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Digitalization of X-band Weather Radar Testing and Calibration Processes

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Abstract

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The present study consisted of the development of a digitalized method for X-band weather radar testing and calibration processes, in the field of electrical engineering. To achieve the outcome the subject was studied to understand the requirements of different stakeholders related to the weather radar customer delivery projects.

Due to the nature of this project, which has been developed internally at an internship in Vaisala Oy during the summer of 2022, some names of the programs and key names have been modified, and some confidential information has not been mentioned at all like reference documents.

At the end of the project, there was a design process which led to the final execution of the weather radar test and calibration processes with the chosen system configuration. Based on the research and study, there was a conclusion on the most suitable procedure and the creation of an electrical procedure instruction, which was tested in a real production environment and implemented afterwards.

Some other phases during the development of the project were collecting feedback and making necessary adjustments and root improvements to the procedure.

Contents

Glossary

FIT	Factory Inspection Test
FAT	Factory Acceptance Test
IEEE	Institute of Electrical and Electronics Engineers
SAT	Site Acceptance Test
PCS	Project and Customer Service
PI	Procedure Instruction
WRM200	Magnetron C-band Weather Radar
WRS300	Solid state C-band Weather Radar
WRS400	Solid state X-band Weather Radar

1 Introduction

The purpose of this thesis work was to study a weather radar using the X-band frequency designed by Vaisala. The goal of the project was to successfully prove and demonstrate the implications and possibilities of digitalization and automation of the FIT at the end of the production line of the WRS400. The research and study performed were heavily based on my own research and brainstorming of different potential solutions using Vaisala's internal resources and documentation as support. The decision process and action taken are purely based on my own personal decision after a thorough evaluation of the characteristics of the processes and technical resources available at the moment of performing this project.

1.1 The X-band

The X-band is a band frequency in the range of 8.0 to 12.0 GHz in the microwave radio region of the electromagnetic spectrum, it is specified by the IEEE. The main uses of this band are radar, satellite communication, and wireless computer networks (Bharj 2007).

More spectral efficiency, less interference, less rain fade, and greater satellite separation are some of the advantages of the X-band frequency (Chambers 2012).

1.2 Weather Radar on X-band

In comparison to other frequencies, the weather radars operating on the X-band frequency have a wavelength of 2.5 to 4 cm, which makes the radar more sensitive and able to detect smaller particles, therefore the X-band frequency offers excellent precision and high resolution for short-range meteorological surveillance (IBM 2020).

Forecasters can use weather radar based on the X-band to provide more accurate forecasts in the face of approaching storms due to the coverage of large areas, high resolution, fast updates, and versatility. By integrating X-band radar into a weather network, you can gather data at short and long distances, from the ground and higher elevations, and in real time. X-band weather monitoring and forecasting in mountainous areas are made ideal by the excellent resolution at low altitudes in real-time (Vaisala 2020).

1.3 Vaisala's X-band Weather Radar

The new Vaisala's X-band Weather Radar can serve as a gap filler in an operating national radar network, it can provide highly accurate measurements over a limited area. Having the addition of X-band radars to the weather radar networks, hazardous conditions in mountainous areas and gaps under sparse radar networks can be detected and forecast accurately (Vaisala 2020a).

It delivers clean data and increases safety while improving operational efficiency thanks to its dual-polarization performance. X-band technology is easy to install and integrate into existing networks, offers automatic and continuous calibration, a simplified signal path, and uses new measurement methods. It is an industry leader in this area. The use of remote operation and diagnostics reduces the need for site visits, improves the availability and quality of data, and allows decision-makers to make better decisions (Vaisala 2020b).

2 Background

This project has been focused on the newest WRS400 Vaisala Dual Polarization Solid State X-band Radar, specifically in the FIT that takes place at the end of the production process.

Before this study, the FIT was a fully manual testing and calibration process that the operator performed with the help of a printed version of a procedure instruction designed for it. It was taken approximately 2-3 days to perform the entire FIT plus the 48h automated test that run at the end of the FIT.

While the operator followed the steps instructed in the procedure instruction, they must collect data by pen and write it in the printed version itself. In total 232 fields of data were filled along all the steps, including serial numbers, reference values and calibration settings. After the test, the operator filled in the digital version of the procedure instruction as well with the same data already collected in the paper version.

Vaisala came to the point where there is a high need to digitalize this process, which has been the same for the last 15 years. The digitalization of the FIT would bring better process control, and more effective data collection and provide a better service for PCS at the FAT.

As a final consideration, the study and implementation of this project could also allow other weather radars like the WRM200, or the upcoming WRS300, to adopt the same structure in the FIT as in the WRS400.

