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Voting System Anomaly Root Cause Analysis Template v2.0

Root Cause Analysis for:

Anker Solix UPS Failures in Electromagnetic Compatibility Testing, Reproduced for VV40ECT-78: Power Dips Tests
VxSuite, Version 4.0 and EAC Certification #VXS4

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March 31, 2025

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Introduction

The purpose of this RCA document is to describe the failures of the Anker Solix C300 uninterruptible power supply (UPS) during Electromagnetic Compatibility (EMC) testing of the VxScan system in the certification testing process at SLI Compliance in March 2025. This is a commercial off-the-shelf (COTS) component with an FCC Part 15 compliance label and CE mark that was previously shown to provide enough backup power to the VxScan system over time in case of power loss in internal tests. However, during certification tests, this Anker UPS showed evidence of general electrical build quality problems. Initial tests suggested the UPS contributed to excess radiated emissions (FCC Class B) in the VxScan system. It also showed potential problems with built-in wireless connectivity features that always have to be turned off to be used properly. Furthermore, the UPS showed signs of causing functional failures in VxScan due to Electrical Fast Transient (EFT) / Burst testing (IEC 61000-4-4 Levels 2-4) and Voltage Dips and Interruptions testing (IEC 61000-4-11).

A response to this failed component in terms of EMC is also described in this report, which included followup testing with an outside firm, NOVO Engineering. In July 2024 NOVO previously tested VxScan for some EMC tests, which VxScan passed, but without the Anker UPS. An alternative UPS was identified to use as a potential replacement and mitigation to the original Anker UPS, addressing the electrical concerns above.

Anomaly Description

Complete all sections. Descriptions must be as detailed as possible, while being clear and concise since the anomaly is the source of the entire RCA. This detail should include a complete list and/or description of the “symptoms” of the anomaly and the conditions present which the symptoms occurred.

Date of Anomaly: March 7, 2025	Time of Anomaly: 9 AM (Mountain Time)
Place of Anomaly: Element, Longmont, CO	Person identifying Anomaly: Jessica Myers, VotingWorks

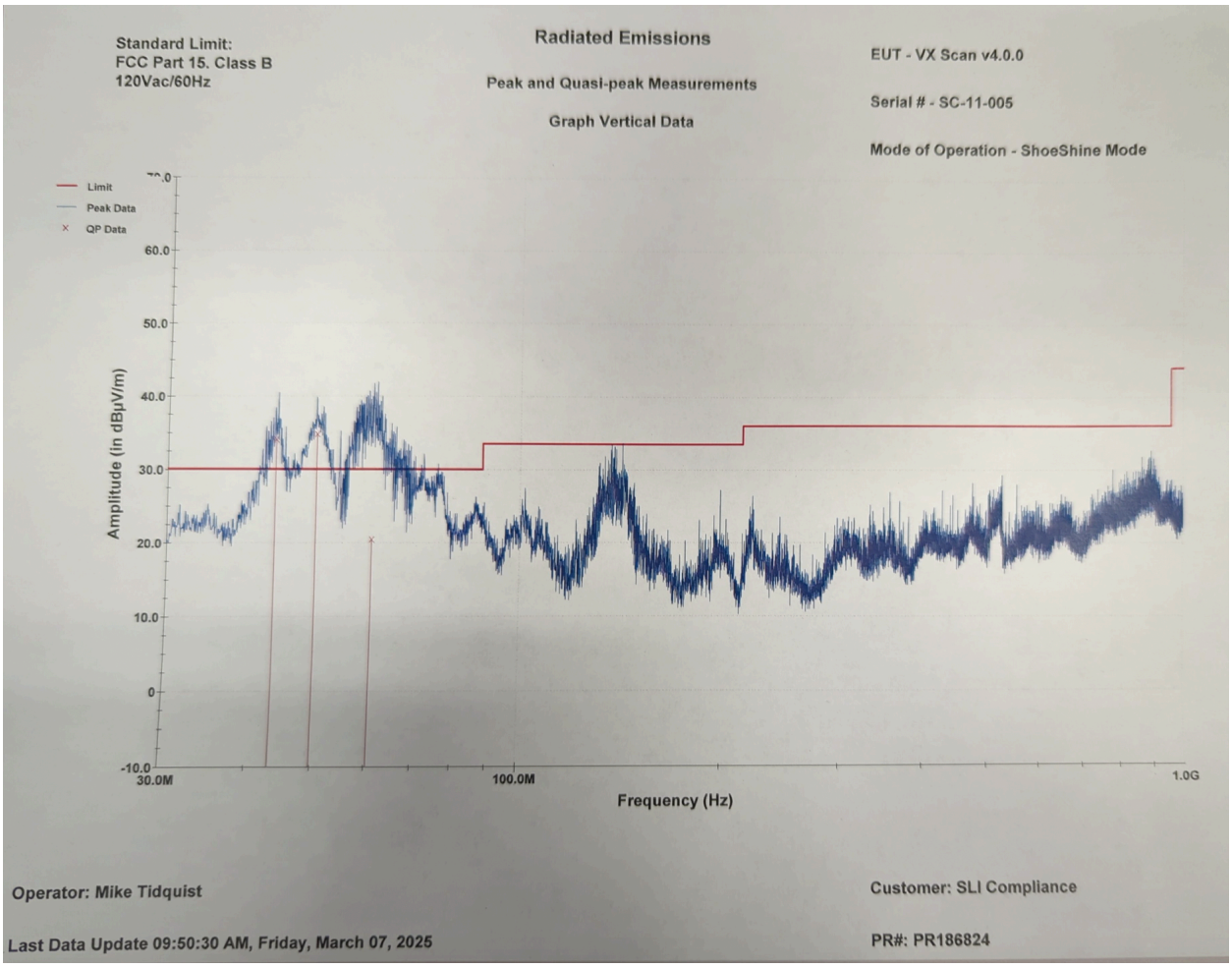
EAC (Election Assistance Commission) Root Cause Analysis

