Monitoring system for 24/7 recording of EMF immissions at 9 kHz to 6 GHz

System overview, hardware, automation, and operation

This document briefly describes the main features of the Automatic EMF Measuring System SignalShark 3330 Outdoor Unit EMF (SignalShark EMF).

The SignalShark EMF performs continuous long-term measurements to record the electromagnetic immissions from radio installations in the frequency range from 9 kHz to 6 GHz without the presence of specialist personnel.

The SignalShark EMF runs frequency selective measurements based on configurable test packages, which for example differentiate between VHF radio, DAB radio, BDBOS/TETRA, DVB-T, 2G/GSM, 3G/UMTS, 4G/LTE, 5G, IoT, and RADAR. The measurement results are saved allowing for a settable threshold value (nominally 40dB below the ICNIRP limit value), and transmitted over the cellphone network to the user's central server where they can be stored and evaluated.

The SignalShark EMF can be operated by non-technical personnel, is easy to transport, and meets a wide range of other requirements including ruggedness, automation, and remote control.

Some of the primary features are:

- SignalShark receiver platform with 8 kHz to 8 GHz frequency range, which makes it suitable for the new 5G mobile communications at 3.6 GHz and for future upgrades
- Isotropic E and H field antennas that have been proven over many years in EMF/EMC
- Flexible configuration of test packages and measurement tasks based on a Windows 10 system with Python programming interface
- Automatic measurement operation following connection to power supply

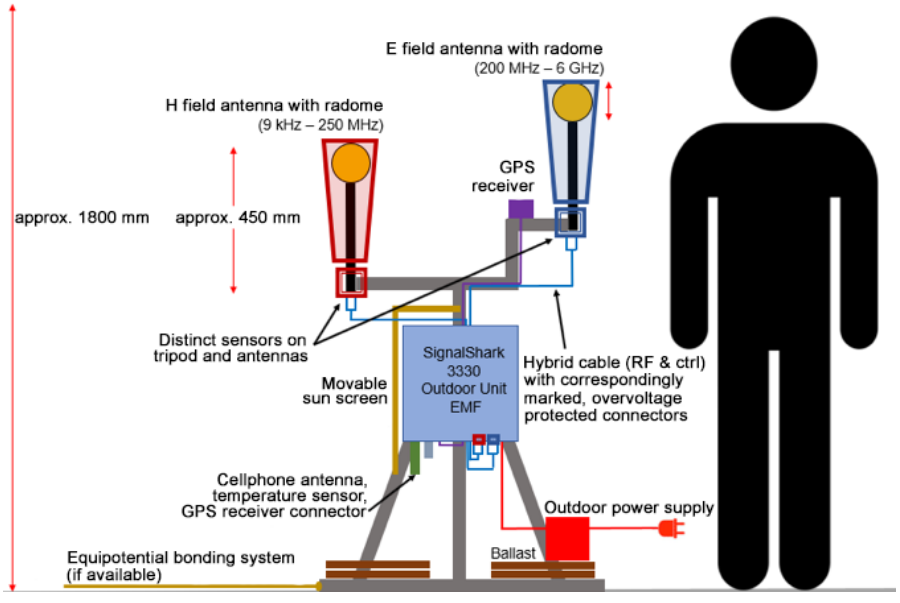


Fig. 1. SignalShark EMF system diagram

System overview

The technological basis of the test system is the SignalShark 3330 Outdoor Unit real time receiver. This is operated with two isotropic, three axis antennas fitted within radomes, which are designed for the EMF / EMC frequency range. Specifically, the antennas are an H field antenna for the frequency range from 9 kHz to 250 MHz and an E field antenna with frequency range 200 MHz to 6 GHz.

The receiver and antennas for the SignalShark EMF are assembled on a folding metal stand. Tear-resistant sacks containing water, gravel or sand as ballast, which can be laid on the ground elements of the stand as required, are used to secure the SignalShark EMF against high winds.

The SignalShark EMF is transported in two off-the-shelf, robust, lockable rolling suitcases with handles, and can be shipped as freight by most logistics services.

Once it has been set up and connected to the power network, the SignalShark EMF starts automatically and begins measurement operations. It runs through a predefined test package, which can either cover the entire frequency range (9 kHz – 6 GHz) or just parts of this range using adjustable measurement parameters. This takes place at a nominal rate of four times per hour, but this rate can be increased if required.

