OMB Control # 3265-0024.
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Voting System Anomaly Root Cause Analysis Template v2.0

Root Cause Analysis for:

VV40ECT-75: Radiated RF Immunity failure at 350-400MHz
VxSuite, Version 4.0 and EAC Certification #VXS4

VotingWorks
548 Market St, Ste 53001
San Francisco, CA 94104-5401

March 27, 2025

Contents

Introduction

The purpose of this RCA document is to describe the cause of a scanner failure in VxScan during Radiated RF Immunity testing with signals at approximately 350-400 MHz, following IEC61000-4-3 (2020) Level 3, in the hardware certification process at SLI Compliance in March 2025. It then describes mitigations for this issue going forward that prevent further testing errors and increase immunity of VxScan to RF emissions near that frequency of interest. That includes detailing the process of finding an appropriate mitigation, and appropriate followup actions.

This RCA also investigates the differences between the immunity testing during this failure and previous testing that showed no failures. Previous RF immunity testing with NOVO Engineering in July 2024 showed no susceptibility to radiated RF emissions, according to the same IEC standard, in the frequency range of 80MHz to 1GHz and four fixed frequencies of 1.8GHz, 2.6GHz, 3.5GHz, and 5GHZ.

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 5, 2025	Time of Anomaly: 9 AM (Mountain Time)
Place of Anomaly: Element, Longmont, CO	Person identifying Anomaly: Jessica Myers, VotingWorks
Expected Results of actions leading up to anomaly: ● VxScan Unit SC-11-004 was expected to run its test utility software continuously without issues while undergoing RF radiation from 80 MHz to 1 GHz in a test chamber for IEC61000-4-3. ● The test software would continuously communicate with the scanner, printer, touchscreen, speaker, card reader, and USB reader components during testing. Scanner function would be seen while in “shoeshine mode,” as a sheet of paper would be periodically scanned and retracted.	

Detailed description of the event / anomaly:

- VxScan was being subjected to RF emissions according to standard procedures, and early in testing, scanner function in “shoeshine mode” stopped. Error messages from the test software utility onscreen suggested that the anomaly could have been from the test software itself, or possibly a hardware issue. Waiting several minutes did not result in the scanner reconnecting, and power cycling the device resumed normal function.
- Restarting the RF immunity test again caused shoeshine mode to stop early in the test. After a few tries at this, it was found that the RF frequency was between 350-400MHz when the scanner loses function. More measurements showed failures around 370-377MHz.

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. Power on VxScan and run the test software utility. Insert a sheet of paper into the scanner to implement shoeshine mode.
- Subject VxScan to RF emissions between 350-380MHz, aiming the antenna horizontally toward the front side of VxScan, during standard tests described in IEC61000-4-3, with 10V/m, 80-1000 MHz, 1% Step, 80% AM, 1kHz sine, 3s dwell.

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	3/5/25, 9am	VxScan was subjected to RF emissions according to standard procedures with SLI Compliance at Element in Longmont, CO. About 10 minutes into testing, shoeshine mode stopped.	Jessica Myers, VotingWorks , with SLI Compliance and Element	The test software utility reported an error message onscreen saying “resetting scanner.” Waiting several minutes did not reset scanner function. It was thought that the test software utility was the source of the error, because it did not automatically resume function of the device if there were any issues. Power cycling the device resumed normal function.
2	3/5/25, 9:30am	Restarting the RF immunity test again caused shoeshine mode to stop, with the paper in the scanner this time.	Jessica Myers, Arsalan Sufi, VotingWorks	Different paper was tried to see if that caused the issue for mechanical reasons. The original paper had a fold and was removed, and new paper was inserted. This did not resolve the

				issue, after trying several times. Powercycling the device resumed normal operation.
3	3/5/25, 9:56am	The RF test was restarted. After 5 minutes, it stopped both the scanner shoeshine and the printer.	Jessica Myers, Arsalan Sufi, Jesse Dewald, Brian Donovan, VotingWorks	Testing was paused while VotingWorks staff discussed the possible causes in software. Plans were made to: ● Get logs from the software utility for further debugging. ● Modify the software utility to create more logs and get more visibility into errors. ● Reimage the VxScan unit with the new modified software utility to get more logs.
4	3/5/25, 12:30pm	A backup unit SC-11-005 was swapped in for testing to see if the failure continued in a new unit. The RF test on this unit also failed. Both VxScan units stopped functioning between 350 Mhz to 400 Mhz radio frequency signals.	Jessica Myers, Arsalan Sufi, Jesse Dewald, Brian Donovan, Matt Roe, Pius Wong, VotingWorks	Logs were obtained from VxScan unit SC-11-04 and analyzed, confirming scanner disconnections being detected during these anomalies. The software does not reconnect the scanner. A new version of the software utility was developed that is more resilient to scanner disconnection, and that records more logs. This was planned to be imaged onto the units (image `2025-03-05-vxscan-electrical-testing-rc2-signed.img.lz4`). One of the units was restarted outside the test chamber, where it functioned without problems for 20 minutes, confirming failure responses to the 350-400 MHz RF signals. Past reports on RF immunity tests conducted in July 2024 were reviewed with another test vendor, where VxScan passed without issues. It showed no differences in test procedures. Hardware differences were minimal, with slight mechanical adjustments, but not in electronics or electrical components. However, the software utility being used was not used in the previous test.
5	3/6/25, 7:46am	VxScan unit SC-11-005 was reimaged with the newer software test utility that is more robust to disconnections and that records more logs.	SLI Compliance, with Jessica Myers, VotingWorks	
6	3/6/25, 9:20am	RF immunity testing was restarted on SC-11-005. The software utility stopped at 370 Mhz.	Jessica Myers, Arsalan Sufi, Jesse Dewald, Brian	Test logs were obtained from the unit and reviewed. The test logs confirmed that the scanner was disconnecting in response to the RF emissions. The new software would continually attempt to reconnect, but it could not reconnect during the dwell period of the RF field, around 370 Mhz. This suggested a hardware mitigation

