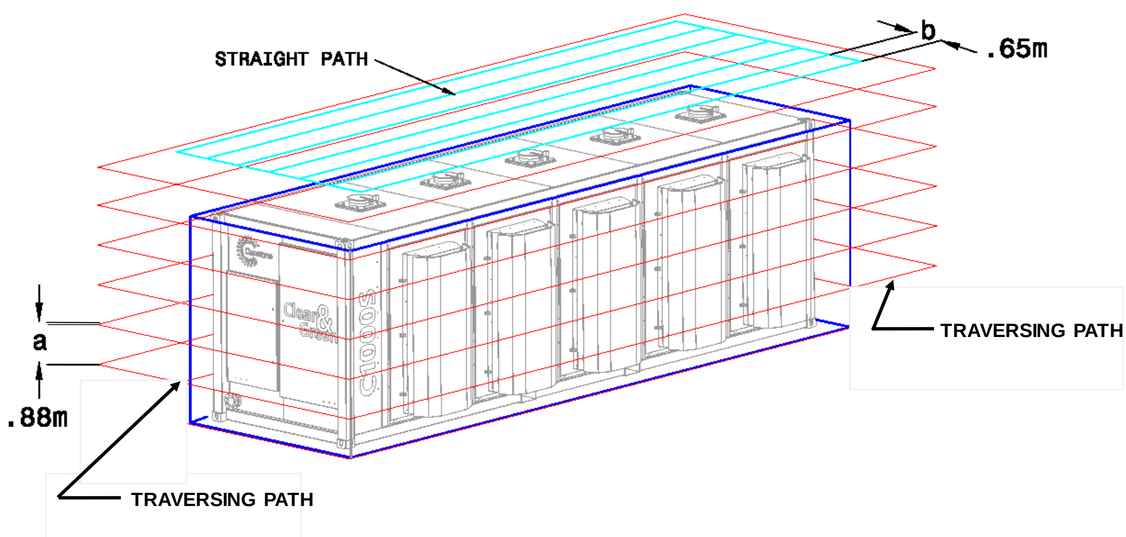

Figure 3. Paths on Measurement Surface

The C1000S and C600S were both tested overnight in order to minimize background noise interference. They were tested one after the other, with an ambient recording made prior to testing the first unit, and another ambient recording made after testing the second unit. Both units were tested at 100% power demand. The sound power testing followed these steps:

1. Prior to testing, one ambient recording was made to determine the background noise level.
2. The test unit was turned on and allowed to run until a steady state was indicated by Capstone engineer (typically 30-45 minutes).
3. Once the unit was running at steady state, scanning was completed along microphone traversing paths. The scanning rate (i.e. the speed the microphone was moved on a path) was approximately 1 m/s. Every path was traversed twice for a period of time greater than 30 seconds for every measurement. If two measurements of a path did not agree within 0.5 dBA, the measurement of the path was repeated. Any extraneous noise interference during a measurement caused the measurement to be repeated.
4. Using acoustics standard ISO 3744, background and environmental corrections were then evaluated (labeled as K1 and K2, respectively). The method by which the corrections were calculated is provided in Appendix B. For these tests, the results of the corrections are discussed in Section 5.1 of this report.
5. After both units were tested, a second ambient recording was made to determine background noise level.

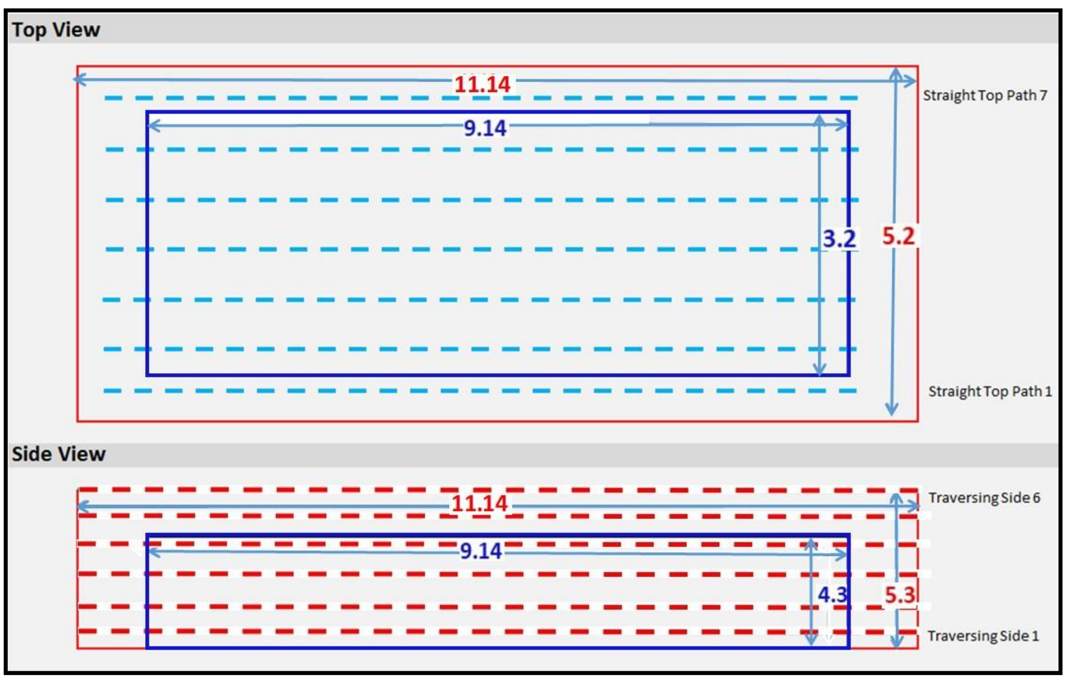

Figure 4. C1000S Traversing Paths and Measurement Surface Dimensions (meters)

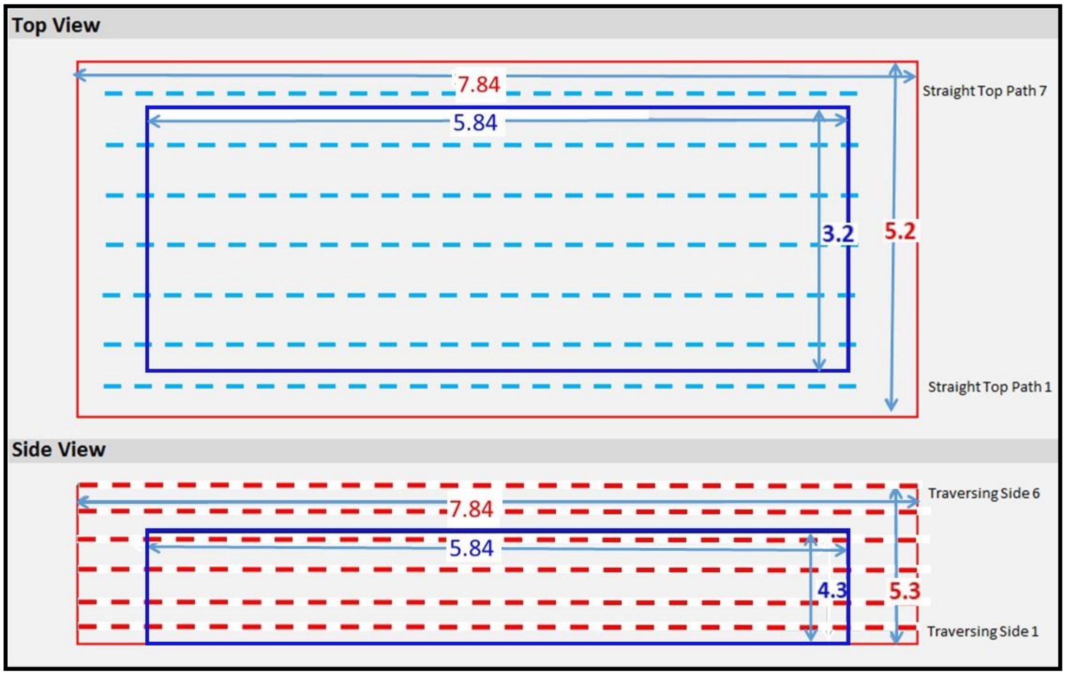

Figure 5. C600S Traversing Paths and Measurement Surface Dimensions (meters)

4.3 Sound Pressure Level Test Method

In order to collect data for directivity, sound pressure measurements were taken at 10m from the acoustic center of the package. The sound level meter was placed at a height of 1.5m above the ground surface and two measurements were taken for 30 seconds each. If the two readings varied by more than 0.5 dB, then the reading was repeated. Readings were taken at 15º polar increments around the package, with the 0º location at the inlet side of the package.

As with the sound power measurements, ISO 3477 provides methods for calculating background and wall reflection corrections (K1 and K2, respectively) when performing sound pressure measurements. The general method used to determine these corrections is provided in Appendix B. The results of these corrections are discussed below in the following paragraphs.

4.3.1 Background Corrections (K1)

The test method allows for zero background correction if the ambient values are lower than the recorded values by more than 15 dBA. Background data collected before and after the test runs showed that this was the case. As such, there was no background correction required (calculations for this determination are provided in Section 7.1 in Appendix B).

4.3.2 Wall Reflection (Environmental) Corrections (K2)

The lowest point on the measurement surface from the acoustic center was 10 meters, and the distance from the acoustic center to the wall was 13.5 meters away; therefore, the environment did not comply with the standard since the required distance to the wall was 30m. For these tests, this distance was exceeded at all polar locations except those near the 90-degree point. For the impacted points, spherical spreading and atmospheric absorption was used to account for the extra distance traveled by the reflected sound (see calculations in Section 7.2 in Appendix B), with the results shown in Table 5. The values in Table 5 indicate that the corrections do not exceed 1 dB.

Since the C1000S and C600S testing used the same acoustic center, the 10 meter measurement locations were the same distance relative to the wall. For this reason, the same wall correction factors can be applied to both data sets for location 0-180 degrees as shown in Table 5.

Table 5. Wall Correction Factors

Polar Angle (degrees)	Wall Correction (dB)
90	0.8
75/105	0.8
60/120	0.7
45/135	0.6
30/150	0.5
15/165	0.4
0/180	0.4

4.3.3 Ditch/Raised Lip Correction

The measurements outside the fence / property line were above a dirt surface that was 0.9 m (3 ft) below the grade of the main concrete parking lot. The profile of the grade change is shown in Figure 6.

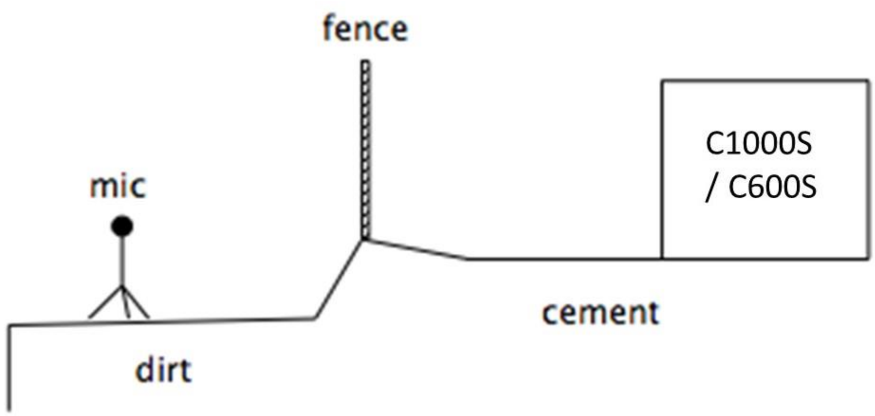

Figure 6. Profile of Grade Change Outside Capstone Property Fence Line
(Figure not to scale)

The effect of the concrete surface lip at the fence line was to block what would be the interference of the reflected sound ray off the ground effectively reducing the sound level. In order to compensate for this, the C1000S was measured, then rotated 90° counterclockwise and measurements repeated so that the affected locations would all be measured in a free field environment.

An evaluation of both C1000S measurements determined that the impact of the raised lip was less than 0.3 dBA when averaged over the complete polar dataset. This is considered an insignificant impact. Because of this and that fact that the 600S had the end bay facing the ditch, and was further from the ditch than the C1000S, rotating the C600S was determined to be unnecessary.

4.4 Meteorological Data

Table 6. Meteorological Data

Test	Pressure	Wind Speed (mph)	Temp (deg C)	Relative Humidity (%)	Date (MM/DD/YYYY)	Time (HH:MM)
C1000S	29.89	8.1	75.0	62	7/28/2017	7:51 PM
C800S	Not tested					
C600S	29.83	5.8	78.1	52	8/10/2017	7:51 PM

5 Data Measurements

5.1 Sound Power Level Measurements

Sound power measurements followed the ISO 3744 standard and the parallelepiped method using a traversing microphone. They were taken 1m from the surface of the reference box as described in Section 4.2. Conversion to sound power levels did not require any adjustments or corrections to the measured data.

5.1.1 Background Corrections (K1)

The test method allows for the zero background correction if the ambient values are lower than the recorded values by more than 15 dBA. Background data collected before and after the test runs showed that this was the case and, as discussed above, no background correction was required.

5.1.2 Wall Reflection (Environmental) Corrections (K2)

The lowest point on the measurement surface from the acoustic center was 3 meters, and the distance from the acoustic center to the wall was 13 meters away; therefore, the environment was in compliance with the standard, and no environmental correction (K2) was required.

5.1.3 Overall A-weighted / Declared Sound Power Levels

The overall A-weighted sound power levels for the tested Microturbines were calculated per Section 7.3 of Appendix B and are provided in Table 7 below:

Table 7. Overall A-weighted Sound Power Levels

Configuration	Overall sound power (dBA ref 1pW)
C1000S	106.0
C800S	105.0*
C600S	103.8

*This value is calculated from C1000S value. See section 7.5 in Appendix A for calculation method.

Based on the test data and sound power levels, the declared noise emission value for a production series of machines was determined per ISO 3744 (see Section 7.4 of Appendix B). This resulted in the addition of 2.5 dB to the measured values as shown in Table 8.

Table 8. Single Value Declared Noise Emissions

Configuration	Declared sound power (dBA ref 1pW)
C1000S	108.5
C800S	107.5
C600S	106.3

5.2 Sound Pressure Level Measurements

Sound pressure measurements were taken 10m away from the center of the units at 15º increments around the entire unit. The location of the units under test at the Capstone facility required some correction factors related to wall reflection, change of grade, and use of additional free field data as discussed in Section 4.3.3. The overall A-weighted sound pressure levels for each unit are given in Table 9 below:

Table 9. Sound Pressure Levels at 10m

Configuration	Overall sound pressure level (dBA) @10m
C1000S	75.8
C800S	74.7*
C600S	72.9

*This value is calculated, not measured. See section 7.6 in Appendix A for calculation method.

6 Appendix A: Measured Data

6.1 Sound Power Traversing Data for the C1000S / C600S

Table 10 and Table 11 respectively detail the raw sound power data (LAeq – A-weighted dBA ref 1 picowatt) for the C1000S and the C600S configurations.

Table 10. C1000S Sound Power (Traverse) Data

	C1000	Traverse Side Measured Data												Traverse Top Straight Measured Data													
	Path	1		2		3		4		5		6		1		2		3		4		5		6		7	
	Trial No.	B	C	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
	Laeq	81.5	81.9	82.6	82.7	85.1	85.1	84.4	84.2	82.5	82.4	80.0	79.9	82.1	82.4	82.8	82.9	83.0	82.9	81.7	81.7	80.2	80.5	79.4	79.1	78.6	78.8
Frequency (Hz)	12.5	1.3	1.2	9.8	8.0	6.7	8.5	8.5	6.6	11.4	10.4	11.5	10.8	-7.7	-7.2	0.4	-6.0	-1.0	3.0	-4.5	-4.5	7.0	-2.9	20.7	20.1	17.4	16.1
	16	6.9	6.1	13.5	12.5	8.5	8.9	10.4	9.0	16.2	14.5	16.0	13.9	1.2	-0.2	5.2	4.1	3.0	4.7	4.1	2.7	12.3	8.2	24.1	25.6	18.2	17.8
	20	13.2	14.3	18.7	16.6	16.7	16.5	18.6	17.0	20.6	17.1	20.5	20.2	9.1	9.3	14.1	12.8	11.1	14.8	11.4	11.9	14.7	11.9	30.5	29.4	24.9	21.8
	25	22.6	23.0	23.8	22.9	20.8	20.7	20.8	20.8	23.1	22.3	23.7	22.8	19.4	20.4	21.2	20.6	21.4	22.3	23.6	22.9	23.0	22.6	33.6	30.9	28.9	25.5
	31.5	30.2	29.9	29.1	28.8	27.2	27.1	29.1	28.8	30.3	30.1	30.6	30.0	31.6	31.6	31.9	32.1	33.9	34.2	34.6	33.8	33.8	33.7	38.3	36.3	34.1	33.1
	40	34.6	34.8	32.3	31.9	32.2	31.9	35.5	35.5	36.4	36.7	36.4	36.0	37.7	38.5	38.7	38.6	40.2	39.9	40.0	39.8	40.5	40.0	42.7	40.8	38.7	38.1
	50	37.1	37.5	35.5	35.6	35.4	35.7	38.0	38.2	38.7	39.1	38.2	38.2	39.6	40.0	40.8	40.6	41.5	41.4	41.1	41.0	41.2	40.8	42.9	42.1	40.7	40.0
	63	42.2	42.3	39.9	39.8	40.3	40.2	41.6	41.4	42.0	41.7	40.7	40.6	41.9	42.1	43.2	42.9	43.9	43.6	44.0	43.9	43.7	43.1	44.7	44.4	42.2	42.3
	80	47.5	47.4	45.3	45.1	46.4	46.4	45.8	45.7	45.0	45.3	44.4	44.4	45.6	45.7	47.1	46.6	47.1	47.4	47.5	47.1	47.5	46.8	48.2	47.6	46.1	45.6
	100	50.2	50.4	51.3	51.4	51.7	51.9	50.9	50.9	51.0	50.9	50.5	50.3	51.9	51.9	52.5	52.4	54.0	53.3	54.1	53.5	53.5	53.5	53.0	53.0	52.0	51.5
	125	55.6	55.3	55.7	55.6	55.2	55.4	57.4	57.1	57.3	57.4	57.0	56.9	58.6	58.5	59.9	59.8	61.3	60.9	60.4	60.9	60.8	60.7	59.6	59.8	58.7	58.1
	160	67.3	66.2	62.5	62.1	61.7	62.0	61.5	60.9	61.4	61.4	60.6	60.9	62.3	62.3	63.6	63.2	63.9	64.1	63.9	63.9	63.6	63.3	62.2	62.1	61.4	61.2
	200	58.8	58.6	57.6	57.5	58.7	58.8	62.6	62.3	63.1	63.0	62.3	62.1	64.2	64.5	65.5	65.5	65.2	65.5	65.2	65.1	64.7	64.5	64.0	64.1	63.2	63.3
	250	66.7	66.5	64.3	64.2	67.2	67.2	71.7	71.4	72.5	72.5	71.3	71.4	73.9	74.1	74.3	74.1	73.7	73.9	73.3	73.0	73.1	73.0	72.3	71.9	71.7	71.6
	315	67.0	66.9	66.4	66.4	69.2	69.2	73.7	73.6	74.4	74.4	72.8	72.8	75.4	75.4	74.5	74.5	75.4	75.3	75.4	75.5	73.9	74.2	72.7	72.2	72.3	71.9
	400	65.7	65.4	64.4	64.4	66.8	66.9	71.7	71.4	71.3	71.3	68.9	68.8	71.3	71.7	72.7	72.7	72.1	72.0	71.0	70.9	69.3	69.7	66.7	66.5	65.6	65.8
	500	65.3	65.0	64.7	64.8	68.0	68.1	73.4	73.1	71.5	71.5	68.9	68.9	72.5	72.7	73.5	73.6	72.9	72.8	70.9	71.0	68.2	68.3	65.5	65.1	63.8	64.0
	630	64.2	64.0	64.9	64.9	68.6	68.7	74.1	73.6	70.3	70.3	69.0	69.0	72.7	73.0	73.4	73.7	72.9	72.8	70.3	70.2	67.9	68.2	65.5	65.0	64.3	64.4
	800	63.7	63.7	64.6	64.6	67.3	67.4	72.0	71.4	68.9	69.0	66.5	66.3	69.3	69.8	69.8	69.6	69.1	69.1	68.1	68.0	66.9	67.2	65.1	64.7	63.7	63.2
	1000	73.0	73.9	74.5	74.8	77.4	77.7	76.8	76.3	73.4	73.3	69.9	70.4	70.8	70.9	71.5	72.0	72.1	72.0	71.3	71.4	69.6	70.5	68.8	69.5	68.4	67.9
	1250	66.6	66.5	64.8	64.9	66.5	66.6	69.8	69.5	66.5	66.2	63.6	63.6	65.8	66.4	66.8	67.1	68.3	68.0	67.2	67.4	63.3	63.8	62.2	62.0	61.7	62.3
	1600	65.9	66.0	65.5	65.4	67.0	66.9	67.0	66.8	65.6	65.6	61.7	61.5	63.2	63.8	64.4	64.2	65.5	65.3	64.1	64.1	59.8	60.3	60.2	59.8	60.3	61.1
	2000	67.7	67.9	67.6	67.6	68.1	68.0	67.7	67.8	66.6	66.6	63.4	62.9	64.0	64.6	65.8	65.7	67.2	67.1	64.8	64.8	59.8	60.9	61.5	61.0	63.1	63.8
	2500	65.5	65.3	64.3	64.8	66.5	66.4	65.1	64.9	63.2	63.0	59.3	59.1	59.4	60.1	63.1	63.0	64.4	64.1	61.7	61.7	57.9	58.4	58.6	58.3	59.0	60.0
	3150	68.2	68.0	69.3	69.9	72.4	72.5	69.7	69.5	66.0	65.6	62.1	61.9	62.1	62.3	64.4	64.4	65.1	65.0	62.9	62.8	60.5	61.0	61.9	61.4	61.2	62.2
	4000	70.1	70.0	71.8	71.4	73.9	73.8	70.5	70.4	66.3	66.1	63.0	62.8	63.4	63.6	64.1	63.9	64.4	64.5	62.7	62.5	60.9	61.4	62.2	61.9	62.3	63.2
	5000	69.1	69.5	70.5	70.6	73.4	73.4	69.0	68.9	65.6	65.4	61.6	61.4	61.4	61.8	62.9	62.9	63.6	63.7	61.4	61.4	60.0	60.5	61.9	61.4	61.0	62.1
	6300	76.6	77.4	78.5	78.6	81.0	81.1	75.9	76.0	74.0	73.8	69.4	69.2	68.0	69.0	70.6	70.6	70.5	70.4	69.3	69.1	68.2	68.8	70.5	69.9	68.8	70.4
	8000	61.6	61.7	62.9	63.1	66.6	66.6	67.0	66.7	64.0	63.8	59.1	58.9	60.8	61.3	63.7	63.5	65.7	65.5	60.7	60.7	57.2	58.0	58.3	57.8	56.9	57.7
	10000	58.6	58.9	60.7	61.1	63.4	63.2	61.9	61.8	59.1	59.1	55.0	54.8	56.6	56.8	59.1	58.8	60.1	59.9	56.1	56.1	53.2	53.9	55.0	54.3	52.3	53.6
	12500	67.9	68.7	70.3	70.9	71.9	71.5	71.1	70.9	67.8	68.0	64.6	64.3	68.0	67.6	69.5	68.8	69.4	68.8	65.3	65.0	62.4	62.8	63.2	62.9	59.9	61.2
	16000	50.3	50.7	55.1	55.9	57.7	57.6	58.8	58.4	54.8	54.8	49.0	48.6	50.1	50.6	53.6	53.3	58.0	57.5	52.6	52.5	47.6	48.2	49.4	49.1	45.6	47.1
	20000	44.1	44.3	50.0	51.2	53.9	53.8	49.6	49.3	44.7	44.8	39.9	39.4	40.8	40.9	43.0	43.1	45.3	45.0	42.3	42.1	38.8	39.1	41.6	40.9	35.1	37.0