The results comprising the spectral power / field strength values for the configured channels are saved as an XML format file on a microSD card plugged into the SignalShark, together with the date, time, GPS position, temperature and some system status information whenever a specific threshold value is exceeded.

The SignalShark EMF transmits the last results it produces once every hour (or at a limited selection of intervals) to the user's server. This is done by means of a cellphone modem built in to the SignalShark. The SignalShark EMF does not perform any measurements during these transmissions to ensure that the measurement results are not affected. If the SignalShark EMF cannot transmit any data because there is no cellphone network available, the data will be retained for at least ten days and the device will attempt to transmit them at a later time. Manual file transfer is also possible by means of remote desktop access.

System access to the SignalShark EMF is extremely transparent: The SignalShark platform is based on Windows 10 and the software running on the device can be closed or minimized just as any usual PC program, to then use the SignalShark's operating system, for example, to open log files. Since the SignalShark EMF has the same characteristics as a network capable computer, it even allows links using the remote desktop protocol (RDP).

Python scripts are used to execute the measurements on the SignalShark EMF. The frequencies to be measured and the necessary parameters can be user-specified as XML based test packages, which are then read out by the scripts and implemented as the measurements. A suitable test package file is provided with the SignalShark EMF. This can be used as the basis for the user's own adaptations. The fact that Python rather than a proprietary tool is used here means that measurement cycles are completely transparent and reproducible. If necessary, the source code of every available script can be viewed, edited and executed in a Python-compatible development environment. Also, completely new measurement tasks can be accomplished later by means of new scripts. The SCPI commands that can be used to control the SignalShark are freely available in publicly accessible documentation, and can continue to be used under Python when the corresponding syntax is employed.

The configuration, selection and execution of a test package does not require any knowledge of Python programming. The user simply selects the main parameters for a test package using a simple graphical interface, such as the start and end frequencies of the frequency ranges of interest, the measurement bandwidth (RBW), and measurement time (see figure 7). The parameters are saved in an XML file which can be transmitted over the cellphone network to one or more SignalShark EMF devices in the field.

SignalShark receiver platform

The SignalShark family is made up from several device types:

- SignalShark 3310 Handheld
  - A portable, battery-operated real time spectrum and signal analyzer with display for radio interference tracking on the move.
- SignalShark 3320 Remote Unit
  - A receiver designed for fixed indoor installation (e.g. rack mounted) for radio monitoring from a fixed location or a vehicle.
- SignalShark 3330 Outdoor Unit
  - A receiver designed for outdoor installation at a fixed location for radio monitoring, which can be connected to an automatic direction-finding antenna. Available in POE and Modem versions.
- SignalShark 3330 Outdoor Unit EMF
  - A receiver designed for outdoor installation at a fixed location, which can be connected to two EMF antennas, and with built-in cellphone modem (3G, 4G) and integrated OpenVPN client.

Fig. 3. SignalShark 3330 Outdoor Unit

All members of the SignalShark family have the same RF module in common. Within a very small space, this module achieves sensitivity, dynamic range, and speed characteristics previously typically only matched by large, laboratory-based measuring instruments.

The roadmap for the SRM/SignalShark family includes downconverter antennas for the FR2 range of the new 5G mobile communications standard, which will mean that the system is well equipped to handle future applications.

SignalShark Outdoor Unit EMF 3330/04, Modem R1 [a, b]	
Frequency range	8 kHz – 8 GHz
Scan speed	50 GHz per second
Real time bandwidth	40 MHz
RBW settings (Scan Spectrum)	1 Hz to 6.25 MHz (stepwise)
Trace detectors	+Pk, RMS, -Pk, Avg, Sample
RT Level Meter detectors	+Pk, RMS, -Pk, Avg, Sample, Cpeak (quasi-peak), CRMS & CAvg
Sensitivity	1 MHz ≤ f ≤ 44 MHz < -160 dBm/Hz 44 MHz < f ≤ 3 GHz < -162 dBm/Hz 3 GHz < f ≤ 8 GHz < -152 dBm/Hz
IP2 at maximum sensitivity	4 MHz ≤ f ≤ 44 MHz > 60 dBm 42 MHz ≤ f ≤ 8 GHz 40 dBm (typ.)
IP3 at maximum sensitivity	3 MHz < f ≤ 44 MHz > 26 dBm (typ.) 44 MHz < f ≤ 3 GHz > 14 dBm (typ.) 3 GHz < f ≤ 8 GHz > 12 dBm (typ.)
Temperature range	-20°C to +55°C
Safety class	IP 65
Power consumption	max. 60 W (230V AC)
Weight	approx. 13 kg