			Donovan, VotingWorks	was needed, if the RF disrupted this software from reconnecting the scanner. The software error indicated the RF was disrupting the data transmission to the scanner, which corresponds to the physical component of the USB cable between the scanner and the single board computer (SBC).
7	3/6/25, 10am	VxScan unit SC-11-004 was swapped back in as the device under test. It was opened up and modified to add ferrites to mitigate the RF signals targeting the system around 350-400 Mhz.	Jessica Myers, Jesse DeWald, Chris Pedersen, Pius Wong VotingWorks	Ferrites were sought to clip onto the USB data cable between the scanner SBC to attenuate RF around 350-400MHz. The ferrites were chosen from a kit from Fair-Rite Products Corp with part number 0199000051, due to its rated applications from 200 Mhz to 2 Ghz. The specific ferrite part number 0461164951 was chosen to use, as it fit around the cable diameter (impedance of 330Ω @250 Mhz, 510 @500 Mhz), and could be applied in two places between the SBC and scanner with minimal disturbance of hardware.
8	3/6/25, 11:15am	VxScan unit SC-11-004 was reimaged with the newer software test utility that is more robust to disconnections and that records more logs.	SLI Compliance, with Jessica Myers, VotingWorks	
9	3/6/25, 12:30pm	RF immunity testing was restarted on VxScan unit SC-11-004. Tests continued without interruption for at least 20 minutes.	SLI Compliance	RF up to 524 MHz in the first orientation of VxScan did not result in the issues seen previously. Testing continues.
10	3/6/25, 3:34pm	RF immunity testing passes for unit SC-11-004 with the ferrite mitigations.	SLI Compliance	

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
Arsalan Sufi - Head of Software
Brian Donovan - Software Engineer
Jesse DeWald - Head of Hardware
Matt Roe - Head of Product
Pius Wong - Lead Test Engineer
Chris Pedersen - Operations & Prototyping Support Technician

Describe the data gathering process:

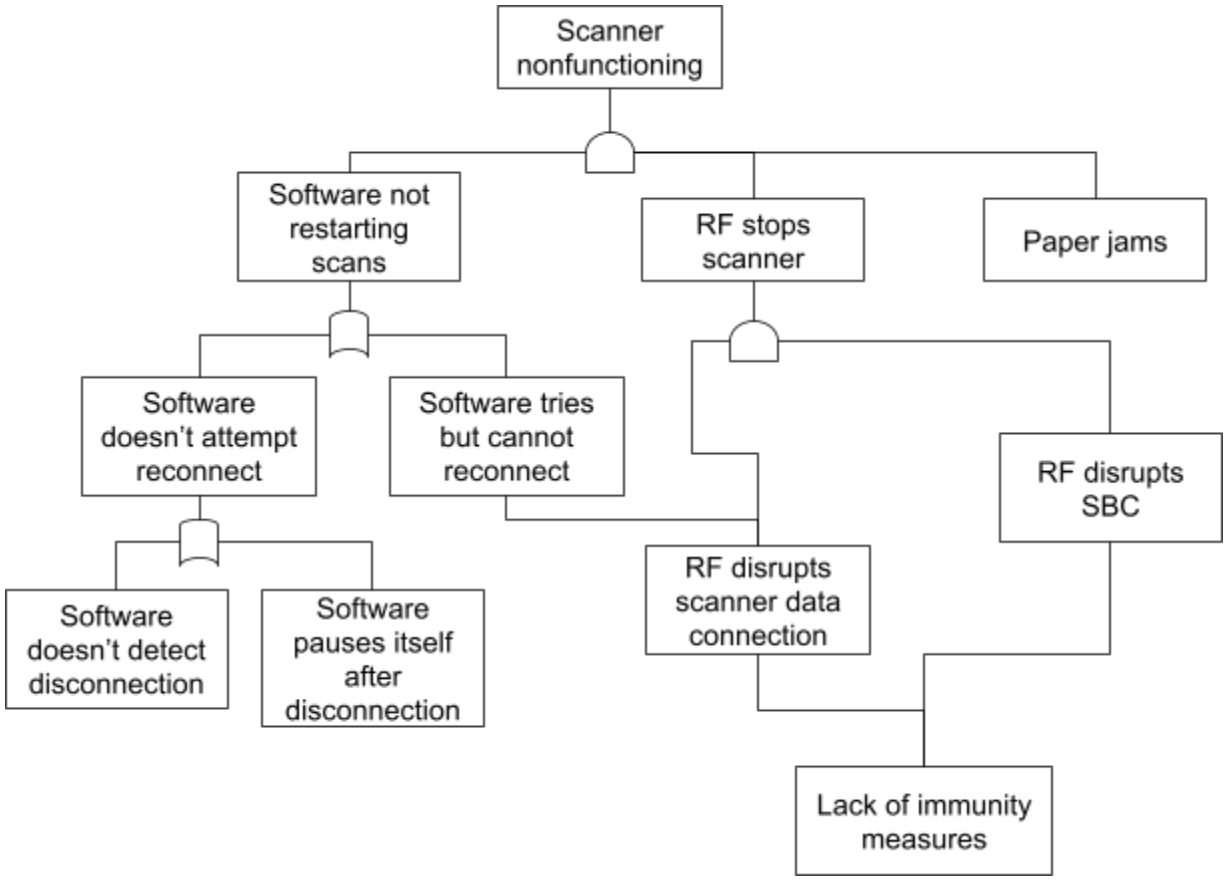
Jessica Myers headed the investigation, as she was in the same building where tests were taking place at Element with SLI Compliance. She directly received the data from SLI, handled the devices under test when needed, and coordinated the response with other VotingWorks staff.

