CEPT ECC
Electronic Communications Committee

ECC Recommendation (19)02

Guidance and methodologies when considering typical unwanted emissions in sharing/compatibility studies

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INTRODUCTION

The demand for spectrum is continuing to grow from both existing and new services and applications. ECC is constantly looking at how to enable more efficient use of spectrum, and to this end conducts sharing and compatibility studies to determine the risk of interference between systems operating in different frequency ranges.

Sharing and compatibility studies consider many different parameters and assumptions that directly impact the accuracy of the studies. These assumptions - with respect to both the interfering transmitters and victim receivers - need to be chosen carefully so that realistic results are achieved that both protect victims and do not over or under estimate probabilities of interference.

Better alignment between the assumptions for unwanted emissions and actual emissions is one of the areas where in some cases there could be improvements in future studies to enable better access to spectrum.

According to the ITU Radio Regulations [3], unwanted emissions consist of spurious emissions and out-of-band emissions[1].

ECC Report 249 *"Unwanted emissions of common radio systems measurements and use in sharing/compatibility studies"* [1] contains a number of measurements on samples of some real equipment types. In most cases the emissions measured in ECC Report 249 were significantly lower than the limits in standards by a margin of several tens of dBs in the spurious domain, except for the harmonic frequencies. The findings of ECC Report 249 have an important implication for the related sharing and compatibility studies which have previously been based on limits set out in standards/regulation, which may not lead to the most accurate outcomes.

This ECC Recommendation gives guidance and methodologies for CEPT/ECC groups on the consideration of unwanted emissions in sharing and compatibility studies.

[1] Out-of-band emissions are on a frequency or frequencies immediately outside the necessary bandwidth which results from the modulation process, but excluding spurious emissions. Spurious emissions are on a frequency or frequencies which are outside the necessary bandwidth and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products, but exclude out-of-band emissions.

ECC RECOMMENDATION (19)02 OF 29 MAY 2019 ON GUIDANCE AND METHODOLOGIES WHEN CONSIDERING TYPICAL UNWANTED EMISSIONS IN SHARING/COMPATIBILITY STUDIES

"The European Conference of Postal and Telecommunications Administrations,

considering

a) that radio spectrum is becoming an increasingly congested resource making it difficult to accommodate new radio applications;

b) that using 'worst case' assumptions based on conformance limits for unwanted emissions in sharing/compatibility studies can lead to less efficient use of spectrum;

c) that the term 'typical unwanted emissions' means the actual unwanted emission level(s) that are representative of equipment deployed in the field;

d) that the outcomes of ECC Report 249 [1] show that some typical unwanted emissions are lower or better than the conformance limits.

e) that typical unwanted emissions are lower than the conformance limits because manufacturers need to ensure that the limits are met for all possible equipment configurations of hardware, software and under a range of operational and environmental conditions. Manufacturers also include margins in their designs for production variations to ensure compliance with the limit;

f) that measurements of unwanted emissions of typical equipment may not represent all types of equipment in different conditions;

g) that in addition to unwanted emissions, other factors such as deployment scenarios, propagation models, aggregate effects and receiver performance can have an impact on sharing/compatibility studies and need to be considered to ensure that compatibility can be achieved;

recommends

1. that CEPT/ECC groups consider this ECC Recommendation when conducting sharing/compatibility studies;

2. that assumptions of unwanted emissions levels used in sharing and compatibility studies should in the first case be based on conformance limits defined in EC/ECC Recommendations/Decisions and ETSI Harmonised Standards if available, and complemented as appropriate with relevant information from ITU-R Recommendations, other ECC deliverables, other ITU-R deliverables, ETSI Technical Reports (including SRDoc) or ETSI Technical Specifications;

3. that if a co-existence issue due to unwanted emissions is indicated on the basis of recommends 2, sharing/compatibility studies could be undertaken on a case by case basis between specific types of radio communication equipment if required, considering results from existing measurement campaigns' reports and/or manufacturer data on unwanted emissions when available and representative;

4. that if co-existence cannot be demonstrated on the basis of assumptions from deliverables (see recommends 2), and in the absence of existing data (see recommends 3) a measurement campaign should be undertaken, if possible, on a case-by-case basis in order to further quantify the risk of interference due to unwanted emissions from specific type of equipment;

5. that measurements should take into account a sufficient number of typical devices and testing conditions as far as possible in order to capture the most relevant usage scenarios;

6. that sharing/compatibility studies should consider relevant mitigation techniques, if any, with respect to unwanted emissions;

7. that sharing and compatibility studies could include a sensitivity analysis to determine the impact of variation of unwanted emissions, as well as the impact of relevant mitigation techniques, for example according to the guidance outlined in Annex 4;

8. that points 1 to 7 above should be implemented according to the method outlined in Annex 1 and the information in Annexes 2, 3 and 4 should also be considered.