3 Scope

This section will explain the scope and goals of this project in sufficient detail. At the same time, there have been heavy adaptations, updates, and corrections to the original procedure instruction to make it compatible with the new solution and implementation.

3.1 Digitalization

Firstly, a decision was made on how to implement the procedure instruction to know how to implement the new format of the FIT. Here important considerations like which software solution to use were studied.

The digitalization of the procedure instruction for the FIT was under study since the very beginning of the project. There were two potential options to use:

- eFlex, a new process control software solution created by eFlex Systems, an American company that provides manufacturing control software for new industries.
- Vaisala VTX is a test platform created and developed by Vaisala for internal uses in production lines in the factory.

3.2 Automation

Secondly, the influence of the software used was heavily related to the possible automation implementation with the current working nature of the weather radar itself.

The automation possibility was the most exciting one and with the most possible benefits, if working. Regretfully big impediments were found making automation very difficult for this product.

3.3 Data Collection

Lastly, a data-collecting method was described and implemented in the procedure instruction as far as possible. This would bring great possibilities to get data from the FIT reliably and easily, allowing to get insightful information to make better decisions for the future, as well as serving the tests followed by the FIT, such as the FAT and the SAT.

There were three potential solutions to collect data:

- eFlex provides capabilities to allow manual data collection.
- Vaisala VTX, with capabilities to automatically collect data.
- Vaisala DataCollector tool, in connection with Vaisala’s Database, provides manual data collection.

4 Digitalization Process Decision

The adaptation of the procedure instruction to a digital format was a must to accomplish and ensure easier adaptability and make the FIT easier and faster to perform.

4.1 VTX

The VTX test platform was one of the main potential solutions to use to digitalize the FIT. This is because VTX is a tool developed by Vaisala itself and has wide use everywhere in the factory, therefore the expertise level was high and with a lot of support from experts in Vaisala.

VTX is used for applications in production, for example in CB testers, configuration stations and tune, adjustment and calibration stations and it contains several utilities and tools.

It operates on the C# language, in which the program runs. It is based on an XML file that defines which test steps should be run for a product. Those test step names are links to a test step setting which decides which C# code should be run and which result should be returned from it.

The complexity of VTX goes to levels where only Software Engineers and Test Architects would be able to configure and create a new VTX test station.

Before going deeper into understanding VTX C# code and implementation for the project, a few considerations were made:

- Deciding on an implementation for the FIT instructions.
- Deciding on a reasonable level of automation.
- Considering a Linux – Windows connection, since the weather radar software operated in the Linus and the test station in Windows.

Due to the complexity of VTX, the potentiality of automation and the time limit of the Vaisala Giant Leap project schedule, the VTX implementation was refused completely and instead the use of an eFlex process control software solution with work instructions was chosen and developed further.

4.2 eFlex

eFlex is a process control software which was selected as the most appropriate solution in a former Giant Leap project back in 2020.

It comes with many advantages in comparison with the paper instructions and the currently used instructions procedures with VTX at some stations, since the correct instructions automatically are shown to the operator, and they will see only what needs to be seen at once.

The creation of a new PI is almost as easy as creating slides in PowerPoint. It takes more time to build from zero because the new PI needs to be more accurate and configuration logic needs to be built to be fully functional in the eFlex platform. Process engineers can develop procedures for an assembly where test development and maintenance resources had to be used earlier.

In a complex product like weather radar, eFlex came quite handy since the operator will go through all the work instructions by order. With this, it can achieve better process monitoring, traceability, and controlled walkthrough of all the instructions.

The adaptability of eFlex forced us to reconsider some parts of the PI due to the change from a Text document format to a Slide format, allowing the information to be more visual, reducing the number of steps shown at once to the operator and subdividing existing step into more little steps. Also, improvements to the procedure itself were made, thanks to the feedback provided by the operators and the first-hand experience with the FIT.

5 Automation Process Decision

Automation implementation was probably the most studied topic during this project since it would have brought great opportunities to make the FIT more autonomous and reliable with minimum interference from human control.

5.1 General Overview

After checking carefully, the FIT procedure instructions, it was concluded how many measurements can be done using the VTX application while the operator connects the cables always before starting the automated measurements and calibrations.

To automate actions that the operator does with the Radar Server utilities, it would require scripts or a production interface. The production interface would be the dream solution, but it would require a lot of work from the R&D team. One important point to consider is the fact that both the scripts and the production interface would need maintenance by someone afterwards, and these are subject to faults if any of the components of the weather radar change. R&D considers how to develop things, so these are easy to maintain at all levels.