Expected Results of actions leading up to anomaly:

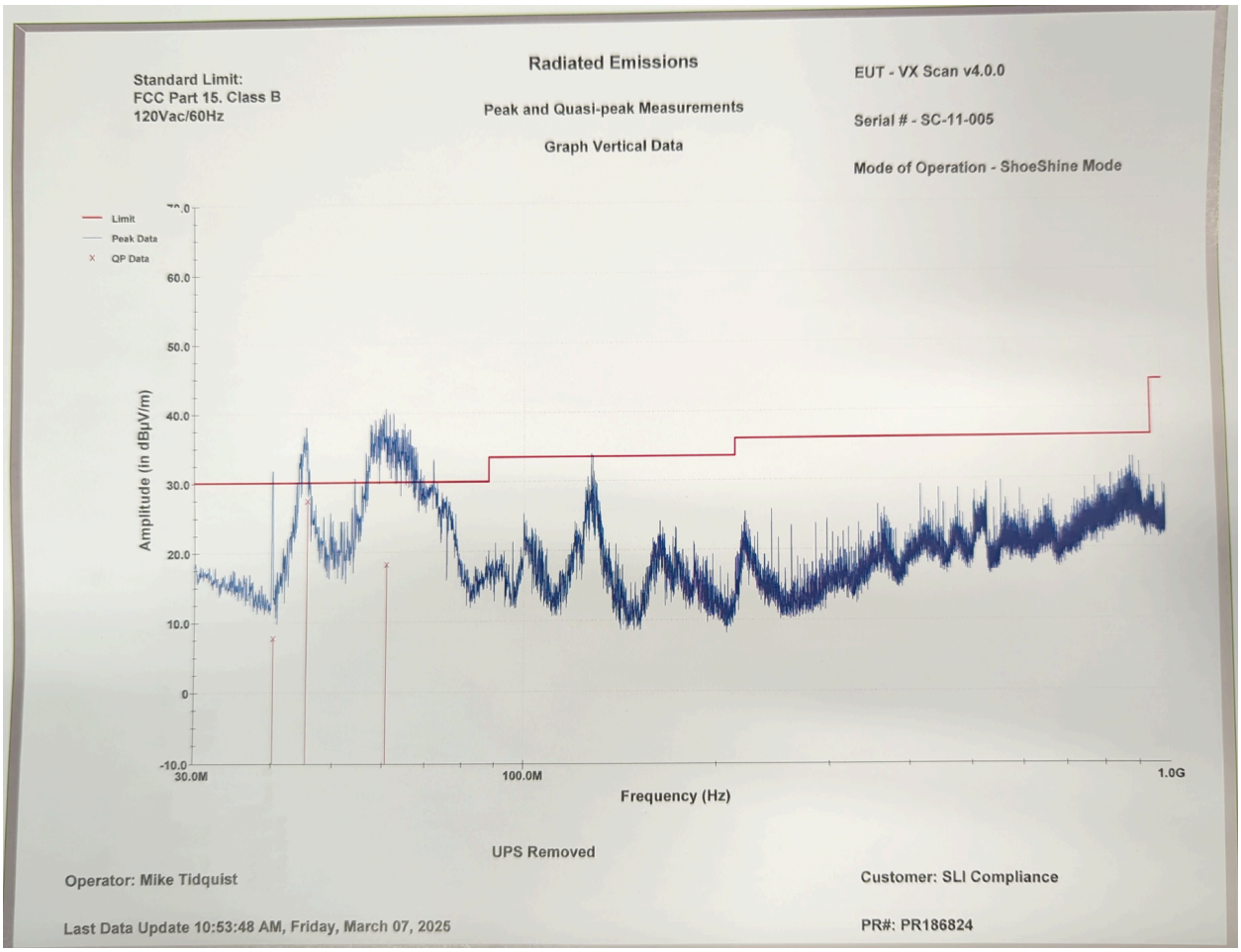
- EMC testing was to begin at Element in Longmont, Colorado on the VxScan system and Anker UPS according to standard tests for radiated emissions (FCC Part 15, Class B), followed by electrical electromagnetic interference (EMI) testing or electrical immunity testing. The immunity testing consisted of a suite of tests that included Fast Transient (EFT) / Burst testing (IEC 61000-4-4 Levels 2-4) and Voltage Dips and Interruptions testing (IEC 61000-4-11), among other standard tests.
- VxScan and the Anker UPS were expected to pass emissions tests, based on past EMC testing with NOVO Engineering in July 2024 where VxScan did not fail. Those past tests did not use a UPS with VxScan. Given that the Anker UPS was a widely used COTS component, it was expected to only improve emissions or at least not make it worse, as well as improve immunity to electrical disturbances.

