

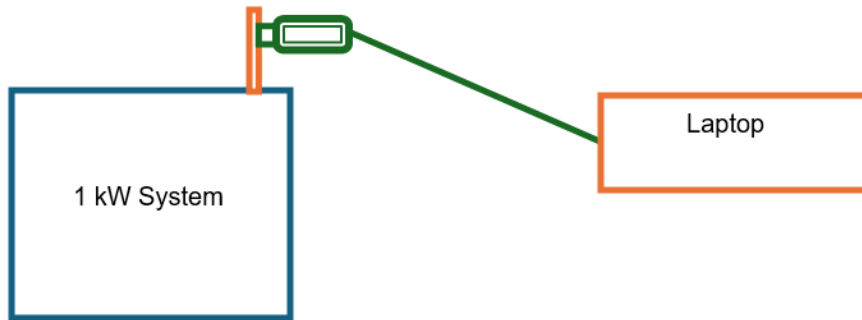
CPI Satcom & Antenna Technologies, Inc.

Test Setup

RF Output Power

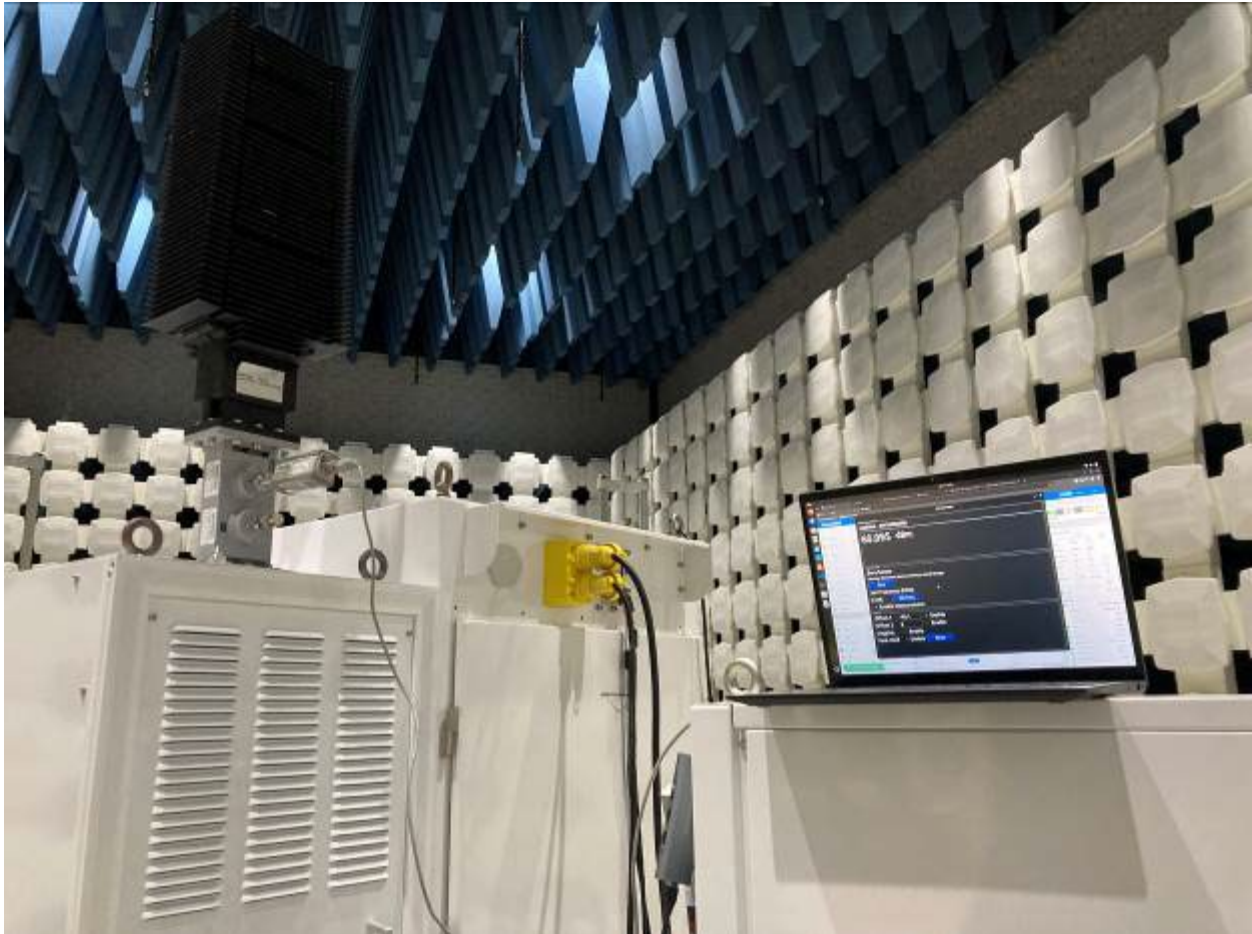
Method

Tests are performed in accordance with ANSI C63.26.



- 1) Testing was performed using the power meter by connecting it to the antenna port.
- 2) The power meter was connected to the laptop via USB [cable](#) and the conducted output power was displayed on the laptop.

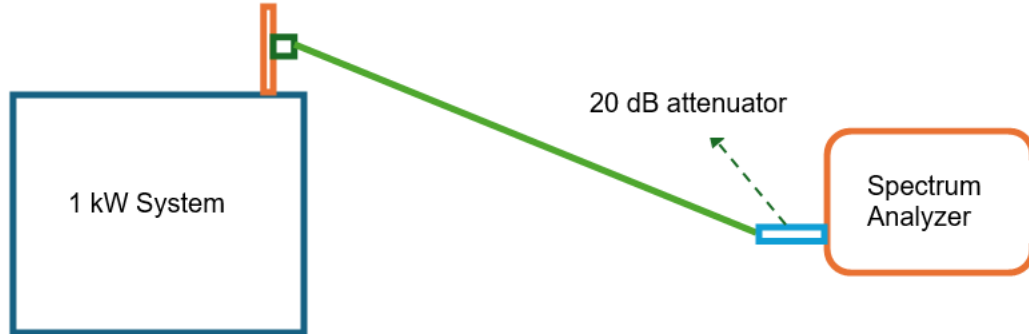
Setup Photograph:



Peak-to-Average Power Ratio (PAPR)

Method

Tests are performed in accordance with ANSI C63.26.