[a] Abstract from SignalShark 3330 Outdoor Unit data sheet, NSTS 0820-E0369A

[b] SignalShark Outdoor Unit 3330/04 basic unit without antennas, stand, or accessories

Additionally, the SignalShark family is equipped with numerous interfaces that can be used within a system or utilized separately:

- The Python script-based control interface allows the construction and automation of user-specific measurement sequences.
- The VITA49.2 compliant I/Q streaming format enables transmission of FFT data and I/Q data as a data stream. These data streams can be combined with the results of other stations, for example to calculate localization results.
- As the SignalShark appears as a Windows 10 computer in the context of IT, it provides many opportunities for linking into a network as well as for the installation and use of additional software that runs directly on the device.

Measurement sensors / antennas

The measurement sensors for the SignalShark EMF comprise two isotropic antennas that have a well-proven track record in the EMF / EMC range:

- H field antenna (9kHz – 250 MHz, item number 3581/02)
- E field antenna (200 MHz – 6 GHz, item number 3502/02)

SignalShark EMF antennas *	
H field antenna	Type 3581/02
Frequency range	9 kHz to 250 MHz
Measurement dynamic range	2.5 µA/m to 560 mA/m
Special features	Three axis isotropic antenna with correction factors stored in EEPROM in the multipin connector
E field antenna	Type 3502/02
Frequency range	200 MHz to 6 GHz
Measurement dynamic range	0.14 mV/m to 160 V/m
Max. field strength	435 V/m
Special features	Three axis isotropic antenna with correction factors stored in EEPROM in the multipin connector
* Abstract from Selective Radiation Meter SRM-3006 data sheet, NSTS 0217-D0272J	

Fig. 4. Isotropic three axis EMF/EMC antenna type 3581/02 or type 3502/02 (both have similar appearance)

Both these antennas allow frequency selective measurement of the H or E field sequentially in three axes. Calculation of the overall field strength is done by the SignalShark Outdoor Unit. The antennas provided here are therefore isotropic antennas, which are commonly used in the field of EMF / EMC measurements. It is also possible to use the axes of either antenna separately for measurements if required.

As the two antennas cover frequencies from 9 kHz to 6 GHz, they are suitable for capturing most of the radio services that are in current use. This includes the traditional broadcast and mobile communications services, and also the recently allocated frequency bands for the new 5G mobile communications standard, for example at 3.6 GHz.

Both antennas are fitted in radomes which provide protection that matches safety class IP 54.

Each antenna has two connectors: RF signal (N plug) and Control (multipin plug). Each antenna is connected to the SignalShark 3330 Outdoor Unit EMF by a hybrid cable (approx. 1.5 m long).

The antenna factors stored in the multipin plug of the antenna are automatically allowed for, as are the attenuation values stored in the multipin plug of the cable. As a result, the SignalShark 3330 Outdoor Unit EMF always indicates the corrected field strength value.

The control cables within the casing of the outdoor are fed through overvoltage protection to the SignalShark RF module.

The two antennas are fitted to the SignalShark EMF system separated by a distance of about 700 mm and at different heights to reduce any mutual interaction as far as possible.

System automation

The SignalShark EMF is designed to boot up as soon as it is connected to a power supply, and then to self-configure for measurement operation and start the test package that has been set, and to begin transmitting data according to the set transmission interval.

If a measurement task cannot be completed despite the presence of an active power supply, the measuring station software will generate a warning that will be transmitted to the PC software during the communications timeslot. The operating status of the SignalShark EMF together with, for example, the temperature and location of the measuring station are also transmitted in this way. If the GPS position cannot be determined or there is no cellphone signal reception, this will be recorded within the SignalShark EMF.

If overmodulation occurs, the SignalShark 3330 Outdoor Unit EMF adjusts its reference level or input attenuation to match the current ambient field strength to protect against overmodulation and to ensure delivery of results that are as precise and valid as possible.

The SignalShark EMF comes with a standard test package which is suitable for automatic capture of radio immissions between 9 kHz and 6 GHz. The implemented frequency ranges are, for example, 2G, 3G, 4G, 5G, UKW, BDBOS/TETRA, POCSAG, DAB, DVB-T, WiFi, and radar. Threshold values that nominally reach up to 40 dB or less below the applicable ICNIRP limit values are considered in each case.

