Voyantic

Application Note

Testing UHF RFID, HF/NFC and Dual Frequency Tags with Voyantic Tagsurance™

12/2016

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1 Introduction

This document explains the testing methodology and test setup for verifying the performance of UHF tags, HF/NFC tags and dual frequency tags in production. The term dual frequency tag refers to an RFID tag that can be interrogated using either UHF frequency and protocol or HF frequency and protocol. The tag consists of one integrated circuit chip and two typically separate antenna structures connected to the IC chip.

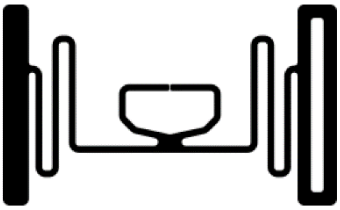

Figure 1. An example of an UHF tag design

An UHF tag has typically a dipole antenna structure, which is used for receiving and transmitting radio waves on UHF frequency from several meters distance to the interrogator.

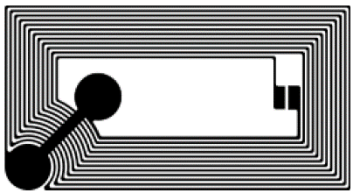

Figure 2. An example of a HF tag design

A HF/NFC tag has a coiled loop antenna structure, which enables magnetic field coupling with the HF interrogator antenna.

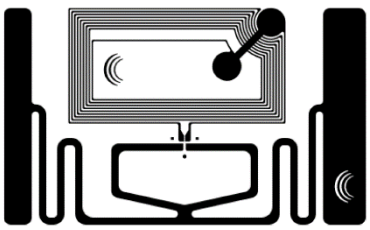

Figure 3. An example of a dual frequency tag design

Having two separate antenna structures, both connected to separate IC chip pads, the dual frequency tag has both UHF performance and HF performance, which need to be tested separately.

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2 What Is RFID Performance?

The performance of an RFID tag affects the tag's ability to respond to commands on certain distance from the reader antenna. This target read distance should not be verified only with the tag in free air, but also on different environments and on different materials, as these will have a significant effect. Rather than trying to measure how far distance the tags can be read with a reader, on different materials and in different environments, the performance of an individual tag can be analyzed by measuring the required wake up power and measuring it on a wide frequency band, to understand also the effect of the materials that detune the tag.

2.1 UHF Performance

An UHF tag is very prone to detuning effect by its surroundings and therefore the tags are typically designed to function at a broad band of frequencies from 800MHz up to 1200MHz. This is the way to enable the use of the same tag on various materials. Alternatively the tag can be specifically designed to be used on a certain material, which requires taking into account the tuning effect when designing the tag. Some special purpose tags, like tire tags, may be designed to function at 2GHz in free air, to reach their best performance at reader frequencies after being embedded into a tire.

In UHF applications there are variables in the environment that can't always be strictly controlled. Trying to minimize for example the amount of different product shapes and materials to be tagged, is typically not something that a retailer would like to do. Therefore, the tags should be able to tolerate as much variation in materials and environment as possible. With a good design this can be done, but in order to bring this advantage fully into reality, we need to be able to verify that each tag from the production performs as it was designed to perform.

Figure 4 gives an example of a good tag design, which enables very stable performance for the tag both in free air and on materials, of which PVC was chosen for this example, but any material lighter in terms of permittivity would fall into this range. The performance of this tag allows the tag to respond from 5-7 meters on either ETSI or FCC reader frequency on various materials from free air to PVC.

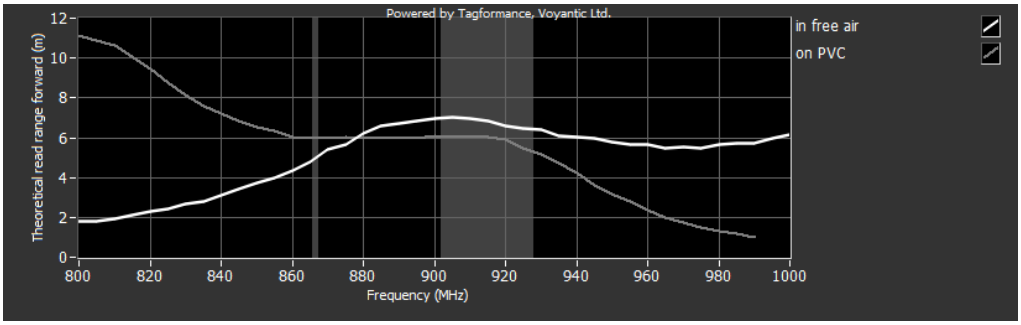

Figure 4. Designed tag performance

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In reality the read range varies though, depending a bit on the performance variation of the tags from production. The graph below shows how the actual read range for the above mentioned tag varied just in free air when we picked some tags throughout the deviation. The white curve represents the median tag response out of 7000 samples, the tag 1 is the best performing tag from this sample batch, tag 2 represents the tag that was worse than 98%, but still inside acceptable range and the rest three of the curves represent examples that clearly differed from the good tags and fell into the last 2%.

