



ECC Recommendation

(11)06

Block Edge Mask Compliance Measurements for Base Stations

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INTRODUCTION

Block Edge Masks (BEM) are being developed as a new regulatory approach for the definition of a set of “common and minimal (least restrictive) technical conditions” optimised for, but not limited to, fixed/mobile communications networks. In this regulatory approach BEMs have been set into effect in order to provide a certain level of protection for wireless systems in adjacent frequency blocks and to reduce the necessity for coordination between the operators.

BEMs are not intended to replace or relax limits set in dedicated equipment standards, e.g. limits for spurious emissions. Those measurements are not in the scope of this document.

The purpose of this Recommendation is to provide a common measurement method which will enable CEPT administrations to verify BEM compliance in the field.

ECC RECOMMENDATION OF OCTOBER 2011 ON BLOCK EDGE MASK COMPLIANCE MEASUREMENTS FOR BASE STATIONS

“The European Conference of Postal and Telecommunications Administrations,

considering

- a) that Block Edge Masks (BEM) are being developed as a new regulatory approach for the definition of a set of common and least restrictive technical conditions;
- b) that in this approach a number of contiguous frequency blocks are assigned to network operators with usually no guard bands in between;
- c) that in this approach it is up to the license holder to decide on the size of any internal guard band inside their block, if needed;
- d) that Block Edge Masks have been set into effect in order to provide a certain level of protection for wireless systems in adjacent frequency blocks and to reduce the necessity for coordination between the operators;
- e) that BEMs are not intended to replace or relax limits set in dedicated equipment standards, e.g. limits for spurious emissions;
- f) that this Recommendation is not intended to replace any conformity assessment procedures;
- g) that additional specific methods can be added to the Annexes to this Recommendation.

recommends

1. that the measurement principles described in Annex 1 should be used for the assessment of compliance with the provisions of all BEMs;
2. that the specific methods described in subsequent Annexes should be used for the assessment of compliance with the provisions of BEMs when applicable.”

ANNEX 1: GENERAL CONSIDERATIONS FOR THE ASSESSMENT OF BLOCK EDGE MASKS

A1.1 INTRODUCTION

Block Edge Masks (BEM) are being developed as a new regulatory approach for the definition of a set of “common and minimal (least restrictive) technical conditions” optimised for, but not limited to, fixed/mobile communications networks. In this approach a number of contiguous frequency blocks are assigned to network operators, with usually no external guard bands in between. No decision is made by the regulatory body on which technology has to be used for the service, which channel bandwidths to be used, and so on. It is even up to the license holder to decide on the size of an optional internal guard band, if needed. This way the maximum freedom is granted the license holder to decide on how to make the best use of the spectrum.

In this regulatory approach Block Edge Masks have been set into effect in order to provide a certain level of protection for wireless systems in adjacent frequency blocks and to reduce the effort for coordination between the operators. BEMs are not intended to replace or relax limits set in dedicated equipment standards, e.g. limits for spurious emissions. Those measurements are not in the scope of this document.

A1.2 TERMS AND DEFINITIONS / LIST OF ABBREVIATIONS

Abbreviation Explanation

| | |
|---------------|---|
| WAPECS | <u>W</u> ireless <u>A</u> ccess <u>P</u> olicy for <u>E</u> lectronic <u>C</u> ommunication <u>S</u> ervices |
| EIRP | The <u>E</u> quivalent <u>I</u> sotropically <u>R</u> adiated <u>P</u> ower of an antenna is the product of the antenna input power and the antenna gain, referenced to an isotropically radiating antenna, which does exist in theory only |
| TRP | The <u>T</u> otal <u>R</u> adiated <u>P</u> ower is used for defining the power limits of terminal stations. TRP is a measure of how much power the antenna actually radiates. The TRP is defined as the integral of the power transmitted in all directions over the entire radiation sphere. For a lossless isotropic antenna EIRP and TRP are equivalent. For a directional antenna EIRP in the direction of the main beam is (by definition) greater than the TRP |
| PAPR | The <u>P</u> eak-to- <u>A</u> verage power <u>r</u> atio of a transmitter is the ratio of the peak value of the output power to its time-averaged value. In some literature this is also referred to as the crest factor |
| RBW | In swept analysers the <u>r</u> esolution <u>b</u> andwidth is the bandwidth of the measurement filter, usually referenced to the 3 dB points, which is used to sweep across the selected frequency range and to measure the signal power which passes the filter. In FFT analysers the RBW determines the FFT bin size or the smallest frequency step that can be resolved |
| OoB | In this document this abbreviation is used for the <u>O</u> ut-of- <u>B</u> lock signal power of a transmitter, i.e. the power density present outside the frequency block assigned to the network operator. It may not be mixed up with the out-of-band power of a transmitter, which describes the output power density outside the necessary bandwidth of an individual transmitter. The frequency range of an out-of-block measurement does not depend on the actual transmit frequency, but only on the edge frequencies of the assigned frequency block |
| DANL | The <u>D</u> isplayed <u>A</u> verage <u>N</u> oise <u>L</u> evel of an analyser is the level of noise which the analyser will display with its input terminated and depends on the thermal noise of all components involved in the signal processing chain of the analyser. It is the absolute minimum signal power which can be measured under specific ideal conditions. The DANL is usually stated for a 1 Hz bandwidth, no input attenuation, active pre-amplifier and maximum amplification in the signal processing chain |
| OMC | The <u>O</u> perations and <u>M</u> aintenance <u>C</u> entre is the central location of a network operator where all important parameters of a network are supervised. |

A1.3 BLOCK EDGE MASKS DEVELOPED IN CEPT DOCUMENTATION

BEMs were developed for the WAPECS bands, e.g. 790-862 MHz [4], 2500-2690 MHz [3] [5] and 3400-3800 MHz [1] [3]. The BEM consists of in-block and out-of-block (OoB) limits depending on frequency offset. The out-of-block component of the BEM consists of a baseline limit as well as transitional (or intermediate) limits, to be applied, where applicable, at the frequency boundary of an individual licensed spectrum block. These limits were derived using studies of appropriate compatibility and sharing scenarios between fixed/mobile communication networks and other applications in adjacent bands but in the same geographical area.

Base station:

The limits are expressed in EIRP or transmitter output power density. The assumed typical values for the antenna gain are 15 dBi for the 800 MHz range and 17 dBi for 2 GHz and 2.6 GHz bands. The in-block limit for FDD is suggested to be in the range up to 56-64 dBm/5MHz (EIRP). For unsynchronized TDD networks or at the transition to the FDD range, a 'restricted TDD block' may be required with significantly smaller in-block power.

Terminal station:

The terminal station may be a mobile, nomadic or fixed station. The power limits are specified as EIRP for fixed terminal stations and as TRP for mobile or nomadic terminal stations, e.g. handhelds. Note that there may be no BEM defined for terminal stations at all, or the limits may refer to the actual channel edge rather than the block edge.

A1.4 MEASUREMENT PRINCIPLE

Basically measuring compliance of a transmitter to a given block edge mask can be compared to measuring a transmitter spectrum mask. The difference is that the transmitter may be actually operating on any system channel within the assigned frequency block. Usually it can be assumed, that the most critical case is a transmitter operating on the lowest or highest system channel within its block. The block edge mask applies to both edges of the assigned frequency block. As usually both edges cannot be measured the same time, in most cases two measurements are necessary.

For the assessment a standard spectrum analyser may be used setting centre frequency and span in such a way, that the relevant frequency span covered by the block edge mask is displayed. The actual transmitter frequency is not relevant here. Usually the RBW is set according to the transmitter's system bandwidth, observing relevant standards, e.g. ETSI EN 302 326-2 [2].

A1.4.1 Reference Level and dynamic range

The assessment of block edge masks usually requires a high dynamic range and high sensitivity. Sensitivity may be increased by (manually) switching off any input attenuator and switching on a preamplifier (internal or external). However, it is very important to avoid any overloading of the analyser, observing especially bandwidth and PAPR of the signal under test (for details see section A1.5).

A1.4.2 Increasing dynamic range

The usable dynamic range of most modern spectrum analysers is limited to about 70 dB. Often higher dynamic ranges are stated for very small RBWs as a result of increased sensitivity with small filters. But this is true only for discrete spectral components. Most digital techniques (e.g. all QAM derivatives) will produce a noise-like continuous spectrum resulting in the above mentioned limited dynamic range.

Most block edge masks require a dynamic range of about 100 dB or more. To increase the dynamic range of the spectrum analyser the in-band-transmission of the transmitter under test has to be attenuated. This may be done using a bandpass-filter tuned to the adjacent frequency block or using a bandstop-filter tuned to the actual transmitter in-band signal. The achieved gain in dynamic range depends on stopband attenuation and sharpness of the used filter. The bandwidth of the filter has to be matched to the relevant adjacent block frequency range of the mask or the bandwidth of the in-band signal, respectively.

The received signal is passed through the filter. As the in-block signal is being attenuated the reference level and input attenuation of the analyser can be decreased, thus improving sensitivity and overall dynamic range. Using the input attenuator the transmitter's signal is levelled in such a way, that the total input power doesn't overload the analyser and at the same time the displayed signal level stays well above the DANL for all relevant frequencies.

The filtered spectrum is measured and stored in numerical format (e.g. csv format) for post-processing.

In a second step the input signal is being disconnected. A tracking generator is being connected to the filter input. Using a suitable generator level the amplitude response of the filter is measured and again stored for post-processing.

In a third step the analyser input is terminated and DANL is measured and stored.

In post-processing the measured spectrum is corrected by the frequency dependent filter attenuation and plotted along with the block edge mask. Eventually the block edge mask has to be renormalized to the used RBW. The system's sensitivity may be plotted along with the result.

A1.4.3 Normalisation

The BEM may be defined either channelized for a certain channel bandwidth or contiguous with a certain reference bandwidth.

In case of a channelized BEM the assessment may be done using a receiver with a suitable channel filter bandwidth tuned and stepped to the relevant channels defined, or using an analyser set to a RBW chosen according to [2] and sweeping over the defined channel. The signal power for all spectral components has to be integrated over the channel; i.e. a channel power measurement, as available on most state of the art spectrum analysers. A re-normalization of the BEM is not necessary.