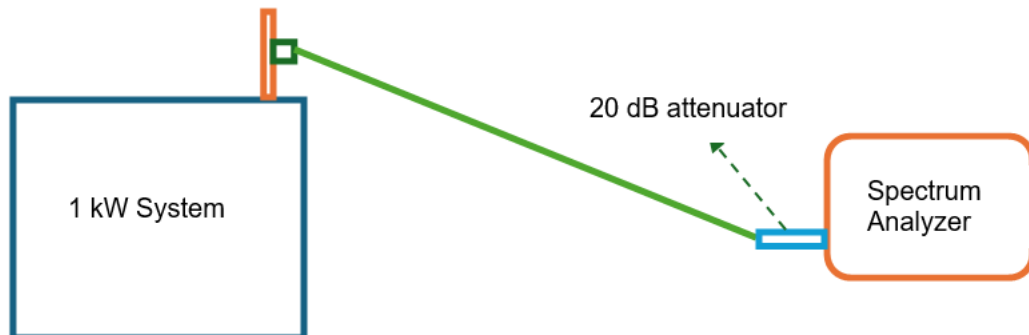


- 1) Testing was performed by connecting the antenna port to the spectrum analyzer via a 20 dB attenuator.

Occupied Bandwidth and 26 dB Bandwidth

Method

Tests are performed in accordance with ANSI C63.26.



- 1) Testing was performed by connecting the antenna port to the spectrum analyzer via a 20 dB attenuator.

Setup Photograph:



Note: SiriusXM Harmonic test fixture was used to support the testing.

Transmitter Conducted Spurious Emissions and Band Edge

Description of the Test Setup

The test setup comprises a directional coupler with its WR340 through-path terminated by a well-high-power WR340 termination. The coupled ports are coaxial N-type. One of the coaxial output ports connects to a bandpass filter to select the portion of the band to be measured and isolate the transmit signal. The filter output is directed to a spectrum analyzer for measurement of the conducted emissions. The block diagram below illustrates the signal flow. The photographs depict the directional coupler and termination attached to the repeater output.

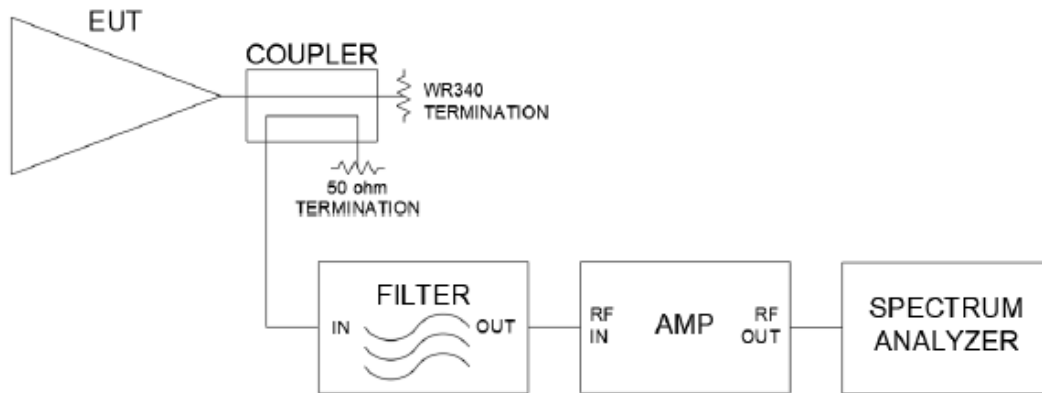
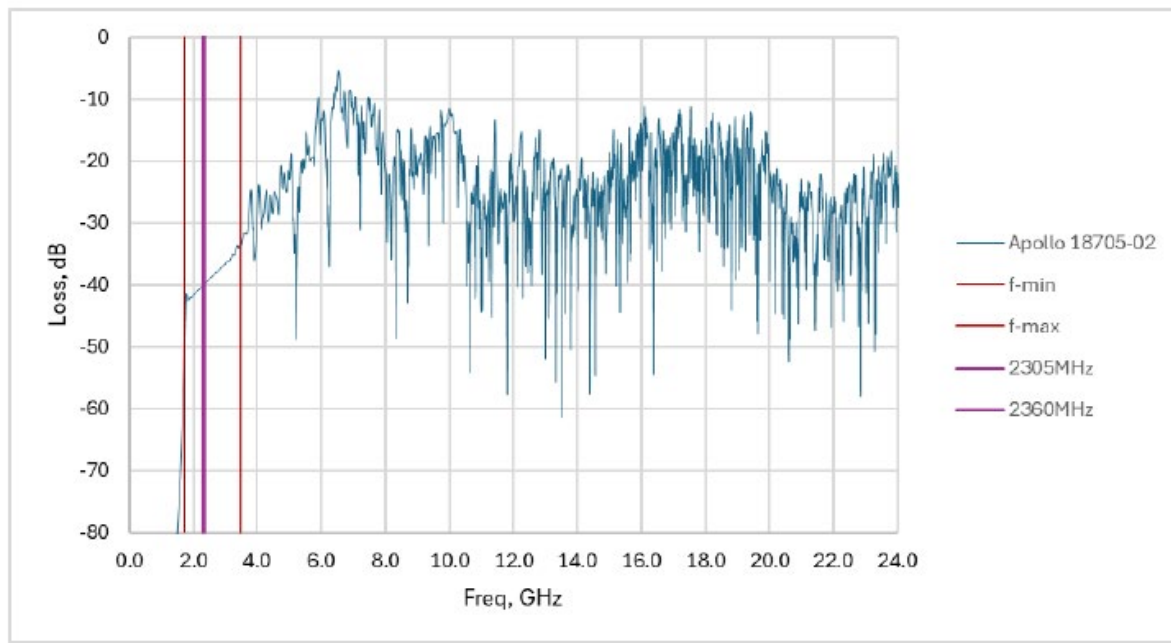


Figure 4 - Block Diagram of the Test Setup

1.1 Sample Measurements

As noted in our initial submission, WR340 cuts off below 1.737 GHz such that any waveguide structure such as a directional coupler has very high attenuation below that frequency. Higher-order modes occur at frequencies above 3.474 GHz and above, resulting in measurement difficulties above that limit.