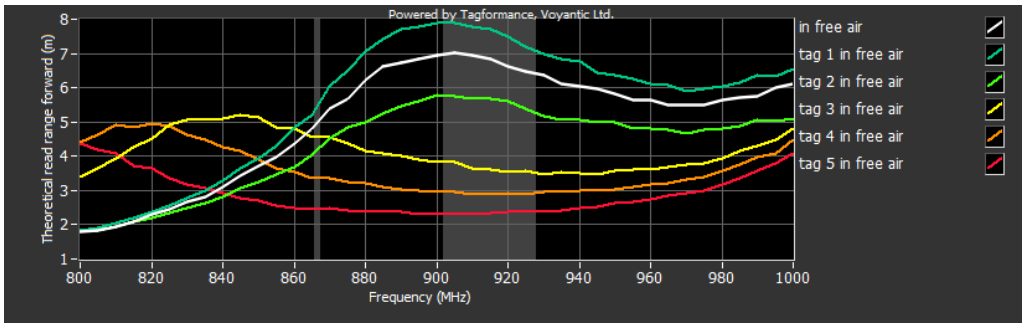

Figure 5. Actual performance of the tags on a single roll from the same production lot

If we look at the performance in free air alone, the read range can vary at FCC frequencies from 2.5m to 8m. Another issue is that when the frequency response of the tags varies this much, unlike designed, the tags behave very unpredictably when attaching them onto materials.

2.2 HF Performance

Similarly as the UHF tags, a HF tag has a performance that can be measured as the lowest power level required to wake up the tag. Traditional way earlier has been characterizing the HF tags with a passive measurement, recording the S11 value through a wide frequency range. This measurement concentrates on measuring how the tag resonant circuit loads the antenna. The problem with this measurement is that the S11 curve changes depending on the transmitted power level, especially when it reached the tag wake up power. The measurement is typically done at below chip wake up power level, and is suitable as such more for antenna characterization, but does not tell about the chip functionality and not so well about the overall tag performance either.

With HF tags the communication is not handled via radiating field, but with magnetic field coupling. In this scenario a HF transmitter (reader or measurement device) is connected to a loop type of antenna that forms a magnetic field into which the HF tag is brought. After the tag is brought into this field, the field changes and the efficiency of power being delivered to the chip is dependent on both the tag and the reader antennas. When measuring the lowest wake up power of the tag, we are actually measuring the power level required for the tag to wake up in this specific setup. Therefore it is essential to know the characteristics of the measurement antenna in detail, to be able to define the pure tag performance. This means that the magnetic field strength on the antenna needs to be defined for the measurement distances to be used and for the frequency range used in the measurement. With Voyantic Tagformance Pro equipment there are two different sized

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fully characterized measurement antennas used for this purpose, and the Tagformance Pro software can calculate the actual required magnetic field strength the tag requires to wake up.

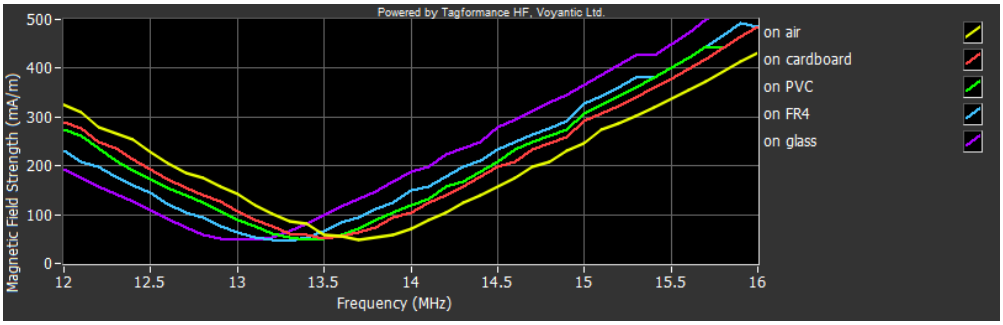

Figure 6. The magnetic field strength required to wake up a HF tag on different materials

Similarly as the UHF tags are detuned by surrounding materials, the HF tags are affected as well. In the above example, the tag was measured on air and on 4 different materials. As can be seen, the magnetic field strength required by the tag to wake up if placed on glass, and if used on the 13.56MHz reader frequency, is double compared to the field strength required on air or on cardboard. This is the reason why many of the HF tags are designed so that the lowest magnetic field strength peak is positioned higher than 13.56MHz in free air, to allow this peak to detune to lower frequencies by surrounding materials.