A long-term measurement over several days that determines the maximum level at the measurement location can be used, for example, to measure the actual local exposure to 5G signals.

The simple user interface of the PC software can be used to configure test packages that survey only parts of the above-mentioned spectrum, i.e. that only capture the immissions in a particular band and / or channel.

The measurement results are stored by the SignalShark EMF for at least ten days. At least up to four measurement runs can be performed in one hour. The current measurement results are transmitted as an XML file via the cellphone network (3G / 4G) to the user's server at least once every hour. No measurements are performed when the transmission is being made (to avoid self-measurement).

Obsolete data is deleted automatically. Data can also be deleted manually via RDP.

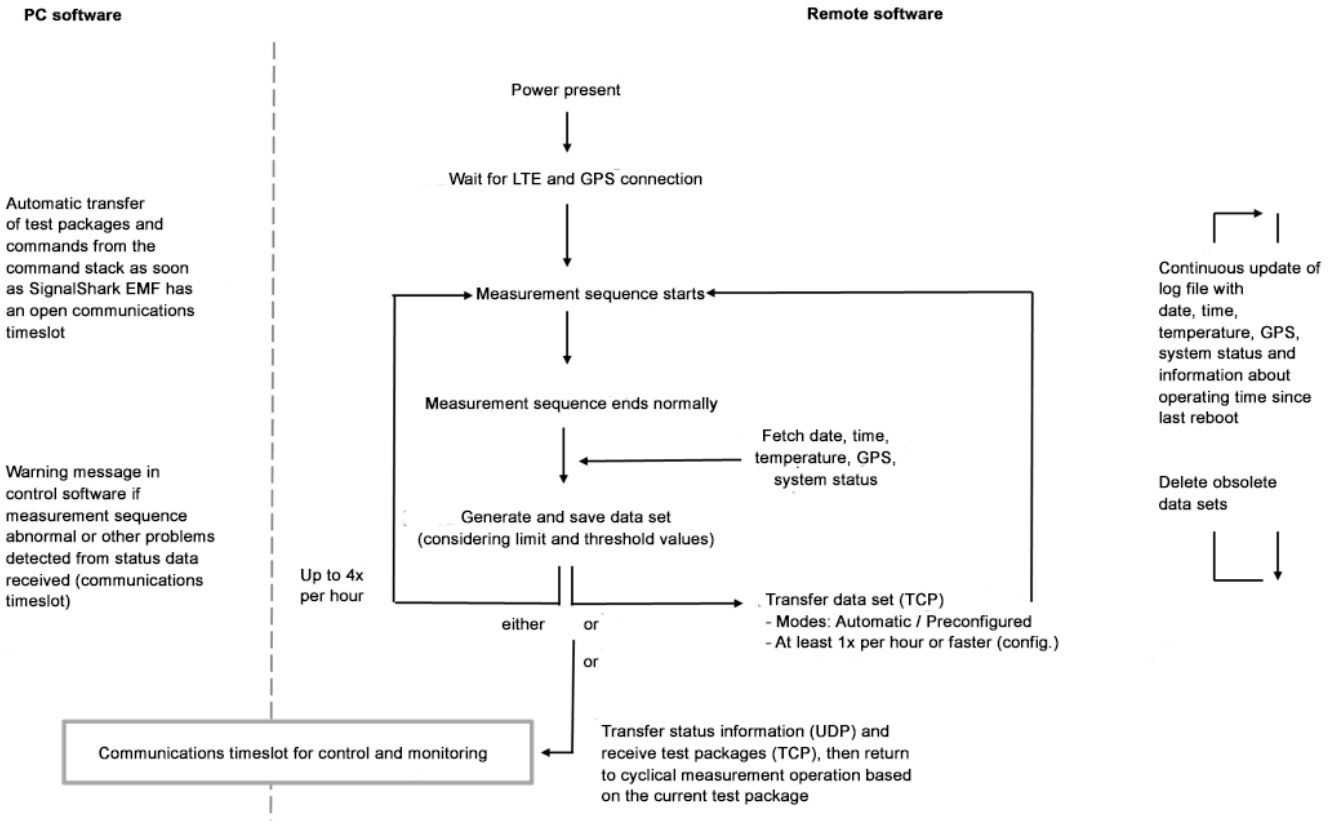


Fig. 5. SignalShark EMF functions and states emphasizing automation, not showing possible RDP link

System operation

The SignalShark EMF can basically be operated in three different ways which are briefly explained here:

1) Identification and monitoring of SignalShark EMF systems in a network

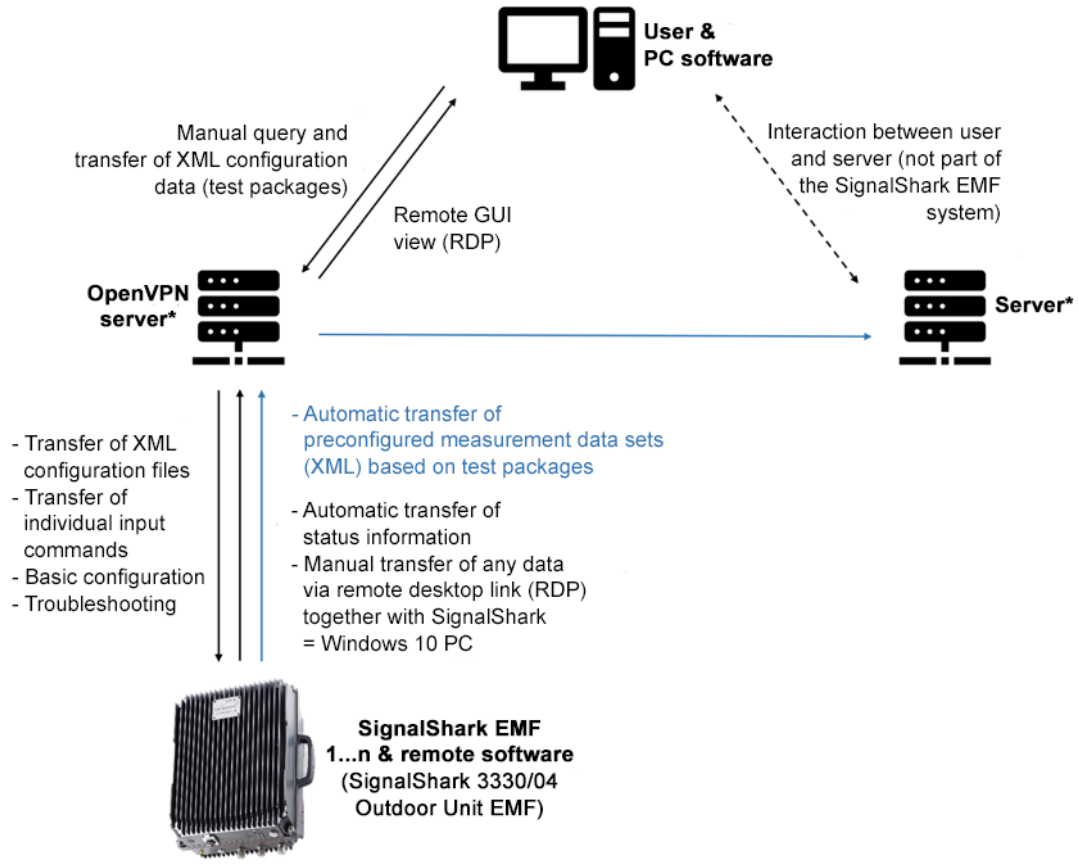
If several SignalShark EMF units have been set out in an area and have started measurement operations, they can each be identified by the user using the PC software, which lists all the SignalShark EMF units in a network. The software also provides a display of the status information for all the SignalShark EMF units.

2) Manual access via RDP

The SignalShark EMF can be controlled manually using the remote desktop protocol (RDP). This makes it possible to use the measurement application for special tasks or to close / minimize it and use the SignalShark just like a normal PC with a Windows 10 user interface. The SignalShark 3330 Outdoor Unit EMF can thus be operated from another network-capable device, with full access to all measurement settings. Mouse, scroll wheel, keyboard, and drag & drop functions are already implemented in this operating mode. It is also possible to transfer data / configurations to the device, delete old data, or transmit new scripts in this way.

3) Transfer of test packages

Users can also transfer test packages to one or more SignalShark EMF units even without an RDP link. This is done using the PC software, which collects the user commands and test packages to be transmitted and transfers these to the SignalShark EMF device or devices at a given time. The SignalShark EMF then executes the new test package and processes the measurement results on the basis of the new definitions.



*Servers are not included in the SignalShark EMF system

Fig. 6. Information transfer sequence between user, SignalShark EMF, and server

A test package that can be configured from the user's computer and transferred to one or more SignalShark EMF units as an XML file includes several variable parameters.