To reduce time spent troubleshooting, several VotingWorks staff joined the problem-solving process in stages as needed. Arsalan Sufi and Brian Donovan joined early as software experts, because the software test utility at first appeared to be a cause, since it was not ever reconnecting the scanner when it stopped functioning without a power cycle. They also adjusted the software and analyzed the software logs.

Jesse Dewald and Matt Roe joined investigations as it emerged that an updated software utility alone may not mitigate the issue. Jesse reviewed hardware solutions, including planning for ferrite additions. Matt and Pius Wong reviewed past data on VxScan for radiated RF immunity. Chris Pederson and Pius worked with Jessica to find and apply ferrites to the VxScan scanner data cable.

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

The investigative team used the strategies of Fault Tree Analysis (and similarly 5 Whys) in discussing, narrowing down, and identifying root causes. The Fault Tree initially was broken down into software and hardware causes, and it became more detailed as more data was obtained. Drilldown through the faults led to other potential causes to investigate shown below:

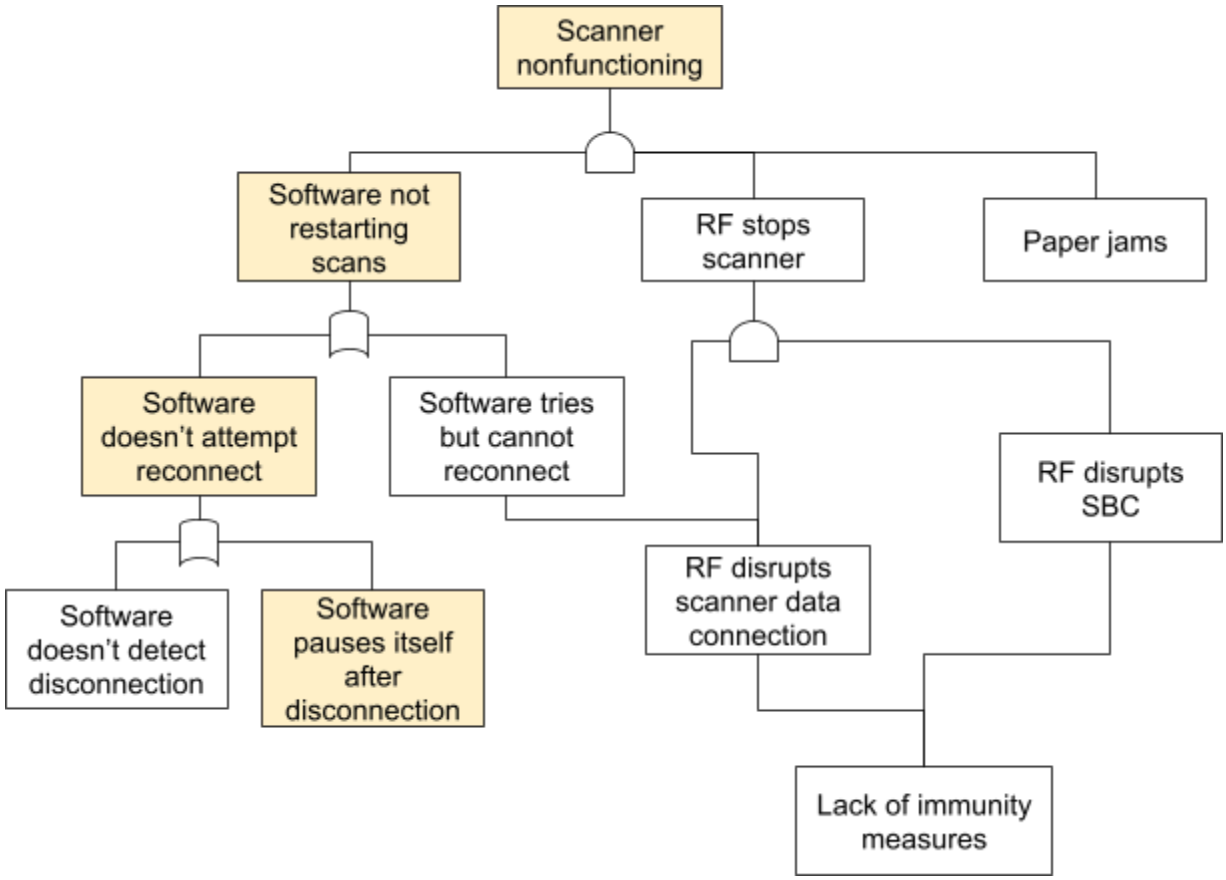


Starting at the top of the tree and working downward, the team would ask of each issue, "Why?" and answer. For example, "Why is the scanner nonfunctioning?" would lead to possibilities of:

- the software not restarting the scanner as evidenced by the onscreen messages
- RF stopping the scanner
- the paper jamming

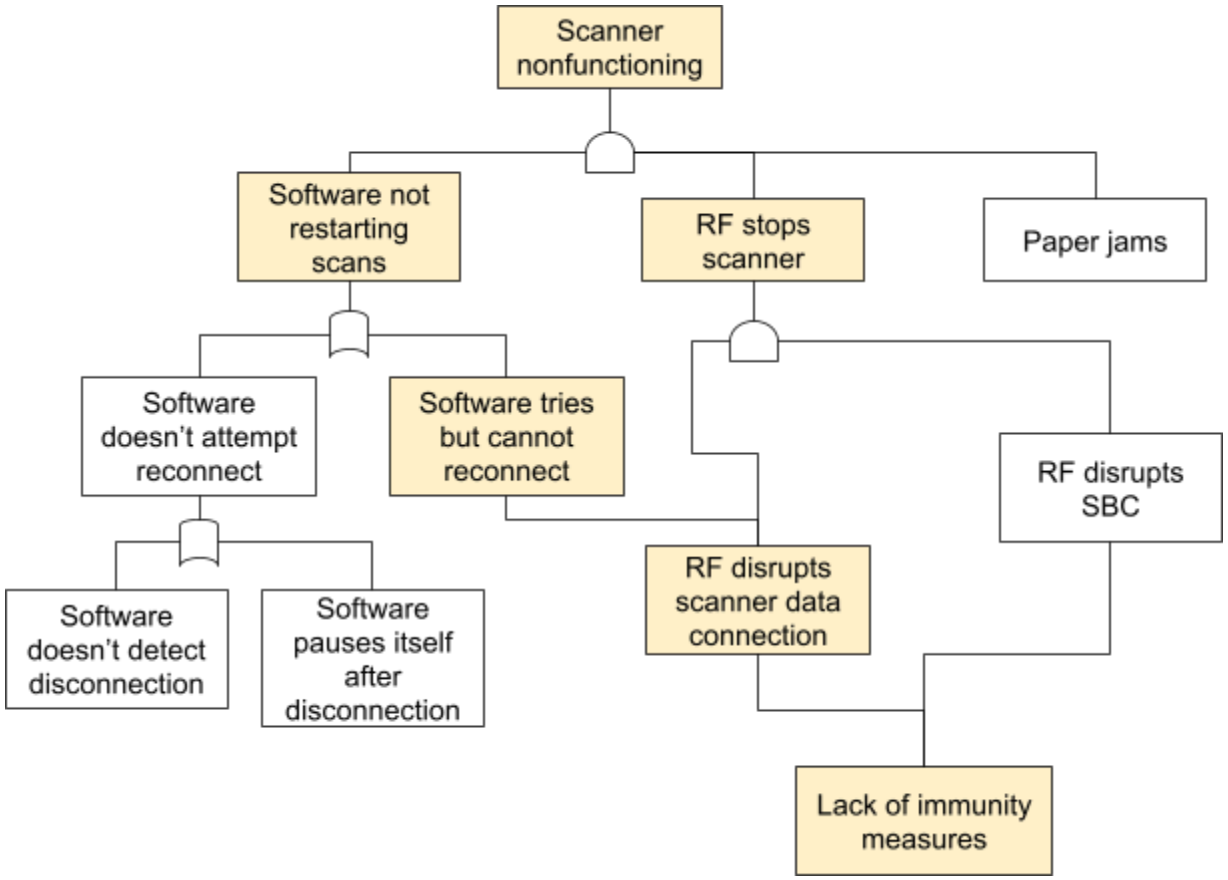
Each possibility was discussed, tested, and/or researched to either rule it out as a fault source or suggest further investigation. As described in the chronology above, an initial investigation followed more of the software fault drilldown, highlighted below:

EAC (Election Assistance Commission) Root Cause Analysis



After the test software was identified to have that fault, it was modified to account for it. The new test software did not pause on any disconnection and instead attempted reconnect to the disconnected component. Following that modification to the test software, it was found that hardware issues ultimately also had to be mitigated at the same time. The fault paths highlighted here ended up determining root causes:

EAC (Election Assistance Commission) Root Cause Analysis



The incorporation of proper immunity measures for the scanner data connection, combined with test software that was more robust to disconnections, led to RF immunity for the whole test.