Table 11. C600S Sound Power (Traverse) Data

C600	Traverse Side Measured Data												Traverse Top Straight Measured Data													
Path	1		2		3		4		5		6		1		2		3		4		5		6		7	
Trial No.	A	B	A	C	A	C	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
LAeq	81.0	81.1	81.8	81.6	83.8	83.9	83.5	83.4	81.2	81.2	79.1	79.2	81.5	81.3	81.8	81.8	81.9	81.8	80.9	80.8	78.3	78.0	76.3	76.3	76.5	76.5
Frequency (Hz)																										
12.5	2.2	5.2	9.7	13.0	0.4	2.7	5.6	5.5	8.9	7.8	10.9	9.6	-6.8	-10.1	-6.3	-4.9	-4.1	-7.4	-5.3	-4.8	13.1	18.1	23.6	23.3	17.9	17.5
16	9.3	9.1	13.3	17.9	5.8	5.9	7.6	6.1	12.4	11.3	15.9	12.4	0.2	-0.4	5.3	7.1	3.2	2.9	2.4	3.0	19.2	22.4	27.8	28.2	23.2	21.9
20	14.2	15.4	19.1	19.5	14.2	15.6	14.8	14.2	19.5	17.2	19.8	20.6	8.2	8.7	9.6	10.6	10.2	9.9	11.1	10.8	21.1	26.0	34.6	33.7	29.2	27.1
25	21.3	21.7	21.7	24.4	19.3	19.6	19.2	18.9	22.3	20.7	23.3	23.6	18.2	18.2	19.2	19.7	21.5	21.2	21.4	20.1	26.1	29.5	38.6	36.4	29.9	29.9
31.5	28.5	29.2	27.8	29.0	26.6	27.0	28.9	28.0	30.5	29.2	29.8	30.7	30.3	29.8	31.1	31.3	32.8	34.5	33.2	32.6	35.0	35.7	40.6	39.3	34.1	34.7
40	34.6	35.1	32.9	33.1	32.5	32.6	35.4	35.0	37.2	36.6	36.1	36.7	37.3	37.5	37.9	38.5	40.3	40.2	40.4	38.7	40.4	40.2	44.6	42.3	39.4	40.1
50	35.5	36.0	34.5	34.6	36.3	36.4	38.4	38.2	38.5	38.6	37.8	38.3	39.3	38.3	39.4	39.8	41.7	41.4	40.9	40.3	40.9	41.8	44.6	43.4	40.3	41.1
63	40.3	40.9	39.1	39.2	40.8	41.0	41.6	41.6	41.1	40.7	40.1	40.8	41.4	41.4	41.6	42.0	43.4	43.0	43.1	42.4	42.4	43.1	45.9	44.8	42.3	41.9
80	45.4	46.0	44.5	44.5	45.9	45.9	45.5	45.4	44.4	44.3	43.5	44.0	44.9	44.9	45.7	45.4	46.6	46.2	46.3	45.8	46.5	45.9	47.4	46.6	45.8	45.2
100	48.6	49.7	50.3	50.1	50.9	50.9	50.3	50.3	49.8	49.8	49.2	49.1	50.3	50.0	50.6	50.3	50.7	50.9	50.9	50.7	51.0	51.0	51.9	50.8	49.9	49.7
125	53.4	54.4	54.6	54.6	54.5	54.3	56.1	56.2	56.3	56.3	55.7	55.8	57.2	56.7	57.7	57.6	58.4	57.9	58.7	58.9	58.4	58.4	57.6	57.2	56.6	56.6
160	63.7	63.7	59.0	59.2	60.1	60.1	60.2	60.0	60.4	60.2	59.8	59.9	60.9	61.1	61.2	61.0	62.3	62.3	62.3	62.5	62.0	61.8	61.0	60.7	60.2	59.8
200	57.1	57.2	56.8	56.8	58.4	58.4	61.3	61.0	61.6	61.5	61.1	60.8	62.3	61.8	63.1	62.8	63.2	63.2	62.7	62.9	61.8	61.9	61.7	61.2	61.2	60.9
250	62.8	63.0	62.7	62.7	66.3	65.9	70.2	70.2	71.1	71.2	70.3	70.2	72.4	72.1	72.1	72.1	71.9	71.9	71.3	71.0	70.4	70.4	68.9	69.0	69.2	69.0
315	63.5	63.4	65.6	65.6	69.0	68.6	73.1	72.9	73.8	73.8	72.2	72.4	74.5	74.4	73.8	73.5	74.4	74.0	74.8	74.4	71.7	71.8	70.0	70.2	69.7	69.7
400	63.9	63.6	63.9	64.0	67.0	66.6	71.6	71.3	70.8	70.7	68.5	68.4	71.1	71.1	71.9	72.4	71.9	71.8	70.5	70.7	68.1	67.8	64.9	64.9	62.8	62.5
500	63.9	63.5	64.3	64.5	67.8	67.3	73.0	72.6	70.2	70.3	68.2	68.0	71.9	71.7	72.2	72.2	72.0	72.1	70.5	70.4	66.3	66.6	63.0	62.9	61.8	61.6
630	65.1	64.7	64.7	64.7	68.5	67.7	73.2	73.0	68.9	68.8	68.0	68.1	72.1	71.8	73.2	72.9	72.2	72.0	69.5	69.6	66.6	66.0	63.4	63.3	61.9	61.7
800	65.9	65.9	64.9	65.0	67.1	66.5	71.3	71.3	67.6	67.3	65.2	65.1	68.7	68.2	68.2	68.3	67.7	67.9	66.3	66.7	64.7	63.9	61.4	61.5	61.4	60.8
1000	73.6	72.7	72.8	73.1	73.9	73.2	74.4	74.2	70.9	70.6	67.6	67.8	70.8	70.7	71.0	71.2	71.1	70.6	70.2	70.2	68.6	67.7	65.0	65.4	63.5	64.2
1250	66.9	66.7	64.8	64.9	66.4	66.0	69.4	68.9	65.2	65.0	62.6	62.8	64.9	65.1	66.7	66.6	67.7	68.0	67.4	67.1	62.0	61.3	59.4	59.4	59.6	59.6
1600	66.8	66.5	65.0	65.2	66.5	66.4	66.5	66.5	64.2	64.0	60.5	60.6	62.2	62.4	63.8	63.8	64.8	64.7	64.3	64.3	59.2	58.6	58.3	57.8	58.2	58.1
2000	69.4	68.4	67.2	67.4	67.5	67.6	67.4	67.0	65.6	65.9	62.4	62.4	64.1	64.2	65.2	65.3	66.8	66.7	65.0	65.4	59.2	59.3	59.4	59.2	60.5	60.4
2500	65.9	65.4	64.3	64.1	64.6	64.5	63.8	63.7	61.8	62.3	59.3	59.2	60.1	59.8	61.3	61.7	62.9	62.3	60.0	60.3	56.1	56.1	55.7	55.4	58.0	57.7
3150	66.7	66.7	68.0	67.5	70.0	69.9	66.9	66.7	63.4	63.5	61.1	60.8	61.6	61.2	61.8	61.9	62.2	61.9	60.4	60.5	57.4	56.8	56.9	56.8	60.7	60.7
4000	69.2	69.2	71.6	71.0	74.3	74.4	69.3	69.0	65.2	65.1	62.5	62.3	63.4	63.0	64.4	64.3	64.9	64.9	63.2	63.1	60.1	59.1	59.4	59.2	61.9	62.2
5000	68.0	68.4	70.0	69.7	72.4	72.9	68.3	68.4	63.9	63.9	60.9	60.6	60.6	60.6	61.8	61.9	63.4	63.1	61.3	60.9	58.9	58.0	58.4	58.3	60.4	60.7
6300	75.9	76.9	77.9	77.5	79.7	80.2	75.6	76.0	72.0	72.1	69.2	69.4	67.1	67.5	68.5	68.3	69.1	68.7	68.1	67.7	66.2	65.1	65.5	65.7	68.8	69.1
8000	59.8	60.0	61.4	61.1	65.3	65.4	66.4	66.3	62.2	62.7	58.3	58.4	60.0	59.8	61.9	61.7	64.0	63.8	61.0	61.0	55.7	54.6	53.3	53.4	55.0	54.6
10000	56.5	56.5	58.7	58.3	61.4	61.6	60.9	60.8	58.0	58.0	54.8	54.9	57.3	56.9	57.9	58.0	58.8	58.7	55.2	55.4	52.1	50.5	49.9	49.6	50.9	50.6
12500	65.6	65.6	68.4	67.8	70.0	70.1	70.0	70.1	68.0	68.1	65.3	65.5	68.6	68.2	68.7	69.1	67.8	68.1	64.9	65.2	62.4	60.2	58.7	58.3	58.8	58.3
16000	47.5	47.4	51.4	50.8	54.9	54.7	57.0	56.7	52.6	52.7	47.6	47.7	49.2	49.1	51.4	51.7	55.5	55.3	51.2	51.2	44.8	43.7	43.3	43.1	43.5	42.8
20000	41.3	41.0	45.7	45.1	50.9	50.8	46.9	47.1	41.9	41.5	38.1	38.4	39.5	39.7	41.0	41.0	42.1	42.6	40.0	40.3	35.0	34.5	35.2	34.8	34.3	34.3

6.1.1 Sound Pressure Polar Data for C1000S

Table 12 below provides the C1000S Sound Pressure Data.

Figure 7 below shows the orientation of the microturbine depicted in the sound pressure data graphs. Figure 8 through Figure 38 provide the Acoustic Directivity (sound pressure) graphs (LAeq, dBA) for the C1000S configuration.

Table 12. C1000S Sound Pressure (Polar) Data

Location	0	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300	315	330	345
LAeq 12.5Hz	0.2	0.9	2.7	3.5	5.6	6.1	7.0	6.9	5.7	5.6	5.1	4.7	5.1	3.8	3.5	4.1	2.4	2.4	1.6	1.7	1.0	0.4	0.8	-0.1
LAeq 16Hz	7.3	7.0	8.6	11.1	13.7	15.1	15.9	15.6	14.6	13.5	12.4	12.4	12.2	12.3	13.1	13.5	13.2	12.4	12.3	11.9	11.5	10.8	10.7	8.8
LAeq 20Hz	16.9	15.7	14.1	13.3	16.4	19.4	19.7	18.9	17.2	17.3	18.9	19.8	20.9	20.9	20.1	19.0	19.8	19.5	18.9	18.2	17.5	16.2	17.1	16.7
LAeq 25Hz	22.4	22.1	21.0	18.8	15.6	16.3	17.6	18.1	20.6	23.3	24.9	25.2	24.7	24.3	23.4	21.6	21.9	22.9	23.2	22.7	21.6	19.8	21.6	21.7
LAeq 31.5Hz	27.1	26.2	28.1	28.6	26.1	23.5	22.5	25.3	28.4	29.2	29.5	29.5	29.2	29.6	29.9	28.5	26.5	27.0	26.8	26.4	25.4	25.1	26.7	26.9
LAeq 40Hz	34.5	34.7	34.9	37.8	39.3	39.7	38.6	39.1	40.4	38.6	37.3	37.2	36.8	37.3	39.4	38.1	34.6	34.7	35.3	34.9	33.9	35.1	35.3	33.8
LAeq 50Hz	41.8	42.7	42.1	41.5	44.7	46.0	46.7	46.7	42.1	44.3	45.4	44.8	44.4	43.7	46.4	43.8	41.2	40.5	40.8	40.3	40.9	40.8	42.6	42.5
LAeq 63Hz	48.1	49.1	49.6	48.6	45.8	48.4	50.6	49.9	46.0	49.6	49.2	49.2	49.7	48.3	51.2	49.4	48.6	45.4	45.8	45.5	45.5	47.5	48.1	48.1
LAeq 80Hz	51.3	50.3	49.8	49.8	50.0	43.9	42.1	46.9	48.6	47.4	47.3	47.5	48.0	48.0	45.3	49.5	45.5	45.3	46.2	45.6	45.5	48.9	49.2	50.5
LAeq 100Hz	52.3	51.0	50.8	50.5	47.5	48.2	47.1	47.4	46.1	47.5	47.7	48.2	47.9	48.5	47.7	47.0	46.5	43.6	44.7	45.2	46.8	49.5	49.5	51.0
LAeq 125Hz	54.3	54.6	52.8	51.4	50.9	47.2	47.0	49.1	48.9	48.1	47.1	47.8	46.9	46.7	48.0	49.1	48.7	45.3	45.7	45.9	49.0	52.2	52.1	53.9
LAeq 160Hz	65.8	65.0	63.0	60.7	60.6	54.8	57.0	55.6	55.7	55.3	51.4	52.3	53.3	52.6	53.4	56.0	52.6	49.3	53.1	54.0	59.7	64.0	62.8	65.2
LAeq 200Hz	50.6	50.5	50.0	50.7	50.7	52.4	52.3	53.1	54.3	54.6	53.7	53.2	53.5	53.7	54.2	56.1	50.8	48.3	48.5	48.9	49.7	51.0	50.7	51.0
LAeq 250Hz	53.7	53.8	54.6	55.6	55.7	55.4	54.9	55.8	58.0	59.7	59.7	59.3	59.4	59.5	59.9	60.0	56.1	53.8	52.7	53.4	54.7	56.0	55.2	55.2
LAeq 315Hz	57.2	57.2	57.6	58.9	59.2	56.9	57.2	58.7	61.0	61.5	62.1	61.0	62.1	62.3	60.2	61.6	57.3	55.9	57.6	57.1	58.4	60.2	58.1	56.9
LAeq 400Hz	59.5	58.7	57.7	59.6	60.3	64.4	64.2	65.1	65.1	65.8	65.2	64.1	63.2	64.3	65.2	66.8	62.9	59.8	59.8	59.9	60.2	60.4	58.6	59.0
LAeq 500Hz	58.6	57.8	58.0	59.3	62.5	63.3	64.1	64.3	66.5	67.2	67.7	66.5	67.1	66.3	67.9	67.0	65.3	60.9	58.7	58.6	60.9	60.7	59.2	59.4
LAeq 630Hz	57.9	57.9	57.4	58.2	57.5	57.9	61.5	62.0	64.6	65.6	64.7	64.7	64.4	65.0	64.5	65.9	62.2	60.9	60.4	58.4	58.1	58.6	59.0	57.2
LAeq 800Hz	59.2	59.2	58.5	58.2	57.4	57.6	59.1	60.7	62.6	63.8	63.7	63.5	63.8	63.4	64.2	64.6	62.5	61.4	60.4	62.3	60.0	59.1	60.5	59.2
LAeq 1kHz	69.7	70.0	69.6	66.8	64.7	66.1	64.7	65.7	70.0	73.1	74.9	70.7	74.2	70.3	69.6	70.0	65.7	62.7	63.8	65.5	66.3	66.0	69.7	69.8
LAeq 1.25kHz	56.5	57.2	57.9	56.7	55.4	56.3	55.7	57.7	60.4	62.5	62.9	62.4	63.3	62.8	62.0	62.9	60.3	58.6	58.5	60.9	60.9	58.0	58.8	56.9
LAeq 1.6kHz	54.9	56.3	56.1	56.3	55.8	54.9	55.5	58.7	61.4	63.1	63.5	63.4	63.5	64.0	63.9	64.4	61.1	60.0	58.0	60.2	58.9	57.7	57.8	55.6
LAeq 2kHz	57.1	58.1	58.7	56.4	55.8	55.0	56.4	60.5	61.4	64.4	65.0	65.8	65.7	66.5	65.4	66.9	63.4	59.9	60.0	60.4	64.4	59.5	59.9	56.7
LAeq 2.5kHz	54.3	54.7	55.4	55.6	54.0	53.1	53.1	58.8	58.9	61.4	61.4	61.0	61.6	62.0	61.7	63.1	59.5	57.0	56.4	58.6	59.0	57.4	56.8	55.2
LAeq 3.15kHz	55.8	56.5	56.7	58.0	56.6	54.3	55.3	62.4	64.0	66.9	67.7	67.9	67.8	67.5	66.8	66.8	61.3	59.3	55.4	57.0	56.7	56.8	56.0	56.4
LAeq 4kHz	59.2	59.3	59.7	60.7	57.2	55.7	56.0	63.2	64.6	67.9	68.1	67.8	67.5	67.8	67.7	68.8	63.0	60.4	56.4	56.8	56.8	58.7	57.9	58.5
LAeq 5kHz	56.5	57.1	57.1	57.2	55.9	55.6	55.0	64.4	67.3	69.5	69.1	67.9	67.8	67.9	68.7	69.5	63.6	60.3	54.7	53.5	52.9	54.7	54.9	56.0
LAeq 6.3kHz	63.2	63.8	63.3	63.9	62.8	64.0	61.9	73.1	77.6	78.2	77.3	75.4	75.5	75.2	77.8	77.8	71.1	69.0	60.2	58.1	57.4	61.6	59.7	61.7
LAeq 8kHz	50.0	51.2	52.5	53.8	50.3	49.7	47.5	57.3	58.7	60.6	60.1	59.9	59.9	59.7	60.1	60.8	56.3	52.8	47.6	47.3	46.7	50.0	47.9	50.7
LAeq 10kHz	46.8	48.0	48.6	49.4	47.5	44.2	42.5	53.5	53.7	57.6	58.0	58.3	58.0	57.8	57.7	57.9	52.2	49.2	43.7	44.9	43.6	45.8	44.1	46.3
LAeq 12.5kHz	57.7	59.9	59.8	61.1	59.5	56.5	53.5	61.7	62.1	67.0	66.4	66.7	66.0	66.5	66.7	67.1	59.6	56.2	48.9	54.7	52.5	56.2	54.6	56.9
LAeq 16kHz	39.4	40.5	40.1	41.6	38.5	36.3	32.9	44.1	45.7	50.4	51.8	52.7	52.7	51.9	51.3	50.8	43.0	40.2	33.6	35.2	33.2	35.4	34.7	37.9
LAeq 20kHz	28.5	29.8	28.9	28.9	26.4	24.5	23.2	36.1	39.8	45.9	47.3	47.6	47.6	47.1	46.8	46.6	36.9	33.4	25.9	26.3	23.3	24.4	25.5	27.6