Detailed description of the event / anomaly:

- Instead of passing emissions tests, the VxScan system when connected with the Anker UPS failed Radiated Emissions testing from 30 Mhz to 1 GHz. Since this was unexpected, a series of additional tests followed to confirm emissions behavior of the system, showing the UPS appeared to show problematic emissions. This can be seen in emissions data from when VxScan was powered through the UPS connected to mains (first graph below, QP amplitudes exceeding desired amplitudes in red):



Powering VxScan directly through mains and no UPS also showed some noisy emissions in a similar frequency range, but the QP amplitudes did not exceed emissions limits in this case. So connecting the Anker UPS appeared to contribute to the excess emissions (2nd graph below, exceeding desired amplitudes in red):



- The additional EMC tests are detailed in the chronology below, and failures in EFT and Voltage Dip & Interruption tests also added to the anomaly of insufficient EMC in this COTS UPS.

If the anomaly is repeatable, provide step by step instructions to recreate it:

- Image VxScan with a test software utility that continuously runs its major components, including running the scanner in shoeshine mode.
- Set up the VxScan system to be powered from the Anker UPS, which in turn is powered by plugging directly into mains.
- Power on VxScan and run the test software utility. Insert a sheet of paper into the scanner to implement shoeshine mode.
- Measure radiated emissions from the system according to FCC Part 15, Class B, standards.
- Conduct (EFT) / Burst testing according to IEC 61000-4-4 Levels 2-4.
- Conduct Voltage Dips and Interruptions testing according to IEC 61000-4-11.

Chronology of Events / Timeline

Provide a detailed chronology of the events leading up to, and following, the anomaly. Add additional events if necessary.

ID	Date/Time	Description	Entity Org/person	Result / Notes
1	3/7/25, 8:30am (Mountain Time)	VxScan + Anker UPS was scanned for radiated emissions, 30 MHz - 1 GHz, according to FCC Part 15, Class B, standards. Two ferrites were clipped onto the scanner USB data cable to the SBC, to address previous successful radiated RF immunity mitigations that led to passed tests..	Jessica Myers, VotingWorks, with SLI Compliance and Element	System failed emissions test, with excess emissions around 40-65 MHz, especially in the vertical direction.. Initial investigations with near-field probe indicate 50 MHz noise from the Anker UPS near the main control panel and screen. The VxScan system also showed a source of noise around the right side of the scanner access panel door, near the printer stepper motor. It was also noted that this noise was present with the UPS wireless functionality switched off according to the user-controlled IoT button on the front. If the IoT button were on, more emissions would be expected in the higher frequency range. Plans were made to retest using an alternate UPS already used for VxMark, another product in the VxSuite family.
2	3/10/25, 12:20pm	VxScan + APC UPS was scanned for radiated emissions, 30 MHz - 1 GHz.	Jessica Myers, Don Chu, VotingWorks, with SLI Compliance and Element	System failed emissions test, with excess QP emissions spikes at about 54 MHz and 66 MHz. Overall noise across the spectrum was lower than in the Anker tests, and the APC data was noticeably cleaner. A near-field probe was used to analyze more sources of emissions around the system. Plans were made to test additional mitigations to the VxScan unit itself to the printer motor housing and cables and the touchscreen control electronics, in an attempt to attenuate potential sources of the spikes.
3	3/10/25, 2:38pm	VxScan + APC UPS, with more mitigations, was scanned for radiated emissions, 30 MHz - 1 GHz.	Jessica Myers, Don Chu, VotingWorks, with SLI Compliance and Element	Data was collected on these potential mitigations with the APC UPS, although no QP data was collected to definitively say if the mitigations could have passed. Similar spikes were seen in the lower frequency range.