In case of a contiguous BEM the assessment is done using a conventional sweep over the relevant frequency range. However, the BEM may be referenced to a bandwidth not suitable for the measurement; e.g. too broad. In this case the RBW of the analyser is chosen according to [2].

Because of the noise-like spectral density distribution of nowadays digital modulation schemes the measured signal power is reduced according to $10 \cdot \log\left(\frac{BW_{Sig}}{RBW}\right)$; where BW_{Sig} = signal bandwidth and RBW = analysis bandwidth. Therefore the BEM has to be re-normalized as well according to

$$A_X^* = A_X - 10 \cdot \log\left(\frac{BW_{Ref}}{RBW}\right)$$

where

A_X^* = amplitude of re-normalized BEM at frequency point X

A_X = amplitude of original BEM at frequency point X

BW_{Ref} = reference bandwidth of the original BEM

RBW = analysis bandwidth.

Note: In the (unlikely) case a transmitter does produce discrete spectral components in its OoB domain, those discrete components may exceed the re-normalized BEM by a factor of

$$10 \cdot \left(\log\left(\frac{BW_{Ref}}{RBW}\right) - \log(N) \right);$$

where

N= number of discrete spectral lines present within a window of size BW_{Ref} .

A1.4.4 Absolute vs. relative defined masks

Block Edge Masks may be defined with absolute power or power density limits or alternatively with power limits relative to the transmitter in-block power. Those masks based on relative limits may be assessed using conducted or radiated measurements. However, the received signal-to-noise ratio has to be higher than the dynamic range introduced by the mask definition. This in turn requires the use of a high-gain antenna, highly sensitive analyser and preamplifier. Also the mobile measurement equipment, which is usually car-based, has to be placed in the direct vicinity of the transmitting antenna and within its main lobe. Although radiated measurements are often desirable, for practical reasons they may often not be possible. Some practical considerations are given in section A1.5.7.

The assessment of block edge masks with absolute power limits should be done using a conducted measurement directly at the transmitter output. Although a radiated measurement is possible in principle it's not recommended, as it will introduce a number of additional uncertainties (e.g. measurement distance). Especially in the case of a BEM based on transmitter output power or output power density for a radiated measurement the knowledge of certain parameters is necessary, which can be acquired only on-site; i.e. feeder loss and antenna gain.

A1.5 PRACTICAL CONSIDERATIONS

The realisation of the measurement principle as described in section A1.4 is relatively straightforward for those systems with non-bursted and constant output power for such block edge masks with constant reference bandwidth and when performing the measurement at the transmitter output. Those systems may be found mainly in broadcasting (unidirectional) radio systems. However, specific characteristics of many mobile communication systems will require special prerequisites, some of which will be detailed in the following sections.

For many systems several of the following aspects will have to be addressed in order to execute a trustworthy measurement. Therefore every block edge mask assessment has to be preceded by a detailed analysis of the signal characteristics of the radio system under test.

A1.5.1 Switchable input attenuator / preamplifier

As described in section A1.4.2 the input attenuator is needed to optimize the input signal level to the analyser's dynamic range. If the dynamic range of the analyser is only a few dB higher than the dynamic range given by the BEM the analyser's internal switchable attenuator may be too coarse (e.g. 10 dB steps). In this case an external switchable attenuator with smaller steps is required.

Especially when doing measurements via the air interface the available signal power may be too low to apply the necessary attenuation; the signal may drop below DANL on some frequencies. In this case a higher gain antenna and/or a low noise preamplifier may be needed. Special care has to be taken that the preamplifier is not being overloaded. This means the drive of the amplifier should stay well below its 1 dB compression point. A high intercept point is needed to avoid intermodulation.

A1.5.2 Bursted signals

Doing a conventional sweep over a bursted signal with RMS detector will result in false readings, as for every sweep point the RMS value is calculated from a number of *on burst* and *off burst* samples. So the reading will be too low depending on the (usually random) ratio of *ON* and *OFF* samples. To overcome this issue one has to make sure, that samples are only taken during active burst times. This can be accomplished using the gated sweep mode, available on most modern spectrum analysers.

In gated sweep mode samples are only taken when the detected input power is above a certain level. The RF detector is usually located directly behind the first filter stage of the analyser, thus isn't affected by the RBW. However, the bandwidth of the first filter often is only slightly broader than the widest RBW of the analyser. As block edge mask measurements may be commenced at a large offset from the actual signal's RF frequency, the trigger might not be fired.

On the other hand on analysers with a special (broad) filter for the RF detector the trigger might be fired erroneously by another transmitter nearby. In this case an external selective trigger source tuned to the transmitter's frequency is needed.

The trigger source might be a second analyser in zero span modes. The analyser is tuned to the actual centre frequency of the transmitter under test, choosing an appropriate RBW. The Sweep time is set according to the burst duration. The video trigger is used to stabilize the display and has to reliably trigger on the bursts only.

The trigger output is being fed to the trigger input of the measuring analyser and used as external trigger for the gated trigger mode. Now the block edge mask can be reliably assessed in the relevant frequency range as described in section A1.4.

A1.5.3 Signals with PAPR > 0 dB

Most wireless systems employ modulation schemes, which not only use phase but also amplitude modulation (e.g. all QAM derivatives). The resulting transmitter output signal has a PAPR > 0 dB (see definition in section A1.2), the actual value of which depending on the actual data sequence being sent. As the peak power of such signals can be much higher than the RMS power there is the risk of overloading the analyser's input without noticing it. Reference level and input attenuation have to be set according to the peak power, not the usually stated RMS power of the transmitter. The same applies to a preamplifier being used for measurements via the air interface. The received peak power has to stay well below the input 1 dB compression point of the amplifier.

In case the modulation bit patterns are not statistically even distributed over time the PAPR may vary during bursts or from burst to burst, adversely affecting the measurement. In this case the relevant standards may define special test models and one may have to activate the test model for the highest PAPR. This of course requires cooperation of the network operator and is accompanied with a service interruption, which may pose an additional threat in implementing the measurement.

A1.5.4 Power Reference

Some telecommunication systems transmit a fixed bit pattern in a certain part of a burst (e.g. a preamble) at the beginning of every burst. This part of the burst usually has a fixed and often the highest output power within the burst. The standard may define this part as the power reference, instead of the RMS power averaged over the complete burst. On those systems it is necessary to limit the BEM measurement to the preamble part of the burst.

A1.5.5 Power Control

In CDMA based systems the actual output power varies with the number of active code channels. The usage of code channels is highly dynamic. As the output power density spectrum in the out of band domain usually can be assumed to be dependent of the actual transmitter's drive, the BEM of a CDMA transmitter cannot be assessed in normal operating mode of the transmitter under test. Again a special test mode (referred to as test models in various standards) has to be activated to achieve a maximum and constant output power.

OFDM systems on the other hand may use sub-channelizing (OFDMA). With this mode of operation groups of OFDM subcarriers may be assigned dynamically to a dedicated client and switched off completely when not needed. Power control may also be applied individually to groups of subcarriers, again resulting in a highly dynamic non-constant below maximum output power of the transmitter. One has to check whether the technology used by the transmitter under test uses some kind of preamble with all OFDM carriers switched to maximum power. This preamble may be used for the assessment. Otherwise a suitable test signal or test mode has to be activated in the transmitter to assess the BEM.

A1.5.6 Assessing customer (client) equipment

Most BEMs are defined for base stations. However, if a BEM is defined also for the terminal equipment, they have to be assessed, too. Unlike base station equipment the terminals usually do not output any signal until a valid base station signal is received. During assembly and test the manufacturer uses a special test interface to put the transmitter in a test mode for rapidly testing the transmitter. However, this interface is

usually not available after final assembly. Therefore a valid base station signal has to be made available to the terminal equipment so that it starts transmitting.

This may be done using a signal generator with programmable IQ modulator. But with most telecommunication standards a sophisticated terminal tester will be necessary, which is able to communicate bi-directionally with the terminal. Those testers are rarely available at radio monitoring services and are expensive. Therefore it might be easier to test the terminal in a real network.

A directional coupler may be connected between antenna and terminal equipment to access the transmit signal without interrupting the RF conversation between base station and terminal equipment.

However, as today's radio interfaces are often highly dynamic (frequency, power, modulation schemes and so on), in-depth knowledge of the respective radio interface is necessary in order to achieve stable and defined conditions. To give an example: In order to rule out power control of the terminal equipment one may connect a switchable attenuator between antenna and transmitter and drive the radio connection to the lowest possible level resulting in base station and terminal station both using the highest available transmit power.

A1.5.7 Radiated measurements

When performing radiated measurements the most critical part is to get enough field strength for the measurement. Furthermore in the case of BEMs with absolute (power) limits one has to ensure to precisely measure the *correct* field strength. To accomplish this it is important to position the receiving antenna within the main beam of the transmit antenna in respect to azimuth, elevation, geographical position, antenna height and polarisation. Note that many terrestrial mobile communications networks use 45° polarisation. Satellite links often use circular polarisation.

The distance to the transmit antenna should be smaller than the distance at which the transmit antenna beam will touch ground and thereby free-space propagation can also be assumed. This will eliminate uncertainties introduced by ground reflections. Furthermore it is necessary to avoid any reflections caused by nearby buildings, trees or anything alike. Such reflections may cause frequency-selective distortion. Check the received signal using a spectrum analyser for any distortion.

On the other hand the distance must be sufficient to ensure far-field conditions. For transmit antennas with apertures being large compared to the wavelength, the far-field region is commonly taken to exist at distances greater than

$$d \geq \frac{2D^2}{\lambda}$$

where d = distance from transmit antenna
 D = largest dimension (aperture) of the transmit antenna
 λ = wavelength

Special care has to be taken to avoid overloading the analyser by strong nearby transmitters. Even when using a highly directive receiving antenna the analyser may be overloaded by other transmitters, which may be located on or near the building of the base station under test. Therefore a pre-measurement over a wide frequency range should be performed. A band pass filter may be used to improve the strong signal immunity of the measurement setup.