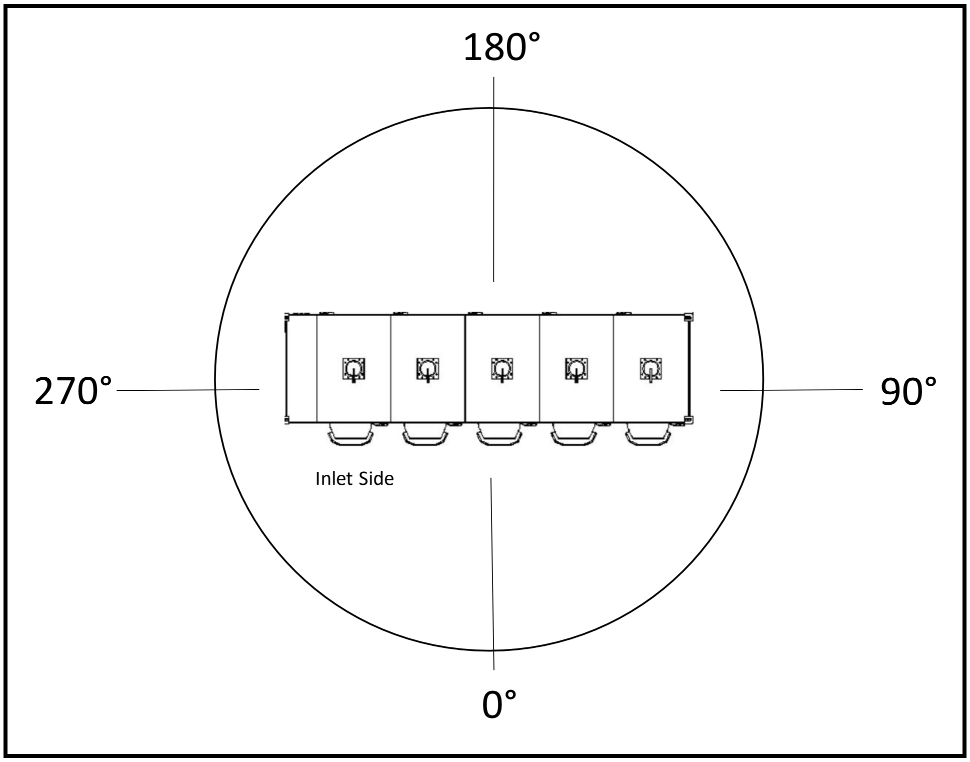

Figure 7. Orientation of C1000S Microturbine in Acoustic Directivity Graphs

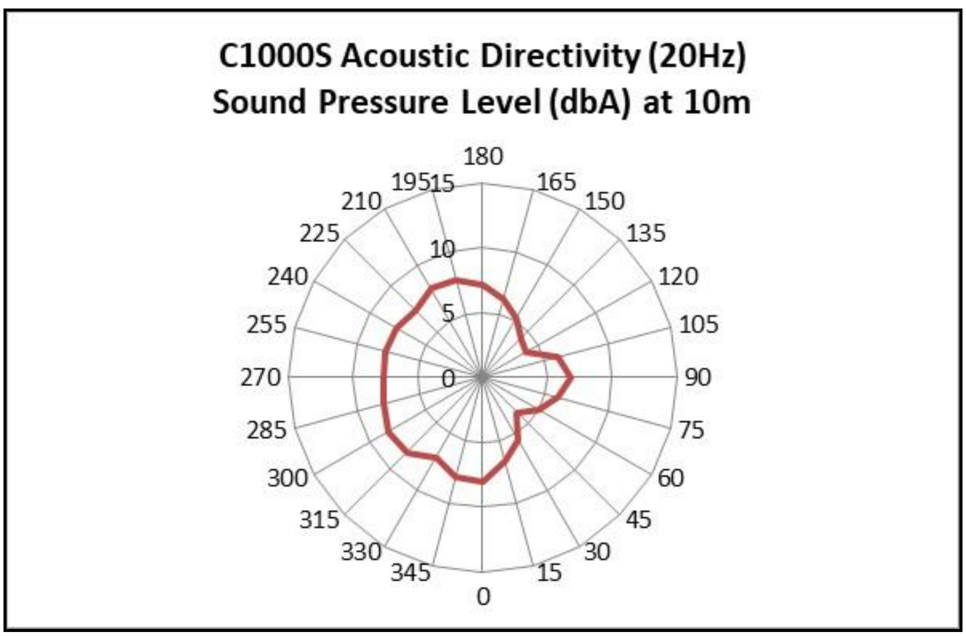

Figure 8. C1000S Directivity 20Hz

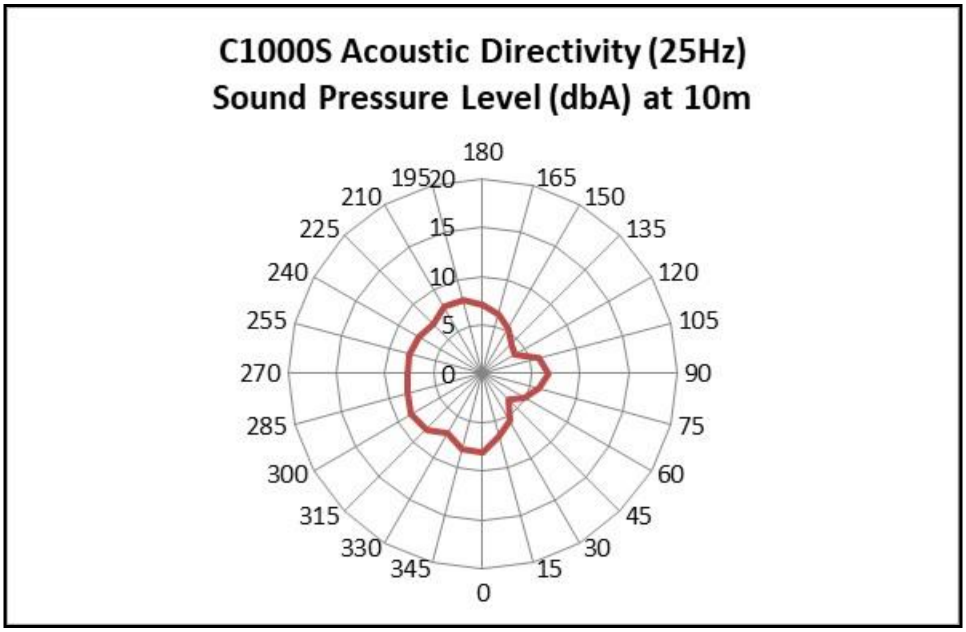

Figure 9. C1000S Directivity 25Hz

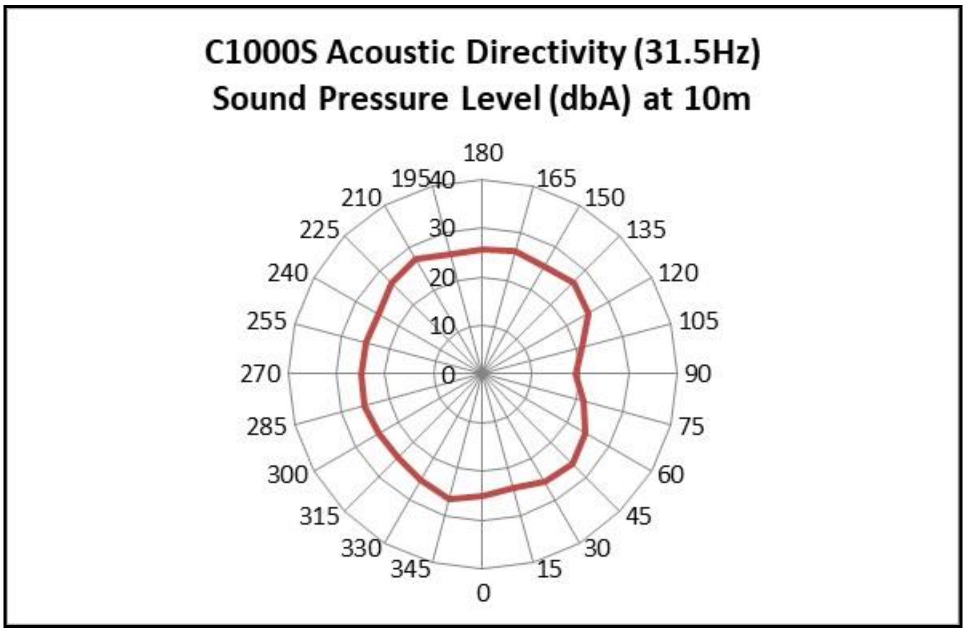

Figure 10. C1000S Directivity 31.5Hz

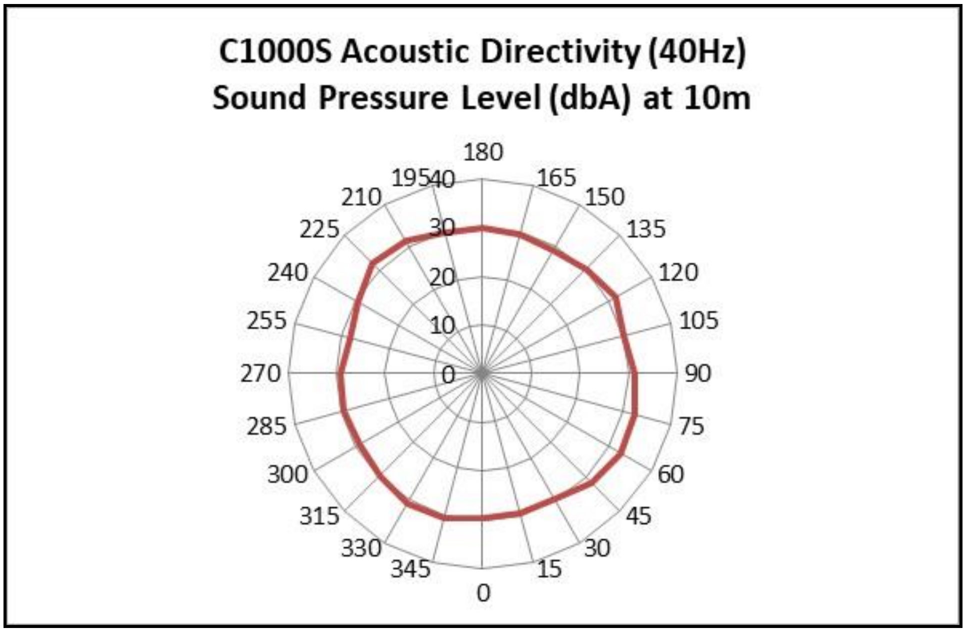

Figure 11. C1000S Directivity 40Hz

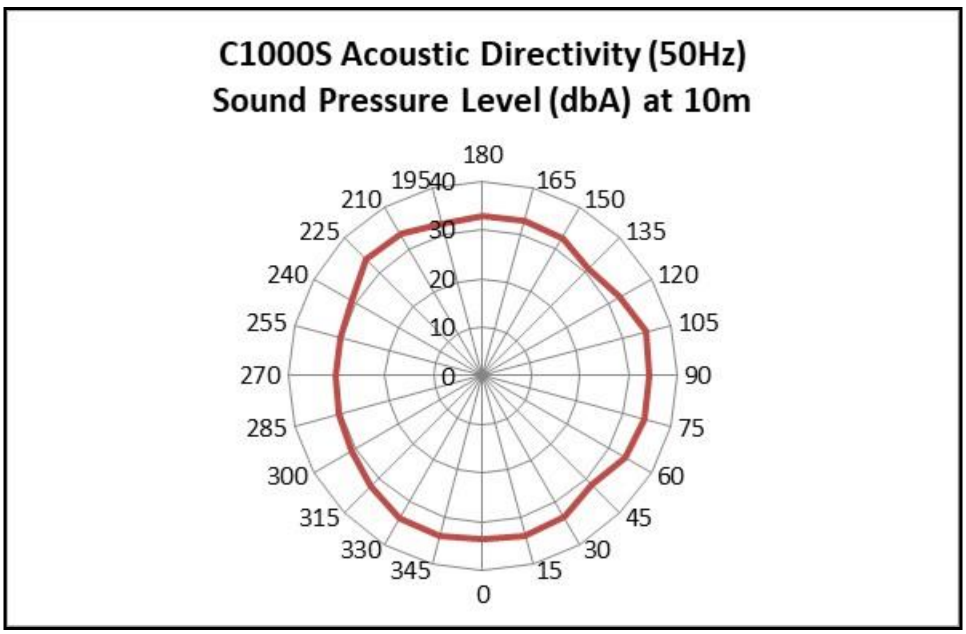

Figure 12. C1000S Directivity 50Hz

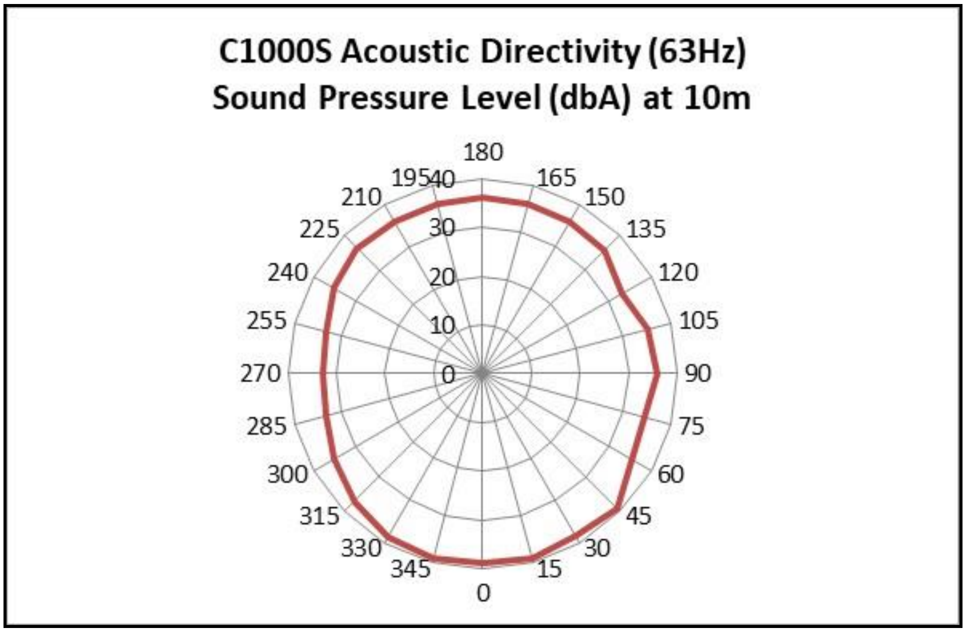

Figure 13. C1000S Directivity 63Hz

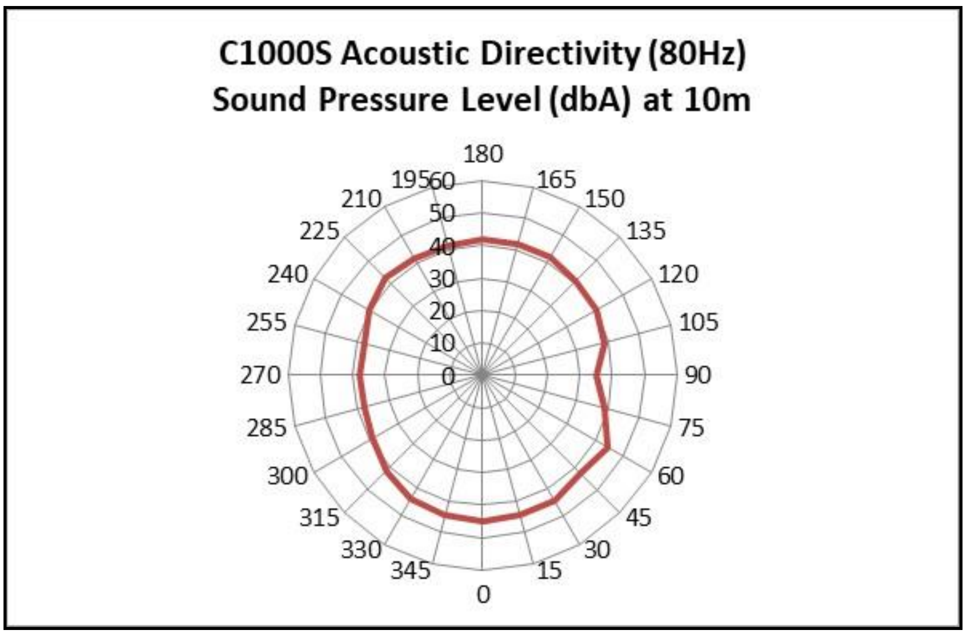

Figure 14. C1000S Directivity 80Hz

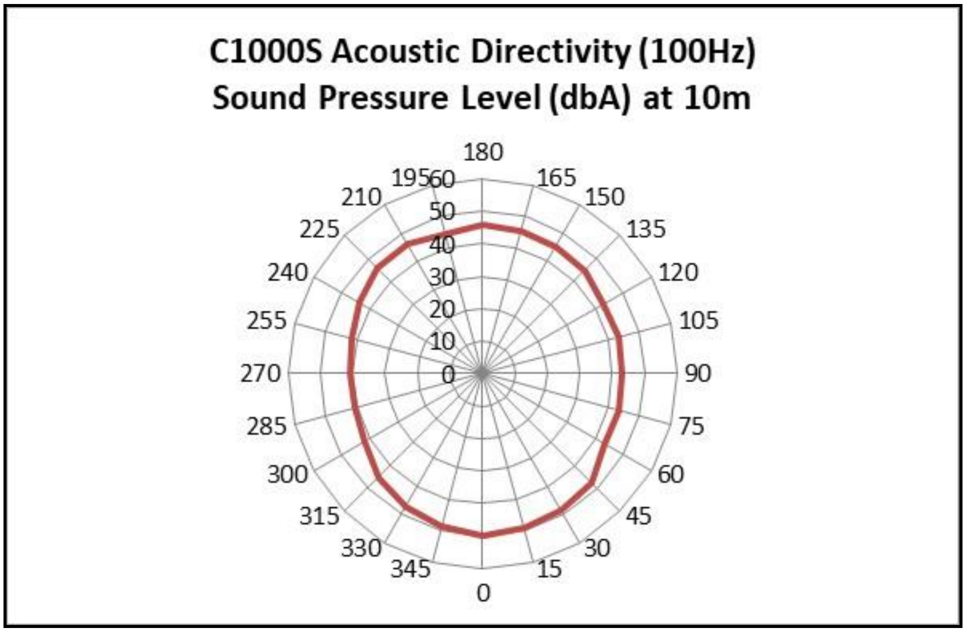

Figure 15. C1000S Directivity 100Hz

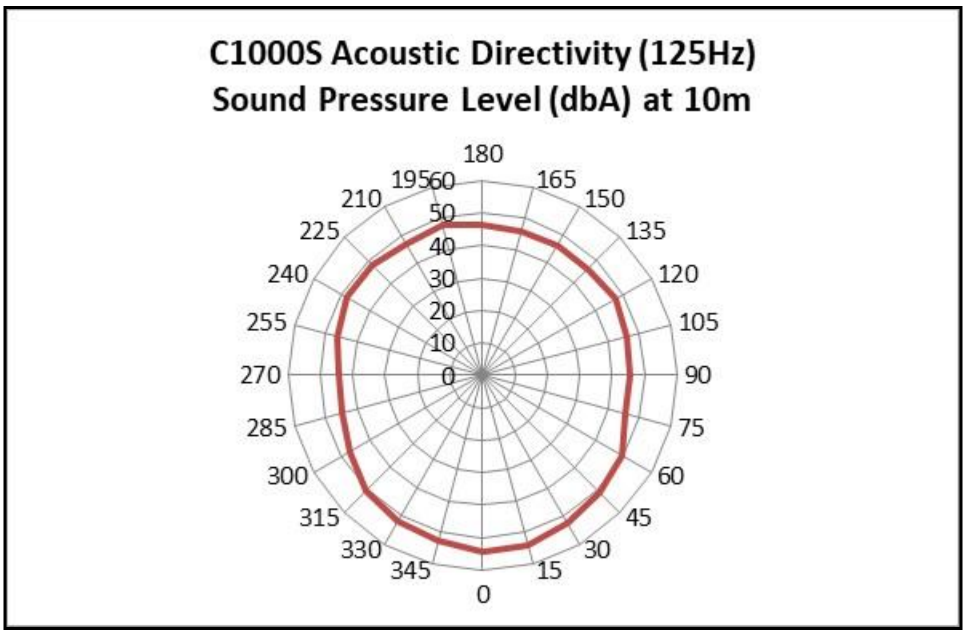

Figure 16. C1000S Directivity 125Hz

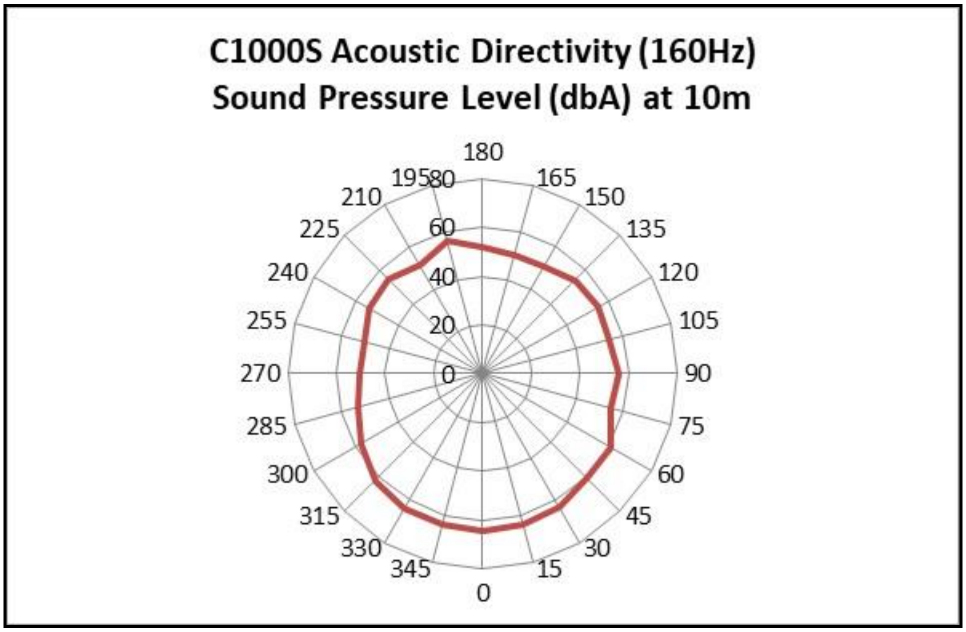

Figure 17. C1000S Directivity 160Hz

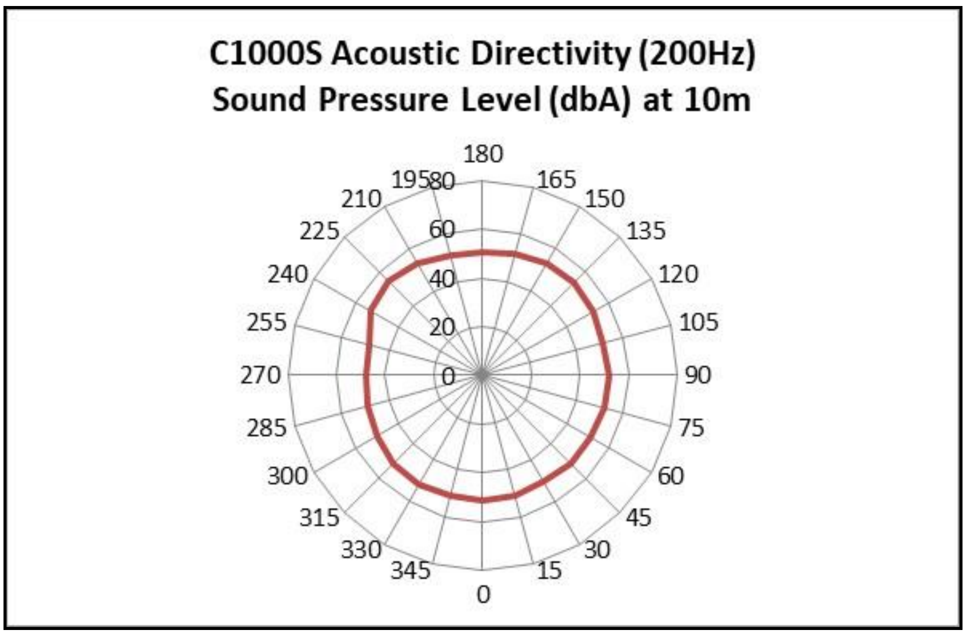

Figure 18. C1000S Directivity 200Hz

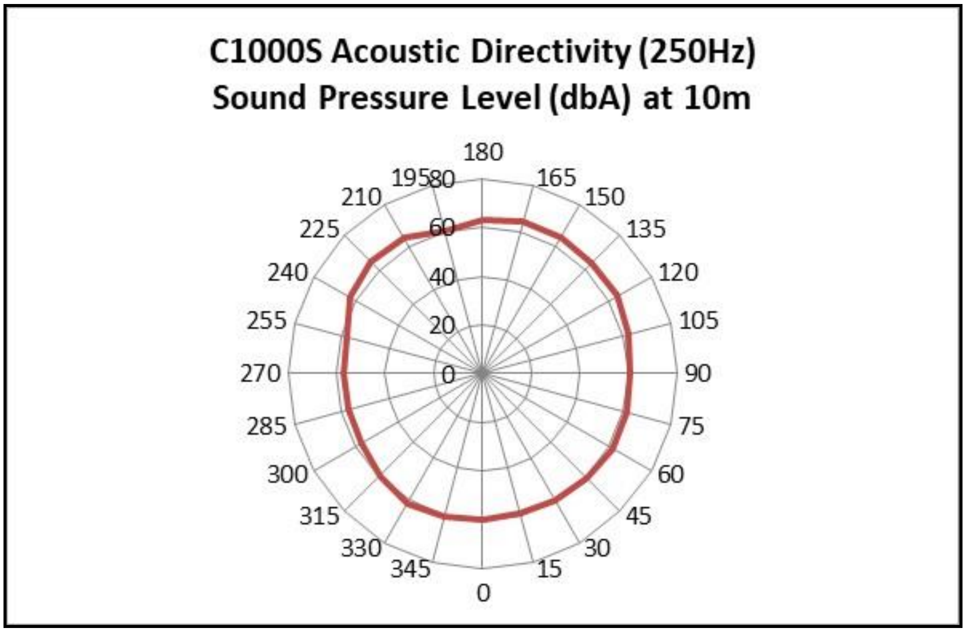

Figure 19. C1000S Directivity 250Hz

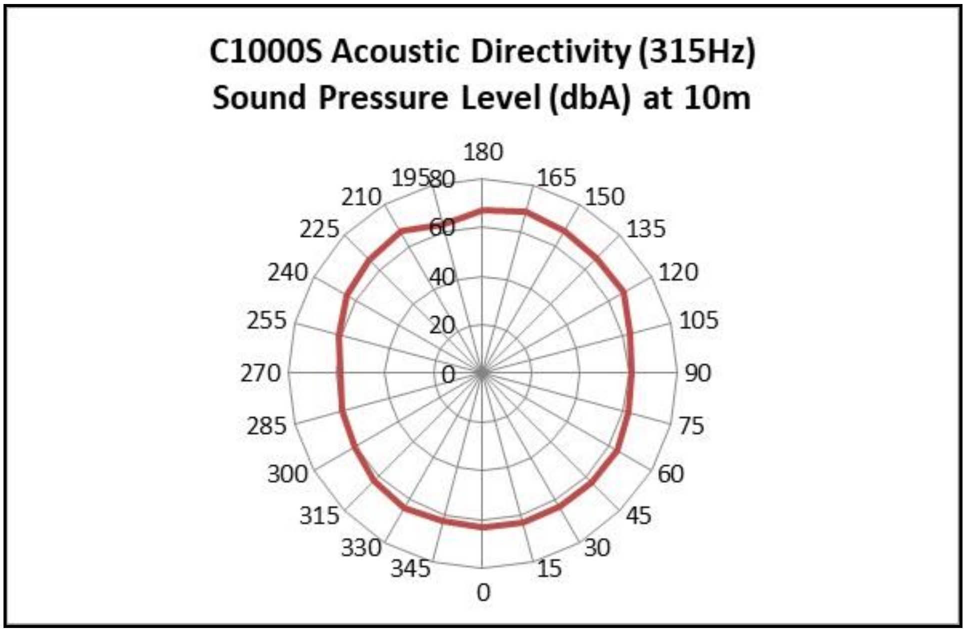

Figure 20. C1000S Directivity 315Hz

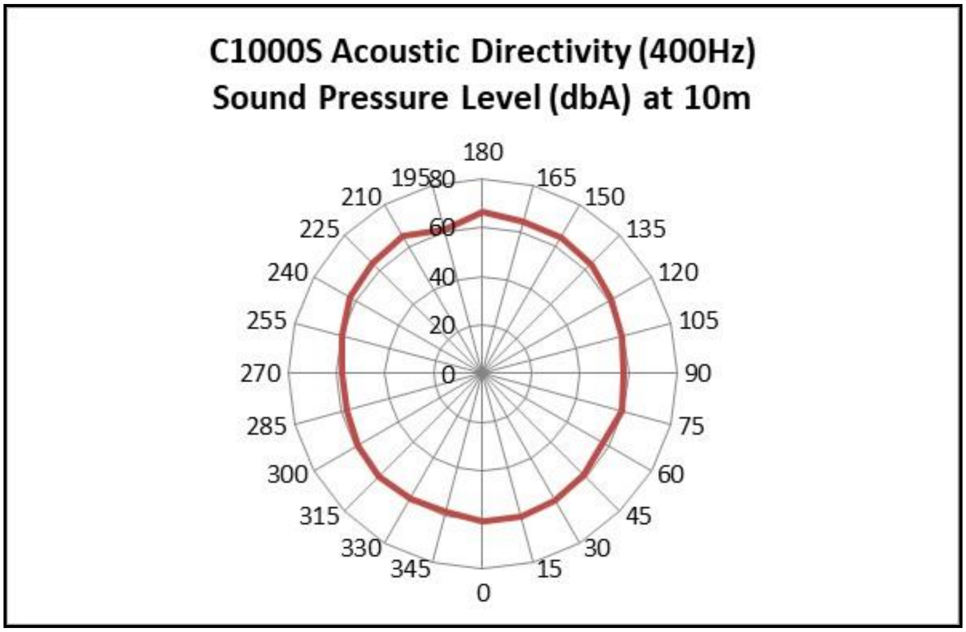

Figure 21. C1000S Directivity 400Hz

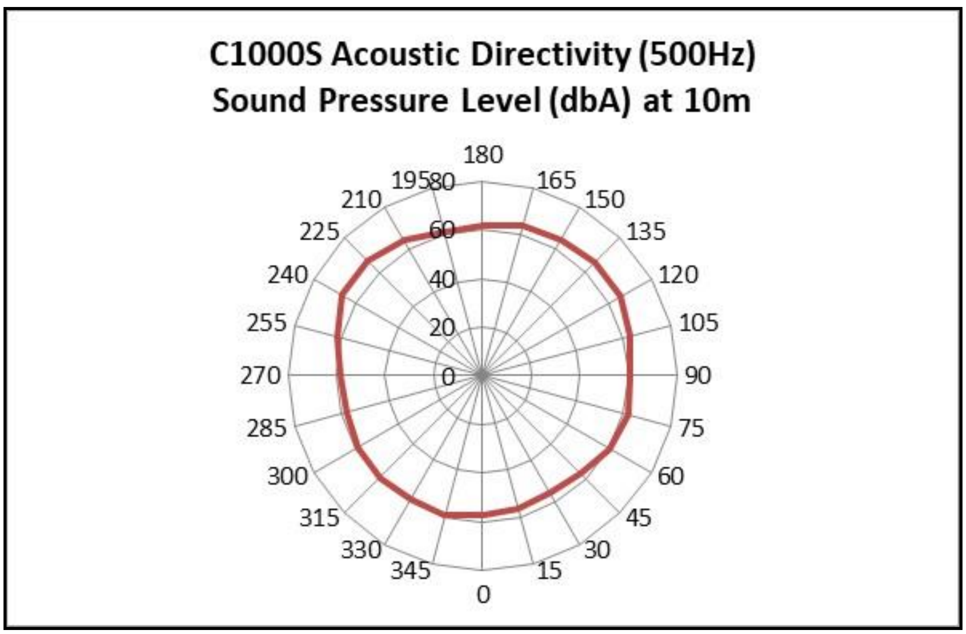

Figure 22. C1000S Directivity 500Hz

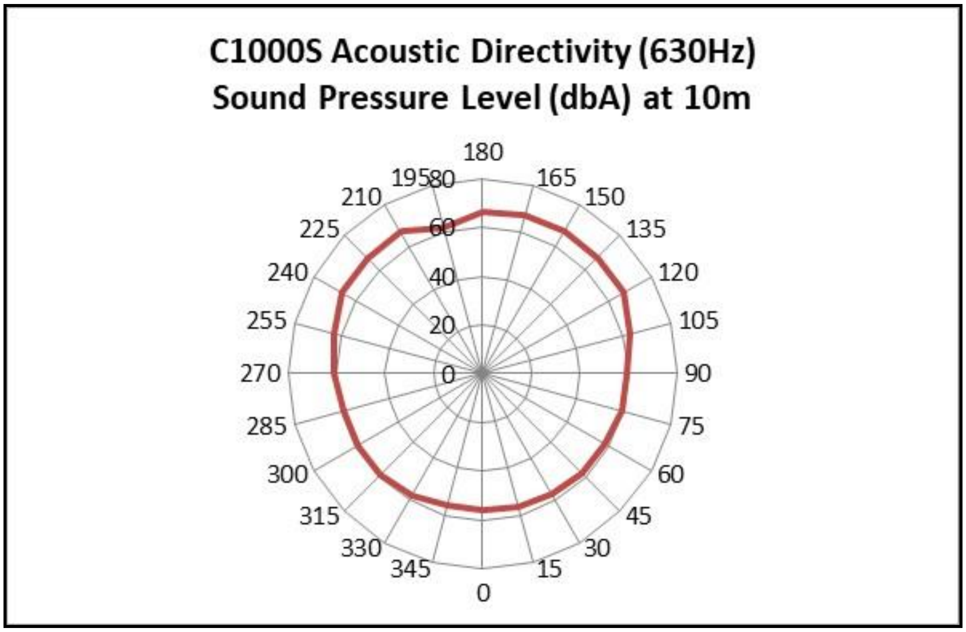

Figure 23. C1000S Directivity 630Hz

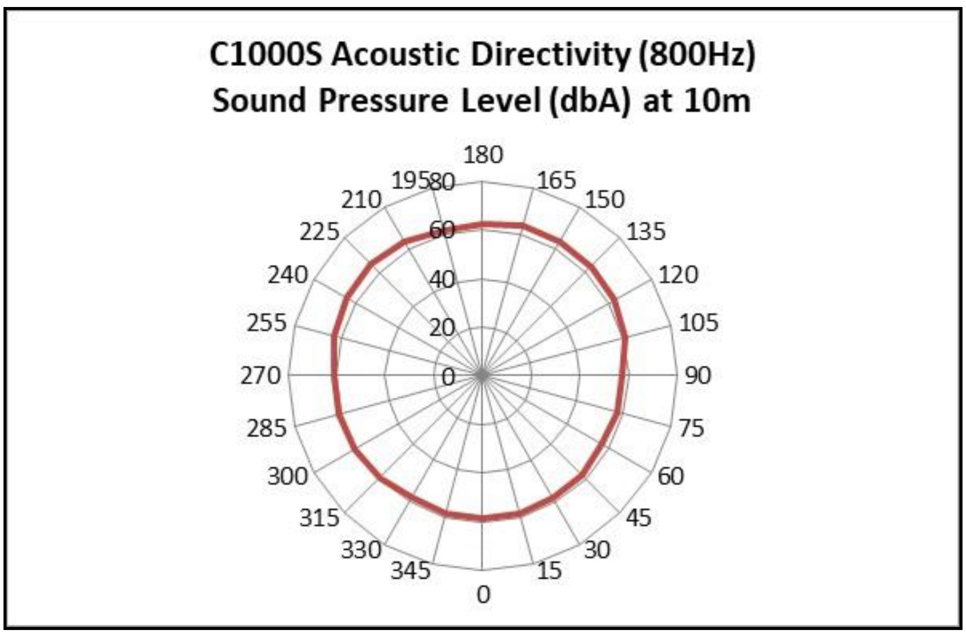

Figure 24. C1000S Directivity 800Hz

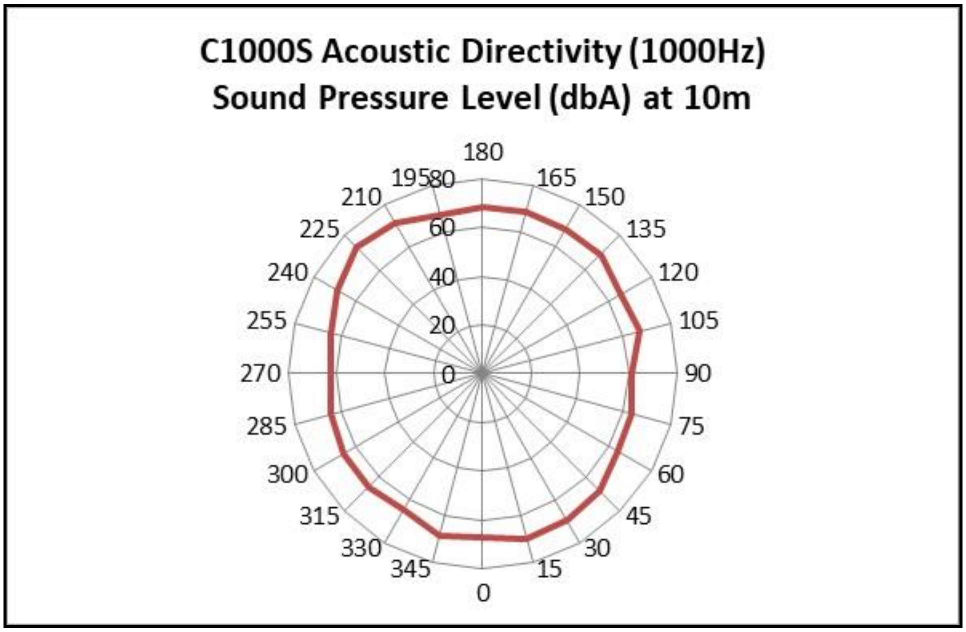

Figure 25. C1000S Directivity 1000Hz

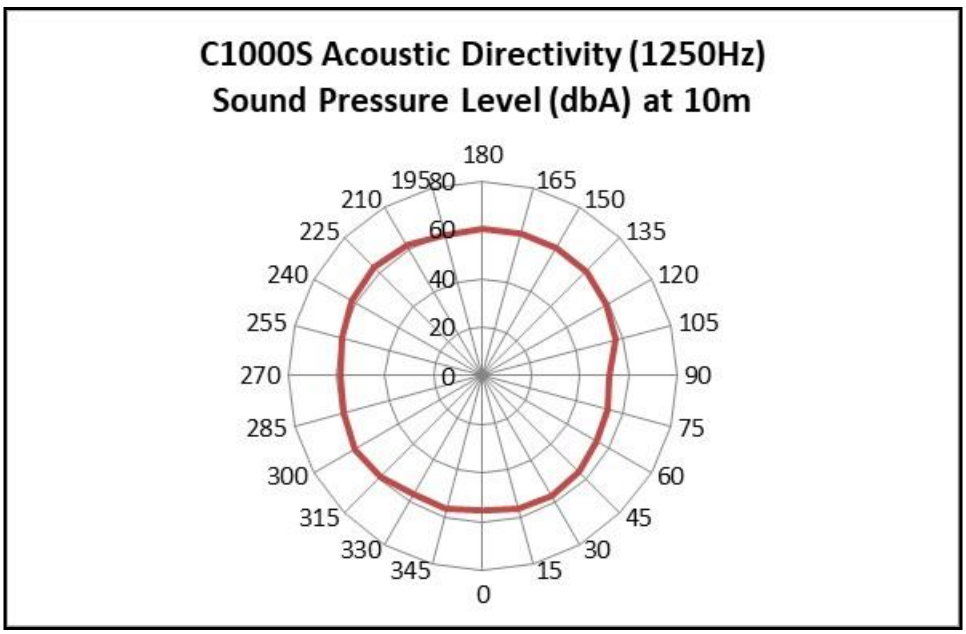

Figure 26. C1000S Directivity 1250Hz

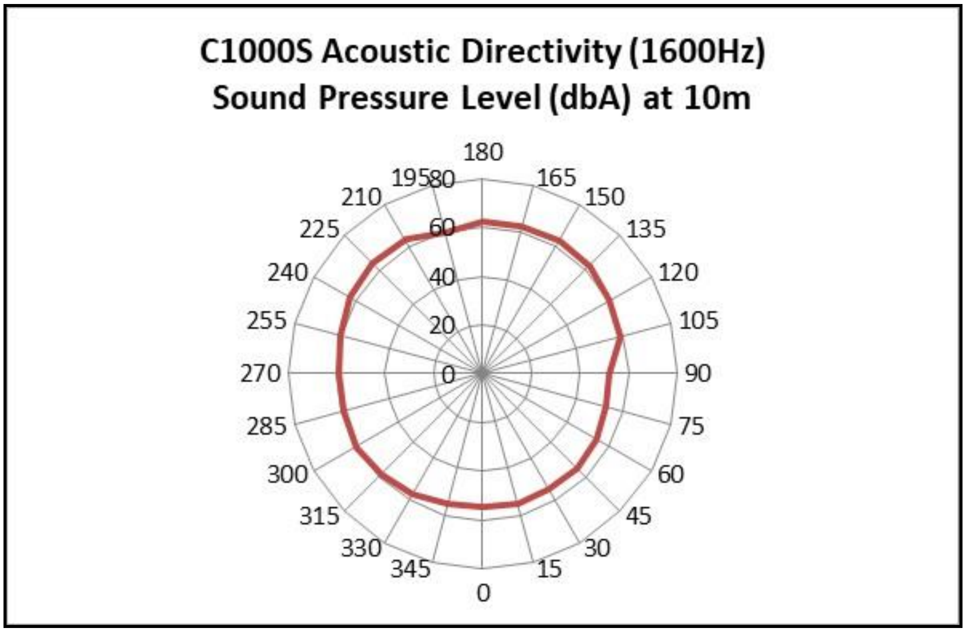

Figure 27. C1000S Directivity 1600Hz

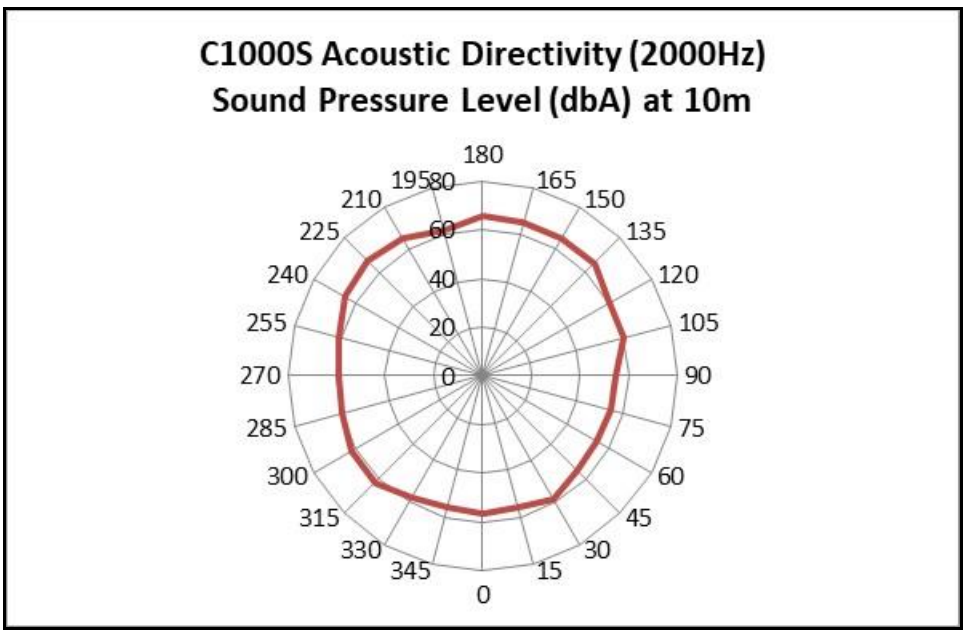

Figure 28. C1000S Directivity 2000Hz

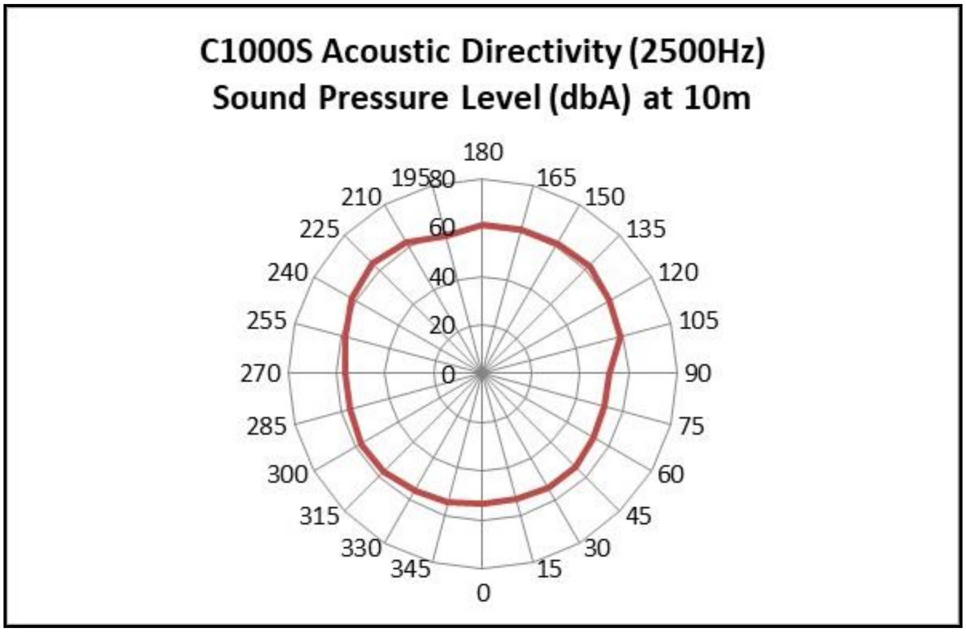

Figure 29. C1000S Directivity 2500Hz

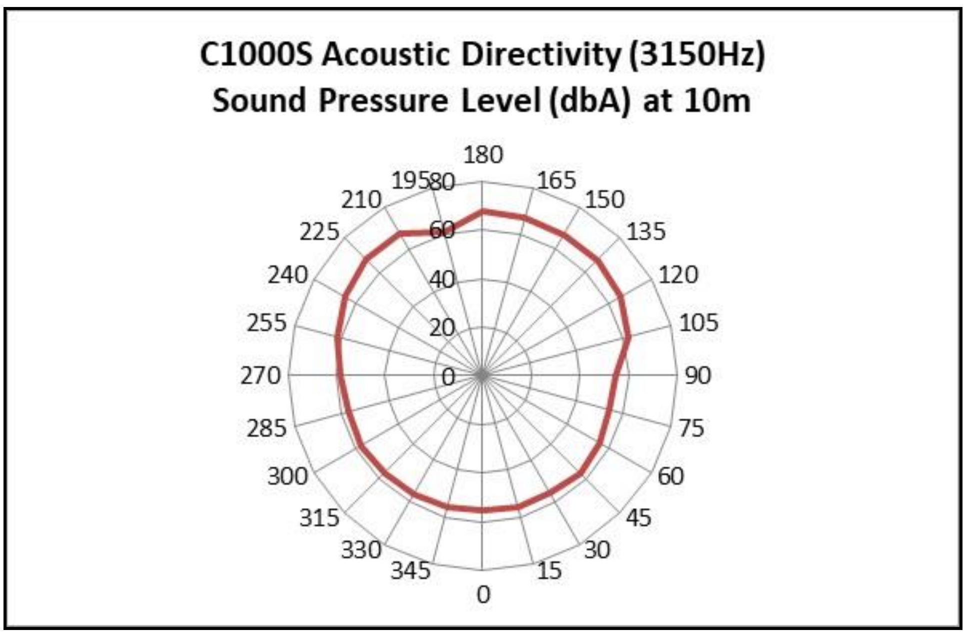

Figure 30. C1000S Directivity 3150Hz

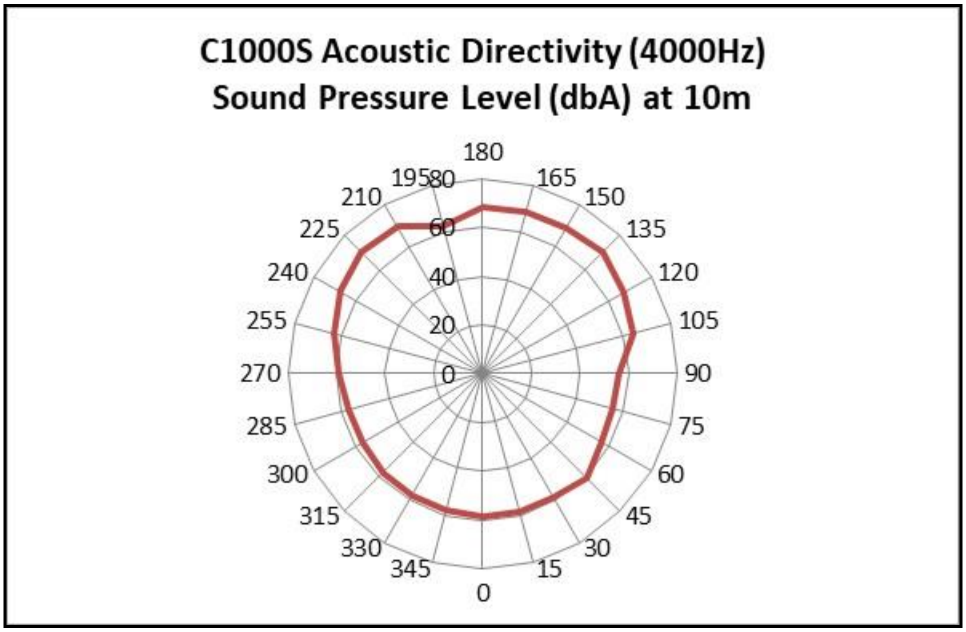

Figure 31. C1000S Directivity 4000Hz

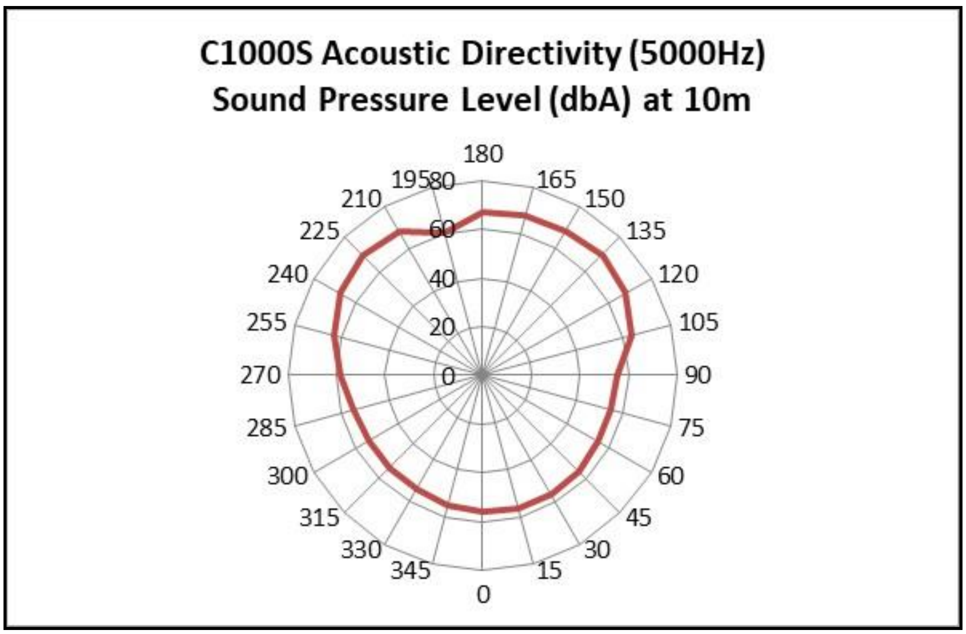

Figure 32. C1000S Directivity 5000Hz

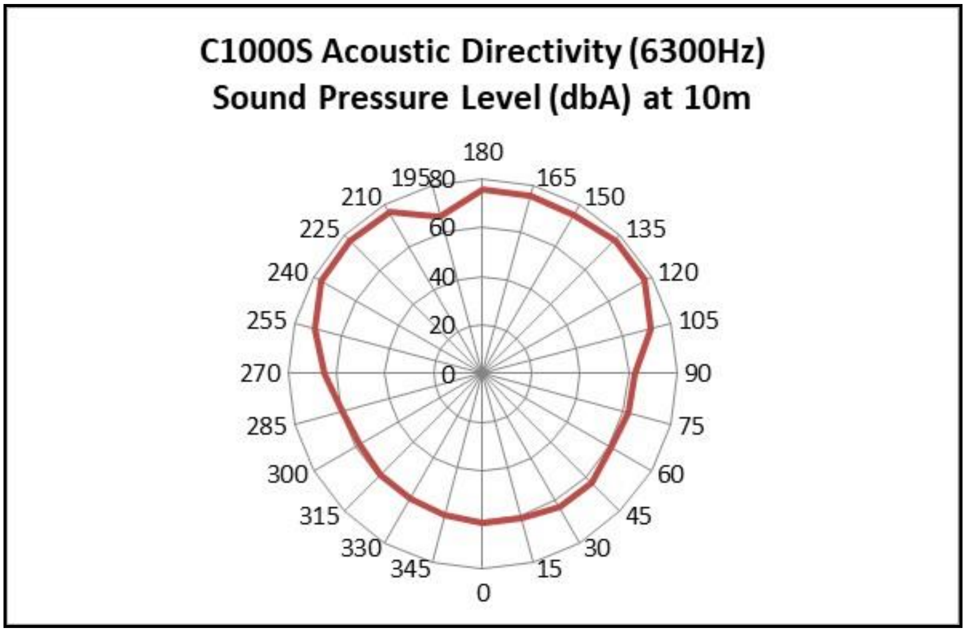

Figure 33. C1000S Directivity 6300Hz

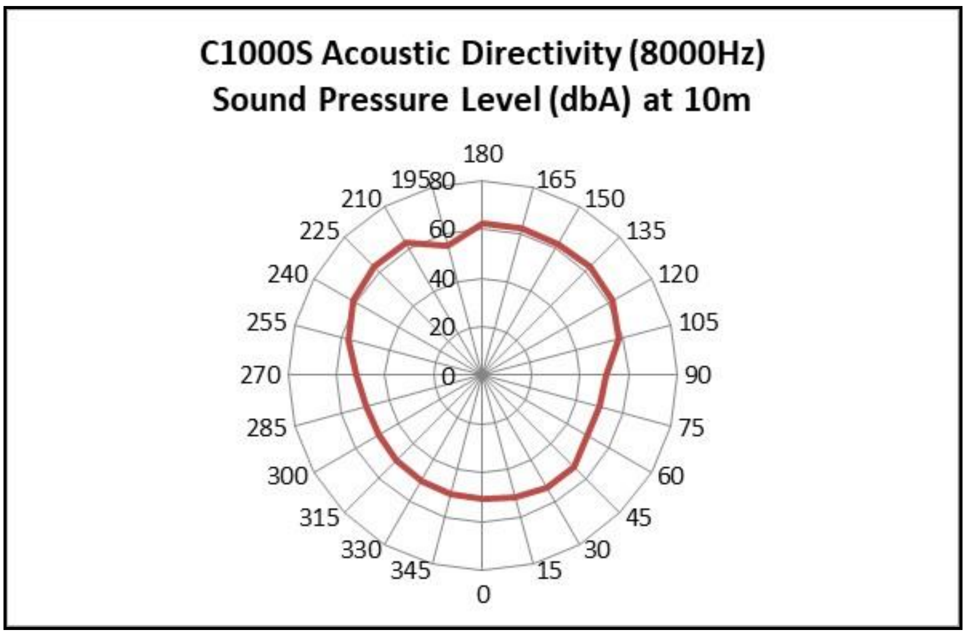

Figure 34. C1000S Directivity 8000Hz

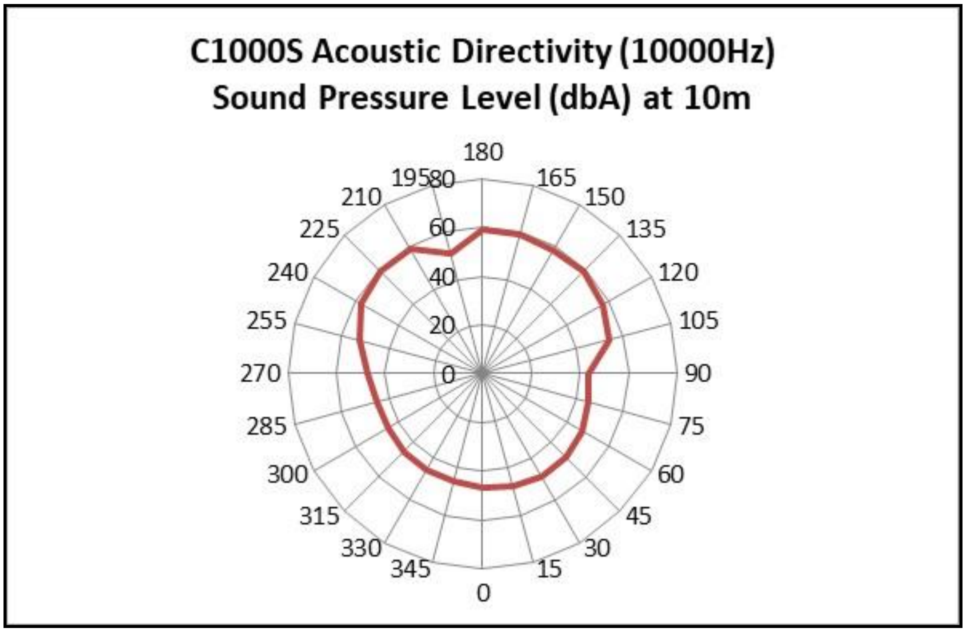

Figure 35. C1000S Directivity 10000Hz

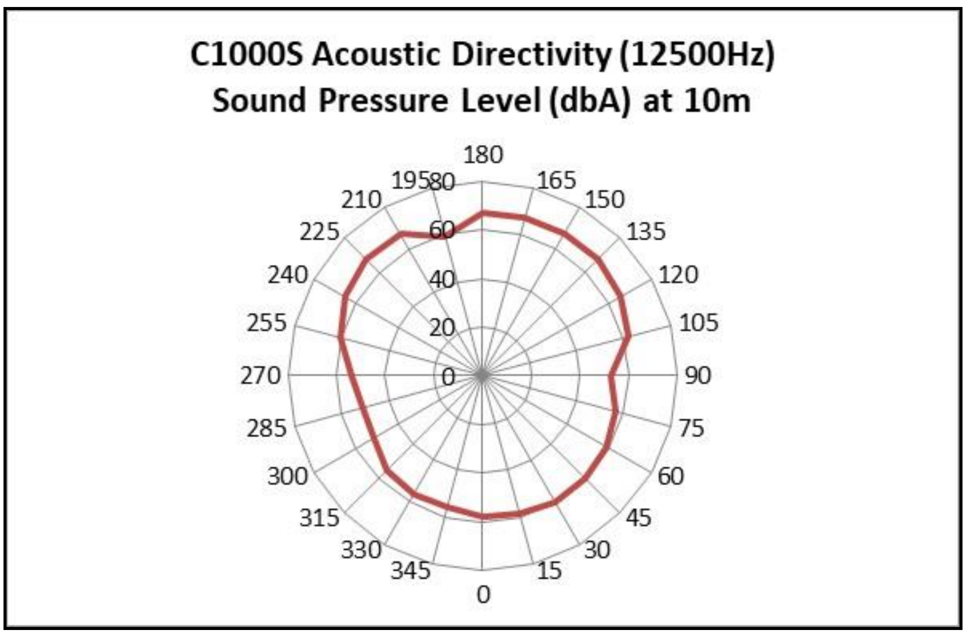

Figure 36. C1000S Directivity 12500Hz