Note: Please check the Office documentation database https://www.ecodocdb.dk for the up to date position on the implementation of this and other ECC Recommendations.

ANNEX 1: METHOD FOR SHARING AND COMPATIBILITY STUDIES USING TYPICAL UNWANTED EMISSIONS

A1.1 FLOW CHART

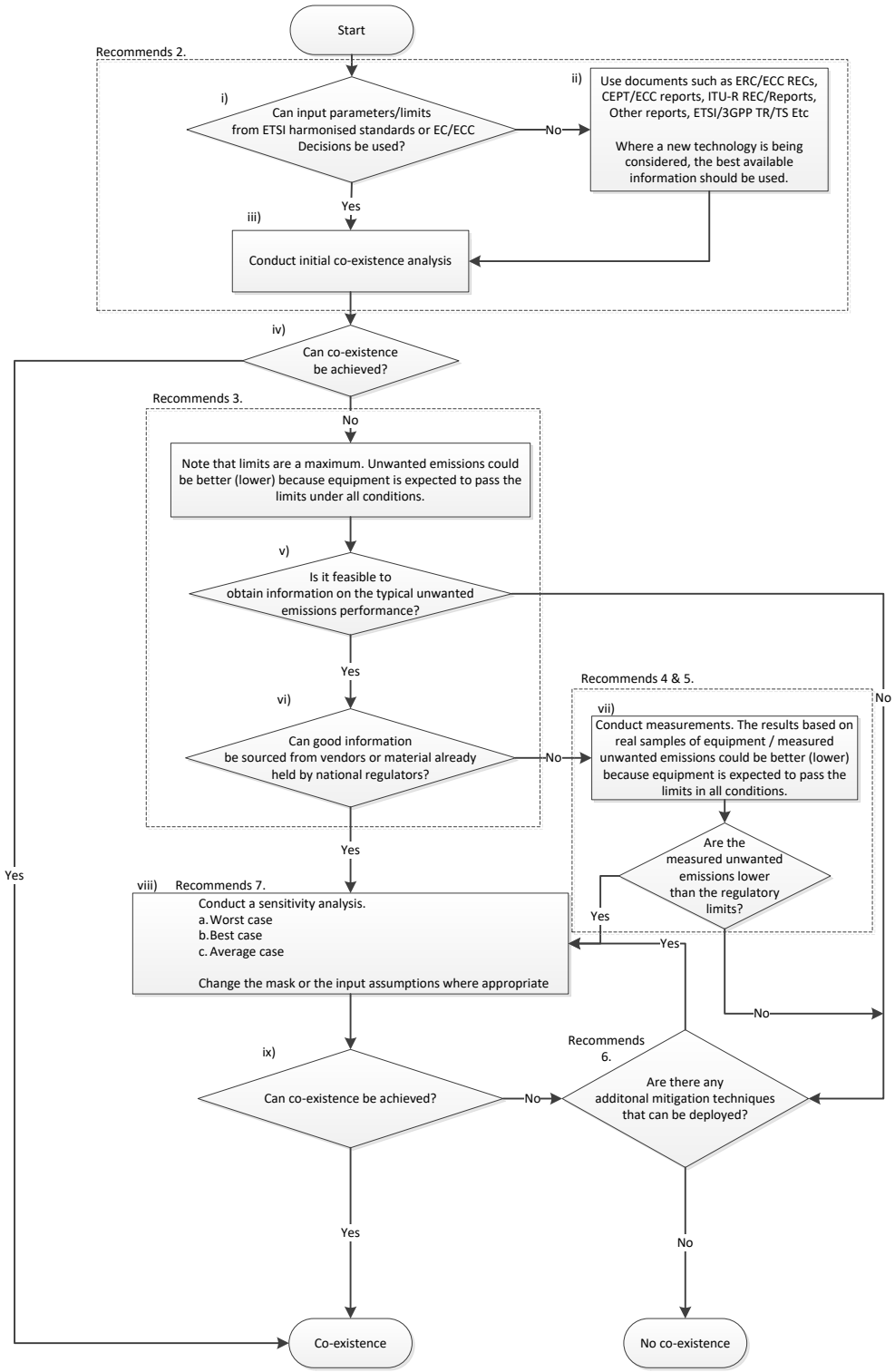

Figure 1: Recommended method for conducting sharing/compatibility analysis

A1.2 EXPLANATORY TEXT TO ACCOMPANY THE FLOW CHART

i) "Can input parameters/limits from ETSI Harmonised Standards or EC/ECC Decisions be used?"

The normal starting point for most sharing and compatibility studies is to source input parameters from existing documentation that specifies the characteristics of the radio equipment. Regarding unwanted emissions levels, for the initial analysis parameters should be based on the limits derived from:

1. EC Harmonisation Decisions or Regulations;
2. ECC Decisions;
3. ECC/ERC Recommendations;
4. Relevant ETSI Harmonised Standards, published by ETSI[2] and listed in the Official Journal of the European Union[3] and/or;
5. Other ECC, ITU-R, ETSI deliverables.

Using the limits from these documents can be considered as a preliminary assumption where actual unwanted emissions will be below these limits.

It is noted that as part of this step there should also be an investigation of all relevant assumptions which will be part of the overall study e.g. deployment, frequency separation, propagation model, receiver parameters.

In Europe, Directive 2014/53/EU (Radio Equipment Directive - RED) [2] requires that radio equipment makes effective and efficient use of radio spectrum. One method[4] to conform with the RED for those placing products (typically manufacturers) on the market within the European Economic Area is to apply a relevant ETSI Harmonised Standard. These are 'EN' standards, listed in the Official Journal of the European Union[5], and that give a presumption of conformity to the essential requirements of the RED.

The limits laid down in ETSI Harmonised Standards, therefore, set a benchmark for equipment performance. The level of unwanted emissions from the real radio equipment must be below the limits. Typically, manufacturers will design and manufacture products with some margin so that the unwanted emissions from their products easily meet the limits. Manufacturers applying limits in standards account for operation across the full output power range, different sets of physical channels and allocations, possible operation with different systems, and operation in varying environmental conditions, including temperature, vibration, pressure