3 Testing the Performance in Production

In the tag development phase, the prototype UHF tag is analyzed using a transmitting far field antenna and ruling out environmental effects and other tags by placing an individual tag in an anechoic chamber. But verifying that each volume produced tag performs equally requires a bit different tools. It is not possible to isolate a tag completely from its environment and other tags by placing into a shielded anechoic space one at a time.

For this purpose Voyantic has the Snoop Pro coupling element, which couples to the whole dipole structure of an UHF tag. Unlike typical near field antennas, the correlation to the tag behavior in far field is typically very good with the Snoop Pro near field.

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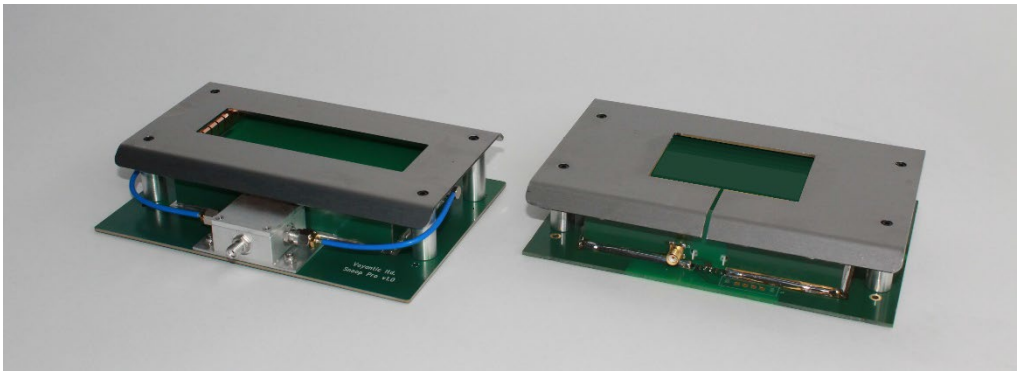

Figure 7. Snoop Pro v1.0 (for UHF tas) and Snoop Pro HF v1.W (for HF tags)

In the application, the HF reader antenna is typically optimized for the exact use case. However, in production the antenna needs to be optimized to tolerate as much alignment difference between the tag antenna and the measurement antenna as possible, without major effect to the coupling between the tag and the measurement antenna. This is to guarantee stable results regardless of alignment tolerance from the machine and to enable testing the tags in a continuously moving line.

For this purpose Voyantic has the Snoop Pro HF coupling element, which has two separate coil structures integrated into one coupling element. One is for smaller, one for larger HF tags and the correct one can be chosen by connecting to one of the two RF ports in the coupling element.

3.1 Test Setup

In a machine installation the Tagsurance units are controlled via direct signal interface, giving the device a trigger signal to start testing and receiving the pass/fail indication as a signal. The Tagsurance unit transmits and receives the RF signal to and from the tag using the Snoop Pro coupling element connected to the Tagsurance device with an RF cable.

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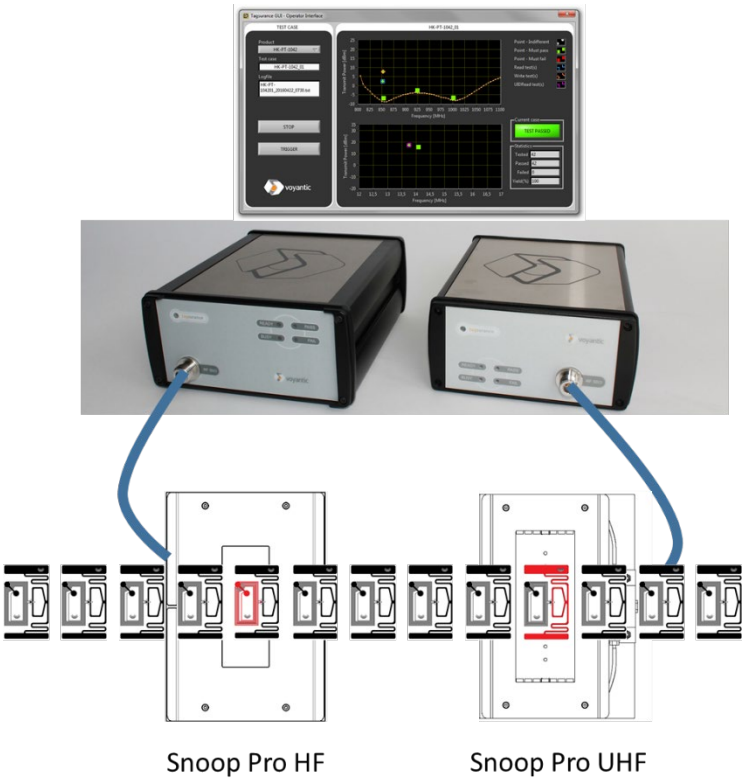