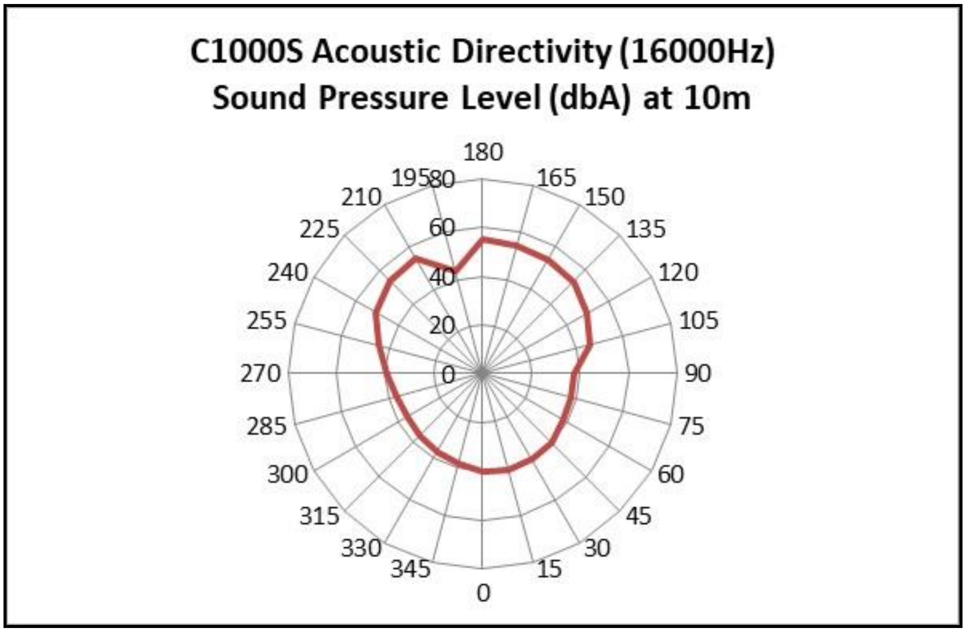

Figure 37. C1000S Directivity 16000Hz

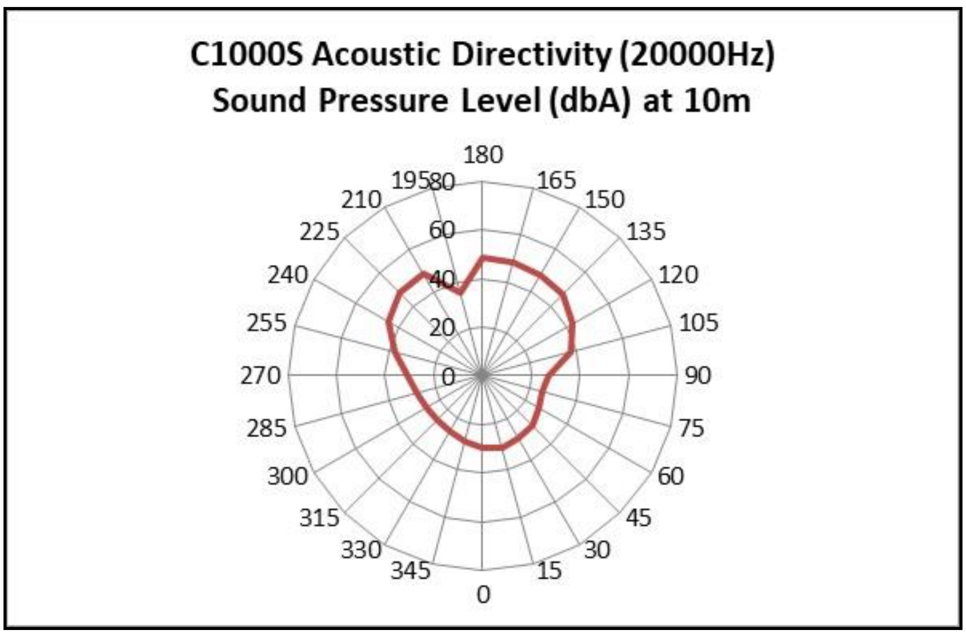

Figure 38. C1000S Directivity 20000Hz

6.1.2 Sound Pressure Polar Data for C600S

Figure 39 below shows the orientation of the microturbine depicted in the sound pressure data graphs. Figure 40 through Figure 69 provide the Acoustic Directivity (sound pressure) graphs (LAeq, dBA) for the C600S configuration.

Table 13. C600S Sound Pressure (Polar) Data

Location	0	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300	315	330	345
LAeq 12.5Hz	-10.1	-10.2	-10.9	-10.1	-9.7	-8.9	-9.3	-9.5	-9.9	-10.7	-10.9	-11.1	-11.2	-10.5	-10.1	-11.3	-11.8	-10.7	-11.7	-12.5	-12.5	-11.3	-11.5	-11.0
LAeq 16Hz	-2.2	-2.3	-2.2	-2.1	-0.8	0.4	0.5	-1.0	-1.7	-1.3	-2.3	-3.1	-2.3	-1.3	-1.5	-1.4	-1.6	-1.3	-2.5	-1.9	-1.2	-2.1	-2.7	-1.0
LAeq 20Hz	7.7	7.2	5.5	4.4	4.9	6.2	7.4	6.8	4.8	4.4	8.2	7.2	7.9	7.0	6.6	7.3	8.9	7.7	7.2	11.4	12.6	6.3	6.1	7.5
LAeq 25Hz	16.0	17.6	16.0	15.5	11.2	9.1	10.3	10.9	13.9	16.2	17.3	16.3	15.7	15.6	15.8	14.7	14.5	15.5	15.7	15.5	14.6	12.7	14.4	14.9
LAeq 31.5Hz	23.4	23.8	25.6	26.6	24.4	23.0	20.6	22.6	25.7	26.5	25.3	23.8	24.6	25.9	25.5	23.1	22.8	24.3	23.8	23.6	22.8	22.5	24.7	24.5
LAeq 40Hz	30.8	30.6	30.2	32.6	33.9	35.3	33.5	32.0	32.4	31.2	29.8	29.5	30.4	30.4	31.7	28.7	26.9	28.0	28.3	28.8	28.0	29.4	31.4	30.4
LAeq 50Hz	33.1	34.1	33.0	32.0	35.4	35.8	35.5	36.0	32.4	31.4	34.1	32.8	32.0	33.8	35.5	30.6	29.2	29.9	30.6	30.1	30.6	31.9	33.5	32.4
LAeq 63Hz	38.6	39.1	38.0	38.6	35.0	34.7	36.5	35.3	33.6	40.2	36.6	35.6	36.3	34.9	36.9	34.2	33.7	35.4	33.8	33.9	35.0	36.5	37.8	37.5
LAeq 80Hz	43.9	43.8	43.1	41.7	43.4	38.8	37.1	40.8	41.0	40.6	41.3	40.7	41.2	41.7	40.8	40.5	36.1	38.7	38.0	36.9	37.4	41.8	42.4	43.2
LAeq 100Hz	48.7	48.2	47.4	46.2	42.9	44.2	43.4	42.9	41.5	43.6	44.9	44.7	44.7	45.8	45.2	43.6	42.2	40.2	40.3	39.8	41.6	45.7	45.6	47.7
LAeq 125Hz	52.6	52.0	49.7	49.2	49.3	45.7	44.8	46.5	46.0	46.1	46.6	45.8	45.4	45.5	47.8	48.0	46.3	43.9	42.6	42.8	46.5	49.3	49.0	50.4
LAeq 160Hz	64.4	62.9	60.6	59.3	60.5	53.7	56.4	49.7	54.4	50.8	52.1	50.3	50.7	50.2	50.3	51.7	51.8	48.5	48.5	50.1	56.7	61.6	61.2	60.7
LAeq 200Hz	49.4	48.9	48.9	48.8	48.9	48.2	48.6	50.0	49.9	49.0	49.0	49.2	49.1	49.3	50.3	50.8	48.9	47.4	45.5	47.1	48.3	50.7	50.0	49.1
LAeq 250Hz	57.3	56.8	57.3	58.4	58.0	58.7	58.3	59.9	60.8	61.8	60.9	61.2	61.0	59.5	60.4	62.1	55.1	55.0	51.9	55.6	54.7	59.0	57.9	57.6