A1.5.8 Uncertainty in BEM Measurement

As with all kinds of measurement the assessment of block edge masks is subject to a number of uncertainties, which have to be taken into account. Uncertainties include but are not limited to level uncertainty of the analyser / receiver, uncertainties in cable loss and filter amplitude response.

Administrations implementing this recommendation should evaluate and express uncertainties of their individual measurement equipment according to the general rules established by JCGM 100:2008 [7] or ETSI TR 100 028-1 and TR 100 028-2: "Uncertainties in the measurement of mobile radio equipment characteristics" (Parts 1 and 2) [8].

ANNEX 2: ASSESSMENT OF THE BLOCK EDGE MASK FOR BROADBAND WIRELESS ACCESS (BWA) CENTRAL STATIONS (CS) WITHIN THE FREQUENCY BAND 3400-3800 MHz USING IEEE 802.16 TRANSMITTERS

A2.1 INTRODUCTION

This Annex describes the assessment of block edge masks for BWA CS transmitters within the frequency band 3400-3800 MHz and operating in accordance to standard IEEE 802.16 [6] using the Wireless MAN-OFDM or Wireless MAN-OFDMA air interfaces.

Those interfaces are based on OFDM modulation and designed for NLOS operation in frequency bands below 11 GHz. Supported modulations of the OFDM subcarriers includes BPSK, QPSK, and QAM. Channel bandwidths can be chosen flexibly between 1.25 MHz and the allocated block size by the operator. FDD and TDD duplexing is allowed.

The transmission has a burst structure with modulation scheme, power and number of active OFDM carriers being variable, even within a single burst.

A2.2 BLOCK EDGE MASK FOR CENTRAL STATIONS

ECC/REC/(04)05 [1] defines the relevant technical conditions for central stations (CS). Those conditions include a maximum in-block EIRP spectral density of 53 dBm/MHz. It is assumed that the total transmitter output power does not exceed 43 dBm. The actual CS EIRP spectral density limit may be adjusted by administrations.

The out-of-block emissions of a CS are limited by the BEM.

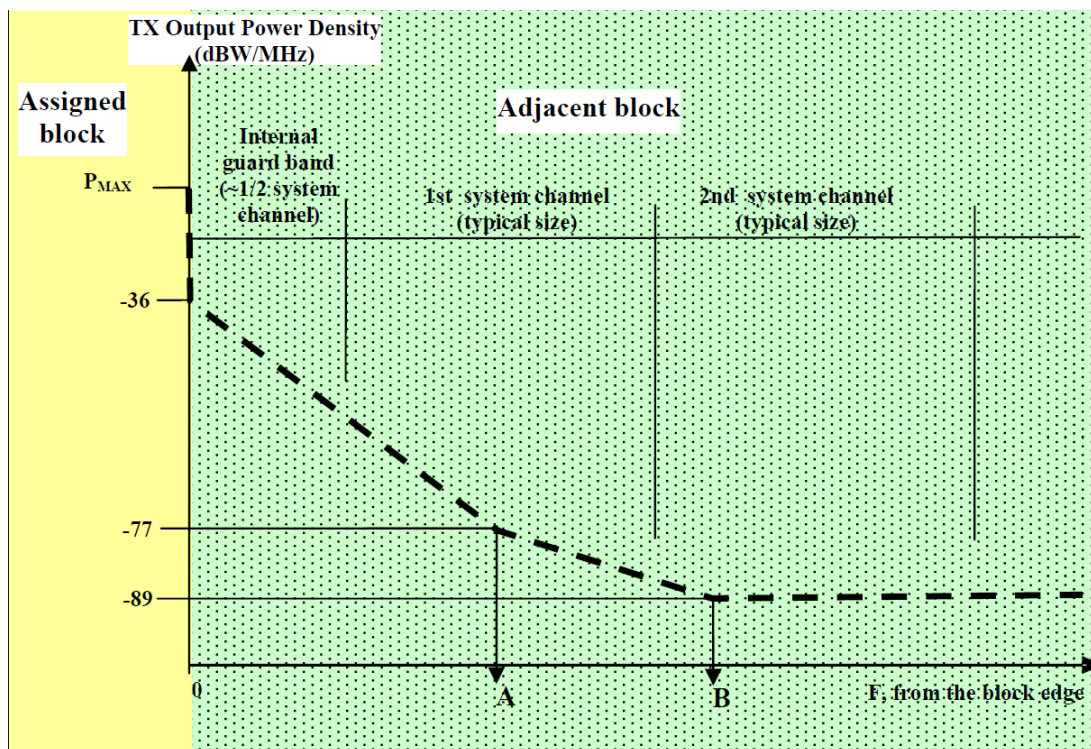


Figure 1: CS BEM as of ECC/REC/(04)05

The BEM consists of three sections: The baseline level is -59 dBm/MHz and is valid for frequencies being away from the block edge more than 35% of the size of the assigned block (point B). The two inner sections

realize the transition from the in-block limit to the baseline level. The first section of the BEM starts at -6 dBm/MHz and linearly decreases to -47 dBm/MHz at point A, which is away from the block edge 20% of the size of the assigned block. In section 2 (frequencies between points A and B) the limit decreases from -47 dBm/MHz to the baseline level.

Example for an assigned block size of 21 MHz:

- Point A is at block edge ± 4.2 MHz, resulting in a gradient in section 1 of -9.76 dBm/MHz;
- Point B is at block edge ± 7.35 MHz, resulting in a gradient in section 2 of -3.8 dBm/MHz.

Note that the BEM is defined in absolute transmitter output power density and does not depend on actual transmitter output power.

A2.3 PREREQUISITES

It is recommended to perform a conducted measurement at the transmitter output port. This avoids any additional measurement uncertainty resulting from uncertainties in CS antenna gain, feeder loss and free space loss.

Based on a maximum transmitter output power of 43 dBm and a baseline level of -59 dBm/MHz, the necessary dynamic range of the measurement equipment is > 102 dB. As the assessment of the BEM cannot be performed using the normalization bandwidth of 1 MHz, the BEM has to be re-normalized to a narrower measurement bandwidth (RBW). This again increases the necessary dynamic range by a factor of $1/\text{RBW}$; where RBW is given in MHz. As the needed dynamic range is far above the dynamic range offered by state of the art spectrum analysers, the dynamic range of the measurement equipment has to be increased using the method described in section A1.4.2.

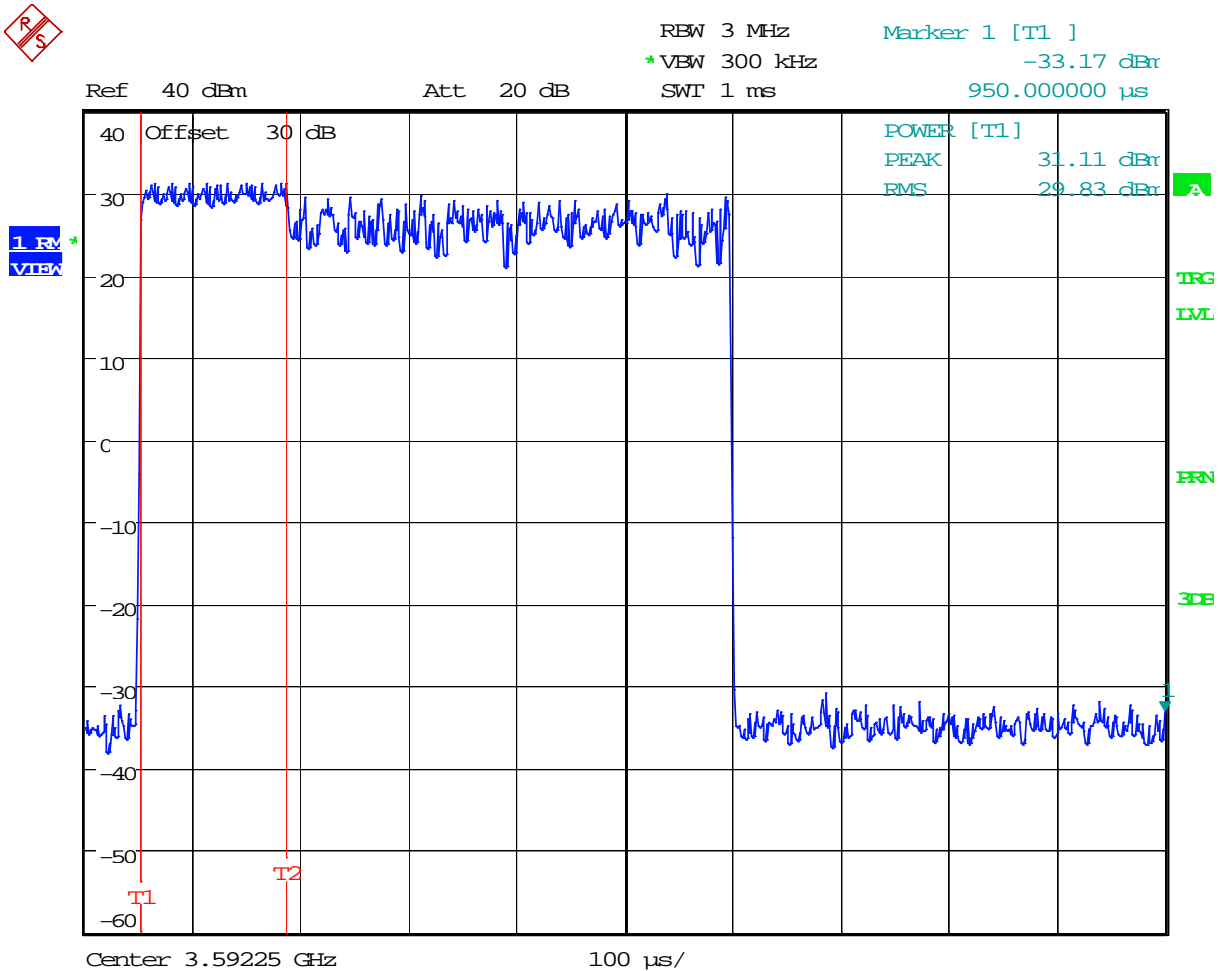
As the CS antenna has to be disconnected for the measurement, care has to be taken to correctly terminate the CS transmitter. As the CS will be transmitting into the stop band of the filter, it will not present the correct impedance to the transmitter. Two alternatives are recommended:

1. Connection of a directional coupler in-line between transmitter output and antenna. The coupling factor should be in the range of 20 ... 30 dB. The measuring setup will be connected to the coupled port.
2. Connection of a 20 ... 30 dB power attenuator between transmitter output and input of the measurement setup (the filter).