etc. Manufacturers also include margin in their design for production variations to ensure compliance with the limit. Unwanted emission limits are normally defined as a straight line vs frequency in ETSI Harmonised Standards whereas, in reality, unwanted emissions are composed of spectral regrowth from active circuitry, spurious products (spikes) and harmonics. There may be improvements in unwanted emissions due to improvements in design and technology.

For co-existence and sharing studies involving deployed systems, the typical or actual, performance of equipment is more relevant to determine if compatibility can be achieved and if harmful interference will occur. The purpose of limits set in ETSI Harmonised Standards for article 3.2 of the RED is to ensure that radio equipment is so constructed "that it both effectively uses and supports the efficient use of radio spectrum in order to avoid harmful interference". If the equipment fulfils all requirements of the RED, it can be placed on the market. This is not necessarily the same purpose as that behind sharing and compatibility studies carried out by CEPT. Consequently, using typical equipment performance may result in improved and more accurate studies, and consequently more efficient use of the spectrum.

Special attention should however be given to the fact that typical unwanted emission levels may not be representative of all deployed systems and equipment, and that such typical levels might be representative of some but not all operating conditions or configurations.

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[3] https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/red_en
[4] The RED provides other methods of demonstrating conformity such as using a notified body.
[5] https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/red_en

ii) "Use documents such as ERC/ECC Recs, CEPT/ECC Reports, ITU-R Rec/Reports, other reports, ETSI/3GPP TR/TS etc."

In certain cases, where new technologies are being studied, documentation and information on unwanted emission limits may not yet be available as equipment could still be under development or in a prototype phase. In such cases, information on the assumed equipment performance could be requested from the relevant ECC working groups, project teams or task groups.

iii) "Conduct initial co-existence analysis"

The limits derived from the documents in the list above should be used to conduct an initial analysis though using the limits from these documents would typically be taking worst-case assumptions.

iv) "Can co-existence be achieved?"