LAeq 315Hz	60.9	61.4	60.2	61.3	60.8	61.7	61.5	64.3	65.1	66.6	66.0	66.3	65.8	64.5	64.0	64.9	59.0	58.3	56.3	57.8	58.5	62.7	61.2	61.7
LAeq 400Hz	60.2	59.5	58.2	59.4	58.7	58.5	58.1	57.8	61.2	62.5	63.2	64.5	65.9	64.7	62.9	62.1	59.8	57.1	56.6	57.6	58.8	58.8	57.2	57.9
LAeq 500Hz	57.3	58.6	56.5	56.3	57.7	58.8	57.7	59.5	61.1	62.0	62.7	61.6	61.3	62.3	61.7	61.6	60.4	57.0	55.5	56.5	58.1	56.8	55.6	56.9
LAeq 630Hz	54.2	54.3	54.5	55.4	56.1	58.3	59.5	62.0	64.1	64.4	63.8	64.9	65.2	62.9	64.4	63.7	60.5	59.4	59.4	59.4	57.4	56.5	54.7	53.2
LAeq 800Hz	56.9	58.3	56.7	56.5	54.8	55.5	56.4	56.9	60.1	61.3	62.6	62.0	61.6	61.4	61.8	62.8	63.1	59.9	59.9	61.9	60.5	56.4	57.2	58.5
LAeq 1kHz	67.1	64.8	68.7	67.1	60.5	65.7	63.0	61.1	61.7	62.5	65.6	66.6	65.8	63.3	64.2	68.2	62.8	60.9	62.3	63.1	65.1	63.6	70.0	66.3
LAeq 1.25kHz	54.4	54.4	55.1	53.8	50.9	52.6	51.7	52.9	55.6	57.5	57.6	59.4	60.0	59.0	58.9	61.3	60.5	57.4	56.6	58.1	59.1	58.8	56.1	54.5
LAeq 1.6kHz	52.1	52.1	52.6	52.8	51.1	51.2	50.1	53.6	56.4	58.3	59.6	60.5	60.5	60.5	61.0	61.4	57.3	57.0	55.0	57.0	56.1	57.2	54.4	52.7
LAeq 2kHz	53.6	55.2	55.5	54.0	53.7	51.9	53.3	56.4	57.1	60.1	62.5	63.5	63.2	63.1	63.5	62.5	59.7	59.1	55.6	59.1	58.3	57.2	57.7	55.6
LAeq 2.5kHz	52.5	52.3	53.2	53.1	52.3	51.4	50.3	55.2	56.5	59.3	59.1	59.1	59.2	59.6	60.7	60.4	57.0	54.7	52.0	54.9	55.9	56.1	54.1	53.3
LAeq 3.15kHz	53.1	53.2	55.4	55.4	54.2	51.9	52.7	58.7	60.6	64.7	64.9	66.3	66.8	66.4	65.1	64.8	59.1	56.5	54.1	53.8	52.7	54.7	53.9	54.0
LAeq 4kHz	55.3	56.0	58.3	57.1	53.5	53.5	54.0	60.2	61.4	65.8	67.1	66.4	65.9	66.7	67.3	66.4	61.4	57.8	53.7	53.4	54.0	56.5	55.6	55.5
LAeq 5kHz	51.0	51.7	52.2	52.4	50.5	50.7	51.9	60.3	63.4	68.2	67.3	66.0	66.3	66.6	67.4	67.4	61.1	59.0	52.2	49.7	48.9	52.5	51.8	52.3
LAeq 6.3kHz	56.7	56.3	58.2	57.5	56.6	58.0	58.7	69.0	72.6	76.8	75.7	73.1	75.9	75.3	76.5	75.5	69.0	69.1	61.2	55.6	54.8	54.9	54.3	55.7
LAeq 8kHz	49.2	51.3	52.3	51.6	46.7	49.0	48.4	54.4	56.4	58.9	58.9	60.5	61.4	59.9	58.9	58.4	54.3	52.1	46.3	45.1	45.0	49.5	48.4	50.0
LAeq 10kHz	44.2	46.2	47.5	47.8	43.3	42.5	41.0	49.6	50.9	54.8	55.5	56.7	56.7	56.6	55.9	53.1	49.1	46.7	40.6	40.7	39.6	43.4	41.1	44.1
LAeq 12.5kHz	55.5	57.7	59.6	59.9	55.0	54.0	49.8	58.0	59.9	64.2	63.6	64.6	65.7	65.4	65.5	61.3	55.9	54.7	46.8	49.9	46.7	52.9	51.6	55.6
LAeq 16kHz	33.2	34.8	36.4	36.7	33.7	35.9	36.6	41.5	43.7	47.4	49.5	52.3	53.0	51.1	49.3	45.0	39.5	37.8	31.4	31.1	29.0	32.1	31.0	33.4
LAeq 20kHz	20.8	21.6	22.4	22.8	20.9	22.1	23.2	32.3	35.5	42.1	44.3	45.4	45.6	45.0	44.0	38.1	31.9	28.8	21.8	20.6	18.7	20.1	19.2	20.8