4	3/10/25, 4:36pm	VxScan + Anker UPS, with more mitigations, was scanned for radiated emissions, 30 MHz - 1 GHz.	Jessica Myers, Don Chu, VotingWorks, with SLI Compliance and Element	Data was collected on these potential mitigations with the Anker UPS, although no QP data was collected to definitively say if the mitigations could have passed. Similar spikes were seen in the lower frequency range. Plans were made to continue other EMC tests to analyze the system and the Anker UPS.
5	3/14/25, 2:45pm	VxScan + Anker UPS underwent EFT / Burst testing.	Don Chu, VotingWorks, with SLI	The system failed, due to the Anker UPS failing and no longer supplying power during the 2kV electrical disturbance. That led to no power supplied to VxScan. The Anker UPS was pulled out of the system, power cycled, and then showed normal function again. The APC UPS was swapped into the test system, connected to VxScan, and also underwent the EFT tests for data collection purposes. The APC UPS showed no issues in this test.
6	3/14/25, 4:13pm	VxScan + Anker UPS underwent Voltage Dip and Interruption testing.	Don Chu, VotingWorks, with SLI	The system failed, again potentially because the Anker UPS failed. This Anker UPS was the same unit that failed in the previous tests. Plans were made to swap out the Anker UPS with a new Anker UPS and retest, to eliminate the possibility that the UPS failed due to being compromised.
7	3/17/25, 10am	VxScan + new Anker UPS underwent Voltage Dip and Interruption testing.	Don Chu, Arsalan Sufi, Brian Donovan, Jesse DeWald, VotingWorks, with SLI	The system failed during Voltage Dip tests in various ways, from 16% Voltage Dip, leading to forced power cycles of the VxScan system when the UPS recovered and started supplying power again. When the VxScan system restarted, the software test utility had irregular function of the scanner and printer functions. The logs from the software test utility were recovered and analyzed, showing that the faulty behavior was likely not permanent damage. Plans were made to investigate emissions, EFT, and Voltage Dip/Interruption tests beyond these certification tests, with NOVO Engineering in San Diego, California.
8	3/31/25	NOVO Engineering finished conducting EMC tests of interest on another VxScan unit, along with a new Anker UPS, APC UPS, and a third Goldenmate UPS for comparison. They summarized their findings in a	Al Walters, Jeff Johnson, NOVO Engineering, with Pius Wong VotingWorks	The Anker UPS failed Voltage Drop tests, while the alternate UPS's (APC and Goldenmate) passed. Minimal differences in the UPS's were found in the other emissions, EFT, and voltage interruption tests.

		report shared with VotingWorks.		

Investigative Team and Method

This section shall describe how the investigative team is assembled by the voting system manufacturer, who it consists of, and how it gathers the data to be used in the analysis. Include the RCA method employed by the manufacturer in conducting the analysis and why this method was used.

Names and Positions of members of the investigation team:
Jessica Myers - Head of Compliance
Don Chu - Lead Design Engineer
Jesse DeWald - Head of Hardware
Arsalan Sufi - Head of Software
Brian Donovan - Software Engineer
Al Walters - Engineer; Jeff Johnson - Engineer; NOVO Engineering
Pius Wong - Quality Assurance Lead
Describe the data gathering process: Jessica Myers headed the investigation at first starting with the radiated emissions tests on 3/7/25, as she initiated testing at Element with SLI Compliance. Don Chu took over on 3/10/25, as he applied his expertise and experience in the design of VxScan to these tests and mitigations. Jessica and Don directly received the data from SLI, handled the devices under test when needed, and coordinated the response with other VotingWorks staff offsite. When EMC tests showed failures, Don planned for systematic investigation to find potential mitigations for the failures, isolating if they were caused more by the UPS or by VxScan components. He analyzed emissions around specific components using the near-field probe, applied shielding and other emissions-attenuating features, and swapped out components as needed to help narrow down possible sources of the failures. Jesse DeWald, Arsalan Sufi, and Brian Donovan advised the mitigations process at various points to evaluate the data being shared. Jesse focused on hardware solutions, and Arsalan and Brian analyzed software logs in the Voltage Dips and Interruptions tests.

Following the failed EMC tests described above (as well as several passing EMC tests), the outside engineering agency NOVO Engineering was recruited to perform more testing on the VxScan system, including using the Anker and APC UPS devices. NOVO previously tested VxScan without a UPS in July 2024, where it passed emissions tests. This time they would also use the same test software utility used at SLI and conduct the failing tests from SLI. Pius Wong coordinated getting results from NOVO to VotingWorks.