The coupling factor or attenuation may be matched to the stopband attenuation of the used filter for optimized measuring sensitivity.

With either alternative the transmit power level will be reduced to a level suitable for the measurement setup while providing adequate impedance matching to the CS transmitter output. Alternative 1 has the additional benefit that the antenna can be left connected during the measurement and service interruptions are reduced to a minimum. Note that the sensitivity of the measuring setup will be degraded by the amount of in-line attenuation.

An IEEE 802.16-2009 [6] frame (which is one RF burst to be measured) always starts with a preamble, followed by a frame control header (FCH) and a number of data bursts. The data bursts may use BPSK, QPSK, 16-QAM or 64-QAM, each with code rate $\frac{1}{2}$ or $\frac{3}{4}$. The FCH is always transmitted using BPSK- $\frac{1}{2}$ and the preamble uses a fixed constellation pattern. Because of this frame structure the output power is not constant within a frame, especially when using QAM. Additionally the preamble is power boosted by 3 dB to improve synchronization. As a result the preamble is the part of the frame with the highest and constant RMS power.



Date: 9.MAR.2010 13:42:07

Figure 2: RF burst of IEEE 802.16 CS [6]

These characteristics make it necessary to limit the gate open time of the gated trigger to *start of frame* (plus settling time of the resolution filter) until *end of preamble*. The preamble always has the length of two OFDM symbols and can be calculated from the OFDM symbol parameters as stated in [6], section A2.1

More easily the preamble length can be derived by displaying one RF burst in zero span modes as shown in the Figure above. The preamble now can easily be distinguished from the data part by the 3 dB power boost and the low PAPR. It has been marked with T1 and T2 in the example.

A2.4 MEASUREMENT SETUP

The following equipment is needed for the conducted measurement:

- **Power attenuator or (uni-) directional coupler:** Needed to terminate the transmitter output and to reduce the power level to a value which can safely be handled by the filter. The attenuation or coupling ratio should be at least 10 dB, usually 20 ... 30 dB is useful.
- **Bandpass or bandstop filter:** Needed to suppress the main transmitter signal while bypassing the OoB domain. The needed attenuation depends on the used analyser and is usually about 40 dB on the transmitter's frequency and should be much less than 10 dB in the assessed frequency range. The resulting steepness can become quite large, especially with transmitters operating near an edge

of the assigned frequency block. The attenuated in-block transmission has to be strong enough for the gated trigger to reliably work! Therefore a bandstop filter is preferably used.

- **Spectrum Analyser:** A model with high dynamic range, good sensitivity, RMS detection and gated sweep capability is needed. Usually an analyser with a DANL < -150 dBm/MHz is adequate. Depending on the available (bandpass or bandstop) filter and the margin in sensitivity a switchable input attenuator with step size ≤ 5 dB is desirable.
- **Signal Generator:** Needed to measure the amplitude response of the filter. It may be built into the analyser or external, but has to be tracked by the analyser.
- **Computer:** Used for post-processing of the data and result display. Additionally the computer may be used for automation of the procedure.

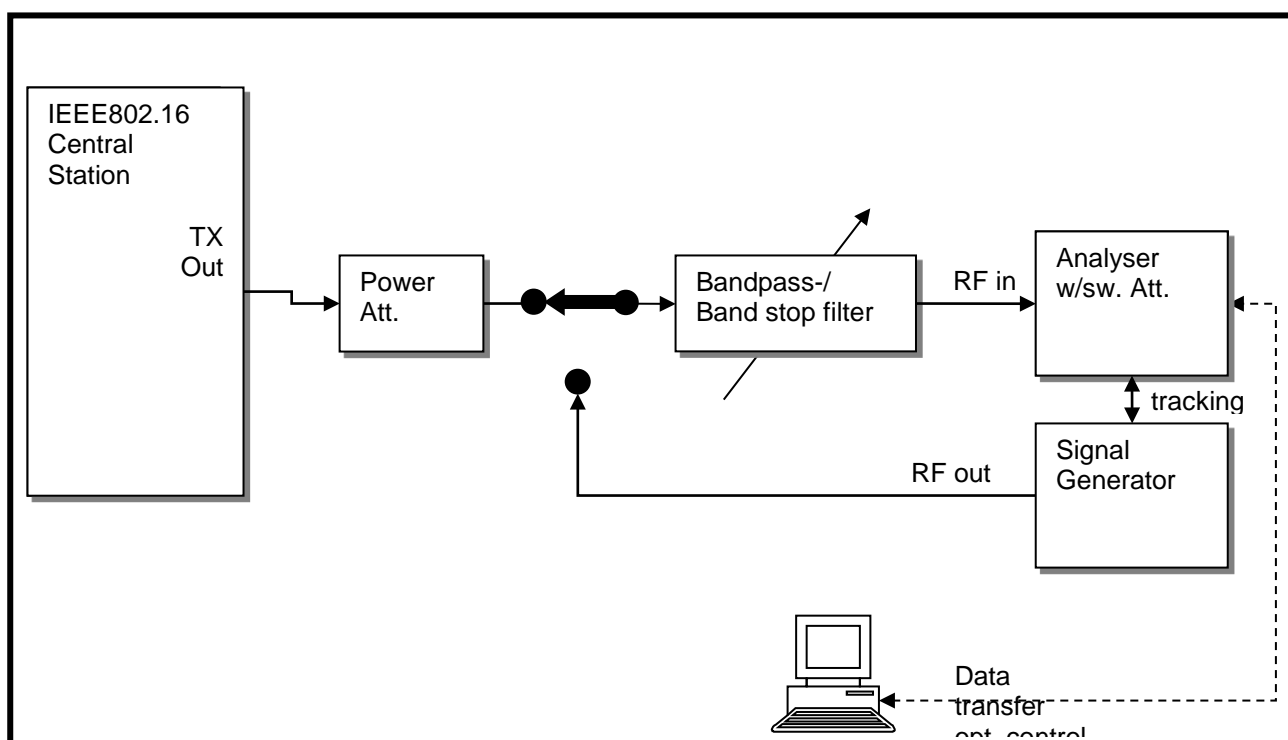


Figure 3: Example of a typical conducted measurement setup

A2.5 MEASUREMENT PROCEDURE

As the measurement is performed at the transmitter output, cooperation of the network operator is necessary. After shutting down the transmitter (locally or via the operator's Operations Management Centre) the power attenuator (see section A2.3) is connected to the transmitter output and the transmitter is powered up again.

It is recommended to start with some initial measurements to register the actual transmitter frequency, bandwidth, power, framing and compare those parameters to the technical standard for which the transmitter was claimed to comply with.

To accomplish this analyser is connected to the output of the power attenuator (without the bandpass filter for now). Observe the considerations given in section A1.5.

The analyser should be set to RMS detection and the reference level be adjusted to the input power. One might also want to enter the level offset of the power attenuator to get true level readings for the transmitter output.

Now is a good point to switch to zero span mode and find out the parameters for the gated sweep, i.e. gate offset, gate length and IF trigger power level. Remember to set RBW according to the signal bandwidth.

Afterwards switch back to spectrum display and choose the RBW according to the precautions given in section A1.4.3, e.g. 100 kHz. Activate gated sweep using the parameters registered in zero span. One should now see the RMS transmitter output spectrum for the preamble. An example is given in Figure 4:

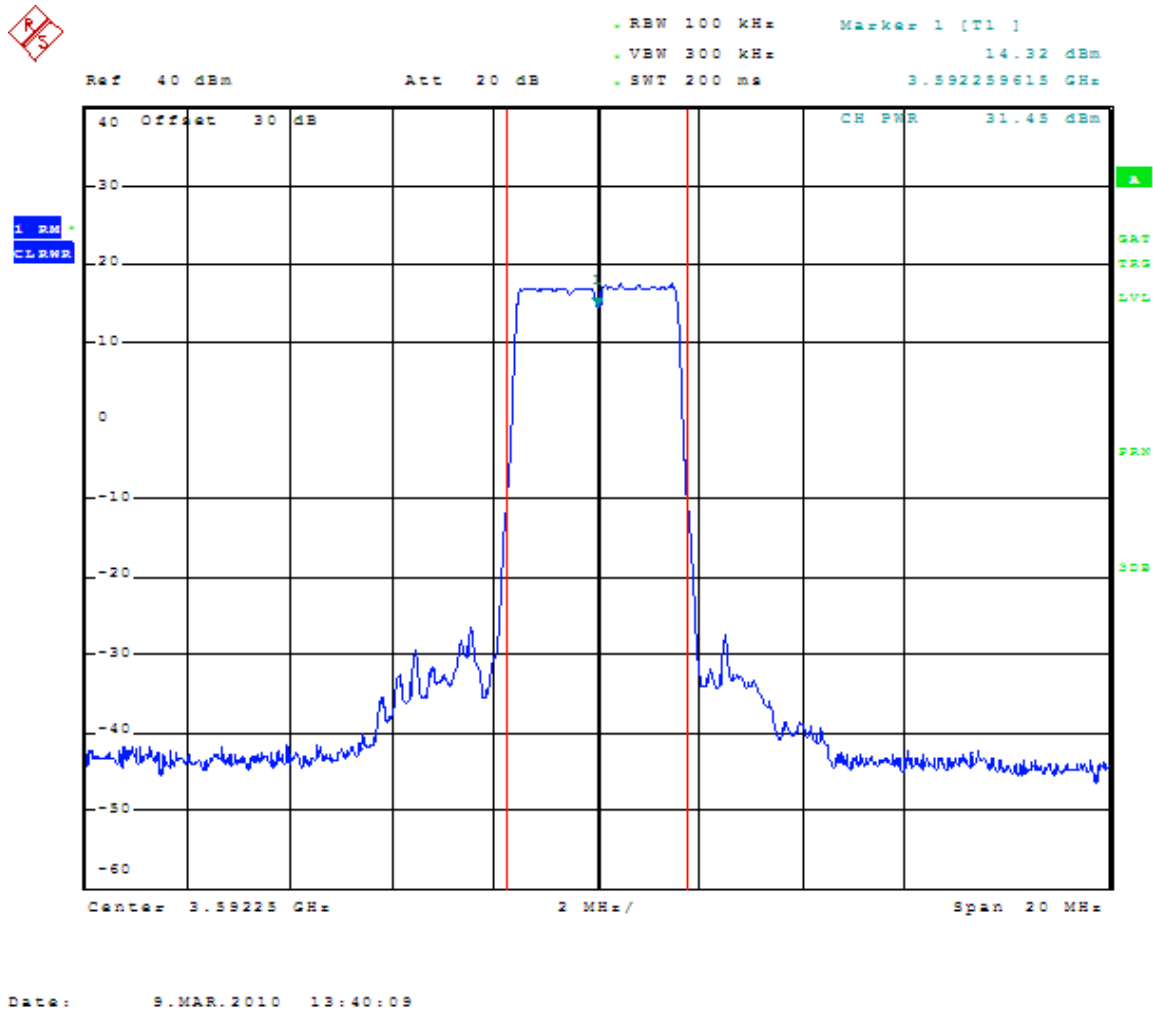


Figure 4: Typical CS output spectrum

Now the filter is connected in-line as shown in the above Figure and tuned in such a way that the transmitter's in-block transmission is sufficiently suppressed while maintaining minimal attenuation in the OoB domain. It might be favourable to pre-align the filter using the tracking generator.

The reference level can now be reduced by the amount of achieved extra attenuation. If the filter is sufficiently steep one should now be able to achieve the maximum sensitivity of the analyser. It may be necessary to readjust the IF power level of the gated trigger.

Now Start and Stop frequency can be set to the desired OoB frequencies. When measuring the lower BEM the Stop frequency equals the assigned block edge frequency; for the upper BEM it's the Start frequency. The Span should be chosen adequately for the block size; e.g. 20 MHz for an assigned block size of 21 MHz. Now the BEM measurement is finally accomplished using the method as explained in section A1.4.2.

An example BEM measurement is shown in the Figure below.

The raw data have to be compensated for the filter response and the power attenuator or coupling ratio of the directional coupler (if not taken into account as *Level Offset*). The results are plotted along with the (re-normalised) BEM.

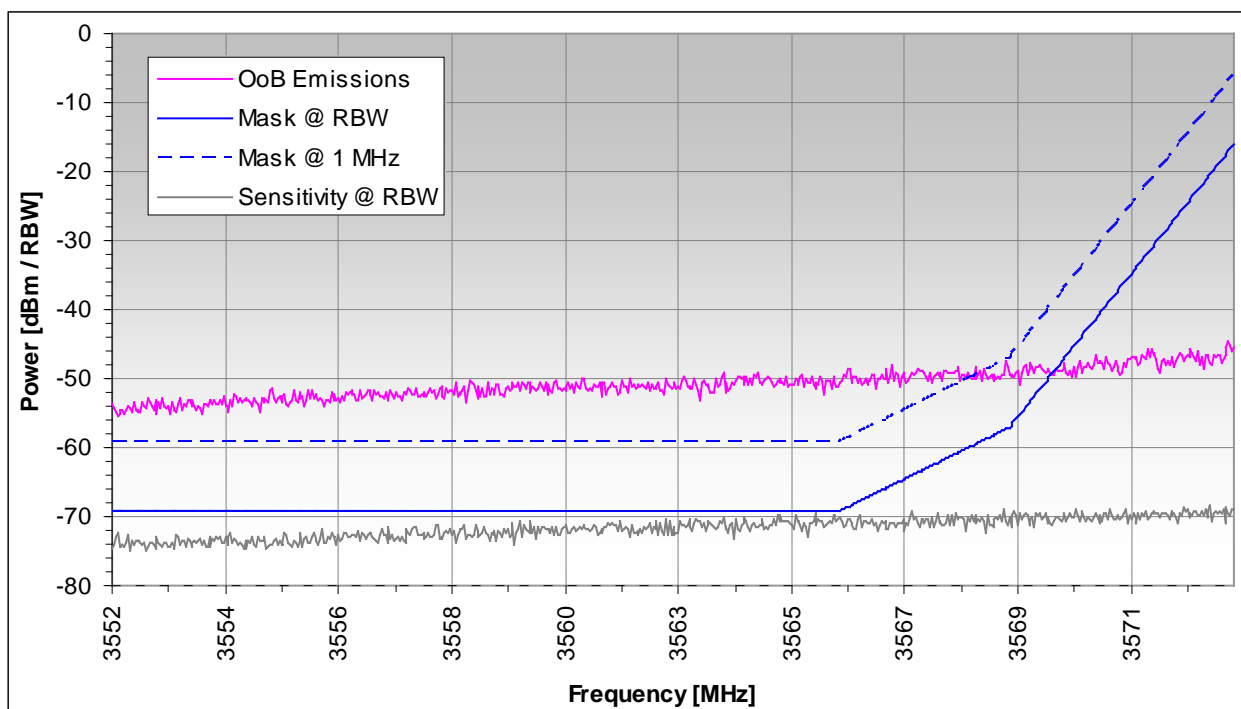


Figure 5: Example of measurement of OoB emissions of a CS

The diagram above shows the OoB emission of the transmitter (in purple), the re-normalized BEM in blue (“Mask @ RBW”), the original BEM (“Mask @ 1 MHz”) referenced to 1 MHz as a blue dashed line and the system sensitivity in grey. The original BEM is only needed in case the OoB emission includes single discrete spectral components (see section A1.4.3). In the above example only the re-normalized BEM is relevant for the assessment. The assigned block for the transmitter under test is 3573 ... 3594 MHz and the assessment were done in the lower adjacent block. The centre frequency of the wanted emission was 3592.25 MHz.

The measurement was made at a central station of a live IEEE 802.16-2009 [6] network referenced to the BEM as defined in ECC/REC/(04)05 [1].

A2.6 SPECIAL RECOMMENDATIONS REGARDING SYSTEM SENSITIVITY

The sensitivity is a key parameter of every spectrum analyser and is usually stated as DANL. However, the sensitivity will be degraded by the selected resolution bandwidth, the power attenuator or the directive coupler, the unwanted passband attenuation of the filter, the analyser’s switchable attenuator (if needed) and the amplification of its internal signal chain; the latter one being depended of the reference level setting. This is why the analyser has to have a low DANL, although the rather relaxed limits of the BEM itself don’t call for high sensitivity on the first view.

To give an example assumes an analyser with a DANL of **-155 dBm/Hz**. This value will be degraded as follows:

- +50 dB RBW = 100 kHz
 - +30 dB power attenuator at transmitter output
 - + 4 dB passband attenuation of used band stop filter, frequency-dependent
-
- 71 dBm.

The example measurement setup will end up with an effective system sensitivity of **-71 dBm**, which is barely good enough for the given BEM. Things will get even worse, if the analyser isn't operated with its maximum internal amplification. The amplification will be reduced on most analysers with reference levels above about -30 dBm (critical reference level). So a bandpass filter has to be selected that allows the reference level be kept on or below the critical reference level.

Additionally in the example above a "bad" filter with broad and flat amplitude response was used. This filter was just good enough, because the actual transmitter's frequency was sufficiently far away from the block edge.

Therefore it is important to plot the effective system sensitivity along with the measurement result to ensure the system sensitivity was sufficient. The raw data for the system sensitivity have to undergo the same compensation as the measurement data itself. As can be seen in Figure 5: the most critical point in respect to system sensitivity is the frequency with the lowest offset to the block edge, where the mask reaches the baseline level; i.e. point B in BEM definition see Figure 1:

ANNEX 3: ASSESSMENT OF THE BLOCK EDGE FOR LTE BASE STATIONS WITHIN THE FREQUENCY BAND 791-821 MHz

A3.1 INTRODUCTION

This Annex describes the assessment of block edge masks for LTE base station (BS) transmitters within the frequency band 791-821 MHz, also referred to as LTE800. The measurement principles recommended here are also applicable to LTE base stations in other frequency bands as long as the block edge mask concepts are equal.

Those interfaces are based on OFDM modulation. Supported modulations of the OFDM subcarriers include BPSK, QPSK, QAM. Channel bandwidths can be flexibly chosen between 1.4 MHz and 20 MHz. FDD and TDD duplexing is allowed. Multiplexing the downlink data streams for different users is done by OFDMA.

The transmission has a burst structure with modulation scheme, power and number of active OFDM carriers being variable, even within a single burst.

A3.2 BLOCK EDGE MASK FOR LTE800 BASE STATIONS

Decision 2010/267/EU [11] of the European Commission defines the relevant BEM to a certain extent. Some figures, however, depend on the actual channelling plan. In order to be able to provide concrete figures, this recommendation uses an example where the downlink band 791-821 MHz is divided into three channels of 10 MHz bandwidth. The centre frequencies of the channels are 796, 806 and 816 MHz. This channelling plan is in accordance to ECC/DEC/(09)03 [12], but it is based on a block size of 5 MHz.

The BEM for LTE800 base stations consists of different sections, the OoB levels mostly being an absolute power, but referenced to different bandwidths. The transition points of the sections are sometimes defined as absolute frequencies and sometimes relative to the centre of the assigned channel.

Figure 6: illustrates the combined BEM.