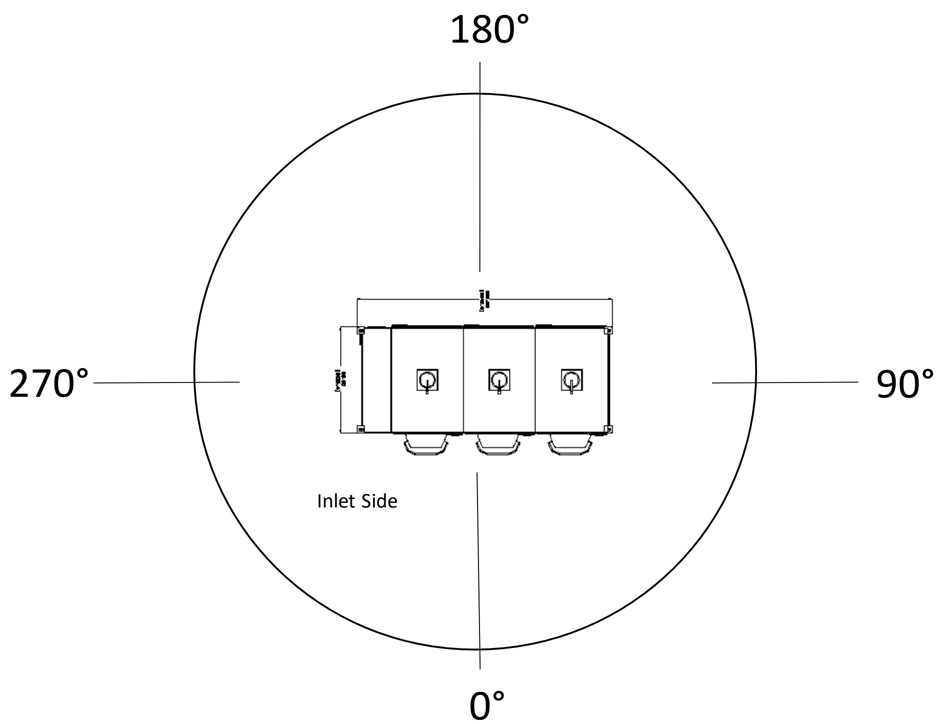

Figure 39. Orientation of C600S Microturbine in Acoustic Directivity Graphs

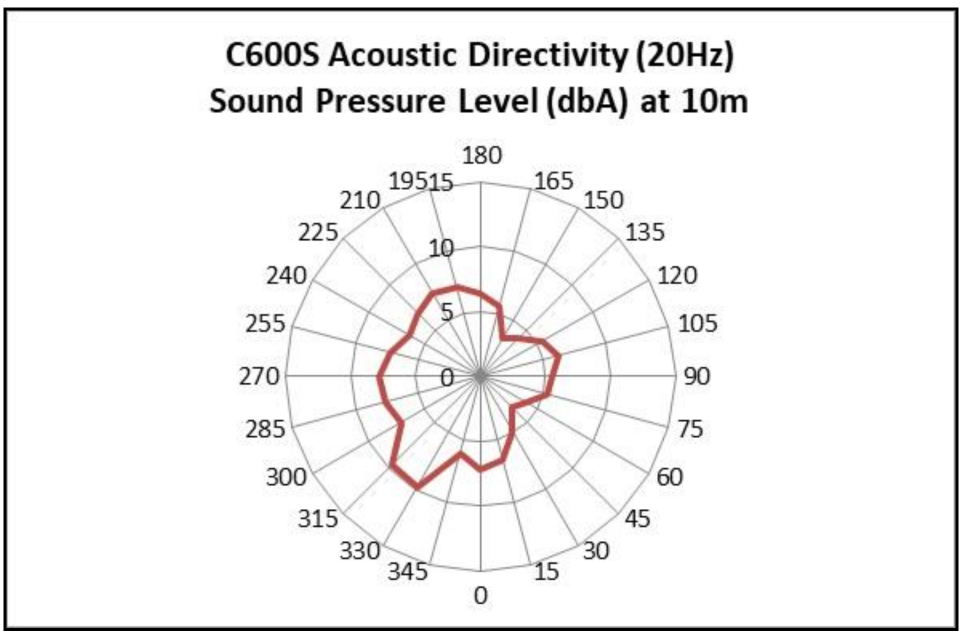

Figure 40. C600S Directivity 20Hz

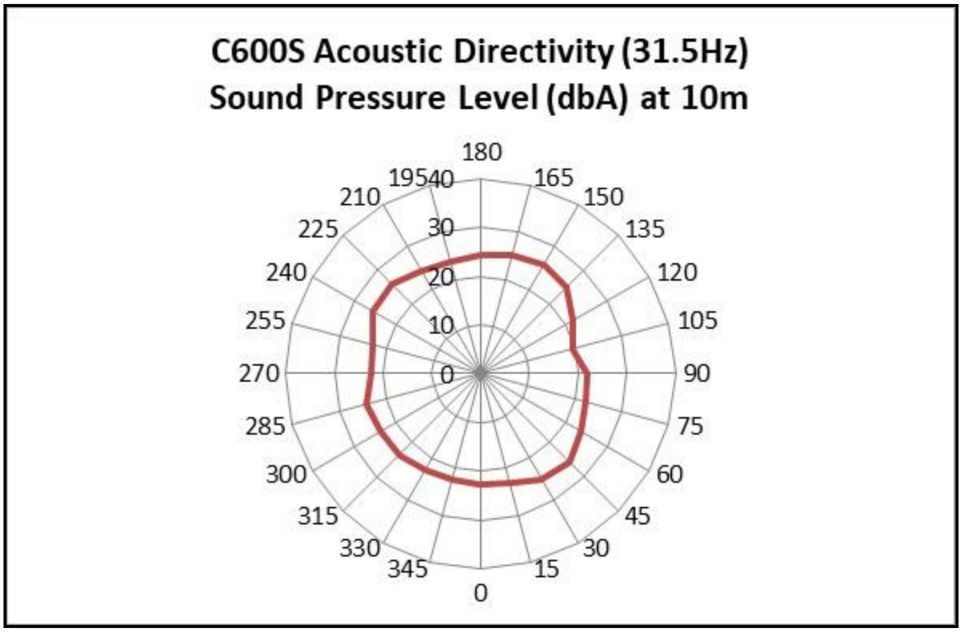

Figure 41. C600S Directivity 31.5Hz

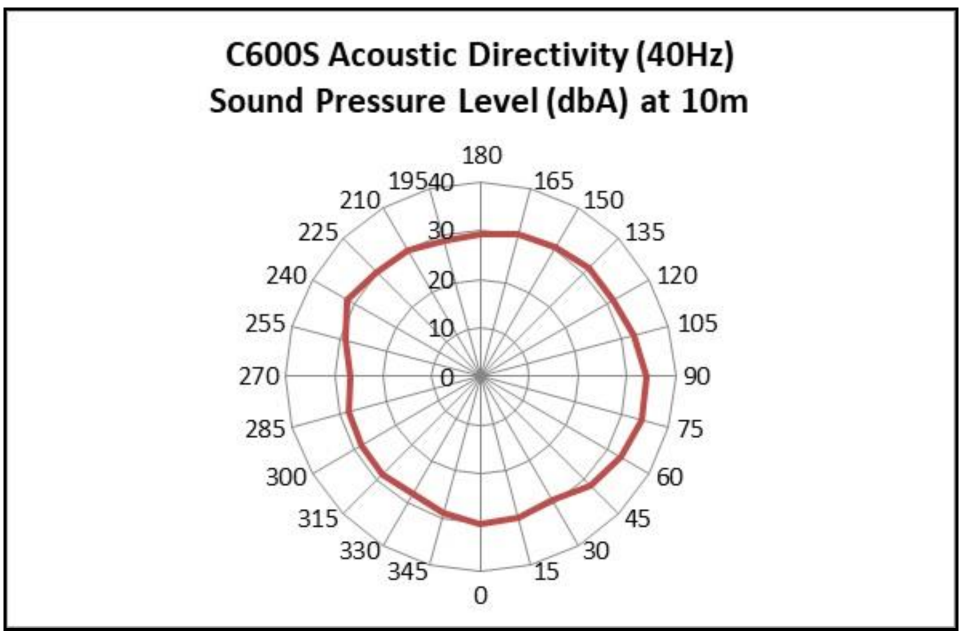

Figure 42. C600S Directivity 40Hz

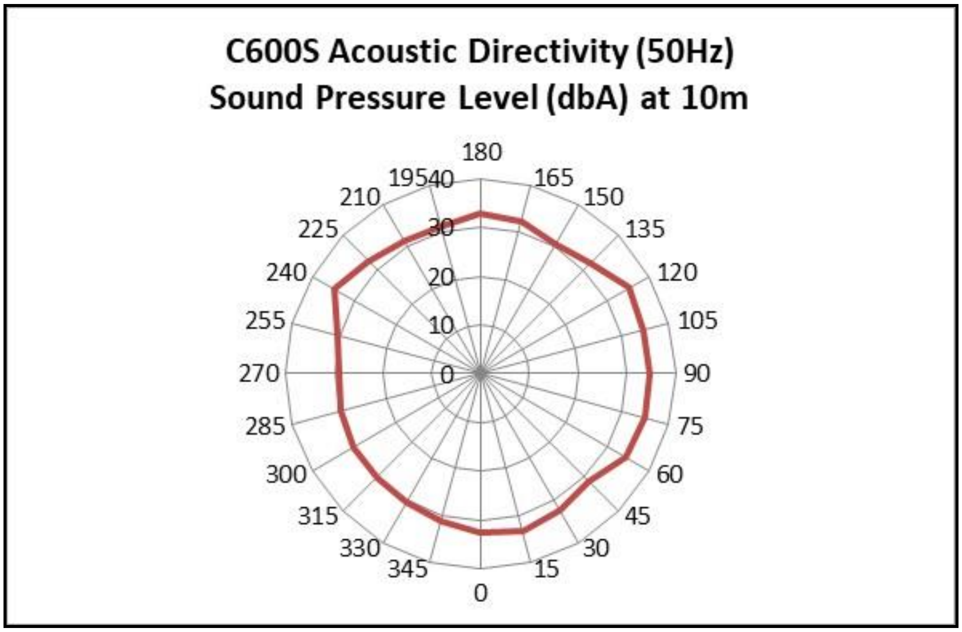

Figure 43. C600S Directivity 50Hz

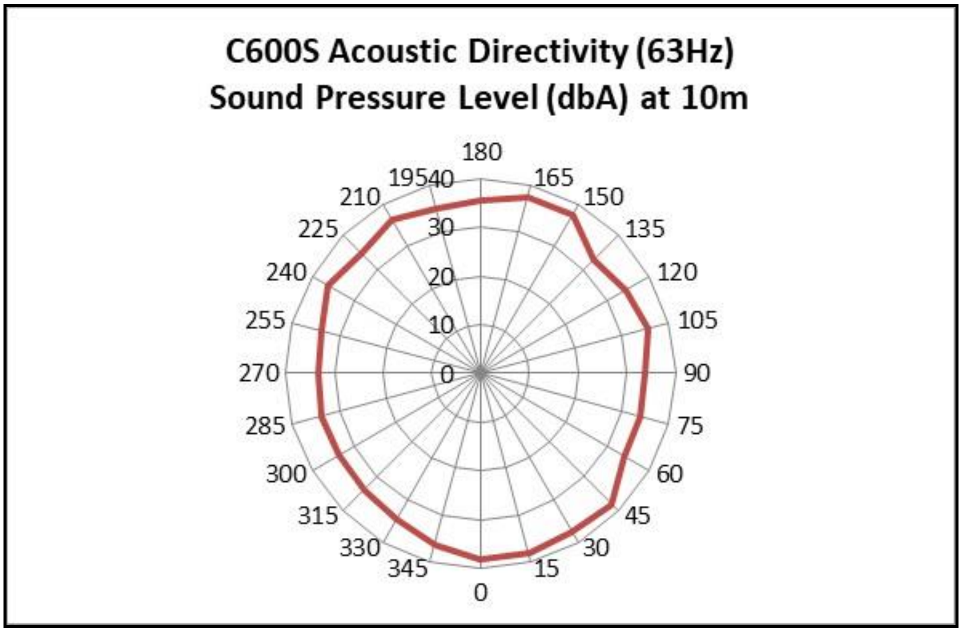

Figure 44. C600S Directivity 63Hz

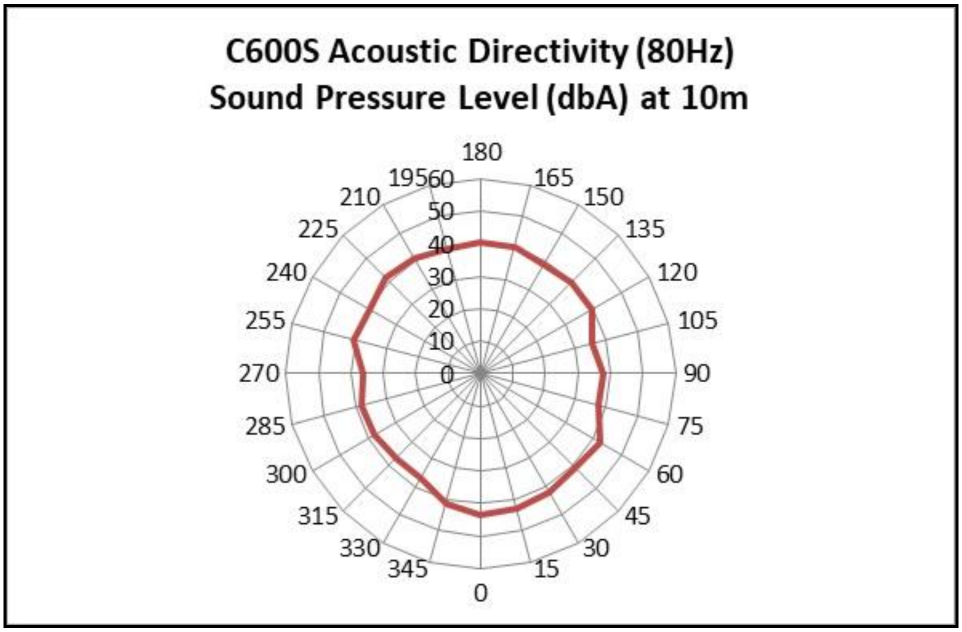

Figure 45. C600S Directivity 80Hz

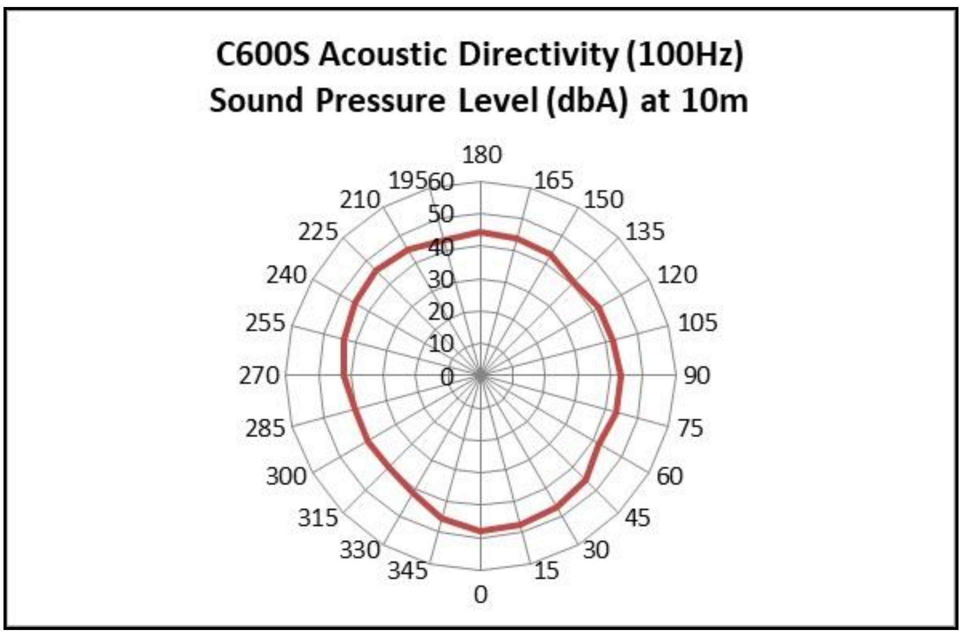

Figure 46. C600S Directivity 100Hz

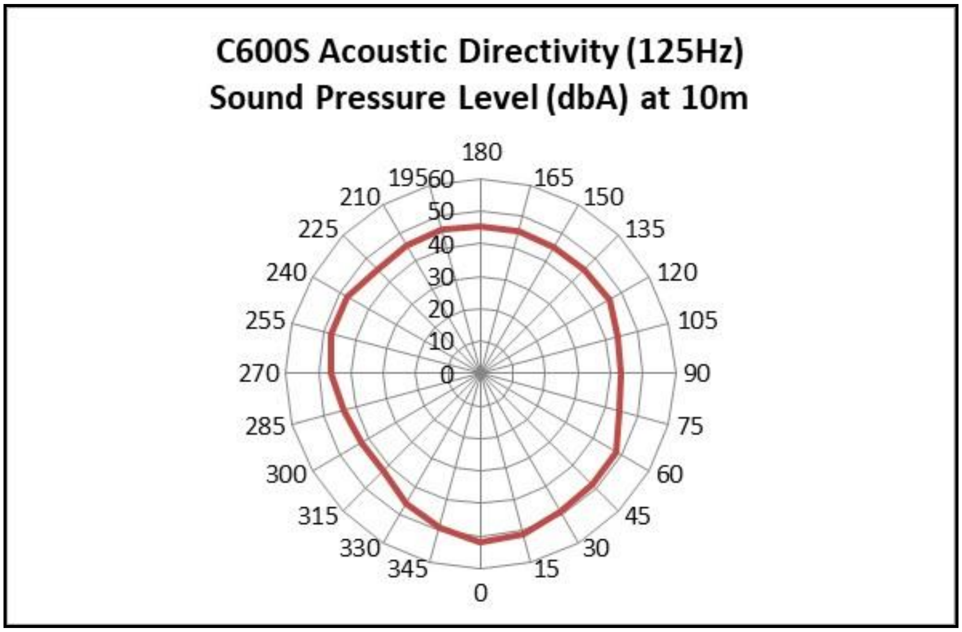

Figure 47. C600S Directivity 125Hz

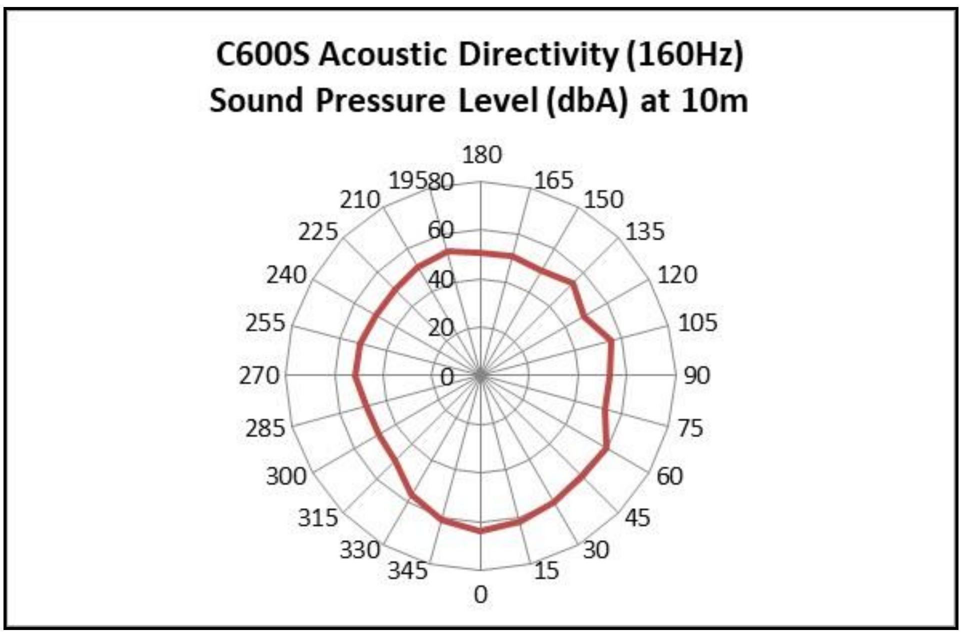

Figure 48. C600S Directivity 160Hz

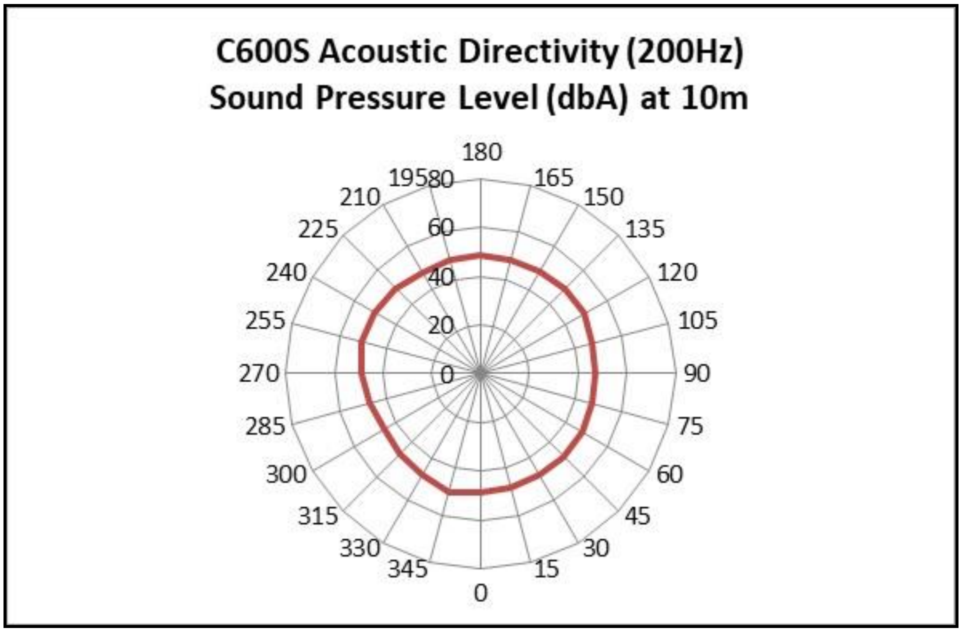

Figure 49. C600S Directivity 200Hz

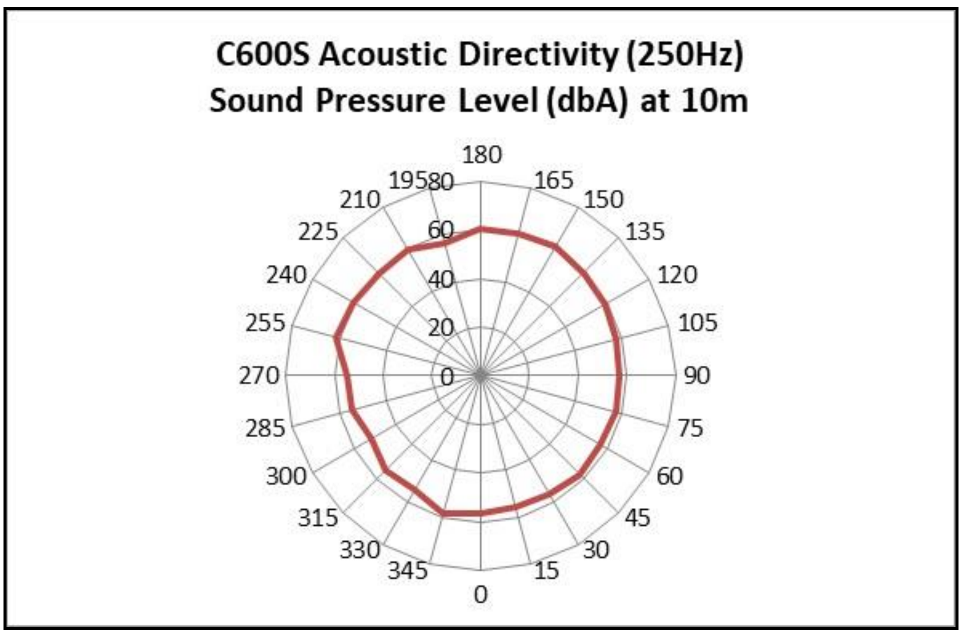

Figure 50. C600S Directivity 250Hz

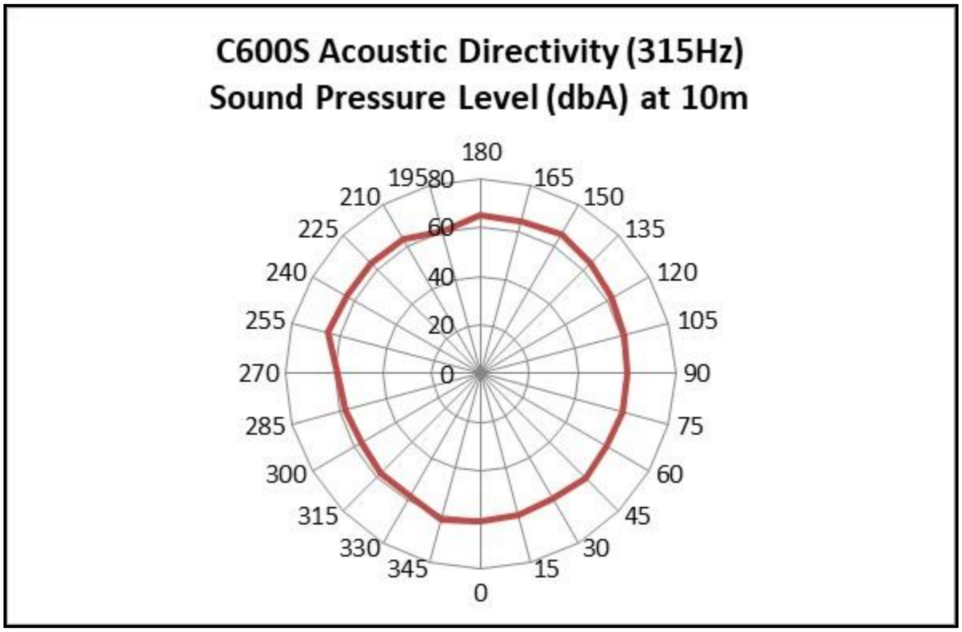

Figure 51. C600S Directivity 315Hz

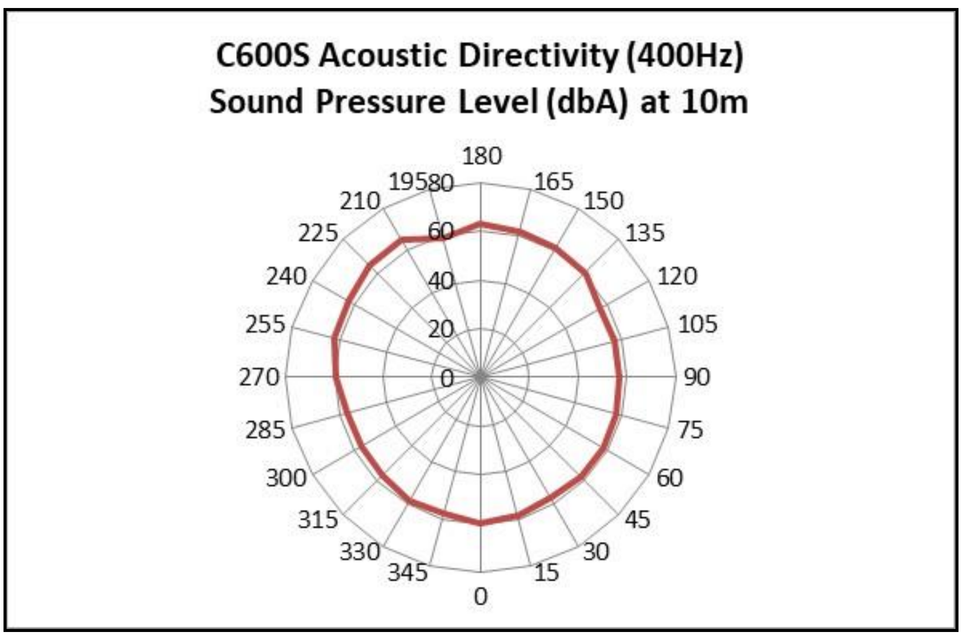

Figure 52. C600S Directivity 400Hz

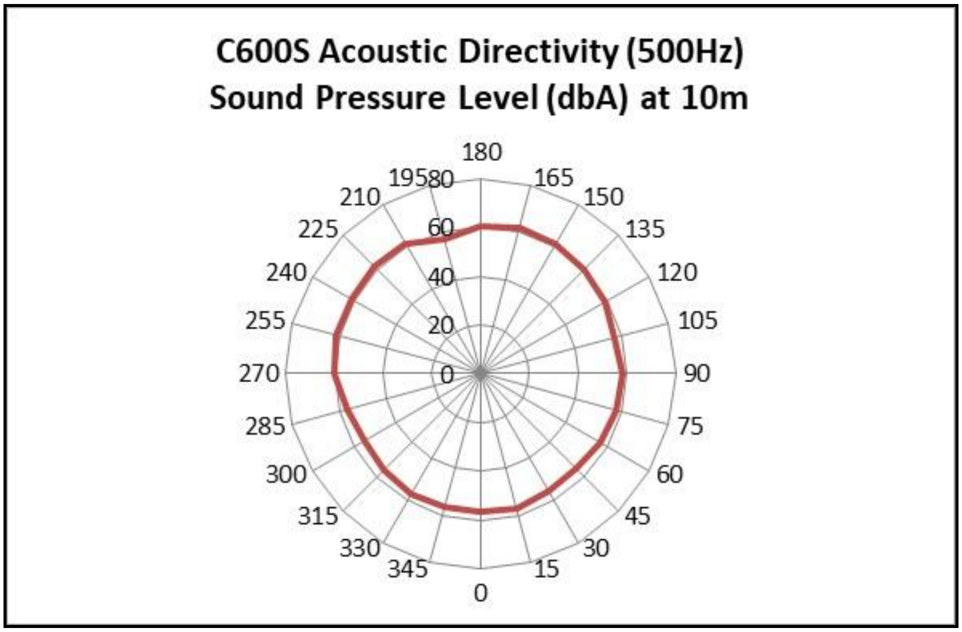

Figure 53. C600S Directivity 500Hz

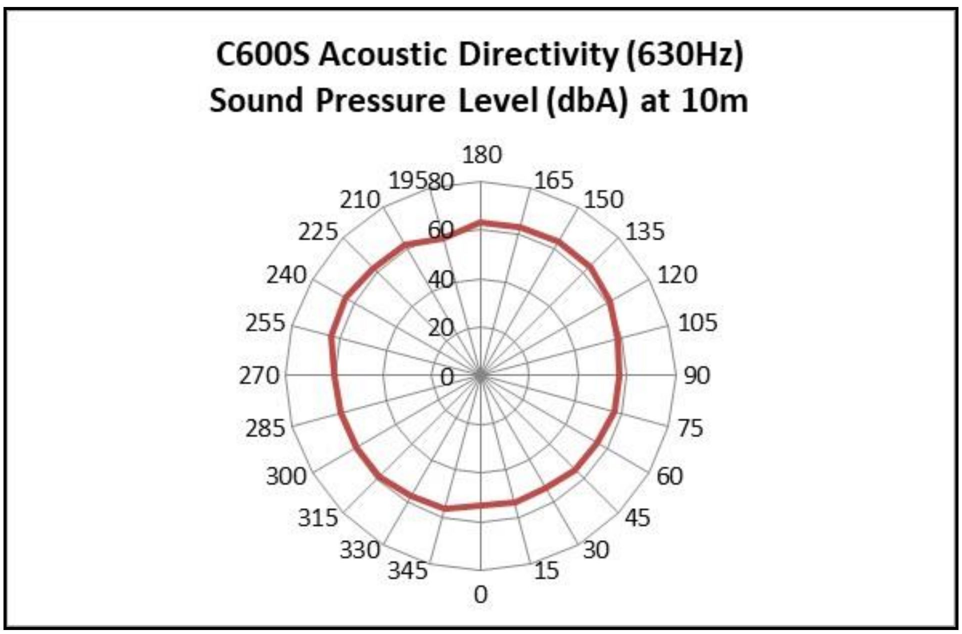

Figure 54. C600S Directivity 630Hz

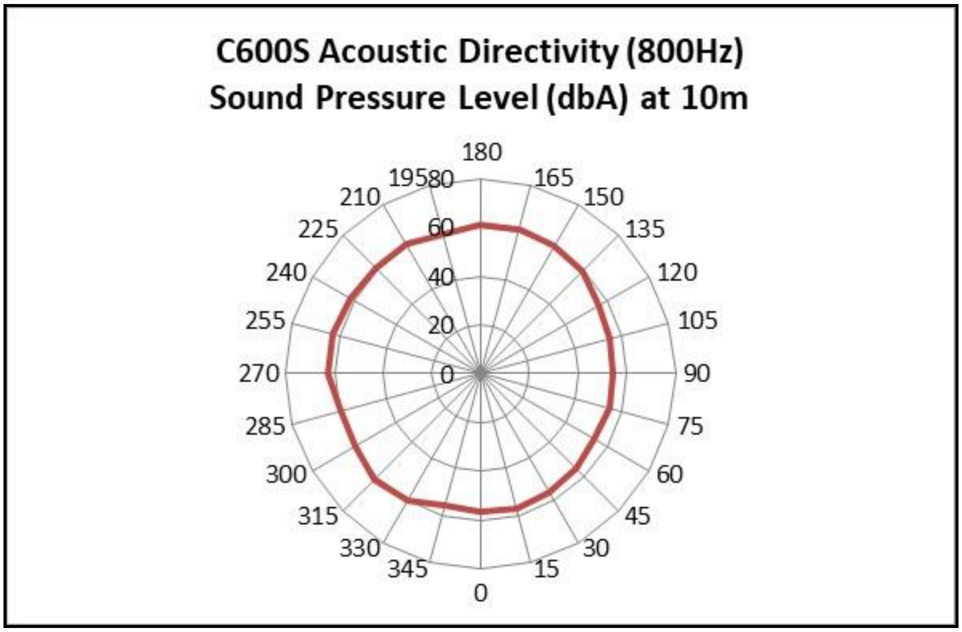

Figure 55. C600S Directivity 800Hz

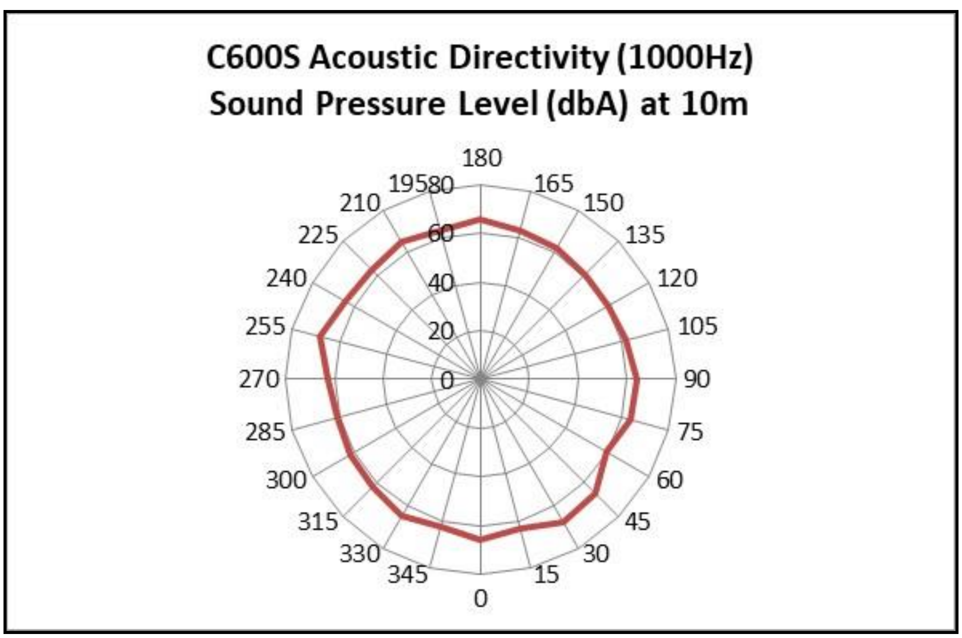

Figure 56. C600S Directivity 1000Hz

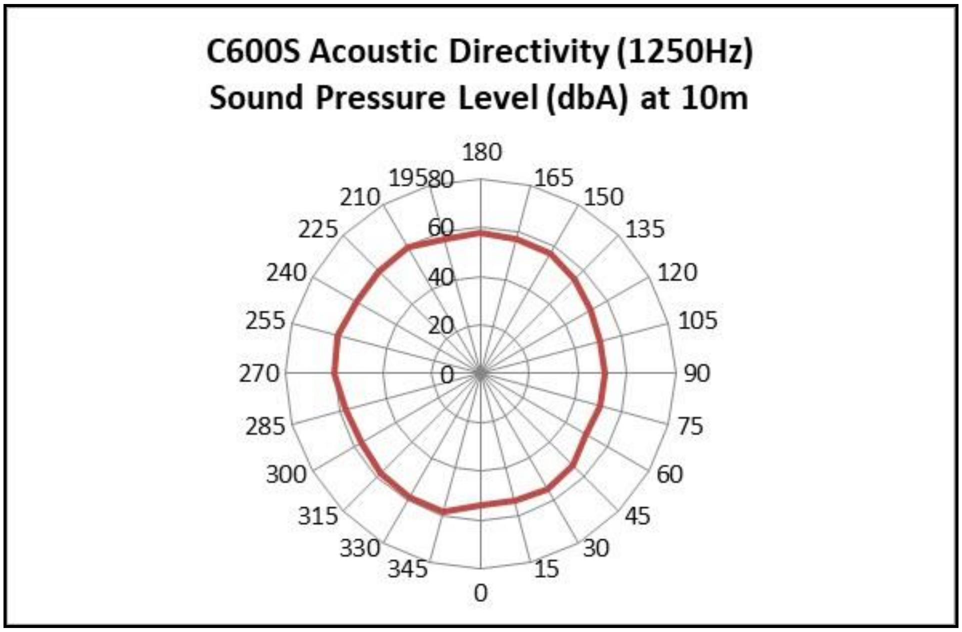

Figure 57. C600S Directivity 1250Hz

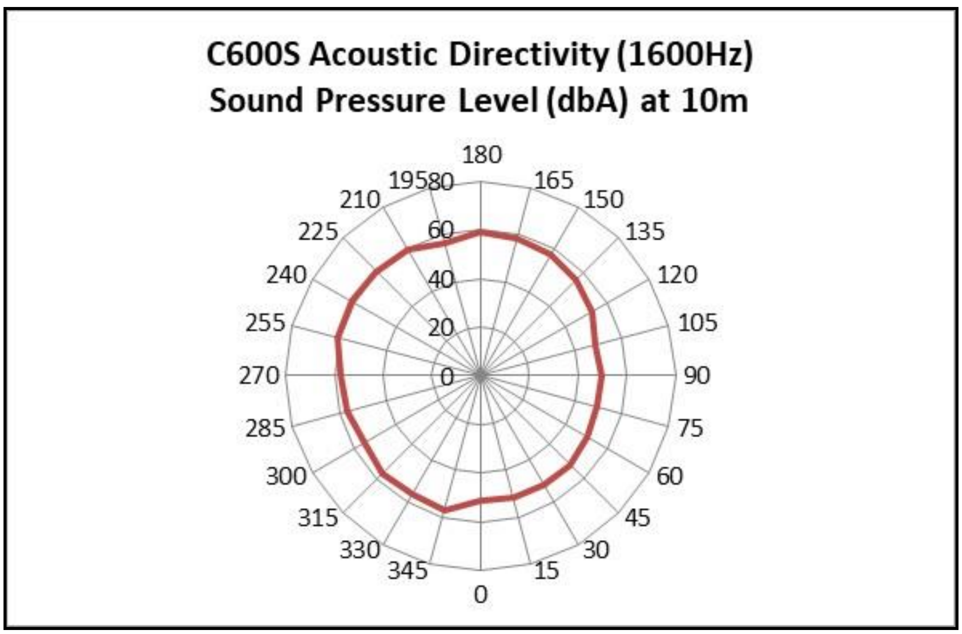

Figure 58. C600S Directivity 1600Hz

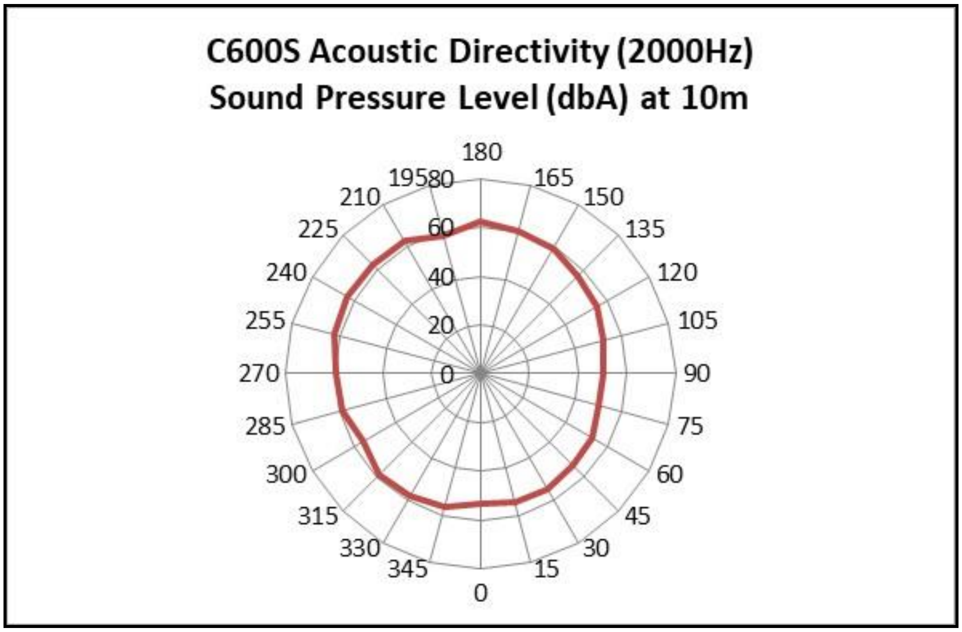

Figure 59. C600S Directivity 2000Hz

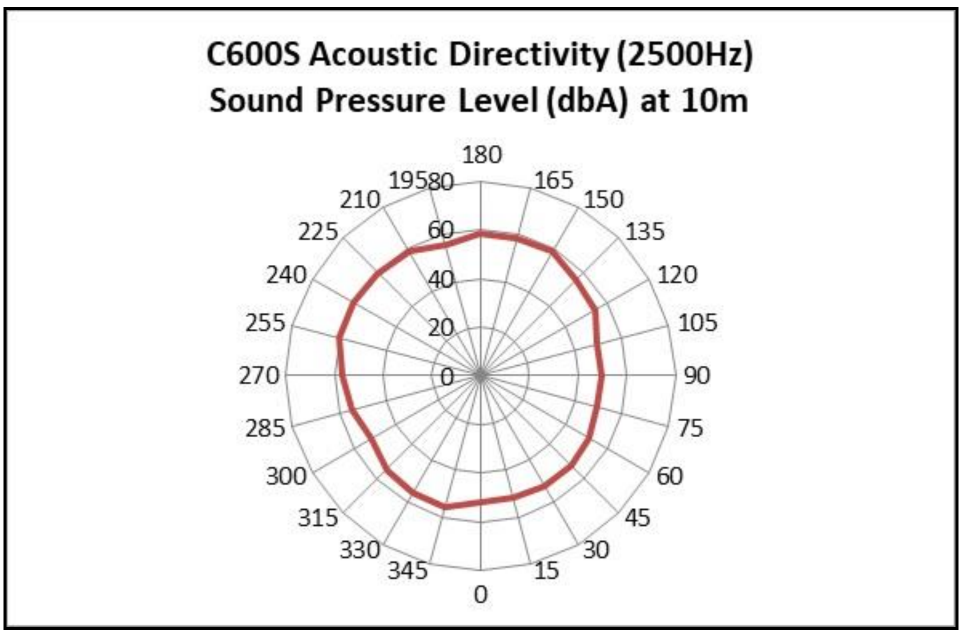

Figure 60. C600S Directivity 2500Hz

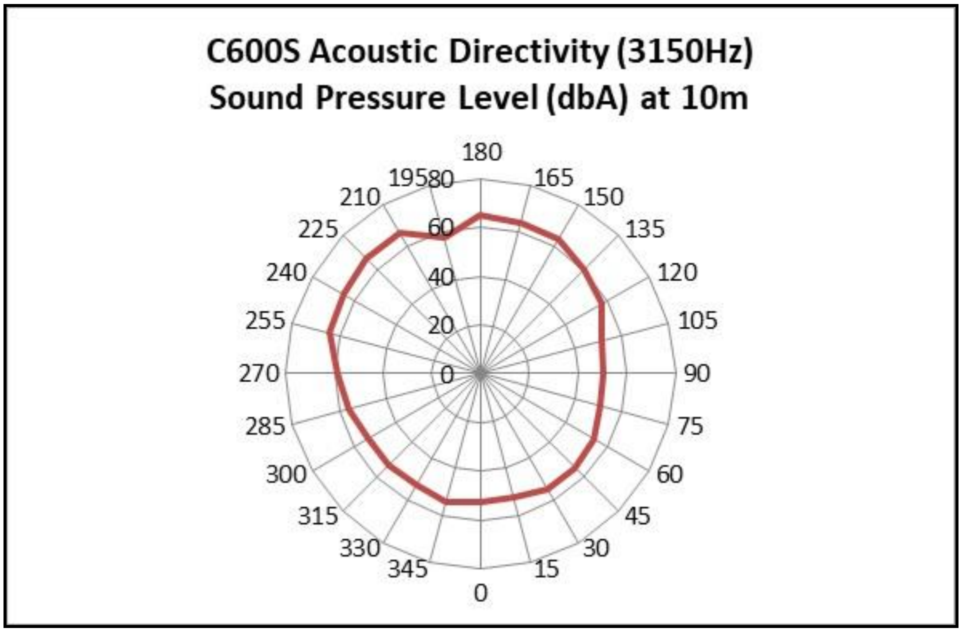

Figure 61. C600S Directivity 3150Hz

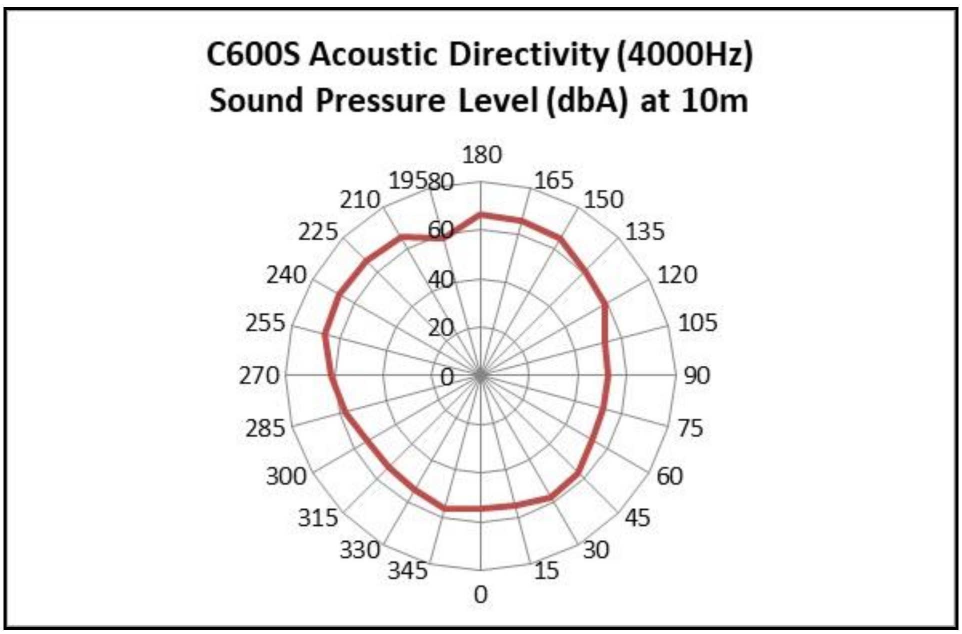

Figure 62. C600S Directivity 4000Hz

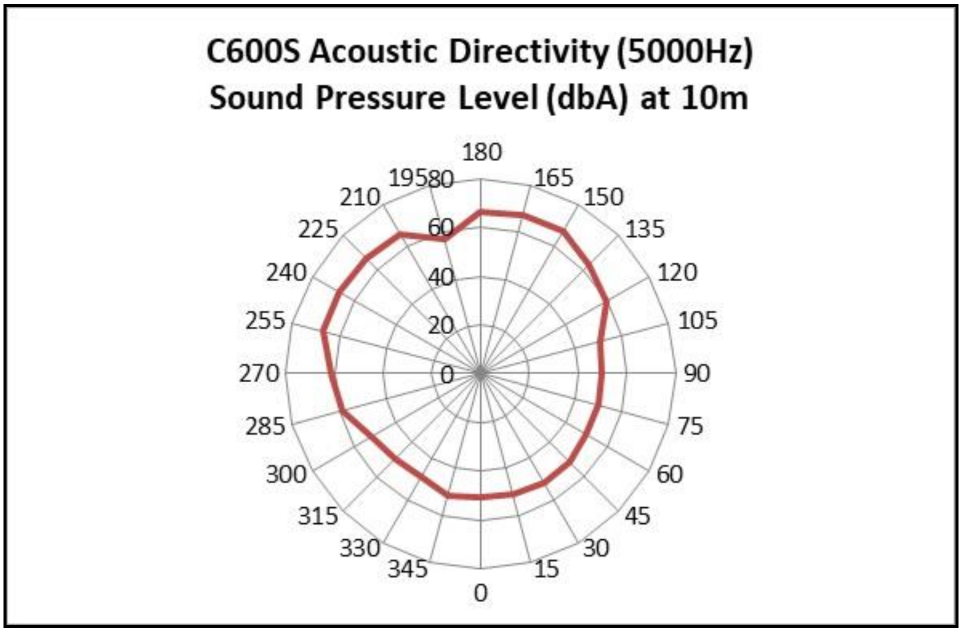

Figure 63. C600S Directivity 5000Hz

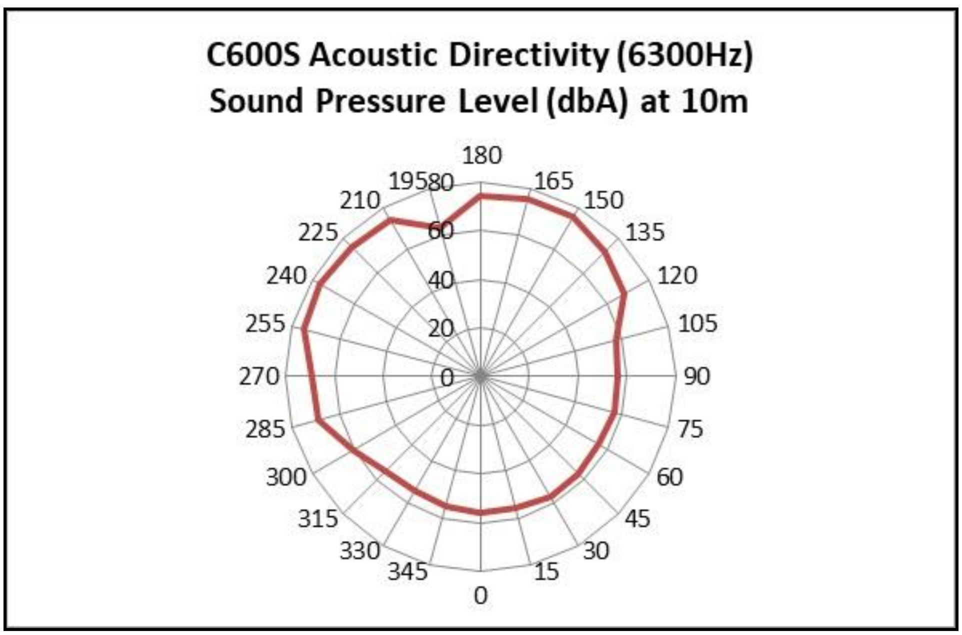

Figure 64. C600S Directivity 6300Hz

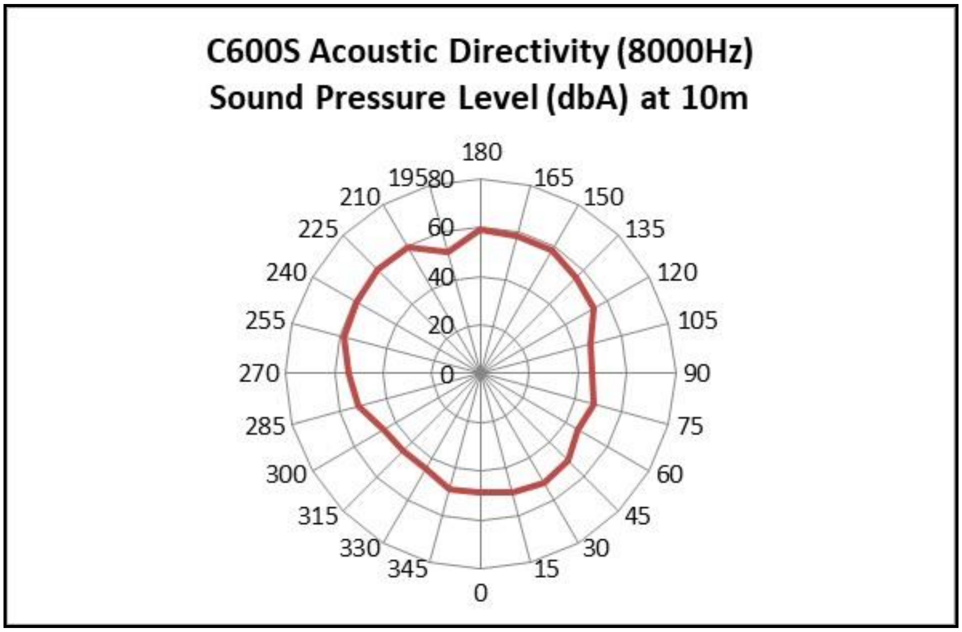

Figure 65. C600S Directivity 8000Hz

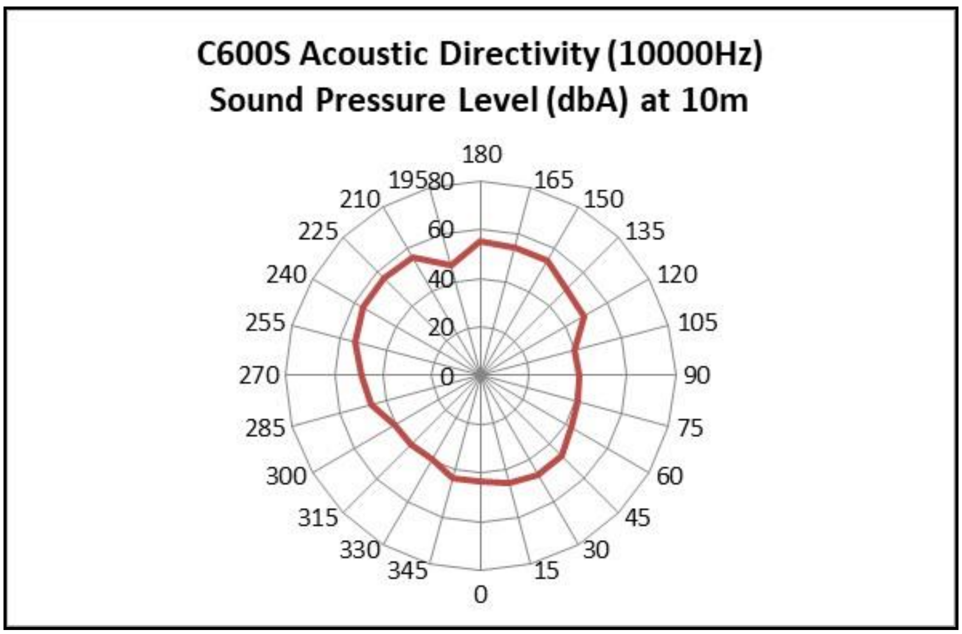

Figure 66. C600S Directivity 10000Hz

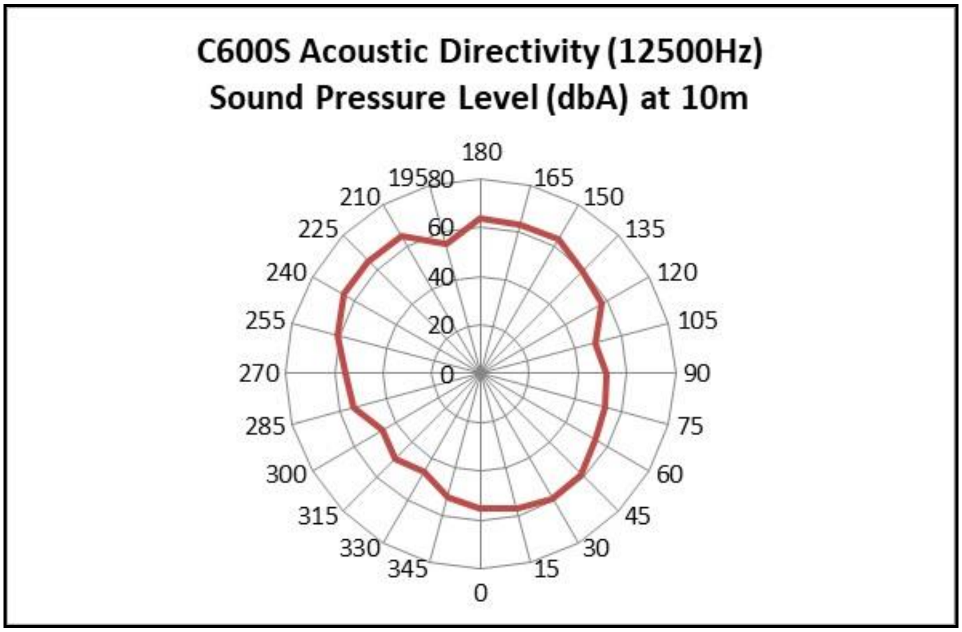

Figure 67. C600S Directivity 12500Hz

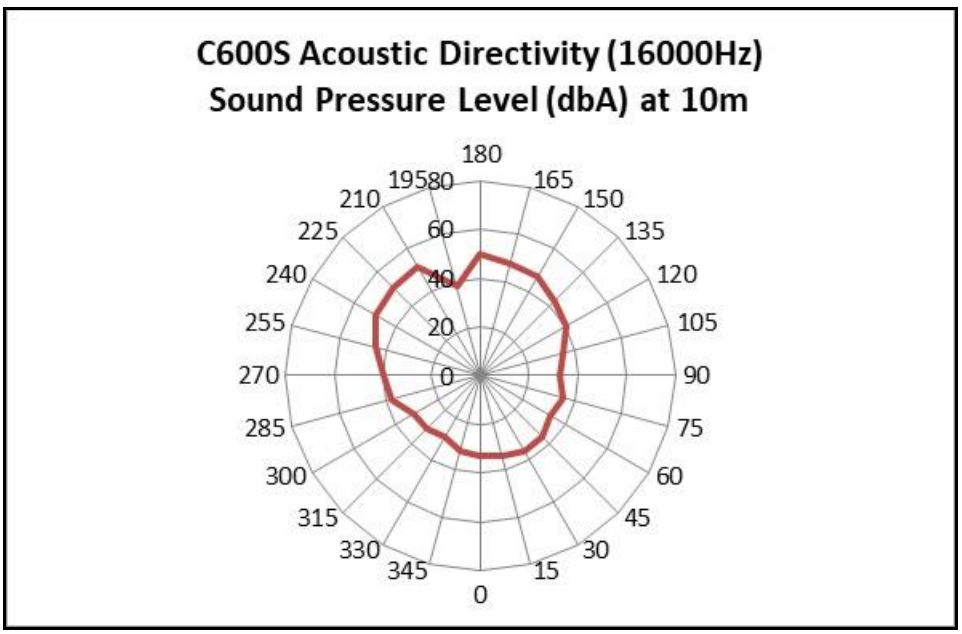

Figure 68. C600S Directivity 16000Hz

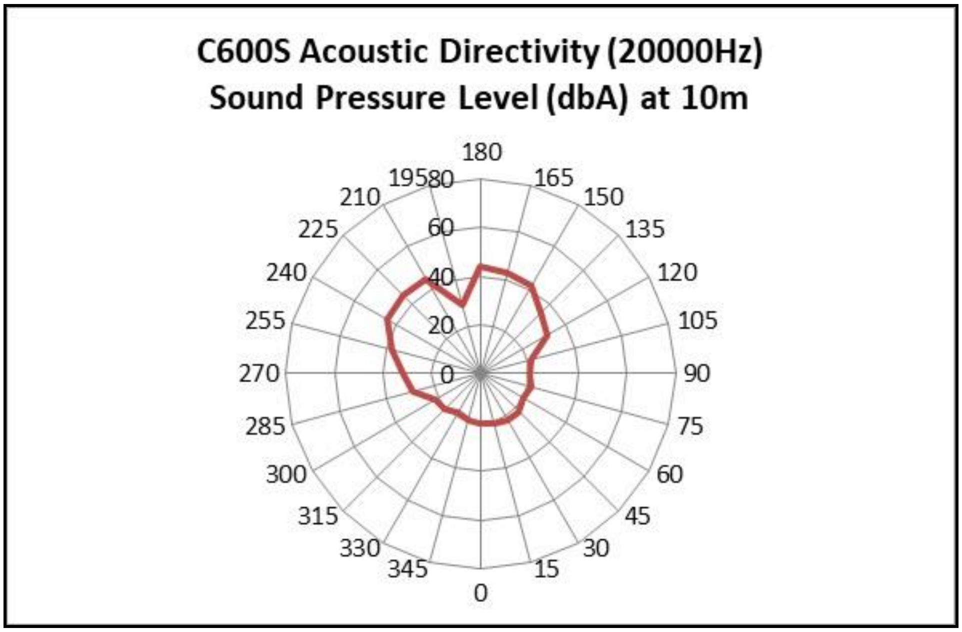

Figure 69. C600S Directivity 20000Hz

7 Appendix B: Calculations

The following formulas were applied as necessary to the results of this test.

7.1 Background Noise Levels (K1)

Background noise levels are critical to the accuracy of the sound pressure levels measured. In general, the noise levels from the source shall be at least 6dB, and preferably more than 15dB, higher than that of the background. If $\Delta L>15$ dB, no correction is made. Where required, the background correction factor, K_{1A}, shall be calculated and considered in the overall, A-weighted sound pressure level emitted by the source.

The A-weighted, background correction factor is calculated as follows:

$$K_{1A} = 10 * \log\left(1 - \frac{1}{10^{0.1*\Delta L_A}}\right) \text{dBA}$$