The plots below illustrate the performance of a waveguide-to-coaxial coupler within and beyond the proposed conducted emissions measurement bandwidth. In the figure below “f-min” and “f-max” delineate the proposed conducted emissions bandwidth of 1.737 to 3.474 GHz. “2305MHz” and “2360MHz” indicate the SDARS terrestrial repeater operating band.



Insertion loss of WR340

As can be seen in the above insertion loss calibration plot of a good-quality WR340 coupler at CPI, the structures begin to mode – creating calibration impracticalities above 3.474 GHz. The result is that insertion loss ceases to be an intrinsic property of the device under test and becomes highly sensitive to the load impedance and mechanical boundary conditions at the measurement ports.

Small changes in the termination's return loss, flange alignment, surface finish, or fixture geometry alter the modal content and phase relationships, causing variable mode conversion and reconversion at discontinuities; power that leaves the DUT in higher modes may be partially reflected by the load and converted back to the dominant mode, producing apparent S_{21} variations that can be 10's of dB. Because each mode has a different cutoff and characteristic impedance, the port impedance is no longer uniquely defined and calibration standards themselves can excite/reflect higher modes, yielding non-repeatable results and frequency ripple.

1.2 Discussion of IEEE/ANSI C63.26-2015

ANSI C63.26-2015 is largely port-agnostic and does not provide waveguide-specific conducted test procedures or guidance about finite single-mode bandwidth or higher-order mode issues. Instead, it prescribes general instrumentation and measurement practices—RBW defined at the -3 dB points, appropriate RBW/VBW and detector settings, bandwidth scaling or integration when RBW is narrower than the reference bandwidth, and special care for broadband signals—intended to be applied regardless of the physical interface.

The most relevant sections of the standard, §4.5.4 of, require characterization of insertion loss for all interposed devices—cables, attenuators, filters, and directional couplers—and frequent checks (monthly or before each use) for deterioration or environmental effects, so accuracy and system uncertainty are maintained [4]. The standard also emphasizes low-loss, impedance-matched, well-shielded RF cables

that are bench-calibrated prior to use. This is violated when the waveguide is not restricted to single mode operation.

CPI proposes that conducted emissions measurements will be performed only within a close-in frequency range around the licensed transmission band (2.32 GHz to 2.345 GHz) where the rectangular waveguide supports a meaningful measurement and calibrations of the interconnecting waveguide and couplers can be made IAW ANSI C63.26 §4.5.4. This range ensures that the waveguide operates in its fundamental mode and avoids frequencies where the waveguide is in cutoff or supports higher-order modes that lead to significant measurement and calibration uncertainty.

CPI will complete complimentary radiated emissions measurements across the full range of frequencies as specified 47 CFR §2.1057 with the waveguide antenna port properly terminated into a load.

1.3 Waveguide Cutoff Below the Transmission Band

The WR340 waveguide is selected to operate within the intended transmission band of the SDARS repeater (2.306 GHz to 2.345 GHz). Rectangular waveguide supports propagation only above the mode-dependent cutoff frequency. For the dominant TE₁₀ mode, the cutoff is given by:

$$f_c = \frac{c}{2a}$$

Where:

- f_c = cutoff frequency (Hz)
- c = speed of light in vacuum (approximately 3×10^8 m/s)
- a = width of the waveguide (meters)

For WR340, the width of the waveguide is 3.4 inches (0.08636 meters).
Substituting into the formula:

$$f_c = \frac{3 \cdot 10^8}{2 \cdot 0.08636} \approx 1.737 \text{ GHz}$$

Therefore, the waveguide is in cutoff below 1.737 GHz, no mode propagates, and the waveguide presents an evanescent section. Any “conducted” measurement below cutoff is dominated by evanescent leakage and fixture parasitics rather than the transmitter port’s spurious content and therefore is not representative or calibratable in a metrologically sound manner. Further, near cutoff, attenuation becomes high – exponentially increasing cutoff, and group velocity is very low.

1.4 Higher-Order Modes Above the Transmission Band

At frequencies significantly above the transmission band, the waveguide supports higher-order propagation modes. These modes are governed by the more general cutoff formula:

$$f_c = \frac{c}{2} \sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$$

Where:

- m and n are mode indices (e.g., TE₁₀, TE₂₀, etc.)
- a = width of the waveguide (meters)

- b = height of the waveguide (meters).

For WR340, the height is 1.7 inches (0.04318 meters). The fundamental mode (TE₁₀) has $m=1$ and $n=0$, with a cutoff frequency of 1.737 GHz. Higher-order modes (e.g., TE₂₀, TE₀₁) occur at frequencies above 3.474 GHz and beyond, introducing significant calibration challenges for couplers and filters.