Describe which methodology(s) is used to conduct the root cause analysis:

The investigative team used the 5 Why's strategy to discuss the causes of failures in radiated emissions tests, EFT, and Voltage Dip tests, and define the next courses of action in the investigations. This started by asking why the VxScan system was showing excess emissions at lower frequencies, leading to possible answers of the Anker UPS and various parts of the VxScan unit itself. The answers led to both the UPS and the VxScan unit being the subject of more questions.

On the UPS side of the investigation, the line of questioning followed the general levels as follows:

- Why does the system show excess radiated emissions?
- Why would the Anker UPS show excess radiated emissions?
- Why would the UPS show radiated emissions at lower frequencies <100 MHz?
- Why would the upper portion of the UPS show higher levels of noise using the near-field probe?
- Why would the IoT, power control, and screen electronics radiate excess emissions? Why do the CE and FCC labels contradict the observed emissions?

Questioning also forked into related topics, starting with questioning the alternative UPS that was available from another VotingWorks product:

- Why does the APC UPS show cleaner radiated emissions data?

Top-level questioning about the the other failed tests included:

- Why did the Anker UPS fail EFT testing?
- Why did the Anker UPS fail to supply consistent power during Voltage Dip testing?

When NOVO Engineering joined the investigation, they were tasked with retesting the UPS and VxScan and attempting to reproduce the failures seen from the SLI tests. They similarly asked "Why did this failure happen, or not happen?" Drilling down from those top-level questions, some answers became:

1. For emissions testing: Near-field probe data did not confirm SLI emissions data, suggesting that this Anker UPS has inconsistent behavior across products. It did confirm excess high-frequency emissions with the wireless or IoT function was on.

2. For EFT testing: Failures were not reproduced exactly like at SLI; however, there were signs that the Anker APC was affected by the transients. NOVO said, “During the burst transients, the touch screen on the VxScan went dark and the application beeping also halted. But, the unit did not undergo a reset or brown out condition. The only way to describe its behavior is that the VxScan unit appeared to undergo a ‘pause’ until the burst transients stopped. Once the burst transients ended, the screen came back on again and the test application resumed its normal operation.
3. For Voltage Dip testing: Failure was reproduced for 40% Voltage Dips using the Anker UPS, but notably not for Voltage Interruption. NOVO explains, “Once in a steady-state of operation the IEC 61000-4-11 Voltage Dip test was initiated and resulted in a reboot of the VxScan unit. Such disruption to the EUT normal operation results in compliance FAILURE.” This failure was not reproduced for the APC UPS nor the Goldenmate UPS.

Findings and Root Cause

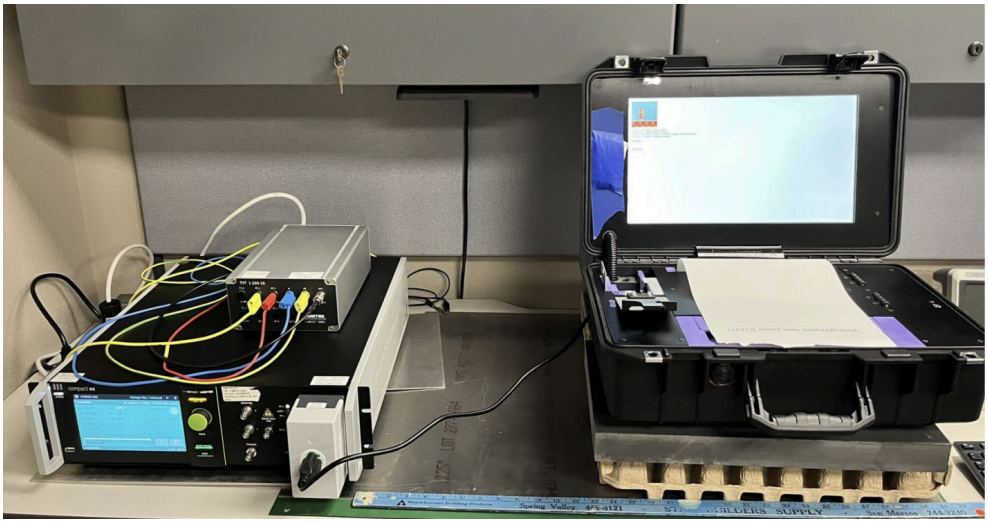
Key findings:
Ultimately the continued questioning of "why" in the investigation as it related to the Anker UPS failures led to several answers:

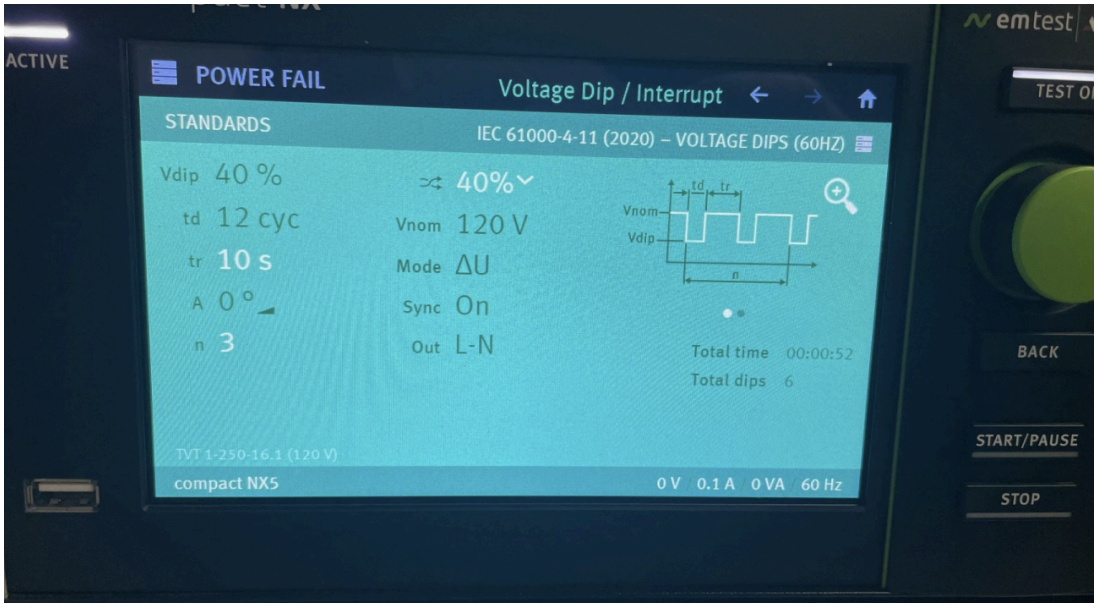
1. The electronics and firmware in the Anker UPS are not able to pass Voltage Dip testing according to IEC 61000-4-11 standards, as confirmed separately by NOVO Engineering and tests with Element/SLI. At least two other UPS products can pass the Voltage Dip test that the Anker UPS failed.
2. The wireless or IoT capabilities of the Anker UPS are problematic. It uses electronics that also may be tied to excess emissions in both the lower and higher frequency ranges of the FCC tests. The IoT functions must be turned off to reduce emissions, but this disabling of the IoT function cannot be guaranteed in practice.
3. The electronics in the Anker UPS are not sufficiently well-manufactured to meet the desired FCC emissions standards consistently. There may be differences in emissions between units or environments.

The root cause of the anomaly in this RCA is that the original Anker Solix C300 UPS is not designed to pass all EMC test requirements required by Element/SLI. It does not handle voltage dips properly, despite handling voltage interruption, which points to weaknesses in electronics and firmware responding to input power. Its wireless/IoT electronics will cause unreliable emissions depending on if it is on or off.

Supporting evidence of Key Finding #1:

- Voltage Dip testing under IEC 61000-4-11 standards testing was carried out with NOVO Engineering using Compact NX5 test equipment loaded with standard modules and settings (setup picture in photos below) and resulted in similar failures as with SLI.

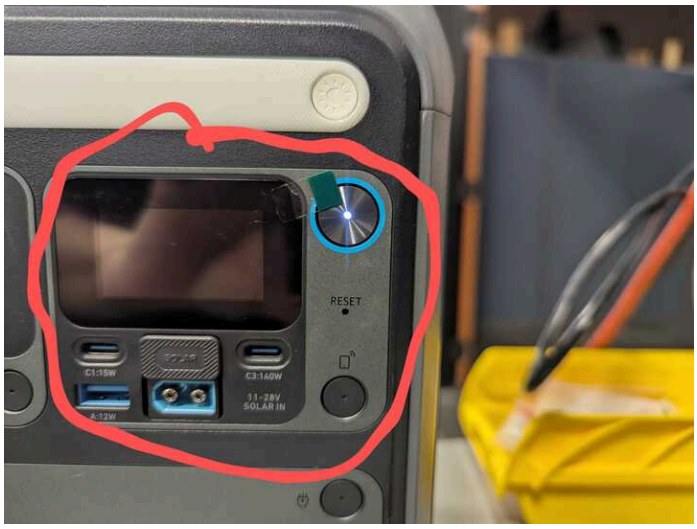




- With exact same setup, the APC UPS did not show problems. As stated by NOVO about the APC connected to VxScan: “Once in a steady-state of operation the IEC 61000-4-11 Voltage Dip test was initiated and did not result in a reboot of the VxScan unit. About 15 seconds later, we initiated the Voltage Interrupt testing which also did not result in a reboot of the VxScan unit. Since no disruptions to the EUT normal operation occurred, pre-compliance testing resulted as a PASS.
- Similarly, the GoldenMate UPS did not show problems. As stated by NOVO about the GoldenMate connected to VxScan: “Once in a steady-state of operation the IEC 61000-4-11 Voltage Dip test was initiated and did not result in a reboot of the VxScan unit. About 15 seconds later, we initiated the Voltage Interrupt testing which also did not result in a reboot of the VxScan unit. Since no disruptions to the EUT normal operation occurred, pre-compliance testing resulted as a PASS.”