where:

K_{1A} = A-weighted, background correction factor,
log = the Base 10 logarithmic function, and
ΔL_A = the difference between background and the source sound pressure levels, A-weighted.

To obtain the actual L_P from the measured L_P, the background correction factor is subtracted from the measurement as follows:

$$\overline{L}_{Pi,actual} = \overline{L}_{Pi,measured} - K_{1A}$$

where

$\overline{L}_{pi,\ actual}$ = the actual sound pressure level emitted from the source at location i,
$\overline{L}_{pi,\ measured}$ = the measured sound pressure level as measured at location i, and K_{1A} = the A-weighted background correction factor.

With the proper location and an adequately quiescent test site, K_{1A} should be relatively constant and insignificant to the source L_P. This procedure will allow the application of the correction factor at the end of data analysis where the overall L_P is determined. Therefore, the actual, *overall* L_P will be the difference between the measured, *overall* L_P and the background correction factor.

Notes:

Overall in this procedure shall represent the calculations that are the combination of three quantities: *spatially-averaged*, *frequency-averaged*, and *mean-average* values, unless otherwise specified by L_P at specific location, *i*, L_P at specific frequency, *f*, or L_P during test number, *n*.

If applicable, this section may be used for supplementary data related to this document. It may be used to append items such as large (multi-page) data tables, plans pertinent to configuration items, specifications, other information, or requirements related to this document.

7.2 Wall Reflection Corrections (K2)

$$wall\ correction = 10log_{10}\left(1 + \frac{\left(\frac{r}{b}\right)^z}{atmabs}\right)6$$

where:

wall correction is the decibel amount to be subtracted from polar measurements,

r is the radius of the polar points (10 m),

b is the distance from the source's image on the other side of the wall to the polar point, and

atmabs is extra atmospheric absorption the reflected sound is reduced by due to the extra distance traveled as compared to the direct sound.

7.3 Converting Un-weighted values to A-weighted

Correction factor shall be added to or subtracted from measured un-weighted value as indicated.

Table B- 1. A-weighting correction factors.

1/3 octave-center frequency (Hz)	A-weighting correction factor (dB)
31.5	-39.4
63	-26.2
125	-16.1
250	-8.6
500	-3.2
1,000	0
2,000	+1.2

Table B- 2. A-weighting correction factors (cont'd)

Octave-center frequency (Hz)	Correction factor (dB) (A scale)
4,000	+1.0
8,000	-1.1
16,000	-6.6

(*adapted from ANSI, 1983*)

7.4 Declared Single-Number Noise Emission Value

The declared sound power for a production series of machines includes a standard deviation of uncertainty based on the technique and environmental conditions required during testing. For a normal distribution of sound power levels, there is a 90% confidence that the true value of the sound power level of a source lies within the range +/- 1.645 σ_R of the measured value. This includes measurement uncertainty associated with repeated measurements on the same noise source under the same conditions.