Several meetings with relevant people from the R&D department took place, discussing and analysing which parts of the FIT could be automated through scripts, for example, to see if it is possible to call a script outside of our radar server from our application. If R&D managed to create some scripts for the test, a test could have been designed to try to run the Phyton scripts.

It is important to keep in mind the adaptability of every automated process since when a change in the product happens, it is important to track how it will impact the current implementation in place.

5.2 Radar Server Utilities

The Radar Server utilities used during the FIT consist of a diverse range of small utilities each one of them covering a specific function inside the weather radar. The following list presents them in simple detail, due to Vaisala's NDA:

- Utilities to control the Sigmet Digital Receiver and Signal Processor RVP900, which serves to configure different parameters of the operation of the radar itself and includes different measurement utilities.
- Utilities to control the Radar Control Processor RCP8, which controls and monitors weather radar system subunits, including the pedestal, power supply unit, transmitter, receiver, waveguide matrix, cabinet cooler, dehydrator, and safety interlock system.
    - Unfortunately, in the RCP8 utilities, no clear path has been found for the potential automation of them effectively.

5.3 Connection Windows - Linux

The connection between the Radar Server, which runs on Linux, and the Test Station, which runs on Windows, was as well a key concern. Luckily this part has been covered with previous development. The VTX application based on the C# language has a method to communicate and manage Python scripts, with a specific method in the code.

An overall procedure has been designed to make the connection possible. The Radar Server should be connected through a LAN port from our test station computer; therefore, we get a fixed IP address. The use of SHH protocol is required to be used as a communication channel to enable the connection. Then via the LAN port, it would be possible to open the communication to the instrument. Following it, the Python script from the server can be run. This will allow reading the results from the same LAN port.

This is an easy implementation since Vaisala has a project in C# which handles the whole communication and does the work behind it, therefore there is no need to worry about the communication itself. The SHH session implements communication, which has been developed before.

5.4 Automation Decision

Four different options were considered and presented during the development of the project:

- Option 1: The operator controls the Radar Server utilities and sets the cables for measurements with the use of VTX which will carry measurements and serve as work instructions, afterwards VTX will save the results of the tests and calibrations to the Database.
  - This option would be possible to implement, but it would imply developing a solution with relatively hard technical difficulty for such a simple solution.
- Option 2: The operator sets cables for measurements by using VTX with Python scripts which will control the Radar Server applications, afterwards VTX will save the results of the tests and calibrations to the Database.
  - An ideal automated solution is relatively fair to implement with the help of other departments R&D, etc.
  - The scripts from the Windows side would be called, since they are located in the server, by pointing to the right IP address, this will allow sending there a command, meanwhile, on the Linux side, there is a method/solution that receives the commands and handles the Python scripts to manipulate the utilities correctly.
- Option 3: The operator sets cables for measurements and will use VTX with a JSON-RCP production interface for setup radar for measurements

and carrying out the measurement, afterwards VTX will save the results of the tests and calibrations to the Database.

  - The best-automated solution, but the most difficult to implement. As well it was considered the fact that RVP9 would not be the ideal hardware to implement this, since JSON does not have anything to communicate in the current software. This situation may change in the future since the Vaisala RVP Signal Processor could be updated so it will be able to handle JSON data format. JSON-RPC is used to communicate with an application that is running on the computer. It uses the HTTP protocol for remote procedure calls and JSON for data representation.

- Option 4: The operator controls the Radar Server and sets cables for measurements. With the use of eFlex which will serve as work instructions. Vaisala DataCollector tool used as side software will save the results of the tests and calibrations to the Database. Also, there is the possibility that eFlex directly collects the data and sends it to Database but a solution to make this possible must be developed separately.
  - This is the less possible automated solution, requires two programs running at the same time but is the easiest to implement, maintain and escalate. Plus, eFlex presents an easier way to create work instructions than in the VTX Instructor.

To make the final decision on which option to choose for implementation, several factors of bigger or lesser relevance were considered. To start, the weather radar sales volumes are low nowadays, since they are always handled as customer projects, and they are not expected to escalate to volumes similar to weather stations for example. Therefore, the time saved by an automated process would not suppose a big time saving for production.

Solution 2 or solution 3 would take considerable time and resources from other departments. With the workload of other ongoing projects, adding to it that most Vaisala employees were away during the summer months. Therefore the implementation of those solutions was not achievable in a reasonable time frame for this project since the help available to develop them would have been very limited.

To conclude, option 4 was chosen since it can be achievable in the project's time frame and does not require much help from other departments to be implemented. Even though this option does not automate any of the processes, it allows creating of procedure instructions with visual capabilities and with the possibility to be updated directly by Process Engineers from the eFlex webpage interface as well as allowing easier scalability to other weather radar products.