Supporting evidence of Key Finding #2:

- Novo reported that when the Anker UPS IoT button is on, near-field probes saw random spurs of emissions around 2.45 GHz, in line with higher frequency bluetooth emissions.
- Internal testing identified occasional difficulties with users confirming the IoT button was truly off, especially if the UPS was previously connected to its corresponding Anker UPS smartphone app.
- Element/SLI saw UPS emissions around the following region using the near-field probe:

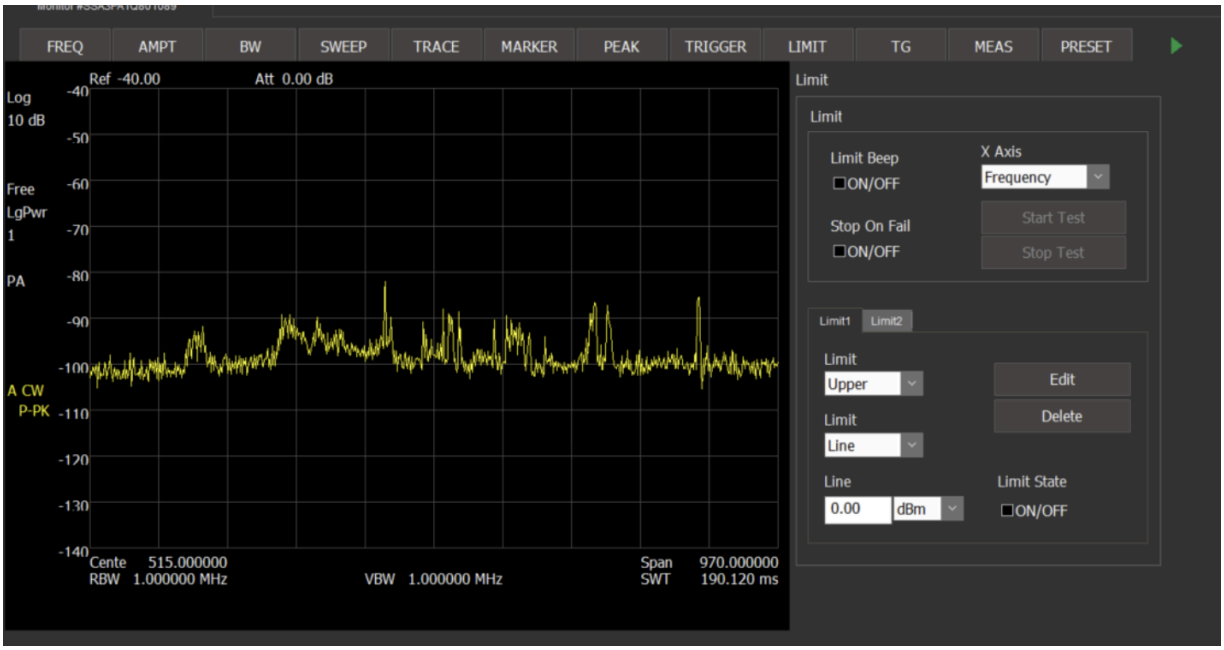


This area of the UPS controls overall power, IoT function, and user displays, and not all these functions can be disabled during use.