The declared single-number noise emission value L_D can be calculated as follows:

$$L_D = L + K$$

where

L = measured noise emission value

K = 1.645 σ_R

Values of σ_R (the standard deviation of reproducibility) come from ISO 3744 standard. In this testing, it was 1.5dB for A-weighted sound power. K would then be 2.5dB (based on engineering grade accuracy – grade 2 measurements).

Therefore 2.5dB was added to the measured values to get the declared values.

7.5 Calculating Sound Power Level by Scaling from 5 to 4 bays

Calculation of the C800S sound power level was made by scaling from 5 bays (C1000S) to 4 bays (C800S) using the following formula:

$$\begin{aligned} L_t &= 10 \log (n\,S / S_{ref}) \\ &= 10 \log (S / S_{ref}) + 10 \log (n) \\ &= L_s + 10 \log (n) \end{aligned}$$

where

L_t = *total signal level (dB)*

S = *signal (signal unit)*

S_{ref}= *signal reference (signal unit)*

n = *number of sources*

L_s = *signal level from each single source*

7.6 Calculating Sound Pressure Level by Scaling from 5 to 4 bays

Calculation of the C800S sound pressure level was made by scaling from 5 bays (C1000S) to 4 bays (C800S) using the following formula:

Lws = +10*log10(#ofsources) = Sound Pressure Level for #ofsources

Accuracy of this calculation is demonstrated by using this formula to determine the C600S sound pressure value then comparing it with the C600S measured value. Scaling the C1000S (5 bays) measurements to the C600S (3 bays) yielded a calculated sound pressure level of 73.5 dBA which is comparable to the C600S measured value of 72.9 dBA.

7.7 Other Sound Emission Calculations

7.7.1 Average sound pressure level of n readings

$$\overline{L}_P = 10 * log\left(\frac{1}{n} * \left[10^{0.1*L_{P,1}} + \ldots + 10^{0.1*L_{P,n}}\right]\right) \text{ [dB]}$$

7.7.1.1 Combined readings from a spectrum of octave bands (full octave bands, f1 to fn):

$$\overline{L_P} = 10 * log\left(10^{0.1*L_{P,f1}} + \ldots + 10^{0.1*L_{P,fn}}\right) \text{ [dB]}$$

7.7.2 Surface area, S, of the parallelepiped surface

$$S = (2a * 2c) + (2b * 2c) + (2a * 2b) \text{ [m}^2\text{]}$$

where

$2a$ = *length* L_1 + *2 x characteristic dimension* d_0,

2b = width L_2 + 2 x characteristic dimension d_0, and
2c = height L_3 + characteristic dimension d_0.

7.7.3 Sound Power Level (calculated from average sound pressure level)

$$L_W = \overline{L}_P + 10 * log\left(\frac{S}{S_0}\right) \text{ [dB]}$$

where

S = calculated parallelepiped or hemispherical surface area, and
S_0 = reference surface area equal to 1.0 m^2.

7.7.4 Extrapolation of Sound Pressure Level to another distance

The sound pressure level, L_{P2} *at location* d_2 can be extrapolated from L_{P1} at location d_1 as follows:

$$\overline{L_{P2}} = \overline{L_{P1}} + 20 * log\left(\frac{d_1}{d_2}\right) \text{ [dB]}$$

where

$\overline{L_{P1}}$ = overall measured sound pressure level at location d_1,
$\overline{L_{P2}}$ = overall calculated sound pressure level to be extrapolated,

d_1 = distance from source where LP1 is measured, and
d_2 = distance from source of interest where LP2 is to be extrapolated to.