Where this initial analysis based on limits from relevant deliverables indicates that co-existence may not be achieved with respect to unwanted emissions, a more in-depth investigation could be undertaken, depending on the type of services studied.

v) "Is it feasible to obtain information on the typical unwanted emissions performance?"

A more in-depth analysis, to better characterise typical unwanted emissions of equipment, would enable more accurate sharing and compatibility studies. Information already held by vendors, regulators or from actual measurements of real equipment can be taken into account.

vi) "Can good information be sourced from vendors or material already held by national regulators?"

See Annex A3.1.

vii) "Conduct measurements. The results based on real samples of equipment/measured unwanted emissions could be better (lower) because the equipment is expected to pass the limits in all conditions."

Typically, the level of unwanted emissions from real equipment will be below the conformance limits given in ETSI standards. Where suitable information on performance of real equipment is not available, a measurement campaign could be performed if possible to characterise typical unwanted emissions and to quantify the risk of harmful interference to radiocommunication services.

A sufficient number of different devices should be tested, considering:

- Deployment scenarios (e.g. density/volume of devices, loading and output power);
- Typical environmental conditions;
- Expected device categories within a given deployment scenario;
- Brands for each device category;
- Models within the brands;
- Market share of the different models.
- Sufficient number of similar devices for each model to obtain statistical certainty.

It should also be ensured that relevant operating modes of the equipment are tested.

See also Annex A3.2.

viii) "Conduct a sensitivity analysis"

If a typical unwanted emission performance is determined from measurements, this could be applied to the study as an alternative set of assumptions and the analysis re-run. The new results can then be compared with the initial results as a sensitivity analysis in the study.

See Annex 4 for more detailed information.

ix) Can co-existence be achieved?

After the co-existence study is completed, results can be taken into account in defining relevant regulatory technical conditions, including any identified mitigations.

ANNEX 2: UNWANTED EMISSIONS IN THE OUT OF BAND AND SPURIOUS DOMAIN CONSIDERATIONS

ECC Report 249 *"Unwanted emissions of common radio systems measurements and use in sharing/compatibility studies"* [1] observed that the measured unwanted emissions of a limited sample of some real equipment types are lower than the limits. This was particularly true for unwanted emissions in the spurious domain.

In many cases the unwanted emissions measured in the report were, except for those due to harmonic frequencies, significantly lower with a margin of several tens of dBs in the spurious domain. Sharing and compatibility studies based on the assumption that equipment would only just meet the spurious domain limits set out in standards may not lead to the most accurate outcomes.

In particular, ECC Report 249 highlighted how actual systems' spurious emissions can be several tens of dBs better than the conformance limits and so studies should consider sets of parameters based on typical performance of the equipment in a statistical manner. For example, assumptions made for emissions in the spurious domain can particularly affect the results of studies, especially if the victim is broadband (>1 MHz). The assumptions chosen can often alter the apparent interfering power by factors of one thousand, and in studies where aggregate emissions from the spurious domain dominate these can skew the study results.

Typically, most sharing and compatibility studies consider frequency bands directly adjacent in frequency to the band of the victim service. ECC Report 249 observed that in such cases unwanted emissions were more predictable than in the case of greater frequency separations, where spikes or harmonics can occur which are less predictable in frequency and amplitude. Some services are also more sensitive to uncorrelated wideband noise than to narrowband interferers.

ANNEX 3: CHARACTERISATION OF TYPICAL UNWANTED EMISSIONS OF EQUIPMENT

When ECC working groups, project teams or task groups have carried out the initial co-existence analysis and have determined that a more in-depth analysis is required, typical unwanted emissions will need to be defined. There are two suggested methods to better characterise and define the unwanted emissions of the equipment:

1 Use pre-existing information sourced from vendors or regulators;

2 Conduct measurements, where pre-existing information is not available.

A3.1 SOURCING INFORMATION FROM VENDORS OR MATERIAL ALREADY HELD BY ADMINISTRATIONS

Information on the typical unwanted emission performance may be available from vendors or could be held by Administrations. Where this information is available, it can be used to define the typical unwanted emissions of equipment and the assumptions in the sharing and compatibility study regarding unwanted emissions. When using this information, ECC working groups, project teams and task groups should use their expert judgement on the quality of the information. What qualifies as good information needs to be judged on a case-by-case basis. Some considerations could include:

- Is the information from a single vendor or multiple vendors?
- Is the information representative of the typical performance of unwanted emissions of products that are expected to be deployed in the band?
- Is the information based on measurement data, estimations, a mask or a theoretical model?
- Is there adequate transparency as to how the information has been obtained?
- How does the information compare with the limits defined in ETSI Harmonised Standards or EC/ECC Decisions?