Figure 8. Simplified setup for testing dual frequency tags

There can be several test devices and antennas in the same test setup. For dual frequency tags, the setup would consist of one test location with Tagsurance UHF and Snoop Pro antenna, and one test location with Tagsurance HF and Snoop Pro HF antenna. Everything would be controlled via one easy to use user interface, which compiles the results for each individual tag.

3.2 Defining the Test Criteria

In both UHF and HF performance testing in production, the test criteria are set based on the known worst acceptable tag. The worst acceptable tag performance is defined by testing first some significant amount of samples on a roll with the full threshold sweep measurement using Snoop Pro coupling element and picking representative set of samples throughout the variation to be analyzed in far field. Based on the comparison of the measured far field performance of the sample tags and the requirements set for the performance by the application, the worst acceptable tag can be defined and the test criteria in Snoop Pro near field can be defined using this sample tag threshold. An example test report with the documented procedure and example data is available from Voyantic to describe this in detail.

In brief, with example data on some UHF tag samples, these would be the steps to follow:

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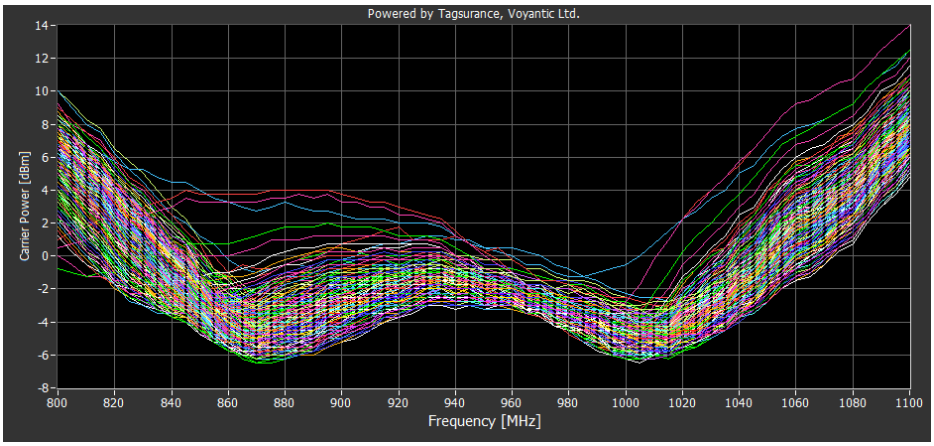
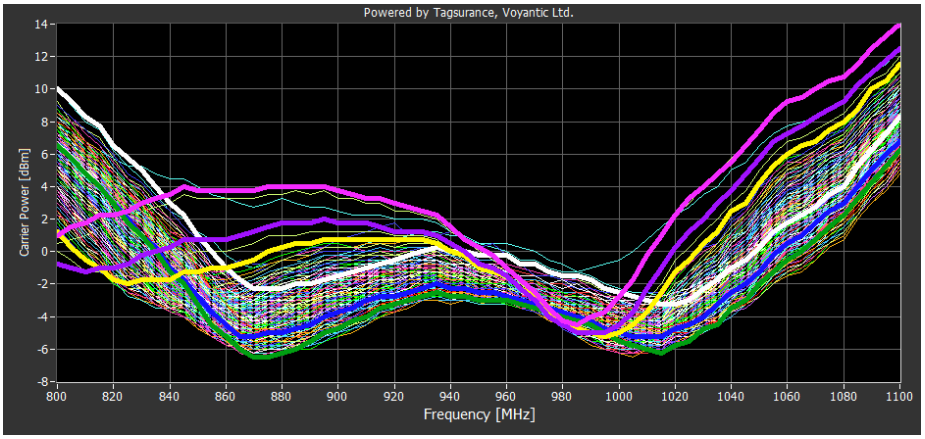
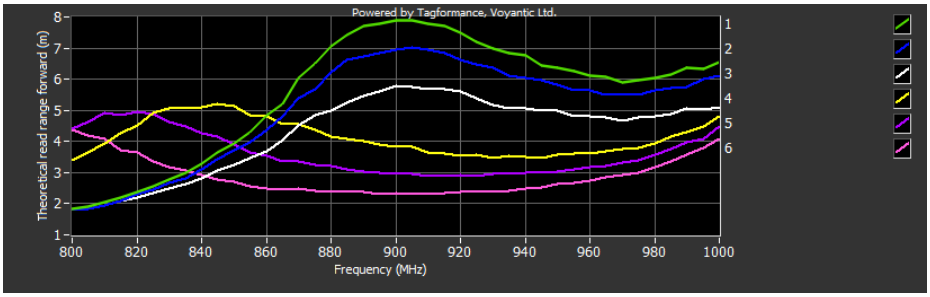
1. Measure a significant amount of samples on a roll with threshold sweep mode