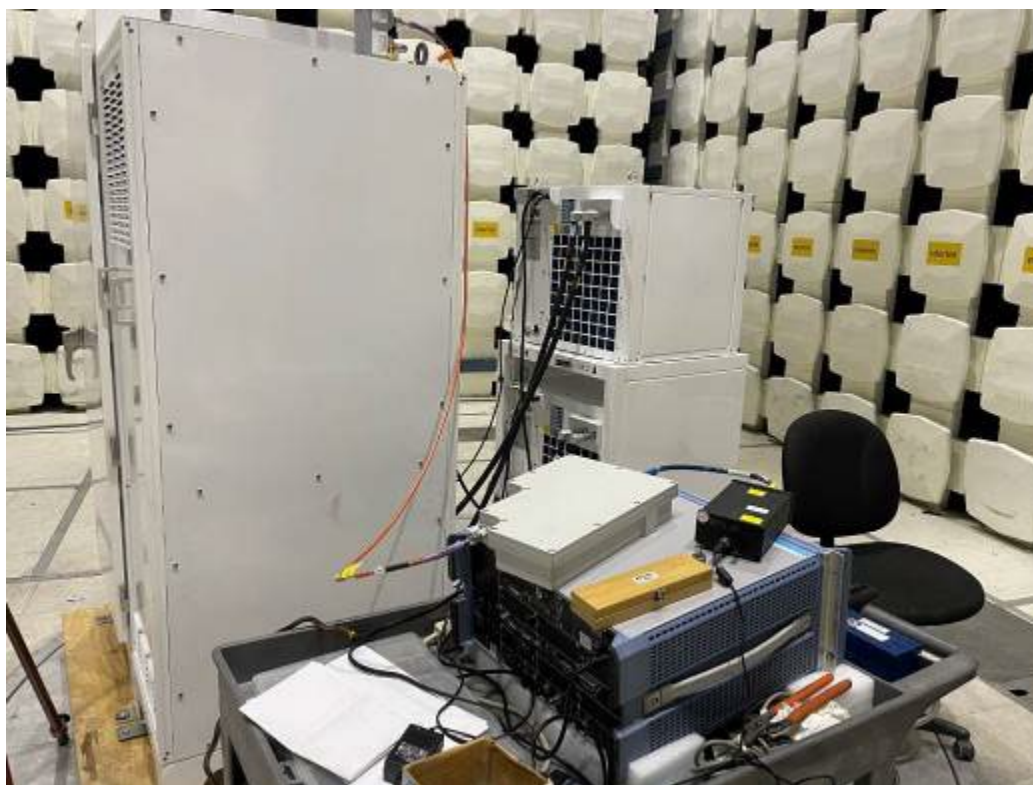
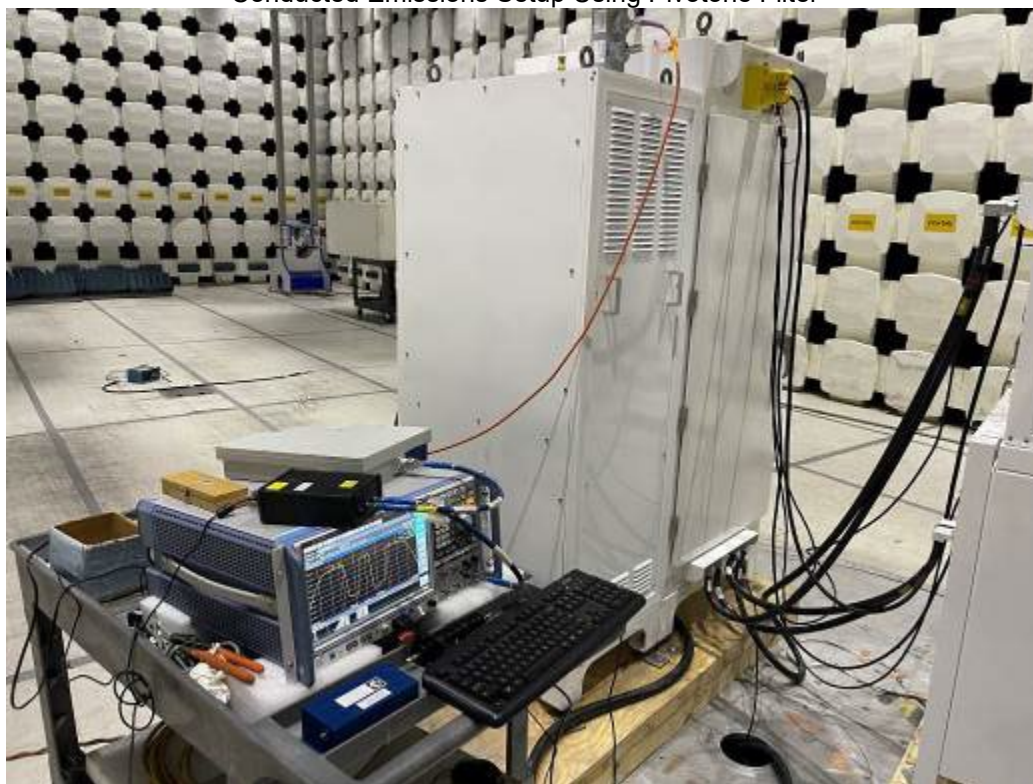
KDB 971168 explicitly restricts conducted measurements to those where “a transmitter RF output port is available and can be properly terminated, conducted measurements at the RF antenna port may be used.” [5] In this context, “Properly terminated” for a waveguide implies a matched termination over the waveguide’s supported modes/band. That condition only holds within the waveguide’s operational - fundamental TE₁₀ mode – band; hence conducted spurious measurements should be limited to that range.

Rectangular waveguides are single mode (TE₁₀) only up to the onset of higher order modes; above that threshold, multiple modes propagate with different field distributions and impedances. Once higher modes propagate, “power at the port” is split among modes in a way that depends on geometry and terminations, so a single conducted measurement no longer represents the power deliverable to the antenna or a matched load. This makes port measurements non-repeatable, non-representative and violates the requirement that the port be “properly terminated”.