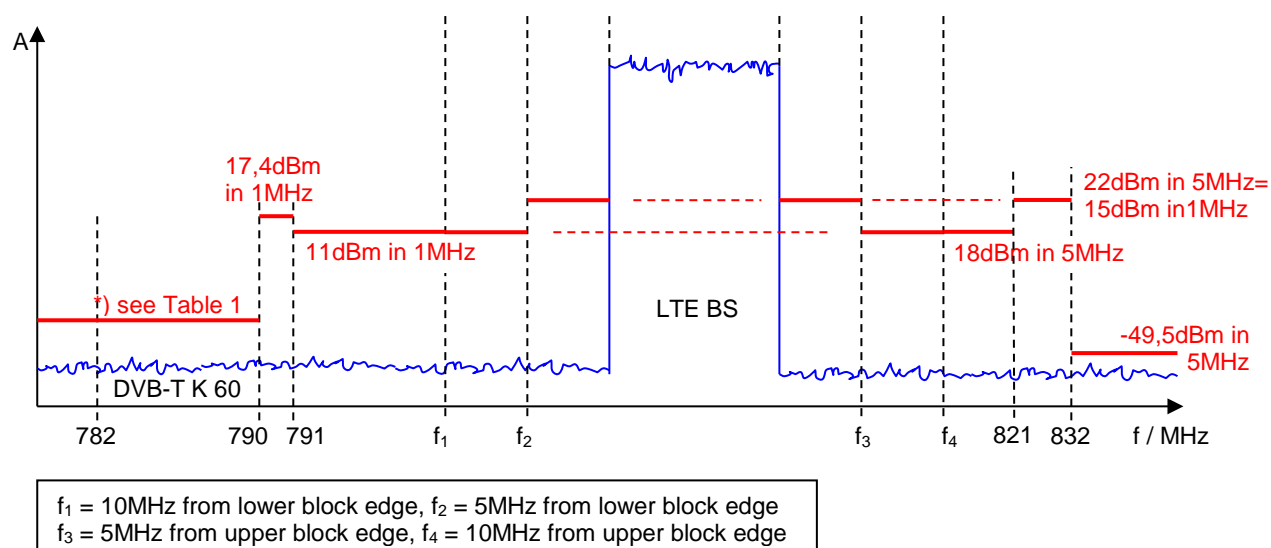


Figure 6: BEM for LTE800 BS according to ECC/DEC/(09)03

The OoB level in the TV band depends on the e.i.r.p. of the LTE800 base station and on whether DVB channel 60 is locally used or not.

Table 1: OoB limits for frequencies below 790 MHz

| Case | Total e.i.r.p. of the LTE800 Base Station P | Maximum permissible out of Block e.i.r.p. in 8 MHz |
|--|---|--|
| A) Channel 60 is locally used | $P \geq 59 \text{ dBm}$ $44 \text{ dBm} \leq P < 59 \text{ dBm}$ $P < 44 \text{ dBm}$ | 0 dBm $(P - 59) \text{ dBm}$ -15 dBm |
| B) Channel 60 is used and special local conditions apply | $P \geq 59 \text{ dBm}$ $44 \text{ dBm} \leq P < 59 \text{ dBm}$ $P < 44 \text{ dBm}$ | 10 dBm $(P - 49) \text{ dBm}$ -5 dBm |
| C) Channel 60 is not locally used | (all powers) | 22 dBm |

It can be seen that the limits for the different sections of the BEM are defined in absolute radiated power levels in different reference bandwidths ranging from 1 MHz to 8 MHz.

A3.3 PROPERTIES AND STRUCTURE OF THE LTE800 BS SIGNAL

The downlink LTE800 signal is structured according to a scheme that uses so-called Resource Blocks (RB) as the smallest assignable unit. One RB consists of 12 OFDM subcarriers in frequency and 0.5 ms in time (6 or 7 OFDM symbols). In addition to resource blocks filled with user traffic, there are certain logical channels organising the traffic, allowing receiver synchronisation and broadcasting information on the BS.

Figure 7: briefly shows the frame structure.

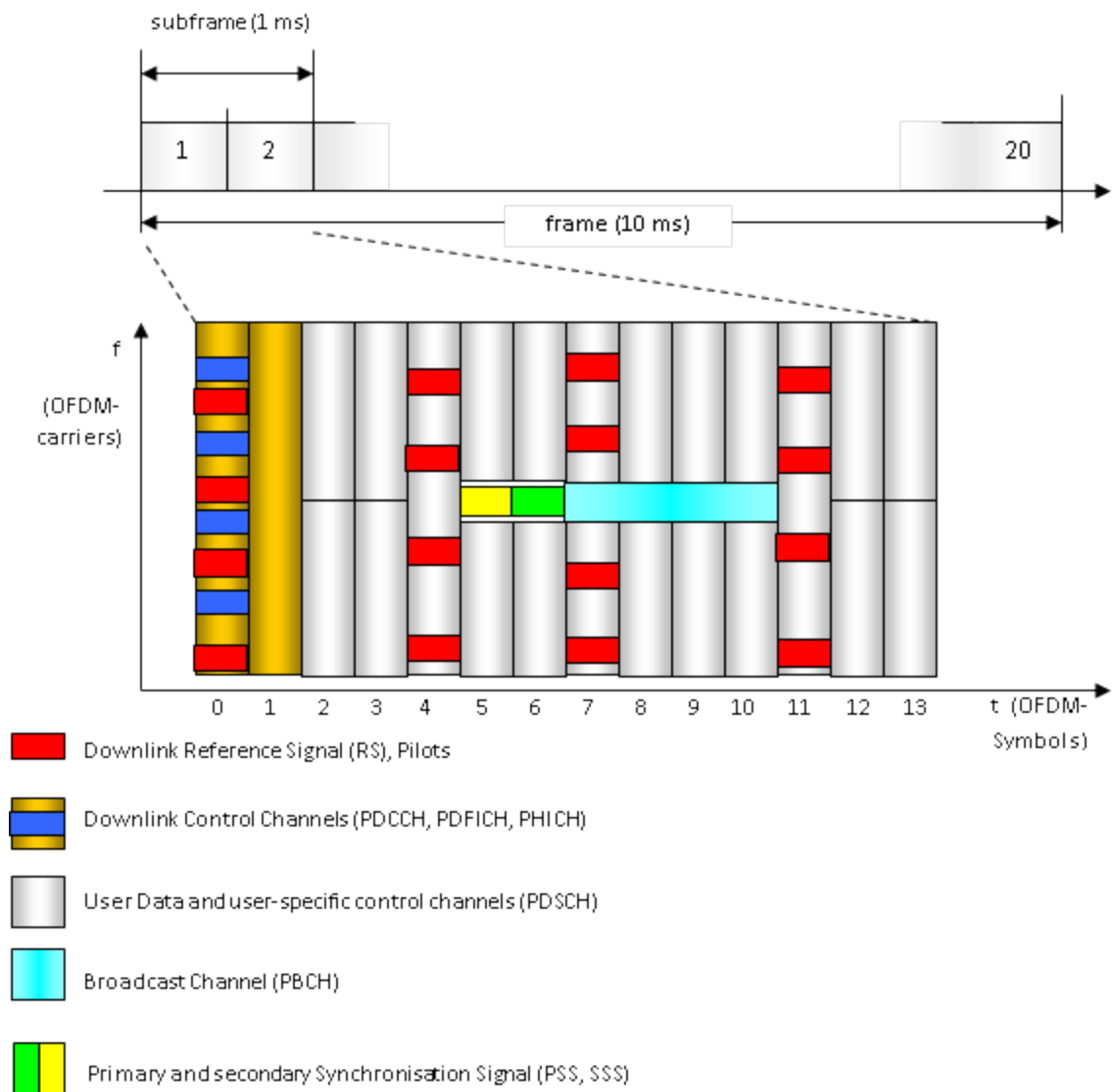


Figure 7: LTE BS frame structure

This frame structure results in a typical spectrum of an LTE BS not being fully loaded as Figure 8:

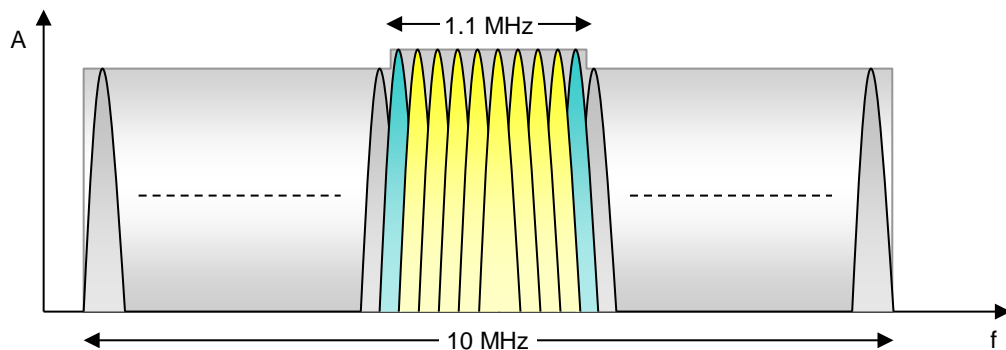


Figure 8: Typical LTE BS spectrum

Although in principle it is possible to “boost” certain symbols, the broadcast channel is normally not boosted. The 10 MHz wide LTE BS signal has a total of 600 OFDM carriers. The broadcast channel occupies the 72 inner OFDM carriers.

It is assumed that the base station operates at its maximum power if all 600 carriers have the same power as the inner 72 carriers at the time of the broadcast channel. So, from the measured level of the broadcast channel P_{PBCH} , the total maximum level of the base station P_{max} is calculated as follows:

$$P_{max} = P_{PBCH} + 10 * \log(600/72) = P_{PBCH} + 9.15dB \quad (1)$$

A3.4 MEASUREMENT APPROACHES AND THEIR APPLICABILITY

In principle, the following three different measurement approaches have to be distinguished:

- Radiated measurement (“off-air”) under normal operating conditions of the LTE base station;
- Conducted measurement under normal operating conditions of the LTE base station;
- Conducted measurement according to ETSI EN 301908-14 [9] while the LTE base station is in a defined test mode.