Findings and Root Cause

Key findings were as follows:

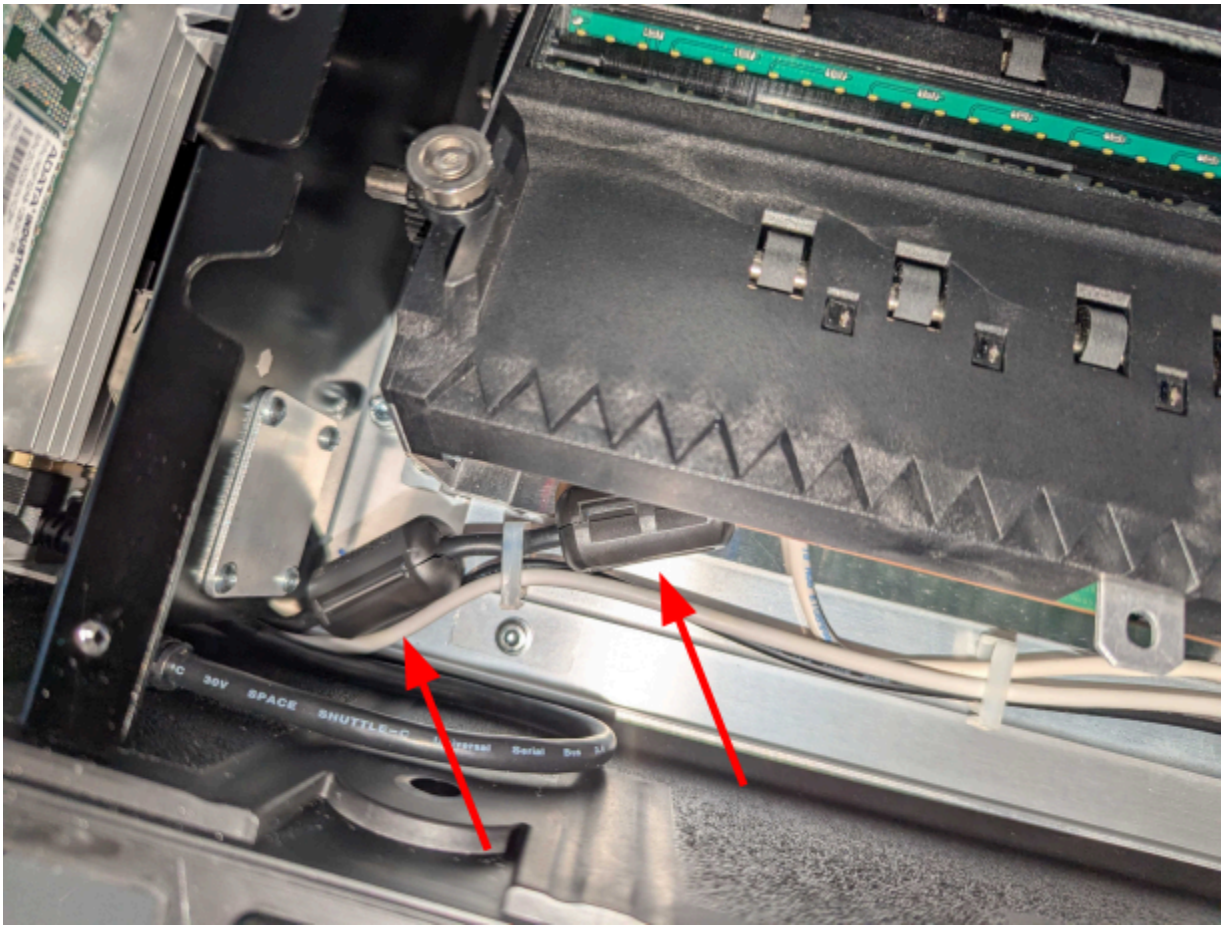
- The scanner data connection is potentially susceptible to RF around 350-400 MHz aimed at the front of the scanner. Before mitigations, that frequency signal consistently disrupted the scanner connection to the SBC in the test software, five times across two devices, and prevented reconnection. This was due to insufficient RF filtering or shielding mechanisms for the USB data cable, which disconnected too frequently for the test software utility.
- The original test software lacked the ability to recover from any disconnections, because it did not attempt to reconnect. This may explain some of why failures were not detected in previous immunity tests in July 2024, when this test software was not used. Instead, a development version of the actual production software was used that had its own shoeshine mode.
- Paper jams and other factors were not an apparent cause of the scanner anomaly in this test.

The root cause of the anomaly described here is twofold:

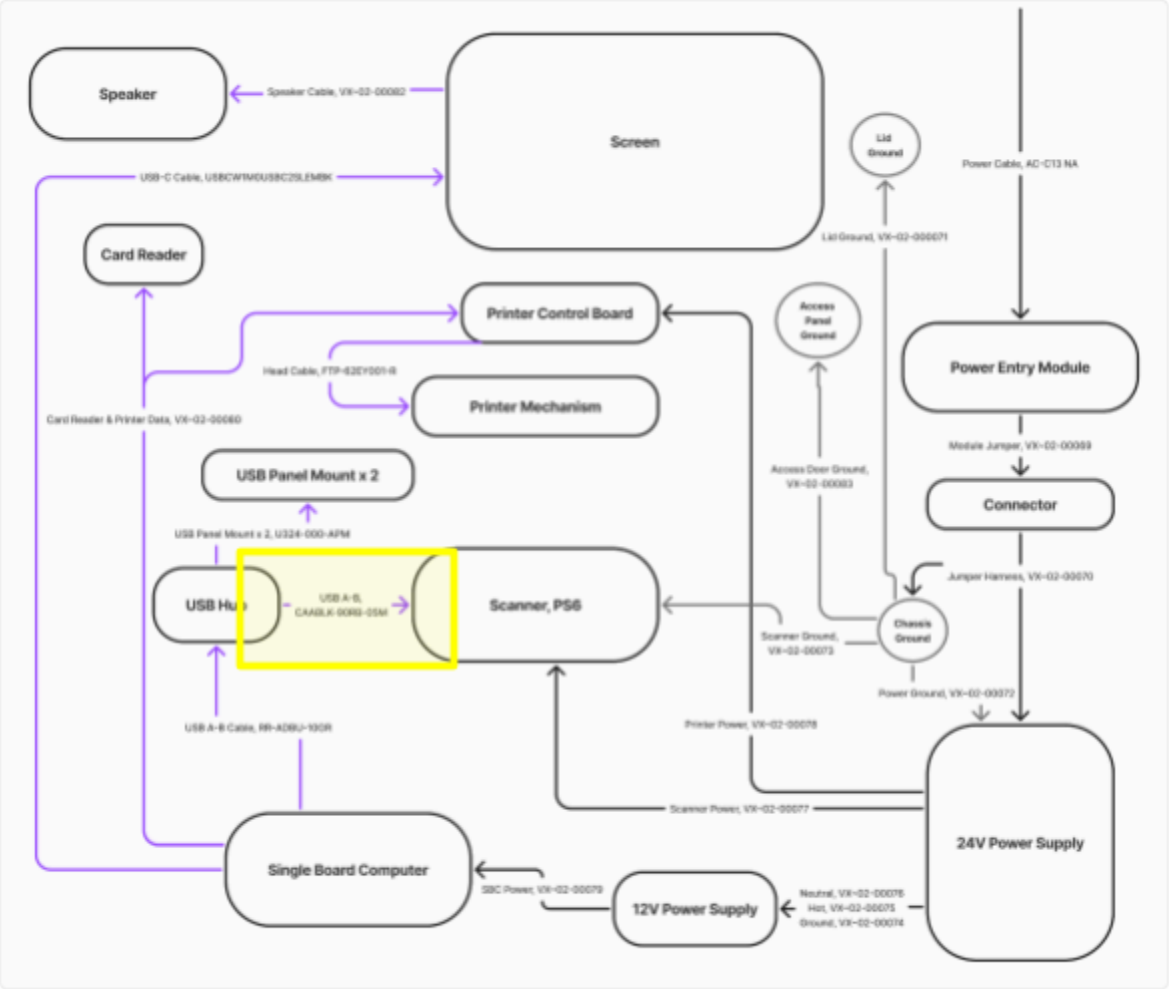
1. The scanner data connection, or USB cable joining the scanner to the SBC, was susceptible to disconnection when targeted with an RF field in the front horizontal direction in the range of 350-400 MHz, facing the cable. These signals induced noise in the USB cable (without any chokes or additional shielding) that stopped data transmission and prevented reconnection across it at those frequencies.
2. The test software utility, which is different from the production app for VxScan, was not robustly responding to any scanner disconnections. It would not attempt reconnection after any disturbance.

Corrective Action(s)

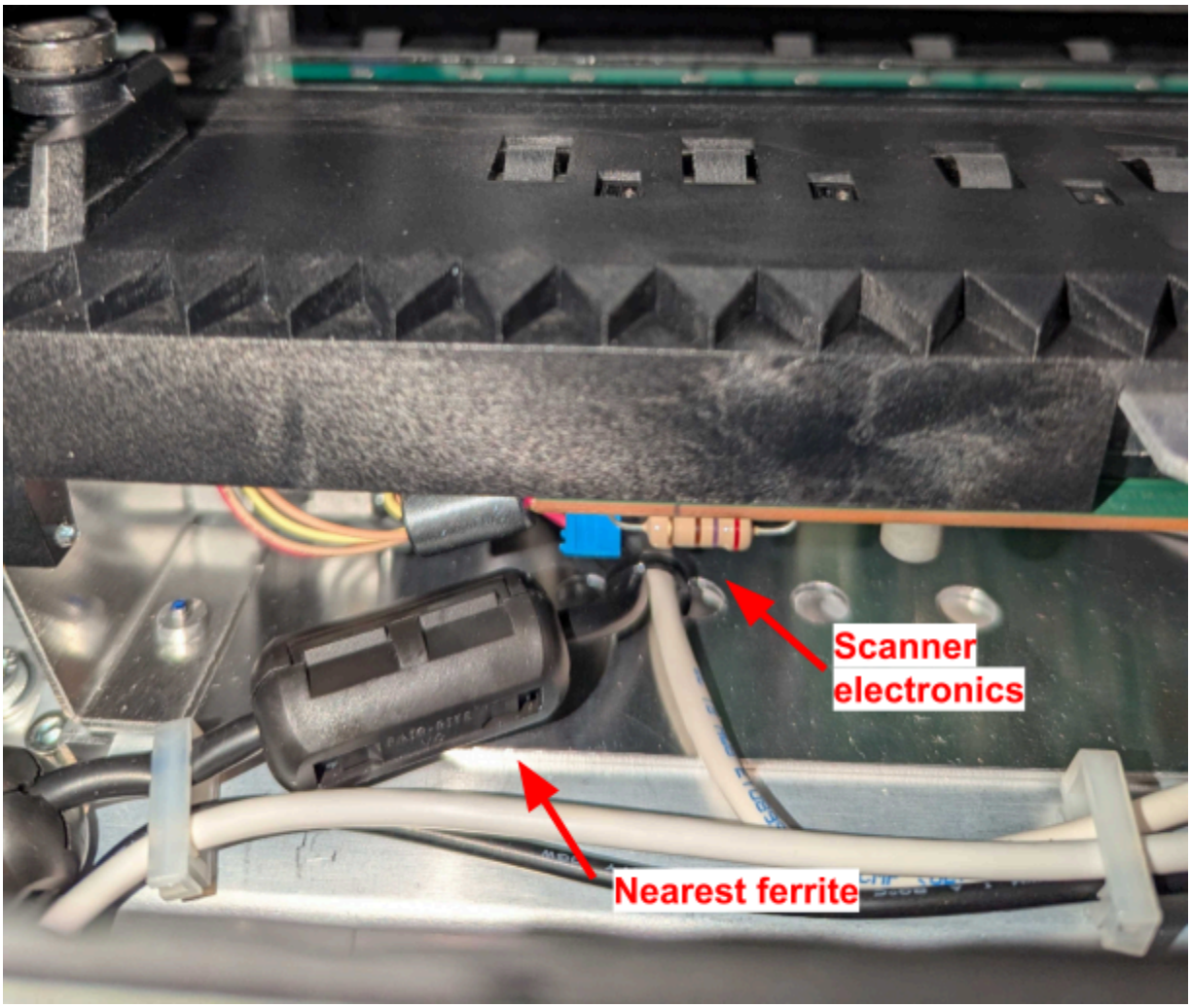
Two ferrites were clipped onto the internal USB cable running from the scanner to the SBC near the front of the VxScan, as shown in the photo and diagram below. The ferrites have impedance 332 Ohm @250MHz, meant for a 4.9mm maximum diameter cable (Fair-Rite Products Corp, part number 0461164951). They are placed to the left and to the right of the cable clip on the left front of the scanner:



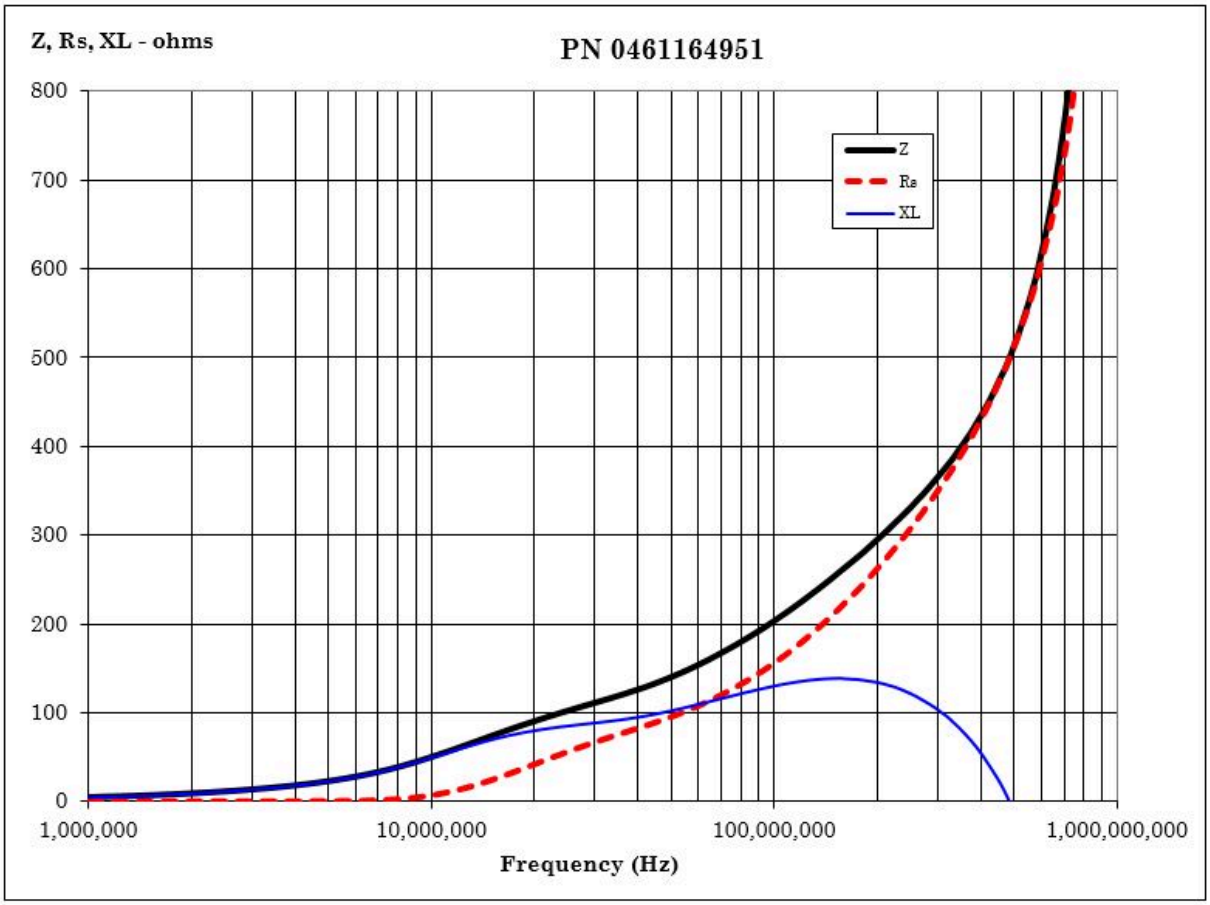
The cable wiring diagram of VxScan v4 is shown below, with the USB cable between the scanner and SBC (via USB hub) highlighted in yellow where the ferrites were clipped:



The ferrites were placed such that they are secure and do not bump into other internal electronics. The photo below shows the approximately 1 cm clearance between the closest ferrite to the scanner and the scanner PCB components:



This ferrite type was chosen based on its impedance profile to attenuate RF from 350-400Mhz, as well as its size to fit securely and easily around the USB cable. The graph below from the ferrite datasheet shows the rising impedance in this range (300,000,000+ Hz):



The test software utility also was upgraded to automatically try to reconnect the scanner when its connection is disrupted, as well as to produce more logs to record what is happening during tests. This test software upgrade will help identify any other issues in the future. It is also different from the official software used on VxScan, which also handles hardware connection issues more robustly than the test software used here.

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.

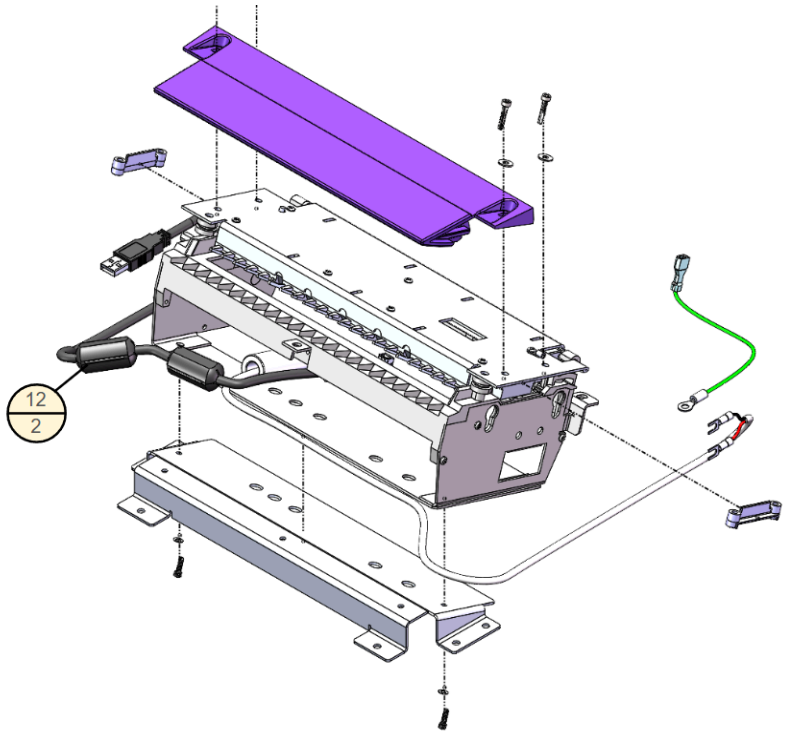
Plans to manage the solution following this RCA are as follows:

Testing and verification:

- Continue electrical certification testing with SLI Compliance with this mitigation in place to verify continued expected functionality.
- Perform electrical testing similar to that done at SLI Compliance, but with NOVO Engineering, to help verify continued expected functionality. As of March 28, 2025, this mitigation has been applied to another VxScan unit with the same test software utility as at SLI. It continues to show normal functionality while undergoing tests for emissions, voltage dips and interruptions, and electrical fast transients, matching results at SLI.

Design:

- Include ferrites into design documentation, bill of materials, and build instructions. A CAD diagram of the scanner subassembly including these added ferrites is shown below, as one example of how it will be included in these documents. The corresponding bill of materials also is below that diagram, with the ferrites highlighted:



VX~01-00009 - Assembly, Scanner with Bracket & Infeed

ITEM NO.	QTY.	PART NUMBER	DESCRIPTION
12	2	FAIR-RITE~0461164951	FERRITE CORE, 5.11mm ID, 17.27mm OD, 36.07mm LENGTH
11	2	VX~99-00131	WASHER, M3, ZINC-PLATED STEEL
10	2	VX~99-00166	4-40X3/8"L, BHCS, ZINC PLATED STEEL
9	1	VX~02-00077	CABLE, SCANNER POWER, 24V
8	1	VX~02-00073	CABLE, SCANNER GROUND
7	1	L-COM~CAABLK-90RB-05M	CABLE, USB 2.0 A TO B, 0.5M
6	4	VX~99-00108	M3X0.5PX16L, SHCS, ZINC-PLATED STEEL
5	4	VX~99-00111	WASHER, OVERSIZED, M3, 9MM OD, ZINC-PLATED STEEL
4	2	VX~02-00041	MOUNT, TOP INFEED TRAY
3	1	VX~02-00040	INFEED TRAY, TOP
2	1	PDI~PS6	PDI PAGE SCAN 6 DOCUMENT SCANNER
1	1	VX~02-00039	BRACKET, SCANNER MOUNT

Production:

- Find functionally equivalent ferrites to the specific part number used in this RCA, as a contingency to avoid supply chain issues. Currently there is ample supply of the particular ferrite used in this RCA (Fair Rite Products Corp, part number 0461164951) from major vendors such as Mouser and Digikey and direct from the manufacturer, but finding an equivalent ferrite could help if the supply ever went down. The ferrite is not unique, and other ferrites with similar impedance profiles and physical characteristics could be used as a backup.