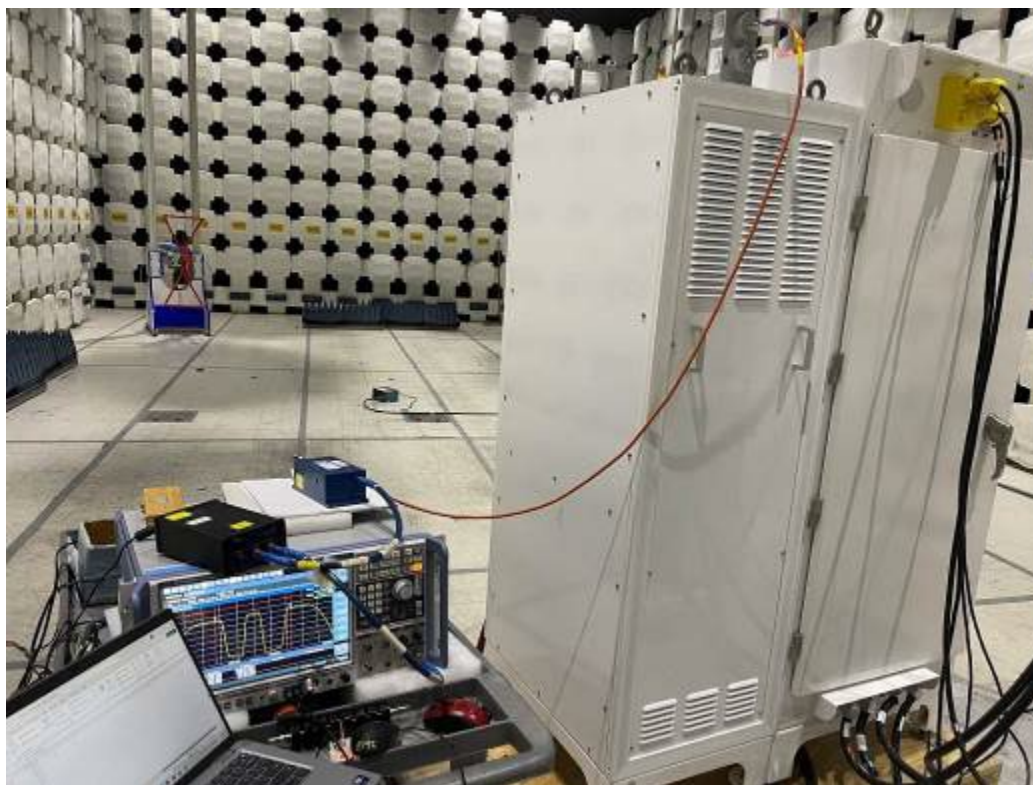
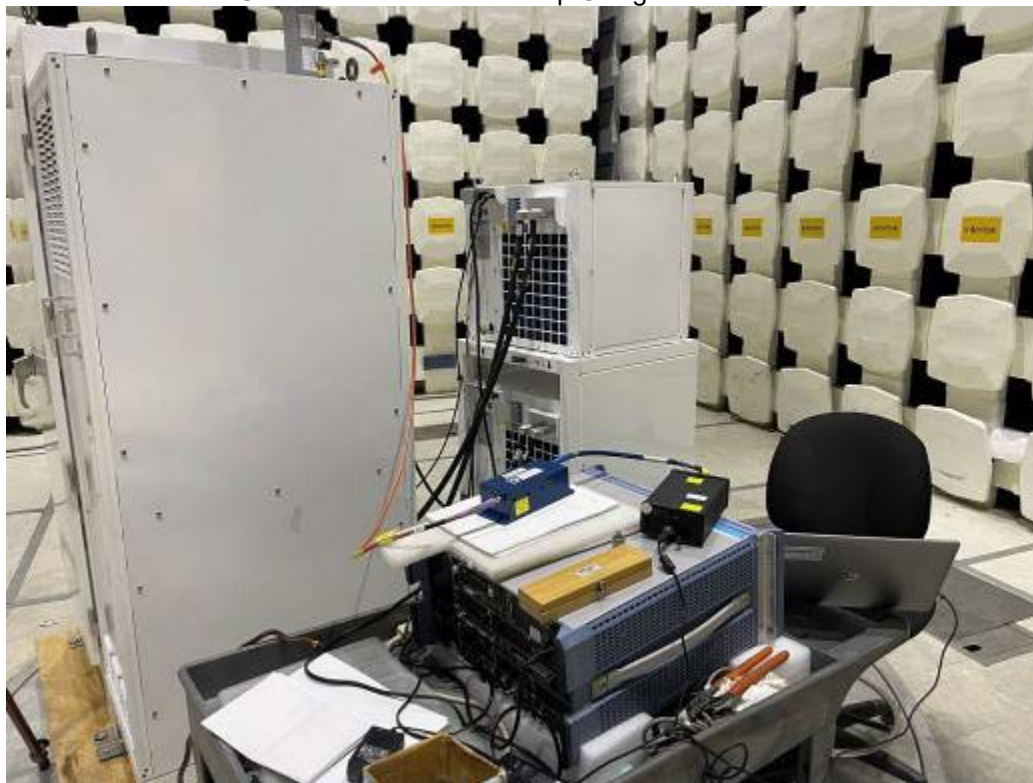
The concept of “conducted power at the antenna terminals” relies on a well-defined port impedance. In coax this is 50 Ω TEM; in waveguide it is mode dependent and only stable in single mode operation. Above the operating band, the port impedance becomes multi valued (per mode), so any single scalar measurement (e.g., via a waveguide-to-coax transition) yields ambiguous results about actual deliverable power. Further, waveguide terminations, sampling couplers, and coax to waveguide transitions are specified for a band with known VSWR and coupling factor. Above that band their coupling and match degrade unpredictably, so the measured levels have large, unquantified errors. CPI proposes restricting the upper frequency of true conducted measurements at the antenna port to less than 3.474 GHz where the higher order modes begin to propagate.

Setup Photographs:

Conducted Emissions Setup Using Pivotone Filter



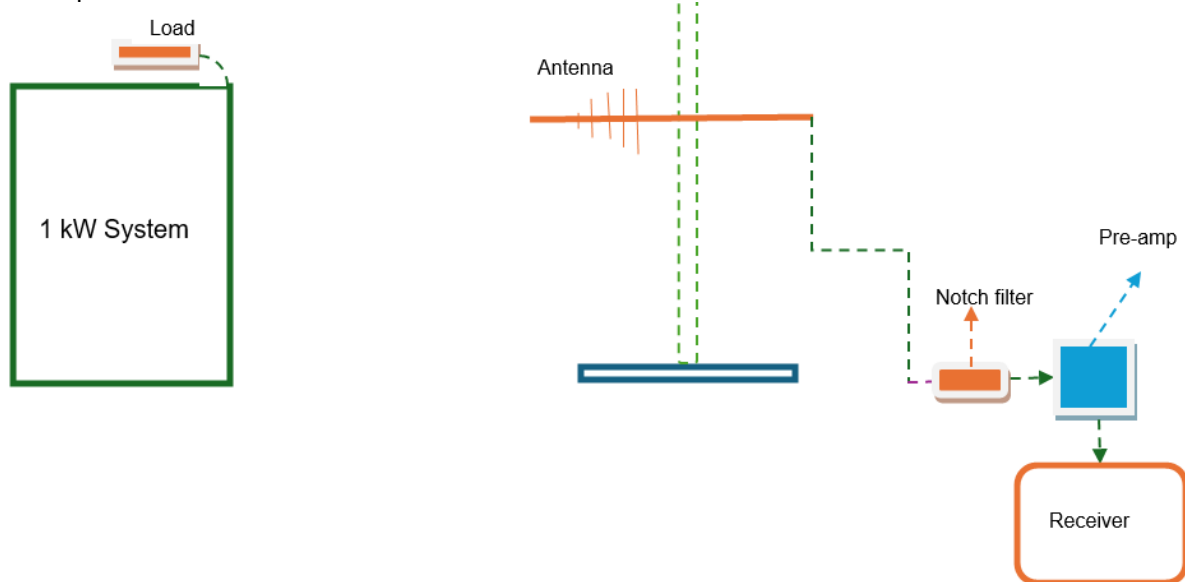
Conducted Emissions Setup Using Reactel Filter



Transmitter Radiated Spurious Emissions

Method

Tests are performed in accordance with ANSI C63.26.