A3.4.1 Radiated measurement (“off-air”) under normal operating conditions of the LTE base station

The BEM is defined in absolute radiated power (see Section A3.2). A direct measurement would require measuring the emissions in the different blocks off-air and calculating back to the radiated power using free space formulas.

For practical reasons the measurement is done evaluating relative levels instead of absolute ones. This makes it possible to separate the process of the e.i.r.p. determination inside the wanted channel from the actual BEM measurement.

The reference for the relative evaluation is the in-channel power which may either be determined through a field strength measurement and calculation, or by simply retaining this information from the operator or licence and assuming that the value is correct.

Advantages of this method:

- The measurement can be performed at any time that is convenient to the monitoring service (no need to involve the network operator);
- The measurement can be performed under normal working conditions of the LTE base station (no interruption of the service necessary);

- There is no possibility for the network operator to make any “adjustments” to the station in order to pass the BEM compliance measurement.

Disadvantages of this method:

- The measurement relies on a number of prerequisites (see following sections) that may not be possible to meet in all cases;
- Emissions from other transmitters may make evaluation of some sections of the BEM impossible;
- In some cases the measurement uncertainty may be higher than that of a conducted measurement;
- The method may not reveal the maximum possible sideband emissions of the LTE base station.

Nevertheless, for practical monitoring applications, the radiated measurement under normal working conditions will be the only method available in most cases.

A3.4.2 Conducted measurement under normal working conditions

It is also possible to measure the BEM compliance conducted at the transmitter output. In this case, feeder cable attenuation and transmit antenna gain have to be assumed or measured and the radiated power in each section of the BEM is calculated.

Advantages of this method:

- There will always be sufficient signal level available to measure the full range of the BEM;
- Emissions from other transmitters cannot influence the result;
- If the feeder cable attenuation and antenna gain can be determined accurately, the measurement uncertainty is lower than that of the radiated measurement;
- The measurement process is simpler because a notch filter can be used (see Section A3.5.3.3) and the process of determination of a suitable measurement location is not necessary.

Disadvantages of this method:

- An appointment with the network operator has to be made to access the station and the measurement cannot be scheduled independently;
- If no test output is available, a short disruption of the service is necessary during insertion of a directional coupler at the antenna port;
- The method may not reveal the maximum possible sideband emissions of the LTE base station.

A3.4.3 Conducted measurement according to ETSI EN 301 908 while the LTE base station is in a defined test mode

This measurement is also performed at the transmitter output port, but following the procedures laid down in the harmonised standard ETSI EN 301 908-14 [9]. One of the prerequisites of measurements according to this standard is that the LTE base station operates in defined test modes where all OFDM carriers are continuously transmitted with maximum power.

Advantages of this method:

- The defined test mode will stipulate the maximum possible out-of-block emissions of the LTE base station, a situation that may not occur during measurements under normal operating conditions;
- If the feeder cable attenuation and antenna gain can be determined accurately, the measurement uncertainty is lower than that of the radiated measurement;
- Because of the defined test mode, this measurement method has the highest reproducibility.

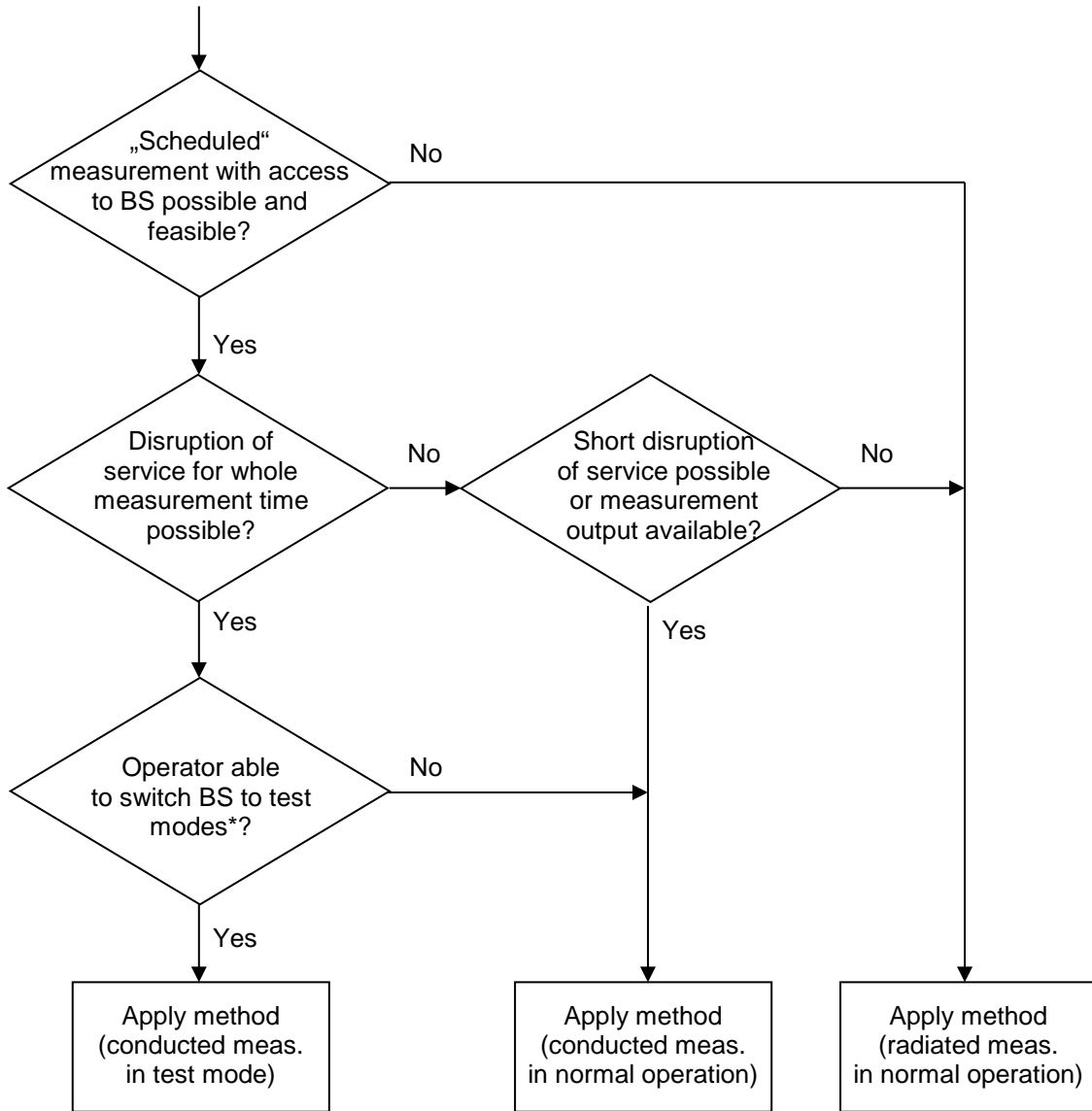
Disadvantages of this method:

- Normal service of the LTE base station is disrupted for the whole time of the measurement;
- An appointment with the network operator has to be made to access the station and the measurement cannot be scheduled independently;
- The measurement requires skilled personnel of the network operator that is able to reliably set the LTE based station into the required test mode.

Although this measurement method may be the most accurate one, it is of little practical relevance for monitoring services because the network operator will often not agree to the long disruption of the service.

A3.4.4 Decision flowchart

The following flowchart in Figure 9:provides guidance on when to apply which of the three measurement methods.



*) Test modes to be used are E-TM 1.1 and E-TM 1.2 described in clause 6.1.1.1 and 6.1.1.2 of ETSI TS 136 141 [10]

Figure 9: Decision flowchart

A3.5 MEASUREMENTS UNDER NORMAL WORKING CONDITIONS OF THE LTE BASE STATION

A3.5.1 Converting the absolute block edge mask into a relative mask

To directly compare the BEM limits to measured channel powers, the BEM has to be converted from absolute into relative spectral density levels, referenced to the spectral density inside the wanted channel, measured in the same bandwidth. The following table illustrates the conversion of the BEM in Figure 6: for an example where the maximum e.i.r.p. of a 10 MHz wide LTE base station on 806 MHz is +59 dBm and the TV channel 60 is locally used.

Table 2: BEM in relative levels for an example LTE base station on 806 MHz, in-block e.i.r.p. is 56 dBm/5 MHz

| Offset from LTE centre frequency | Frequency range | e.i.r.p. limit according to BEM definition (ECC/DEC/(09)03 [12]) | Reference bandwidth | Level | Relative level |
|----------------------------------|-----------------|--|---------------------|--------------|----------------|
| < -16 MHz | < 790 MHz | 0 dBm | 8 MHz | -9 dBm/MHz | -58 dB |
| -16...-15 MHz | 790...791 MHz | 17.4 dBm | 1 MHz | 17.4 dBm/MHz | -31.6 dB |
| -15...-10 MHz | 791...796 MHz | 18 dBm | 5 MHz | 11 dBm/MHz | -38 dB |
| -10...-5 MHz | 796...801 MHz | 22 dBm | 5 MHz | 15 dBm/MHz | -34 dB |
| -5...+5 MHz | 801...811 MHz | 59 dBm | 10 MHz | 49 dBm/MHz | 0 dB |
| +5...+10 MHz | 811...816 MHz | 22 dBm | 5 MHz | 15 dBm/MHz | -34dB |
| +10...+15 MHz | 816...821 MHz | 18 dBm | 5 MHz | 11 dBm/MHz | -38 dB |
| +15...+26 MHz | 821...832 MHz | 11 dBm | 1 MHz | 11 dBm/MHz | -38 dB |

Example:

The relative level of -58 dB for the frequency range below 790 MHz is derived as follows: According to Table 1., if channel 60 is locally used, the limit in Case A (row 1) applies. For stations with an e.i.r.p. of 59 dBm, the maximum absolute level of sideband emissions is 0 dBm in a reference bandwidth of 8 MHz. This relates to an absolute level of -9 dBm in 1 MHz bandwidth by applying the bandwidth conversion described in A3.5.4 (formula 3). The 0 dB reference level in-band of a station with a total power of 59 dBm in 10 MHz bandwidth relates to 49 dBm in 1 MHz bandwidth. The absolute sideband level of -9 dBm/MHz is therefore 58 dB lower than the in-band reference level of 49 dBm/MHz. This difference is stated in the right column of table 2 as the relative level in dB/MHz.