A distinction must be made between:

- Global attributes / parameters: These apply to the entire test package
- Local attributes / parameters for a specific measurement task
- Technical measurement parameters that apply to a specific band / channel

Within a measurement task, the user is free to directly define a frequency range (e.g. VHF radio) or to define a sub-hierarchy with certain channels (e.g. for 5G). Individual measurement parameters can be defined for each measurement task and for each subordinate channel.

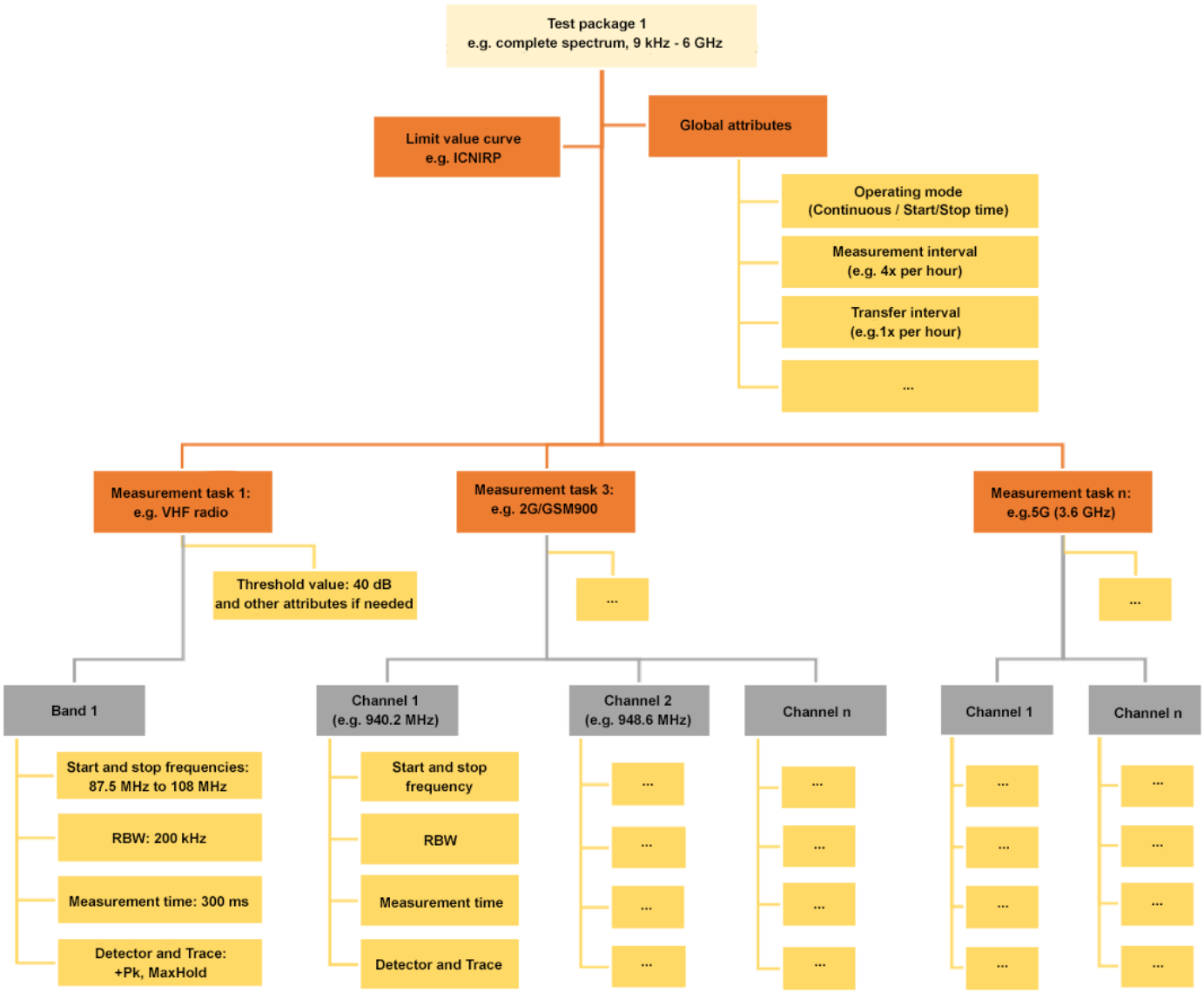


Fig. 7. Example of a hierarchical test package and the measurement tasks and variable parameters that it contains

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