Also by using the Vaisala DataCollector tool the operator can collect manually data from the test in a digital interface instead of using paper and pen and then pass the results to an Excel file and add the results to a digital version of the PI like nowadays.

6 Data Collection Process Decision

A great method to collect data can provide Vaisala with numerous advantages for everyday business decisions. Good data can help recognize and confirm issues, hypotheses, and discernments about processes, in this case, tracking better the results obtained from the FIT. Also, it can serve to proactively address issues, measure progress and gain by potential open doors. Gathering information can assist with estimating a general situation, not restricted to explicit cases or occasions.

The data collection method to be selected had to be strongly dependent on which solution was chosen for the digitalization of the Procedure Instruction since the operator, while following the digital instructions, will collect data manually.

eFlex was the solution chosen, therefore the data must be collected while the operator goes through the different tasks of the WRS400 FIT eFlex test station.

6.1 Vaisala DataCollector Tool

The first solution is to use eFlex work instructions alongside the Vaisala DataCollector tool. This implied that both software should be opened at the same time in the testing station, one window with the browser (preferably Chrome) with the eFlex interface and another window with the Vaisala DataCollector tool. eFlex will instruct the operator with the help of the work instructions when has to input data and what data is in the Vaisala DataCollector tool. The program also will have the same kind of numerical format as eFlex to allow an easy visual relation between both software.

To be able to collect data, first, a Planning phase is required where the test specifications should be created and stored in the Database. To be able to create the test specification a username registered in the VTX Users Database should be added with administrator rights.

Then comes a Production phase in which the operator will load the Specification File from the Database using lists of allowed Product Types and Test Descriptions in the DataCollector tool. The operator will input the right information to find the corresponding test file so it will allow to manually enter data in the program. Once the FIT procedure instructions will be completed, the operator will be able to upload all the data gathered in the Vaisala DataCollector tool.exe to the Database. Later this data can be analyzed in many ways for example by downloading it in a CSV file or analyzing it on other platforms, which is a service for statistical process control and quality data analytics.

6.2 eFlex Data Collection

The second solution consists of directly using the capability that eFlex offers natively to collect the data at the same time as showing the work instructions.

For this method, the Task Configuration settings should be open, and in the Model-Specific tab, the test specifications can be added manually in a similar way as the SpecEditor.exe allows to do it.

Unfortunately, in this method nowadays the only data outcome we can get is a CSV file that can be downloaded from the Part Reporting/Part History section of the main menu in eFlex. This CSV file would contain the following information:

- ***Serial Number*** of the product (usually obtained from Planet).
- ***Station***, in our case, will be the Factory Inspection Test.
- ***Date/Time*** at which the task was performed.
- ***A user*** who performed the task.
- ***Build Status***, which can be Good or Rejected.
- ***Task Name***, referring to the chapter of the FIT.
- ***Task Type***, in our case all, are Button types.
- ***Status***, which can be Good, Rejected or Not Required.
- ***Cycle Time***, second the operator was in a specific task.

If data is collected the following three fields will show information as well:

- ***Process Data Name***, name of the parameter to measure.
- ***Process Data Value***, numerical or string value.
- ***Process Data Units***, unit of the parameter.

The possibilities and usefulness for Vaisala of this CSV file are unknown nowadays, and it could be useful if an application or script would be developed able to extract the needed information from it. Then this information could go to the Vaisala's Database for example or to a Vaisala calibration report.

Ideally, an integration between eFlex and Vaisala's Database would make the data collection process a smooth path that will allow directing the use of only one software solution where work instructions and data collection takes place.

During this project, several discussions have taken place with the eFlex support team concerning the possibilities of this.

Three different options were considered and presented to the relevant parties:

- Option 1: Use the Vaisala DataCollector tool at the same time as the eFlex work instructions. The information then will be added to the Database. System-wise, this option using the Vaisala DataCollector tool would be best but might not be best for the processes.
- Option 2: eFlex generates a CSV file, which will get transferred using an FTP to a shared Database by Vaisala and eFlex. Then with the help of an app/service developed by Vaisala, it will collect the data from the shared Database and the information will be added to Vaisala’s Database. The disadvantage here is that using a CSV file is the most outdated option, and a shared Database could involve some security risks for Vaisala.
- Option 3: Vaisala can access to eFlex’s API, then with the help of an app/service developed by Vaisala, it will collect the data from the shared Database and the information will be added to Vaisala’s Database. This option would require the app/service in the middle step to be not only created but also maintained by someone.