The 1 kW System was tested in a 10M chamber. The EUT, antenna, notch filter, and pre-amp were located inside the chamber and the receiver was placed outside in the control room.

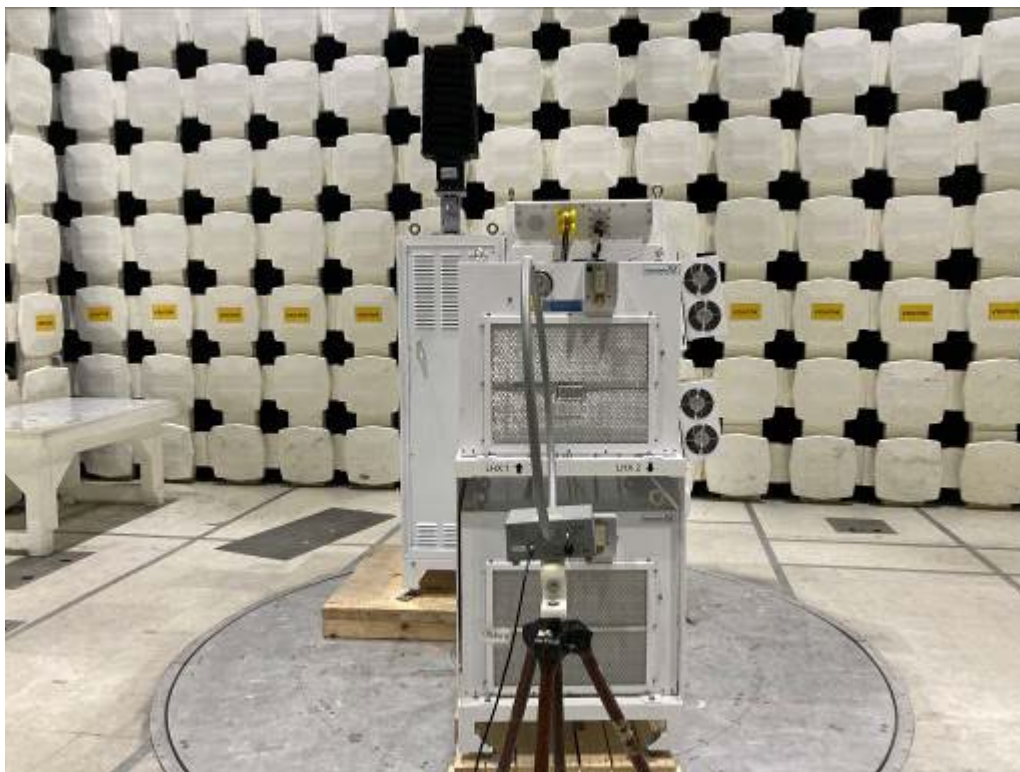
Radiated Measurement Distance (as proposed by CPI)

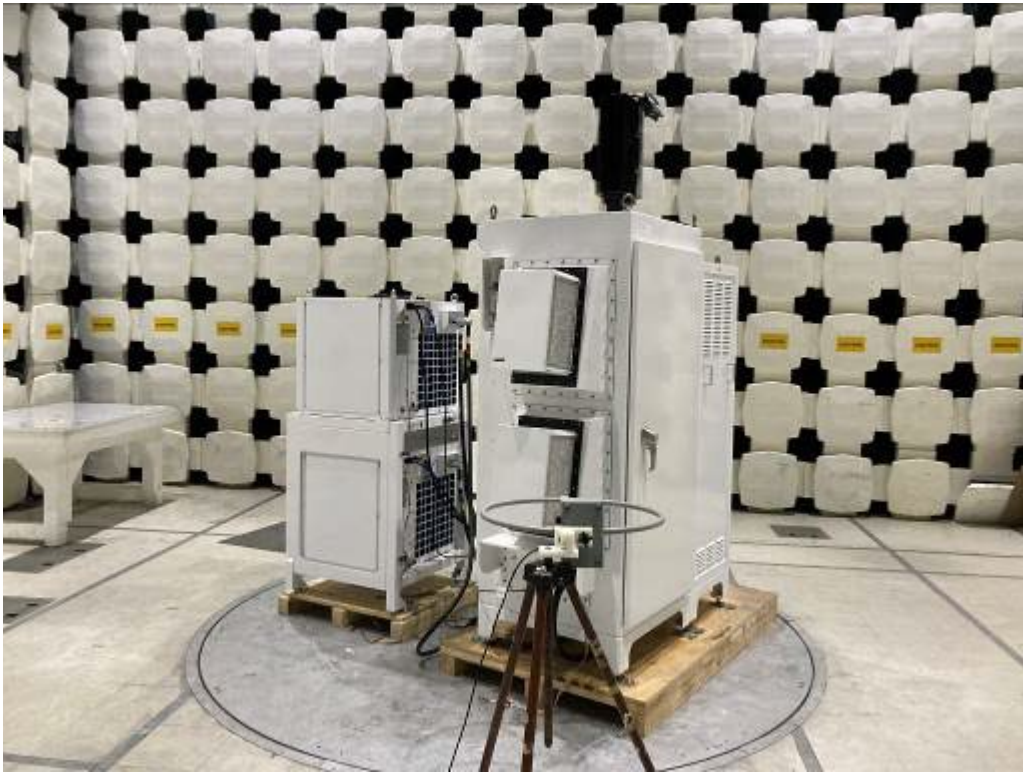
We have an additional question regarding the limit for SDARS terrestrial repeaters operating above 2 Watts, which is specified as -60 dBm. Our accredited test lab, Intertek, has been attempting for several months to obtain equipment capable of measuring below this limit in the far field, as outlined in ANSI C63.26:2015. Despite testing multiple preamplifier models, Intertek has been unable to achieve a sufficient noise floor to meet the measurement requirements.

Given these challenges, we respectfully request permission to conduct the required radiated emissions measurements at a closer distance, such as 20 to 30 cm, to ensure accurate detection below the specified limit. This adjustment would allow us to comply with the measurement requirements while addressing the equipment limitations.