2. Pick a representative set of samples throughout the variation



3. Measure the performance in far field using Tagformance Pro and RFID measurement cabinet



4. Define the acceptable performance level for the application

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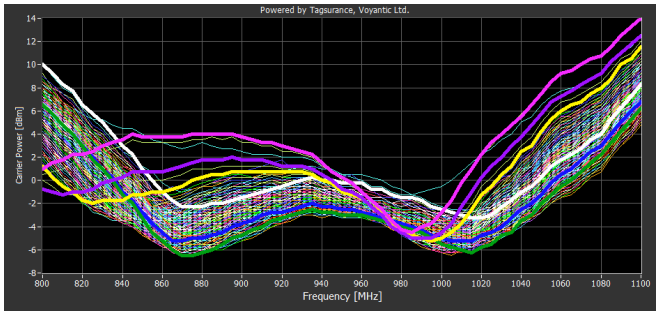
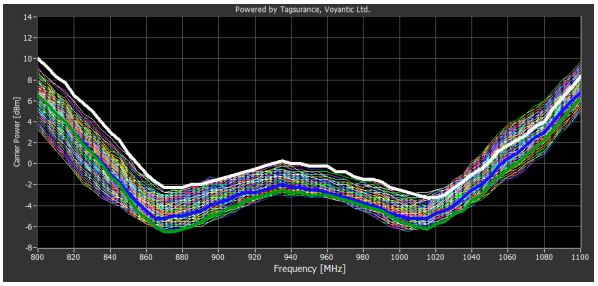
Accepted performance can be defined based on the far field analysis. The sample tags can also be tested in the actual application to see if they comply. Alternatively, they can be applied onto target items and the TIPP grade can be determined. TIPP (Tagged-Item Performance Protocol) is defined by GS1 for retail industry to be able to define a required performance for the tagged item. Also other industry specific item level analysis may apply, with which the tag should comply. Important thing here is to determine which of the picked sample tags still meet these criteria.

5. Prepare the test criteria based on the worst acceptable tag



All tested



Samples that would pass the test criteria

Typically testing even on a few different frequencies, if chosen carefully based on the particular tag, is enough. In the example, we set the acceptance criteria based on the tag with the bolded white threshold curve so that the tag should respond at no lower power level than -2dBm at 870MHz frequency and at no lower power level than -2.75dBm at 1115MHz frequency. With these acceptance criteria, only the tags with the threshold curves in the lower graph shall pass the test.

The example was made with UHF tags, but the same approach would apply to HF tags. The Snoop Pro HF antenna is optimized for testing the tag also in movement, so here we would need to define the difference between the tag performance curves measured using Snoop Pro HF and the antenna used in application, as the efficiency of power being delivered to the chip is dependent on both the tag and the reader antennas. Or we can concentrate on the pure tag performance by using Tagformance Pro equipment, which can measure the actual required magnetic field strength the tag requires to wake up. The essential thing here as well would be to find the worst acceptable tag and to define the test criteria based on it.