Option 1 is currently implemented and fully operational since it just depended entirely on Vaisala’s current infrastructure to collect the data internally. Option 3 was the most preferred by Vaisala and as well accepted by the eFlex support team. Due to time limitations in the Giant Leap project schedule, this option has not been developed during this period, but a clear roadmap has been defined in Chapter 7 of this document to be able to implement it shortly afterwards.

Both data collection methods depend heavily on the work instructions stored in eFlex. These procedure instructions have been designed in a way that they can work with both data collection methods depending on the needs of production.

7 Roadmap for the Future

A clear roadmap can be defined after the Giant Leap project, mainly in the data collection implementation which will be explained in this chapter.

There are two main options for the development of a solution to allow the data transfer from the tests run in eFlex to Vaisala's Database.

7.1 SAP Analytics Cloud

The first option consists of the upcoming SAP Analytics Cloud that will arrive at Vaisala, which will provide a new business intelligence reporting system. This system could be used for this project. To do that we would be needed to incorporate a subcontractor who will be responsible for importing the data. To do so we would just be needed to provide the eFlex's API and then they will import it allowing us to be able to create the reports wanted.

Unfortunately, access to the SAP Analytics Cloud is still limited nowadays, but there are plans to include Vaisala's Database in it as well which could be beneficial in long term for projects of the same nature as this one. It would be a good option to consider for the upcoming future.

7.2 eFlex integration in Vaisala Database

The second option consists of the direct use of Vaisala's Database. For that, it would be needed to create a middle step presented by creating an app/service that should be connected to the eFlex API, with that it would be possible to access it to get the test definitions and then send them to the Vaisala's Database. The Specification File, which is an XML file, will move, add, and combine the data. The app/service itself will store the data in the Vaisala Database. In the end, the Specification File in Vaisala's Database in an XML file and the CSV file from eFlex should be combined.

7.2.1 Specification File Handling

It should be noted that the Specification File should usually be stored beforehand in Vaisala's Database, regardless of if the app/service is the one which would collect the data and not the Vaisala DataCollector tool itself. That Specification File should correspond sufficiently with the test names used in eFlex is crucial so the application can pinpoint where to get the data from correctly. The names in the Specification File do not have to be the same ones as the data test field names present in eFlex. This is because there should be a clear way to pinpoint a result from eFlex to the corresponding one in the Specification File stored in Vaisala's Database.

If there is the possibility to export the test definitions from eFlex, then the app/service could create an XML file directly which is needed to create the Specification File. In this way, it will not be a need to create and update separately the Specification File in Vaisala's Database when a change in the tests in the eFlex procedure instructions takes place.

7.2.2 App/service Possible Requirements

The app/service would be easy to develop and implement on Vaisala's side. Once developed it should be in one of Vaisala's virtual machines and run from there. The connection between eFlex's API and our app/service would be also easy to create since eFlex most likely has defined and documented its API. Also, it is important to consider that the data structures used in this project are simple.

The concept of the app/service can be started to be developed right away, and once the documentation of the eFlex API is delivered to Vaisala, it would be possible to start the discussion process with the process engineers and train them on how to create the test definitions in eFlex and how to create the Specification File in the Vaisala's Database. The process engineers would be responsible ones to update the Specification File in Vaisala's Database when needed afterwards.

It affects the app/service functionality, whether the data is obtained from the eFlex's API directly or from the CSV file. In the case of the CSV file, there would be a trigger for the data transfer, which must be studied as a way how the app/service could perform it to create the process to move the data to Vaisala's Database. An idea for it could be when the data is transferred to Vaisala, there could be a have a folder, and if a new CSV file gets added there, then it gets processed and added to Vaisala’s Database, this is a normal way to transfer data for Vaisala subcontractors. The API is a more modern way to get the data and it would be just needed to have a trigger to move the data, it could be a very simple tool to input the serial number and then just allows it to move the data to Vaisala’s Database directly.

8 Conclusion

After three months of study, in which the WRS400 was studied along with his FIT process and the different software solutions present at the Vaisala’s premises, the outcome of the project was built with a satisfactory result although perhaps not quite as expected at the beginning.

Digitalization was successful and it serves not only for the WRS400 FIT, but also to promote and encourage other production lines to switch their digital instructions using eFlex as a software solution. If it was able to be adapted to such a complex as weather radar, it could also serve its purpose for simpler products. On the other hand, the automatization was concluded as not manageable for this kind of product which is also a great find and an acceptable outcome for it. Finally, providing two possible data collection methods allowed the adaptability from all procedures to the new one in a more flawless way, while ensuring the needs of data collection are ensured. The final steps to follow for the future to achieve the best method of data collection are very useful findings for the hands-on of this project once the internship was finished.

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