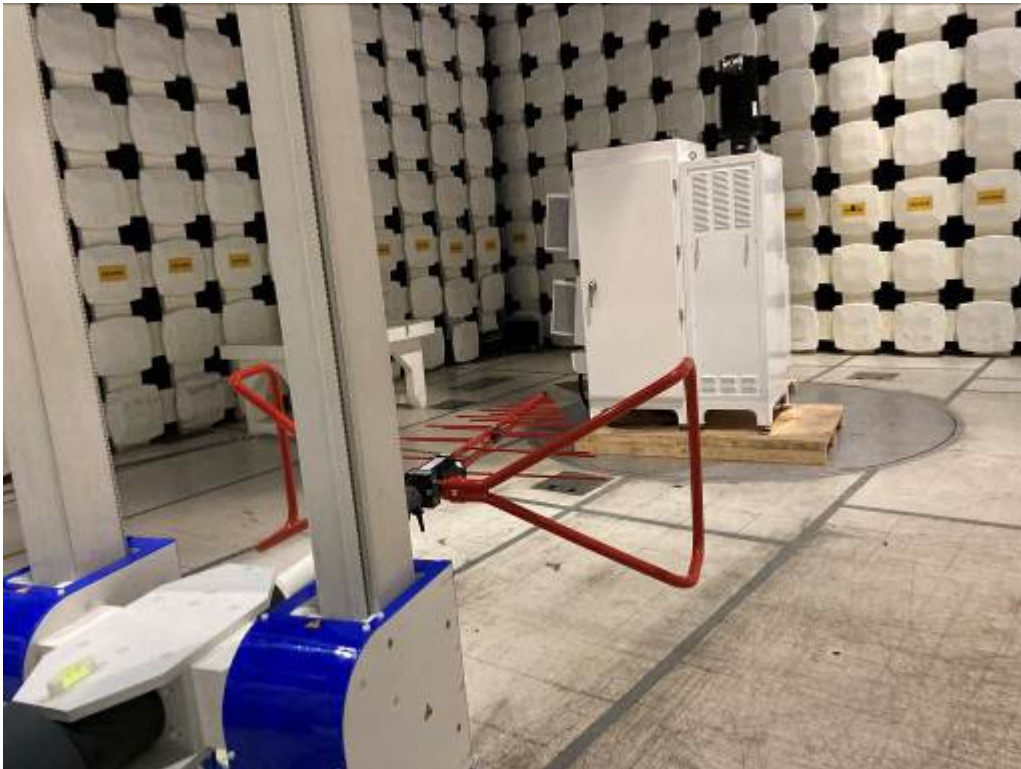
Setup Photographs:

9kHz – 30 MHz





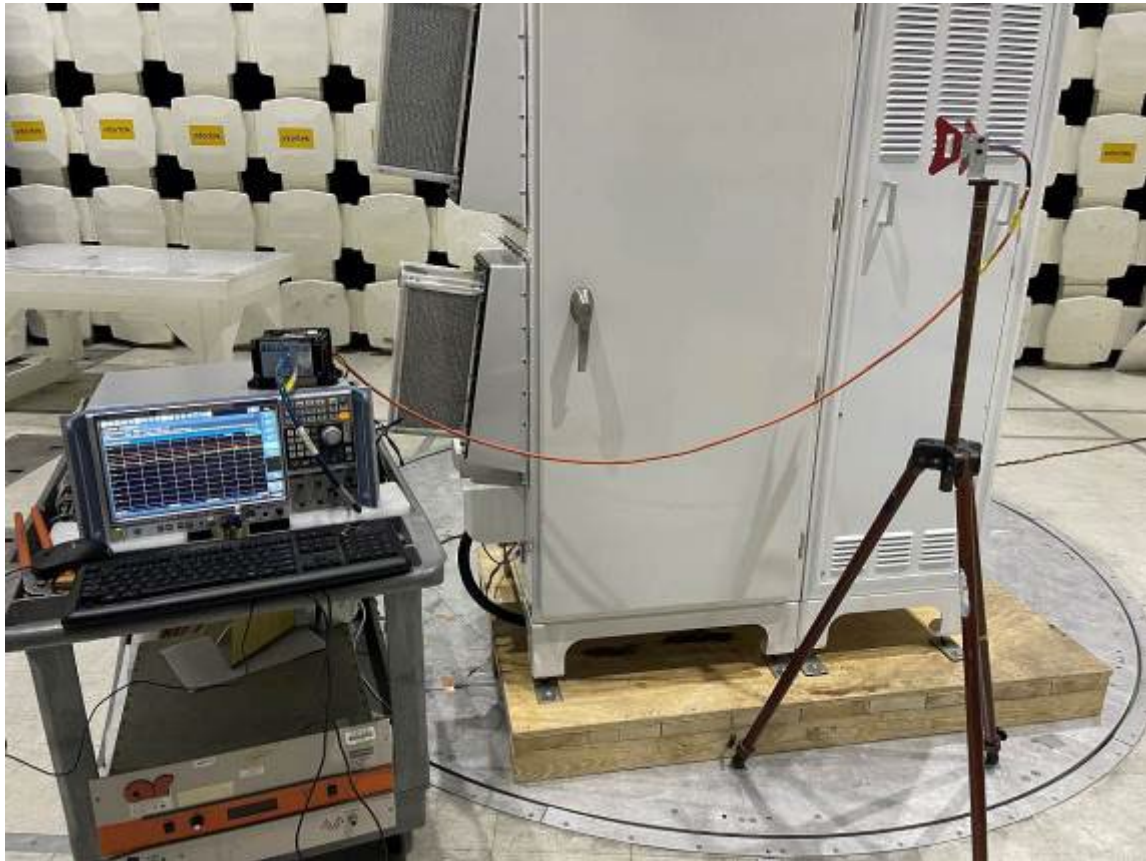
30 – 1000 MHz



1 – 18 GHz



18-24 GHz

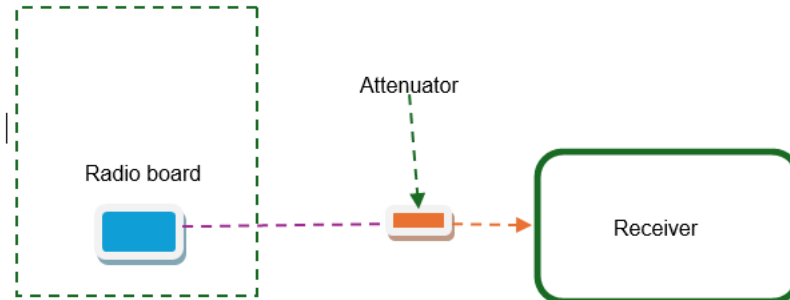


Notes: Testing was performed manually at 5 cm around the EUT.