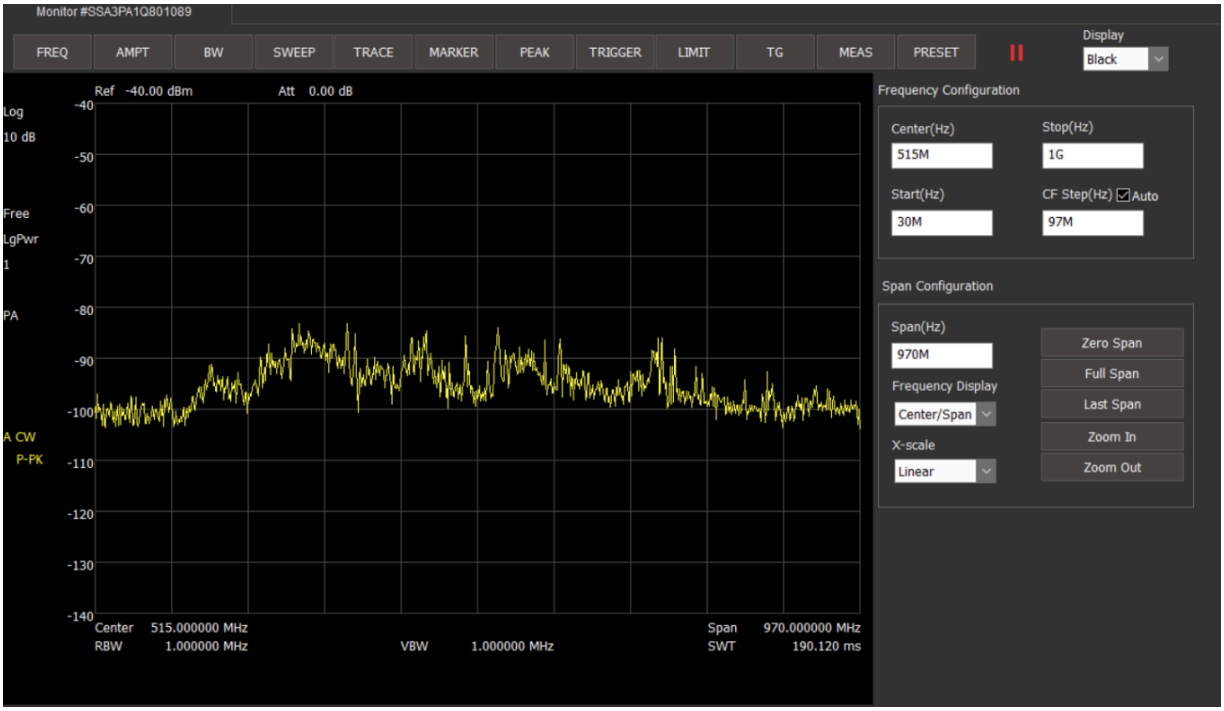
Supporting evidence of Key Finding #3:

- Near-field probe analysis of the Anker UPS connected to VxScan at NOVO did not immediately reproduce the excess emissions seen with Element/SLI (noted above). No unusual emissions sources were identified near the power control or user display of the Anker UPS when using a near-field probe, except when the IoT button was definitely on. This points to some inconsistency in product performance between units or environments, if not differences in analysis methods.
- NOVO did find general rise in emissions of 10db when comparing a UPS plugged into mains, vs a UPS not plugged into mains, but nothing clearly problematic, and nothing particularly at the lower frequency range at issue with the testing at Element/SLI. NOVO writes, “Scans all around both the UPS and VxScan unit did not show any notable spurs or significant jump in the observed frequency spectrum.” Again this points to some inconsistency between Anker UPS units. Snapshots of emissions readings taken before and after plugging in the Anker UPS are below, showing benign emissions.

  Before plugging in UPS to mains:



After plugging in UPS to mains:



Corrective Action(s)

Two main corrective actions will be taken:

1. Testing will continue with Element/SLI on the VxScan system with the APC UPS. Based on data supplied by NOVO Engineering as of March 31, 2025, at least two UPS's are viable alternatives to the original Anker UPS, and one of them is the APC UPS of interest: the Back-UPS Pro 10-Outlet UPS (model number BN1500M2). It not only passes the tests at NOVO currently but also is part of the VxMark system.

2. Testing will continue with NOVO Engineering on the VxScan system with the APC UPS and the third GoldenMate UPS. This is to more fully understand the emissions issues with the system. As shown earlier, the APC UPS does clean up the emissions data and is a legitimately better option than the Anker UPS in this respect. Nevertheless at least at SLI it did not appear to eliminate all spikes in the lower frequencies. NOVO did not reproduce that finding, and so more investigation is needed to pinpoint the sources of emissions from VxScan itself when paired with any UPS, and then to mitigate those emissions. That would be the subject of a later RCA focused on VxScan itself.

Solution Management

The purpose of this section is to manage the corrective action(s) moving forward. This should detail all process changes to manage those corrective actions, and steps taken to ensure the actions eliminate the anomaly over time.

Plans to manage the solution following this RCA are as follows:

Testing and verification:

- Continue hardware certification tests at Element/SLI for VxScan using the APC UPS. This will help confirm normal function with this UPS in the system.
- Continue EMC testing at NOVO Engineering with VxScan and the APC UPS and other UPS. This will help identify other ways to reduce the chance of system failure, in addition to using the better APC UPS.

Design:

- The APC UPS will replace the Anker UPS in the VxScan bill of materials.

Production:

- Sourcing, shipping, and distribution plans will be modified to account for the APC UPS, which is larger and more expensive than the Anker UPS. Multiple vendors are available supplying the UPS.