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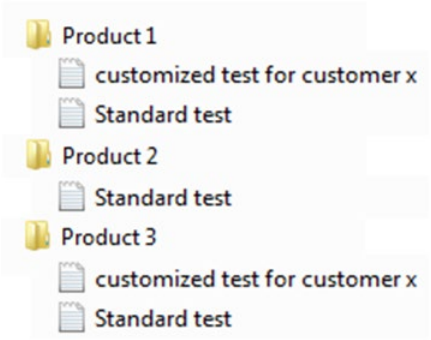
3.3 Operating the System in Production

After the test has been defined, the operation in production is simple. The operator needs to define the correct test, start the test and the results will be recorded into a log file after the test is completed. The latest test results are also monitored during the testing.

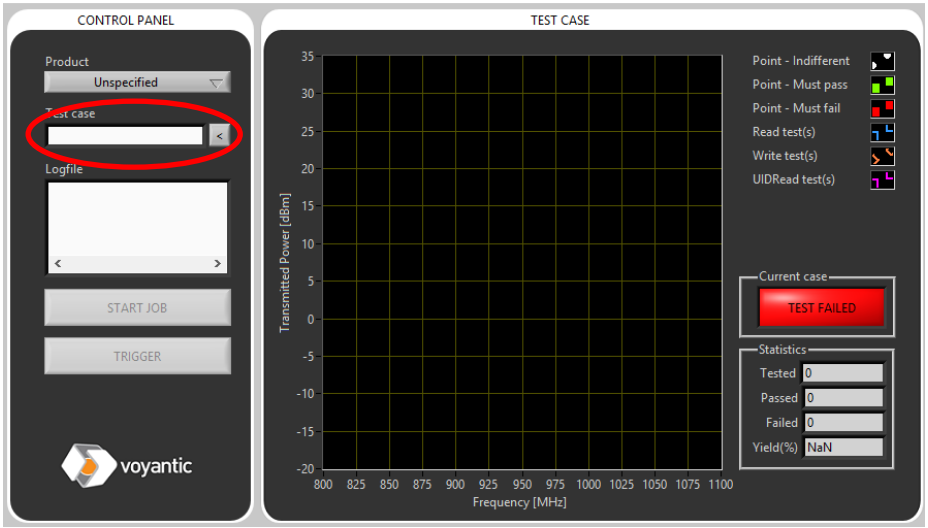
For example, when starting a test for a dual frequency tag, where the setup consists of two antennas and test devices (one for UHF one for HF), the initialization of the production test would be as follows:

1. Choose the product from a dropdown menu

   This list is available based on the folder structure defined when storing the test cases. For every product there is its own folder and if necessary, there can be several test case options available depending on product variant or target customer.



2. Choose the test case available for this product from a dropdown menu



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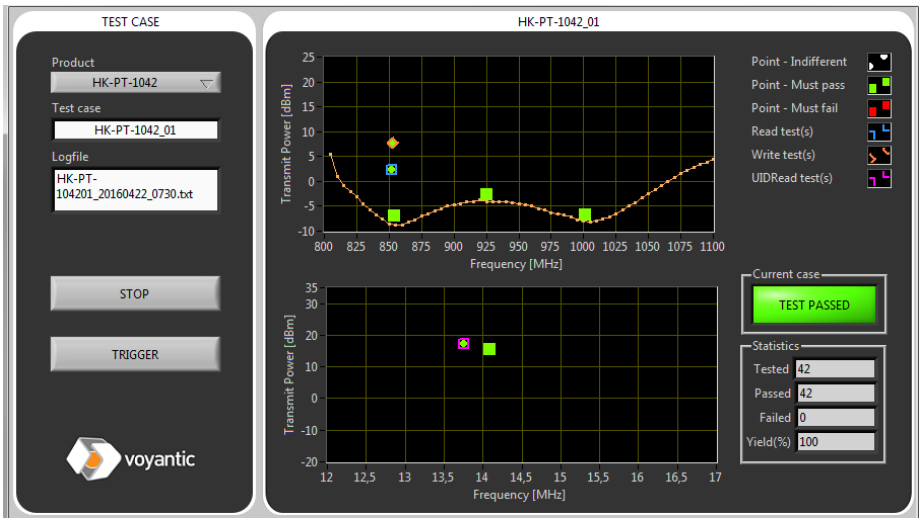
3. Press start job



The log file will be named automatically based on the test case file and time stamp. Both measurement devices receive separate trigger signals from the machine indicating the exact time when the tag is on the antenna and the test can be executed. The Tagsurance test case includes the information of the offset between the two test locations and the results for each tag are displayed together after both HF and UHF tests have been done for the tag. Similarly they are recorded into the result log file on a single row. The results log file row can include read TID, UID, other memory contents, wakeup power values at specific frequencies and information if tag responded or not at a certain power level on set frequency, depending what was defined in the test case.

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