A3.2 CONDUCTING A SERIES OF MEASUREMENTS BASED ON REAL SAMPLES OF EQUIPMENT

A series of measurements on real equipment would help to characterise and define the typical unwanted emissions for use in sharing and compatibility studies. Measurements are likely to give the best characterisation of unwanted emissions leading to the most representative sharing studies. Each series of measurements will need to be done on a case-by-case basis relevant to the study. ECC working groups, project teams and task groups will need to use their own expert judgement on the best way to proceed. Some suggested factors to take into account are:

- The number of equipment samples to measure; it could be preferable to look at products from different vendors representative for the market share and from the range of products that could be used in the band in several scenarios. However, there is no definitive guidance on this, nor is there any minimum number; this is for the judgement of the ECC working parties and project teams but needs to be statistically significant and documented;
- The conditions or usage scenarios that the equipment is tested under;
- Environmental conditions and production variation as appropriate.

When investigating new technologies, it may not be possible to obtain production units for measurement. In such cases, it may be possible to perform a set of measurements to better characterise the possible level of unwanted emissions as follows:

- Measure prototypes and make a judgment on how the measurements could be representative of a production product;

- Measure products or individual components of products that may provide a good representation of the likely production product.

As there will be more uncertainty in this type of approach, a sensitivity analysis could be needed.

A3.2.1 Measurement process and setup

This section provides typical setups for the measurement of unwanted emissions in the out-of-band and spurious domains. The setup to use depends on the required dynamic range of the result and on whether the emission is pulsed or continuous. The provided setup can be used in defining the typical unwanted emission performance of equipment for sharing studies. Measurements will need to be performed on a case-by-case basis and specific to the study. Consequently, ECC groups could use alternative setups.

The following setups are based on Annex 1 of ECC Report 249 [1] and were used to carry out the measurements presented in that report.

For conducted measurements of transmitters not requiring a return path, the signal can be derived directly from the transmitter output, after suitable attenuation (dummy load) or from a measurement output (if provided). In case external output filtering is applied, the measurement point can be after the filter.

For conducted measurements of transmitters requiring a return path and not having a measurement output, the signal can be taken from the output of a directional coupler that is inserted into the transmit path. A major disadvantage of this method is that the signal to be measured is attenuated by the directional coupler (typically 20 dB) which limits the detection level of unwanted emissions especially for devices with very low power. Some systems allow access to the transmit line before the Rx/Tx splitter which is then the preferred measurement point.

For transmitters that do not have an antenna port, measurements of the radiated signal are required, preferably in an anechoic chamber or G-TEM cell with known RF properties. Care should be taken regarding the design frequency range of the antenna noting that it may be subject to changes in antenna pattern - both gain and lobe structures.

For radiated measurements of bigger transmitters where a passive antenna is used, the signal is taken from a measurement antenna. The most critical issue in this measurement is to gather as much RF energy as possible. Moreover, the frequency range of interest should be free of emissions from other transmitters. Both issues can be addressed by using an antenna with high directivity (and therefore high gain) pointing directly at the transmit antenna and at the shortest distance possible.

A3.2.1.1 Setup Type 1

If the required dynamic range is less than the difference between the maximum level that the measurement receiver can handle without being overloaded and its own noise level, the following simple setup, as shown in Figure 2, can be used for continuous signals:

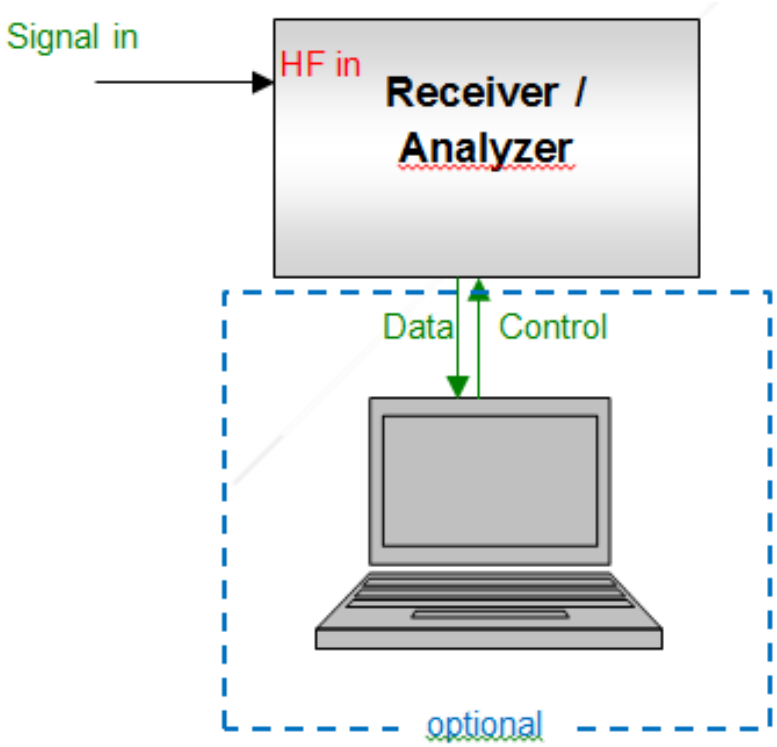

Figure 2: Principle measurement setup Type 1

A3.2.1.2 Setup Type 2

This setup illustrated in Figure 3 can be used for continuous signals when the required dynamic range of the result exceeds the capabilities of the measurement receiver/analyser.

To enhance the dynamic range of the measurement receiver/analyser, the wanted signal has to be suppressed by a (tuneable) filter. First, the filtered spectrum on the wanted channel/frequency as well as in the out-of-band (OoB) or spurious domain is measured and recorded. In a second measurement, using the same receiver/analyser settings, the attenuation (frequency response) of the filter is measured and recorded. Then, both curves are added to obtain the original spectrum of the signal.

Depending on the application, frequency and bandwidth of the signal under test, a band pass filter or a band stop filter may be used. For spurious emissions, a band stop filter tuned to the wanted frequency is preferred as it allows measuring the whole spurious range at once. For out-of-band measurements, band pass filters tuned to the frequency range of the out-of-band domain to be measured could also be used.

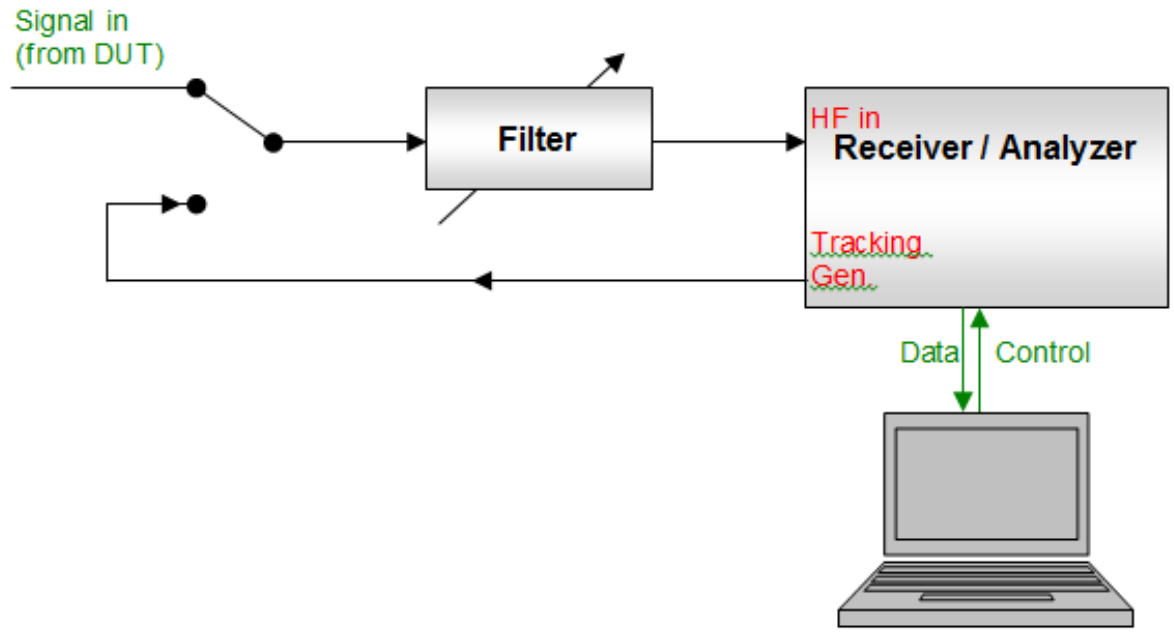

Figure 3: Principle measurement setup Type 2

A3.2.1.3 Setup Type 3

For Time Division Multiple Access (TDMA) systems that transmit in bursts, the limits usually apply to the times where the transmitter is on. Unless the peak level is specifically mentioned in the relevant recommendation or standard, the average burst level has to be measured which is the root mean square (RMS) level during the burst only. This is done by externally triggering the measurement receiver to the burst start and adjusting the measurement time to match the burst length. The trigger can be derived from a second spectrum analyser, operated in zero span mode and tuned to the wanted frequency, as shown in Figure 4.

The measurement process is identical to the setup Type 2.

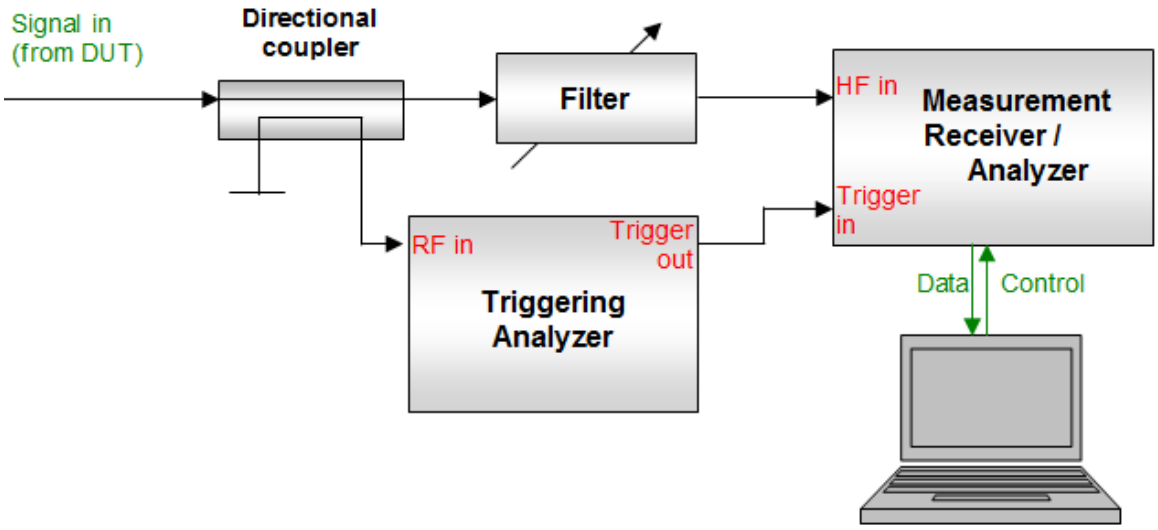

Figure 4: Setup Type 3 for measurements of TDMA systems

A3.2.1.4 Data processing

The measurement bandwidth is always chosen to be equal to, or smaller than, the reference bandwidth stated in the relevant recommendation or standard. In particular in the vicinity of peak spurious emissions and in the Out-of-band (OoB) domain close to the wanted frequency, where it is necessary to use a narrow measurement bandwidth as otherwise the measured spectrum would be unduly widened, leading to an overestimation of the unwanted level.

The signal levels (or spectral densities) taken in the selected measurement bandwidth are linearly converted to the corresponding levels or power densities in the reference bandwidths using the formula:

$$P_{refBW} = P_{measBW} + 10 * \log_{10}(\frac{refBW}{measBW})$$

With:

- P_{refBW} = power level in reference bandwidth;
- P_{measBW} = power level in measurement bandwidth;
- *refBW* = reference bandwidth;
- *measBW* = measurement bandwidth.

ANNEX 4: SENSITIVITY ANALYSIS - APPLYING TYPICAL UNWANTED EMISSIONS TO SHARING AND COMPATIBLITY STUDIES

Each sensitivity analysis regarding unwanted emissions would be on a bespoke, case-by-case basis and would depend on how typical 'unwanted emissions' of equipment were defined and applied in the study. It would require the judgement of the ECC working groups, project teams and task groups as to how the sensitivity analysis is carried out. Factors to consider:

- **Where the worst case unwanted emissions levels are used:** This could be, for example, where the level of unwanted emissions used in the analysis is based on the worst performing device either from measurements or other documentation. This is likely to lead to the most conservative results and most pessimistic outcome.
- **Where the best case unwanted emission levels are used:** For example, if the level of unwanted emissions used in the analysis is based on the lowest levels of unwanted emissions from devices, this is likely to lead to optimistic results.
- **Where the average case or a statistical distribution of unwanted emission levels are used:** This, for example, could be where there is a distribution in the level of unwanted emissions from devices, and either an average or the full distribution has been used in the analysis. In this case, an additional sensitivity analysis could consider varying the average level, and then re-running the analysis to see what the impact on results is.

It is noted that it may be desirable to vary different input assumptions in relation to unwanted emissions to check the sensitivity of the results. It is also noted that this may be part of a broader sensitivity analysis aimed at looking at other parameters in the study not directly related to unwanted emissions.

There could be some additional factors that ECC groups may wish to consider in the sensitivity analysis regarding spurious emissions. These could be:

1. The interfering system might be operating over different bandwidths where other (wider or narrower) bandwidths might be available currently or will be in the future.

2. Likelihood and impact of a discrete spurious emissions and harmonics, considerations could include:

   a) Whether it is likely to fall within the bandwidth of the victim receiver? If there is any time/device to device variation that needs to be considered?

   b) What is the discrete spurious emission bandwidth compared with the receiver bandwidth, what sort of bandwidth adjustment should be applied?

   c) How does the receiver behave to a discrete spurious emission?

   d) If the levels of unwanted emissions in the spurious domain are based on conducted levels, what impact may arise from the antenna used and its directivity?

3. Dependence on assumptions for spurious emissions:

   a) Are spurious emissions from the equipment actually dominant in the interference scenario? For example, the results of the studies could be compared with the transmitter being active and inactive where the spurious emissions switched 'on' then 'off' (i.e. the interferers transmission masks be set to an arbitrarily low value, e.g. to -200 dB, beyond the OoB domain). Markedly differing results should be treated with caution.

4. For AAS type systems, the time varying spatial filtering property of the system and its impact could be considered.

Caution has to be taken when conducting a sensitivity analysis of unwanted emissions where others parameters are not well defined (e.g. deployment and propagation models). Unwanted emissions are just one of many parameters in sharing and compatibility studies (i.e. receiver blocking). While it may seem that

there is a margin in regard to unwanted emissions alone, variation of the other parameters may mean that there is no margin in the overall sharing and compatibility scenario, and interference could occur.

There are some general examples of ECC Reports that performed sensitivity analyses, including unwanted emissions with different approach as in Annex 1. These Reports are:

- ECC Report 174: “Compatibility between the mobile service in the band 2500-2690 MHz and the radiodetermination service in the band 2700-2900 MHz” [4];
- ECC Report 239: “Compatibility and sharing studies for BB PPDR systems operating in the 700 MHz range” [5];
- ECC Report 271: “Compatibility and sharing studies related to NGSO satellite systems operating in the FSS bands 10.7-12.75 GHz (space-to-Earth) and 14-14.5 GHz (Earth-to-space)” [6];
- ECC Report 283: “Compatibility and sharing studies related to the introduction of broadband and narrowband systems in the bands 410-430 MHz and 450-470 MHz [7].

ANNEX 5: LIST OF REFERENCES

This annex contains the list of relevant reference documents.

[1] ECC Report 249: “Unwanted emissions of common radio systems: measurements and use in sharing/compatibility studies”, April 2016
[2] Directive 2014/53/EU of the European Parliament and of the Council of 16 April 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC (Radio Equipment Directive)
[3] ITU Radio Regulations, Edition of 2016
[4] ECC Report 174 : “Compatibility between the mobile service in the band 2500-2690 MHz and the radiodetermination service in the band 2700-2900 MHz”, April 2012
[5] ECC Report 239: “Compatibility and sharing studies for BB PPDR systems operating in the 700 MHz range”, September 2015
[6] ECC Report 271: “Compatibility and sharing studies related to NGSO satellite systems operating in the FSS bands 10.7-12.75 GHz (space-to-Earth) and 14-14.5 GHz (Earth-to-space)”, January 2018
[7] ECC Report 283: “Compatibility and sharing studies related to the introduction of broadband and narrowband systems in the bands 410-430 MHz and 450-470 MHz, September 2018