How to Measure PMSE Live Spectrum Use?

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• Since 2006, DKE has been collecting information on professional event production, the wireless production tools (PMSE) and their typical radio spectrum use.

• It summarizes this information in application reports.

• These reports are made available to regulatory and standardization bodies.

• The working group includes experts from the DACH region.
The issue in a nutshell

PMSE, e.g. wireless microphones, require radio spectrum...

...but how much...

...and how can this be measured?
Introduction (2)

• After many years of spectrum recordings we would like to summarize some results.

• In addition some recorded events might present an evolution of spectrum demand for content and event production. Therefore, some spectrum scans of several Eurovision Song Contests were analyzed by using the latest PMSE Occupation Recorder release.

• This presentation is an update to the presentations of EuMW2013 (Nuremberg) and EuMW2015 (Paris). Therefore, you are kindly asked also to consider the previously presented information in the presentations of the last years EuMWs.
Handover

Lets take a look at some typical recordings of productions that took place in the UHF-TV band.
The Eurovision Song Contest

Over the last years the Scanning Team in our DKE WG has recorded many international events.

For a typical output we like to present brief records of ESCs in

- **2011, Dusseldorf, Germany**
- **2014, Copenhagen, Denmark**
- **2015, Vienna, Austria**
- **2016, Stockholm, Sweden**

Notes:
- In all recordings we are focusing on Audio PMSE in the UHF TV Band. However, we see in the recorded spectrum a mix of signals.
- The production of every ESC was running over several weeks. However, we focus only on last three days in production.
Aggregate spectrum

Spectrum allocation which exceed the stat threshold level

Estimated spectrum resource to scanned and coordinated narrowband links
The graphic of the aggregate spectrum shows all recorded signals in the frequency domain:

This provides a detailed view of the spectrum use by Broadcast, Mobile Service, PMSE and Interference.
The graphic of the signals that exceed the threshold level shows narrow band signals in the time domain:

The purple color shows PMSE signals that are considered in the production’s coordination table. The green horizontal line shows changes on the day.
This graphic is a simple calculation of required RF spectrum for PMSE operation in an artificial channel grid of 600 kHz:

The green color represents the recorded narrow band signals. The yellow color refers to the number of PMSE links that are listed in the event’s coordination tables.
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Observation of events during production is the main task of the DKE spectrum recording.
- Productions in the UHF TV band –

With the emergence of potential new bands for audio PMSE these bands also need to be scanned to check real-world conditions.
In this section we start to presented the results of impressive real-time spectrum measurements which have been captured at both static live events and across 1000’s of Kilometres during mobile spectrum scanning activities.

Questions to be answered;

1. What is the local spectrum density of operated Services or applications?
2. Is there clean-spectrum to meet a given production’s quality requirements and will it remain clean for the duration of the production?

To answer these questions, in the exiting scanning software, an additional mobile recording mode and a tool for the final data analysis were added.
Mobile Recording Tools

But software is only one of several issues during mobile scans:

1. The car has to be modified so Scanner Hardware and Computer can be operated during driving.
2. Mobile RF scanning and GPS antennas are required, that need to be securely installed on the vehicle.
3. All this equipment needs to be calibrated to ensure acceptable levels of accuracy in the results.

Next page..
The car’s scanning antennas

For the scanning tour in United Kingdom the car was equipped with 3 additional antennas:

1. Air band 960 to 1170 MHz
2. L-Band 1200 to 1600 MHz
3. GPS

The required RF bandwidth of antennas in combination with a small wind resistance is a real challenge. Each day we had to drive more than 700 km!
In an EMC test environment the gain of the car antennas was tested. See below the Air band antenna gain from 960 to 1170 MHz:
The mobile antenna is connected to a amplifier and filter combination on the scanner’s input by a flexible antenna cable. This cable inserts an additional loss before the scanner input of about 3 dB @ 1525 MHz.

Cable loss of 2\textsuperscript{nd} car antenna (>1200MHz)
Feasible Receiver Sensitivity (1)

In a laboratory test, the antenna input was connected to a test signal of -80 dBm. The picture below shows a typical output graphic in a spectrum recording of 5 minutes in 1515 to 1560 MHz; RBW=1MHz:

Note: RBW=100kHz was operated in DAN, parts of DE, SWE and UK, RBW=1MHz was additional operated in A, CH, part of DE and FL
The picture below shows a typical output graphic in a spectrum recording of 7 minutes of a signal 1525 MHz / -80 dBm; RBW=100kHz.

Summary: the mobile scanner can record weak signals, close to noise
RF filters decreasing interference

- A typical (midscale) spectrum analyzer could behave in its core parameters similarly to PMSE receivers of category B/C (EN 300 422). So one might get a preliminary impression of the interference in the frequency band under observation. Note: Sometimes a very expensive spectrum analyzer can show clean spectrum, however, the question is if this truly represents the real situation for audio PMSE.

- Spectrum analyzers mainly have no input filters – they are an open window to spectrum and also produce self-sourced interference. Therefore, in our setup input filters were added for the L-Band and Air band scans.
The possible effect of RF filters

Amplifier and Filter Combination for Air Band Scans

(+)
Filter significantly reduces out-of-band interference

(-)
No selectivity for IMT signals close below 960 MHz
Sometime the scenario is hard

The scans in United Kingdom presented here, sometimes have interference from adjacent IMT operation (below 960 MHz).

Therefore the addition of Notch-Filter was discussed.
Limitation in RF filtering

(+): This filter reduces the interferer in a 2 MHz band by >6 dB.

(+): No effect above 960MHz

(-): Some might not like several of these heavy filters (each >10 kg) in the car.
The closer the interferer in the adjacent spectrum gets to the scanning area, the more difficult will be an effective filter solution.

Alternatively, the affected data-sets could be removed.

In UKs Air band we recorded in the more than 37 thousand scan files. Less than 400 files were affected by strong intermodulation. Therefore, the affected datasets were removed manually.

-> This was a time-consuming job.
Get further information..

..and see many results of scans in several bands in today’s presentation by Alan March..

“The Suitability of Fixed Service, Aircraft and Satellite Spectrum to Share with PMSE”
Last but not least

Sometimes our spectrum records contain interesting scenarios that might improve our practically experience;

See on next page typical examples.
Identification of special scenarios

**Air band radar operated in the L-Band**

In some regions Air-Band Radar Systems are operated, in the L-Band below 1350 MHz. See a typical example:
Sometimes the spectrum recording shows untypical interference scenarios. Sometimes, “broken hardware” could be identified after analysis of recorded RF spectrum:
Summary

• Spectrum recording during live events is a particular challenge which can be overcome only through intensive collaboration with the event organizers and/or producers and/or building owners.

• Mobile scanning is a special challenge with regards to technical details and costs.

• Our aim is still to provide information in the greatest possible detail for further use e.g. in the context of standardization and regulation.

• To this end, the DKE WG 731.0.8 has developed a specialized methodology and associated software.
Where is the DKE data taken into account?

Technical bodies, such as the CEPT or ITU-R, take into consideration and evaluate DKE measurement results and frequently publish them within their own documents.

In addition, APWPT publishes an array of technical documents and DKE reports:

http://www.apwpt.org/technical-papers