Frequency Stability

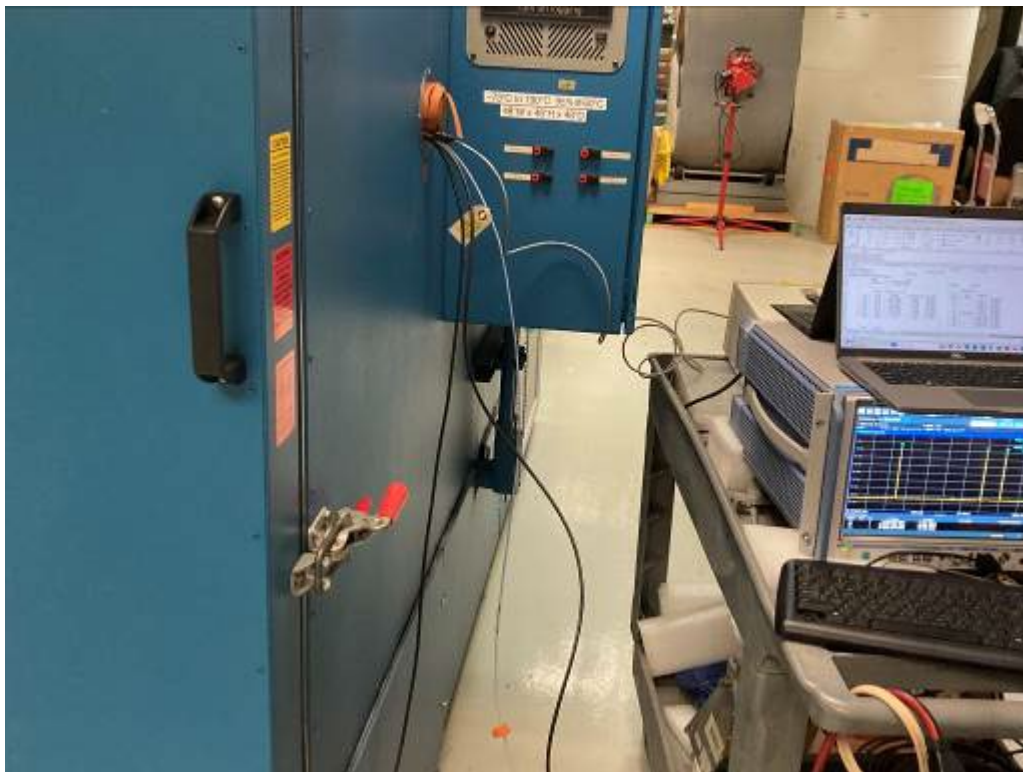
Method

Tests are performed in accordance with ANSI C63.26.



Testing was performed by placing a transmitter board inside an environmental chamber. Antenna port was connected to a receiver via an attenuator.,

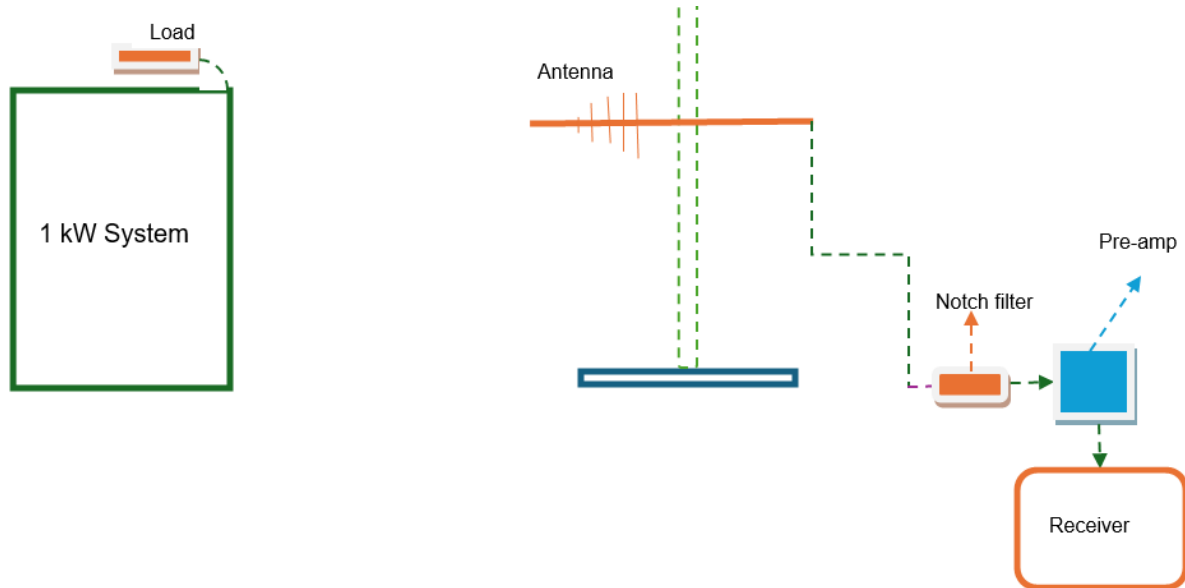
Setup Photograph:



Radiated Emissions of Digital Device

Method

Tests are performed in accordance with ANSI 63.4.



The 1 kW System was tested in a 10M chamber. The EUT, antenna, notch filter, and pre-amp were located inside the chamber and the receiver was placed outside in the control room.

1.5 Setup Photographs:

30 – 1000 MHz

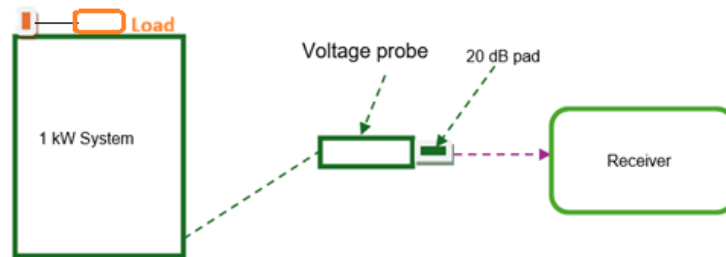




AC Mains Conducted Emissions

Method

Tests are performed in accordance with FCC Part 15 Subpart B and ANSI C63.4.



Testing was performed by connecting each phase to a receiver via a voltage probe and 20 dB pad. |

1.6 Setup Photograph:

