Monitoring system for 24/7 recording of EMF immissions between 9 kHz and 6 GHz

System overview, hardware, automation and operation

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 need for specialist staff to be present.

The SignalShark EMF measurements are frequency selective and based on configurable measurement packages. They thus differentiate between such services as VHF radio, DAB radio, BDBOS/TETRA, DVB-T, 2G/GSM, 3G/UMTS, 4G/LTE, 5G, IoT, and radar. The measurement results are saved in XML format on the measuring station.

An optional threshold value (e.g. nominally 40 dB below the ICNIRP limit value) can be incorporated into the measurements. The results can subsequently be transmitted via the mobile network to the user's central server where they can be archived and evaluated.

SignalShark EMF can be operated without technical staff, is easily transported, and meets wide-ranging requirements for ruggedness as well as for automation and remote control:

- SignalShark receiver platform with frequency range 8 kHz to 8 GHz and therefore suitable for the new 3.6 GHz 5G NR mobile system and future enhancements
- Isotropic E and H field antennas with a proven track record in the EMF/EMC sector
- Fits into three standard carrying cases and can be shipped by most logistics service providers
- Can be set up and put into operation quickly even by untrained personnel
- Automatic measurements once connected to power supply
- Flexible configuration of measurement packages based on a Windows 10 system with a Python programming interface

System overview

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

The receiver and antennas of the SignalShark EMF are mounted on a plug-together metal stand. Tear resistant bags that can be filled with water, gravel, or sand as ballast are used to secure the SignalShark EMF against strong winds by distributing them as needed on the base elements of the stand.

SignalShark EMF is transported in three standard, rugged, lockable wheeled cases with carry handles for transport and can be shipped as freight using the majority of logistics services.

Once it has been set up and connected to the power network, the SignalShark EMF starts automatically and begins making measurements. It runs a predefined measurement package that either covers the entire frequency range (9 kHz – 6 GHz) or only parts of the range using adjustable measurement parameters. The number of measurements can be determined by the measurement package as well as by specifying a time period.

The measurement results are stored as an XML format file on the SignalShark EMF and include the following in addition to the field strength values for each frequency point: date, time, GPS position, and temperature.

The SignalShark EMF transmits the latest measurement results it has produced once per hour (or at a selectable interval) to the user's server. A built in mobile communications gateway in the SignalShark is used for this. The SignalShark EMF does not perform any measurements while this transmission takes place to ensure that this does not affect the measurement results. If the SignalShark EMF is unable to transmit the results because there is no mobile network connection, the results will be stored for at least ten days. Alternatively, remote desktop access can be used to transfer data manually.

Access to the SignalShark EMF system is very transparent: The SignalShark platform is based on a computer running Windows 10. Software running on the device can be closed or minimized when the SignalShark operating system needs to be used, such as when opening log files. Because it acts just like a computer that can be accessed through a network, it is even possible to make connections to the SignalShark EMF using the remote desktop protocol (RDP).

The frequencies to be measured and the necessary parameters can be specified by the user in XML based measurement packages. These are read and converted into measurements by the Python based SignalSharkEMFBU software installed on the SignalShark EMF.

The SignalShark EMF is supplied with a measurement package file that can be used as a basis for individual customizations.

No programming expertise is needed to configure, select, and start a measurement package. Using the separately available Python based SignalSharkEMFPC PC software, users can use a simple graphical interface to select the main parameters of a measurement package such as the start and end frequencies of the frequency band of interest, the measurement bandwidth (RBW) and measurement time. The parameters are saved in an XML file and transmitted to one or more SignalShark EMF measuring stations out in the field.

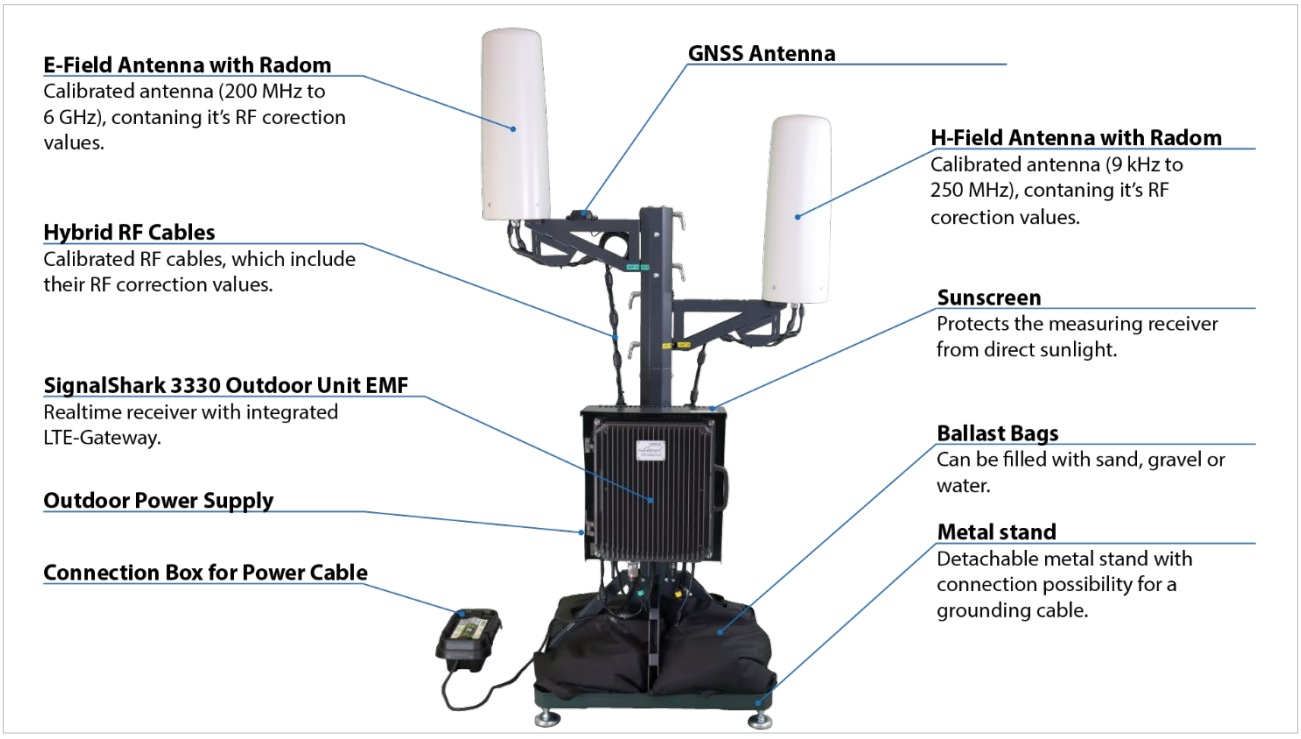

Fig. 1. SignalShark EMF measuring station

SignalShark receiver platform

There are several different instrument types in the SignalShark family:

- SignalShark 3310 Handheld
  - A portable, battery operated real time spectrum and signal analyzer with display for tracing radio interference on the move
- SignalShark 3320 Remote Unit
  - A receiver designed for fixed, indoor installation (e.g. in a rack) for stationary or vehicle-based radio monitoring
- SignalShark 3330 Outdoor Unit
  - A receiver designed for fixed, outdoor installation for radio monitoring with connection facility for an automatic direction finding antenna. Available in POE and modem versions.
- SignalShark 3330 Outdoor Unit EMF
  - A receiver designed for fixed, outdoor installation with connection facilities for two EMF antennas and built in mobile communications gateway (3G, 4G) with integrated OpenVPN client.

Fig. 2. SignalShark 3330 Outdoor Unit

All members of the SignalShark family are based on the same RF module. This module packs into the smallest space the sensitivity, dynamic range, and speed that were previously typical of large laboratory based measuring instruments.

Downconverter antennas for the FR2 frequency range of the new 5G mobile communications standard are already part of the roadmap for the SRM / SignalShark family, so the system is well equipped to also handle future applications.

SignalShark Outdoor Unit EMF 3330/04, Modem R1 [a,b]	
Frequency range	8 kHz – 8 GHz
Scan rate	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 highest sensitivity	4 MHz ≤ f ≤ 44 MHz > 60 dBm 42 MHz ≤ f ≤ 8 GHz 40 dBm (typ.)
IP3 at highest 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
Protection class	IP 65
Power consumption	max. 60 W (230V AC)
Weight	approx. 13 kg

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

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

In addition, the SignalShark family is equipped with many different interfaces so that it can be used as part of a system or for individual applications:

- User-specific measurement sequences can be set up and automated using a control interface based on Python scripts.
- 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 offset against the results from other stations in order to calculate localization results, for example.
- The fact that the SignalShark appears as a Windows 10 computer from the IT perspective means that there are many possibilities for linking it into a network and for installing and utilizing additional software that runs directly on the instrument itself.

Measurement sensors / Antennas

The measurement sensors for the SignalShark EMF are two antennas that have a proven track record in the EMF/EMC sector:

- H field antenna (9 kHz – 250 MHz)
- E field antenna (200 MHz – 6 GHz)

SignalShark EMF antennas*	
H field antenna	Probe Module 3581/901
Frequency range	9 kHz to 250 MHz
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 plug
E field antenna	Probe Module 3502/901
Frequency range	200 MHz to 6 GHz
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 plug
*Further information upon request	

Both of these antennas allow frequency selective measurement of the H field or E field on three axes sequentially. Calculation of the total field strength is done by the SignalShark Outdoor Unit. The antennas provided here are “isotropic” antennas as commonly used in the EMF/EMC sector. It is also possible to use specific axes in both antennas for specific measurements if required.

As the two antennas together cover a frequency range from 9 kHz to 6 GHz, they can be used to capture most of the radio services that are in common use today. This includes the classic broadcast radio and mobile communications services, as well as the newly allocated 3.6 GHz frequency band for the new 5G standard.

Fig. 3. Probe Module: Isotropic three axis EMF/EMC antenna in a radome, with antenna arm for mounting.

Both the antennas are equipped with a radome and therefore comply with protection class IP 54.

There are two connectors to each antenna: RF signal (N connector) 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 together with the attenuation values stored in the multipin plug of the cable are automatically taken into account. This ensures that the SignalShark 3330 Outdoor Unit EMF always indicates the corrected field strength value.

The control cables are fed to the SignalShark RF module within the outdoor casing via an overvoltage protection circuit.

The two antennas are separated by about 700 mm and mounted at different heights on the SignalShark EMF system to reduce any mutual interference as much as possible.

System architecture and terminology

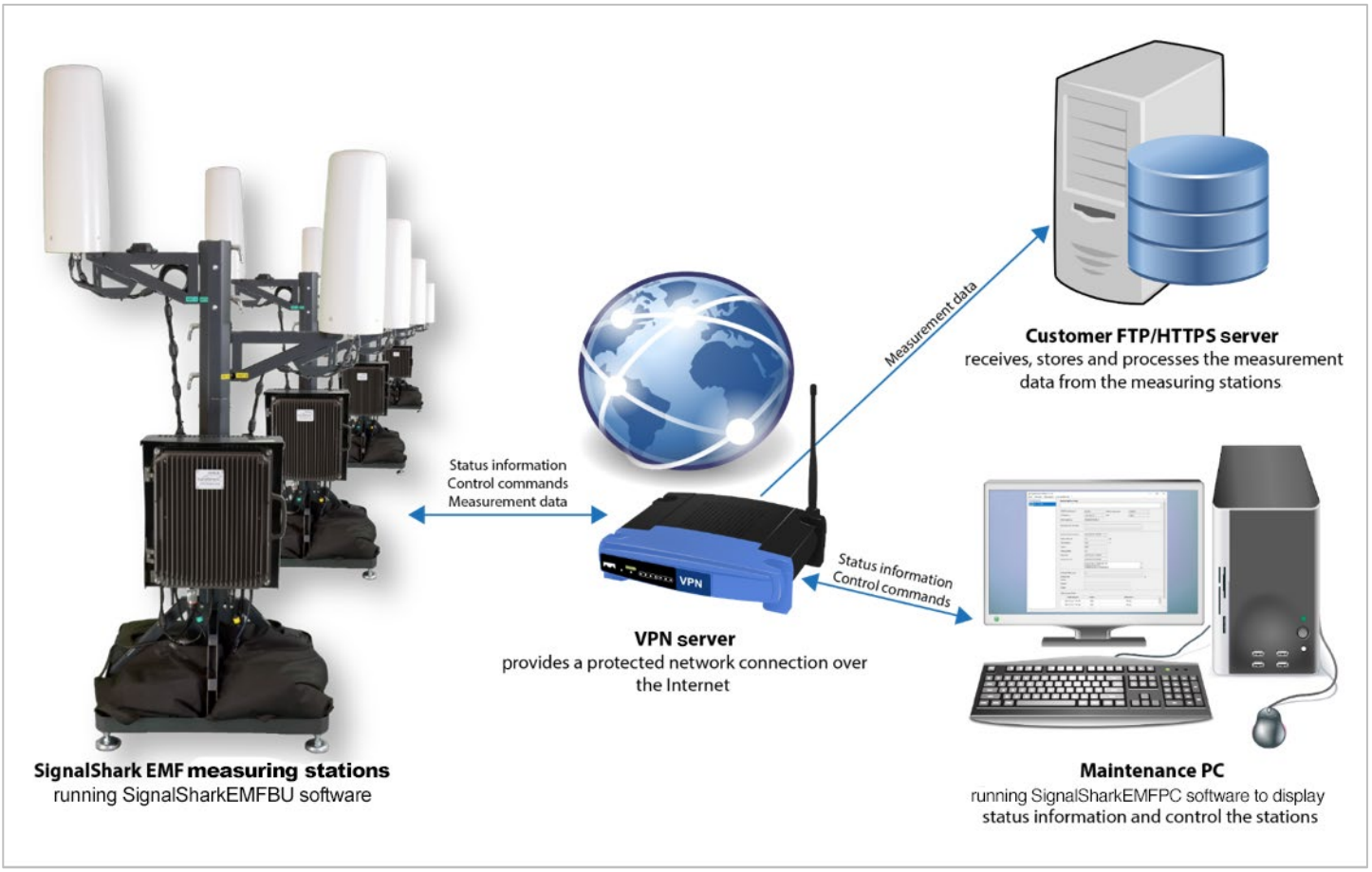

Fig. 4. System overview

SignalShark EMF measuring station

SignalShark EMF measuring stations basically consist of a SignalShark 3330 Outdoor Unit and two isotropic antennas fitted to an easy to assemble stand. They start up automatically as soon as they are connected to the power supply, log in to the mobile network, and start to transmit status messages. They can be controlled using network commands and autonomously perform measurements based on measurement package files.

SignalSharkEMFBU

The SignalSharkEMFBU software is installed on each measuring station and performs the actual measurements among other functions.

SignalSharkEMFPC

The optional available SignalSharkEMFPC PC software enables monitoring and control of the available measuring stations in the network. Measurement packages and limit value curves can be created using the software, which can then be transmitted to the measuring stations as part of a measurement assignment. Various other network commands can also be transmitted to one or more measuring stations in addition to the actual measurement tasks.

Measurement packages

Measurement packages are XML based files that can be created and edited using a simple entry mask in the PC software. They contain all the information needed to enable a measuring station to perform a sequence of measurements. The measurement packages determine which frequency channels are to be measured and the parameter settings to be used (e.g. RBW, measurement time).

Limit value curves

Limit value curves are also realized as XML based files that are created and edited using a simple entry mask in the PC software. The maximum permitted level values for each frequency as defined in the particular standards can be set using them. These values can be used as thresholds for the measurement data that is to be saved.

Transmission of status information and commands

At regular intervals, each measuring station transmits (by a UDP broadcast) status messages that contain information such as the GPS position, status, start time, current measurement and the actual ambient temperature. These messages can be received by all the PCs in the network by means of the SignalSharkEMFPC software.

As soon as the PC software receives a status message, it can transmit a command to the particular station within a short time window to start a new measurement, for example.

Status interval

Each station sends a status message approximately every 15 seconds by default.

The time period between two status messages can be set using parameters in the SignalSharkEMFBU software. No communication takes place while a measurement is in progress so that the measurement results are not distorted.

Network (VPN connection)

LTE gateways are built in to the SignalShark EMF measuring stations. These allow a data link to be set up using a cellular modem. For security, the devices cannot be addressed directly over the Internet. Instead, communication is tunneled through the Internet via a virtual private network (VPN). This functionality is also provided by the built-in LTE gateway. The measuring stations act as VPN clients.

VPN server

To set up the VPN network, a VPN server is required to which the measuring stations can connect. The VPN server can be implemented in different ways, depending on the customer requirements, and is therefore not included in the package.

FTP / HTTPS server

The measuring stations connect at predefined intervals with an FTP / HTTPS server in the network. This receives the data transmitted from the measuring stations, saves and processes them. This server is a part of the customers system and is therefore not included in the package.

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