To achieve a reasonable accuracy of the measurement, especially near the block edges, it is necessary to perform the actual measurement with a much smaller bandwidth than the reference bandwidths.

The measurement may be done with a spectrum analyser in the zero span mode or a measurement receiver. The required range of the spectrum is scanned in steps of the measurement bandwidth. The highest RMS level inside a certain measurement time is recorded and stored. Then, from all stored samples, the channel power is calculated for each section of the BEM and compared to the channel power measured inside the wanted channel.

As can be seen from the table above, the low out-of-block power limits require a dynamic range of the measurement in excess of 100 dB which cannot be provided by any spectrum analyser or receiver. It is therefore necessary to suppress the main LTE emission by a filter in order to allow sensitive measurement in the sideband range without overloading the receiver. This can be either a band pass filter for the sideband range to be measured, or a band stop filter for the main LTE emission. In environments where more than one LTE block is transmitted from one site, a band pass filter is mandatory.

A3.5.2 Measurement Prerequisites

The most important prerequisites for a BEM compliance measurement with acceptable accuracy are:

- Sufficient wanted signal level;
- Sufficient suppression of other emissions in the frequency range in question.

The necessary input levels are described in Section A3.5.1. “Other emissions” include those from other LTE stations located at the same site.

If the measurement is performed off-air, it may only be used if all the following prerequisites are fulfilled:

- The level or the limit of the LTE sideband emissions in each section of the BEM is above the system sensitivity;
- The sideband level of other stations is at least 10 dB below the sideband level of the measured LTE station in each frequency range;
- No other LTE stations in the 800 MHz range are located on the same site as the measured LTE station. Should this be the case, the out-of-block emissions cannot be assigned to one of the LTE transmitters, i.e. if the BEM is exceeded, an additional measurement at the transmitter output has to be performed.

The required out-of-block suppression in the frequency range above 832 MHz is so high that in most cases it won't be possible to measure them off-air because of insufficient signal level.

A3.5.2.1 Required signal level

The following table provides guidance on the minimum required input level and the frequency ranges that may be measured. The table below assumes the sensitivity of common spectrum analysers with internal preamplifiers (noise figure 10 dB), the maximum in-band e.i.r.p. of 56 dBm/5 MHz and that the noise level of the spectrum analyser is 6 dB below the lowest part of the mask.

Table 3: Minimum required input levels for BEM measurement

| Wanted signal level at measurement antenna (Peak/MaxHold in 1 MHz RBW) | BEM Measurement possible in the frequency range |
|---|--|
| < -50 dBm | No measurement possible |
| ≥ -50 dBm | 790 ... 832 MHz |
| ≥ -30 dBm | < 790 ... 832 MHz (TV channel 60 used) |
| ≥ 15 dBm | < 790 ... 862 MHz (whole range of BEM) |

A3.5.2.2 Suppression of signals from other transmitters

For the proper assessment of the BEM compliance, the level of the signals of other transmitters should be at least 6 dB below the mask.

In the frequency band(s) where this suppression requirement is not met, the measurement cannot provide a valid result.

For the particular example in A3.5.1 (e.i.r.p.: 56 dBm/5 MHz), the maximum spectral density levels of the other transmitters – relative to the wanted in-band LTE signal – are shown in the following table.

Table 4: Maximum relative level of the other (unwanted) transmitter

| Offset from LTE centre frequency | Frequency range | Max. relative level of the other transmitter (Peak in 1 MHz RBW) |
|----------------------------------|-----------------|--|
| < -16 MHz | < 790 MHz | -64 dB |
| -16...-15 MHz | 790...791 MHz | -37.6 dB |
| -15...-10 MHz | 791...796 MHz | -44 dB |
| -10...-5 MHz | 796...801 MHz | -40 dB |
| -5...+5 MHz | 801...811 MHz | -6 dB |
| +5...+10 MHz | 811...816 MHz | -40dB |
| +10...+15 MHz | 816...821 MHz | -44 dB |
| +15...+26 MHz | 821...832 MHz | -44 dB |
| > 26 MHz | > 832 MHz | -111.5 dB |

The requirements for the suppression of the other transmitters are the most demanding on the frequencies above 832 MHz – in the FDD uplink band where the mobile terminal stations transmit. While the suppression of the unwanted fixed transmitters (base stations and broadcasting transmitters) can be improved by the proper selection of the measurement location and using directional antennas, this method cannot be used for the suppression of the signals of the mobile terminal stations. The mobile terminals – operated by a walking person or in a moving car – may change their position and transmit power fast during the measurement time. The signal coming from the mobile may lead to a false indication that the emission of the measured base station exceeds the BEM. The sufficiently low signal level from the mobile terminals to the measurement setup can be ensured by keeping them out of a protective distance from each other. Assuming 0 dB antenna gains on the transmitter and on the receiver side as well, 23 dBm transmit power of the mobile terminal and free space propagation, the necessary protective distance is about 230 meter. In practice one can rarely be sure that there is no operating mobile terminal in such a large area, especially in an urban environment. Consequently if the off-air measurement indicates an infringement of the BEM requirements in the FDD uplink band, it does not necessarily mean that the emissions originate from the base station. Then the results may be confirmed by a conducted measurement.

A3.5.3 Measurement Procedure

A3.5.3.1 Selecting a suitable measurement location

This section only applies if the measurement is performed off-air.

The main aim is to find a measurement location that provides the highest possible receive level. However, the measurement location has to be in the far field of the transmit antenna (see Annex 1 Section A1.5.7 for guidance on the calculation of the far field distance).

If signals from other stations are present in the frequency range in question, the location also has to provide good suppression of these other signals using the directivity of the measurement antenna. Many highly directive antennas have good front-to-back ratio, in which case it would be ideal to select a location close to the wanted transmitter but along a straight line between wanted and unwanted transmitter(s).

If planning tools are available, they can be used to plot the area where the main beam of the wanted LTE base station is 10 m above ground or less. A typical down tilt of the transmit antenna of 5° may be assumed for this calculation.

To find the actual location with maximum receive level, the area in question may be searched with the measurement car using a non-directional antenna at rooftop height and the following analyser settings:

- Centre Frequency: Centre of wanted LTE transmission (F_w);
- Span: Zero;
- RBW: 1 MHz;
- Detector: MaxPeak;
- Trace: ClearWrite;
- Sweep time: 100 s.

For the actual BEM measurement a directive measurement antenna has to be used.

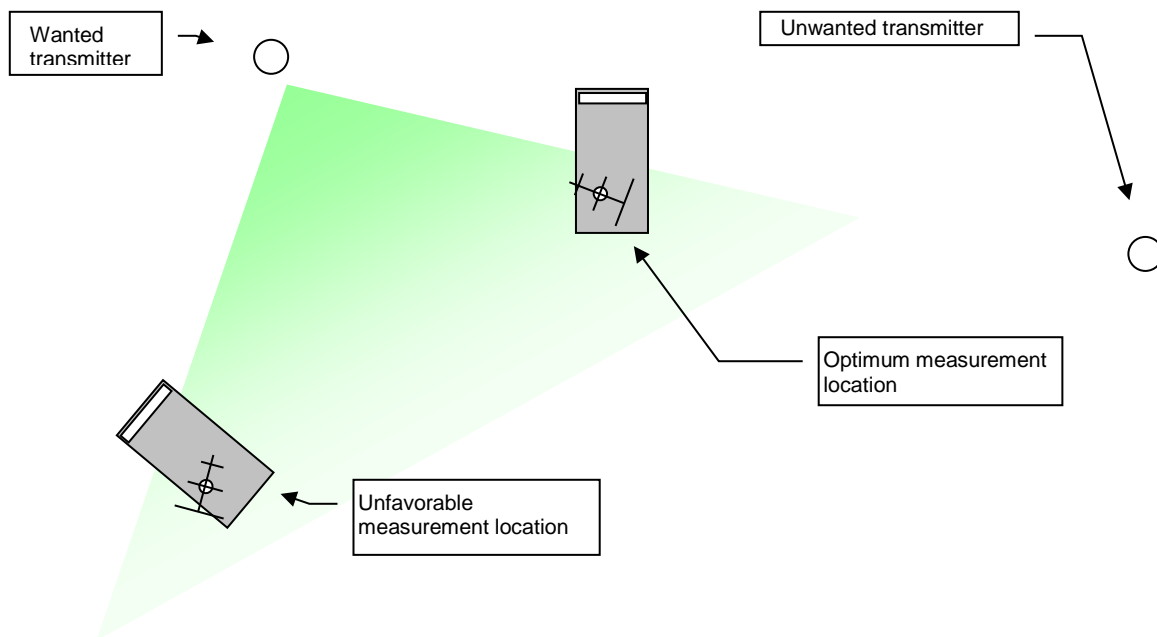


Figure 10: Sample measurement locations (sketch is not in a true scale)

A3.5.3.2 Measurement of wanted and unwanted signal level

The level measurement of the wanted and any unwanted signals in the BEM frequency range is measured with the directional antenna pointed towards the wanted transmitter and using the following analyser settings:

- Start Frequency: 780 MHz;
- Stop Frequency: 840 MHz;
- RBW: 1 MHz;
- Detector: MaxPeak;
- Ref. Level: adjust that the peaks are just below the upper display limit;
- Attenuation: reduce as far as possible avoiding overload;
- Preamplifier: on;
- Trace: MaxHold;
- Sweep time: (automatic).

The required wanted signal level is shown in Table 3. If it is not reached, another measurement location has to be found.

The required C/I (difference between wanted and unwanted signals) is taken from Table 4. If these values cannot be reached, the respective frequency range cannot be measured or another measurement location has to be found.

A3.5.3.3 BEM Compliance Measurement

The measurement setup is as follows:

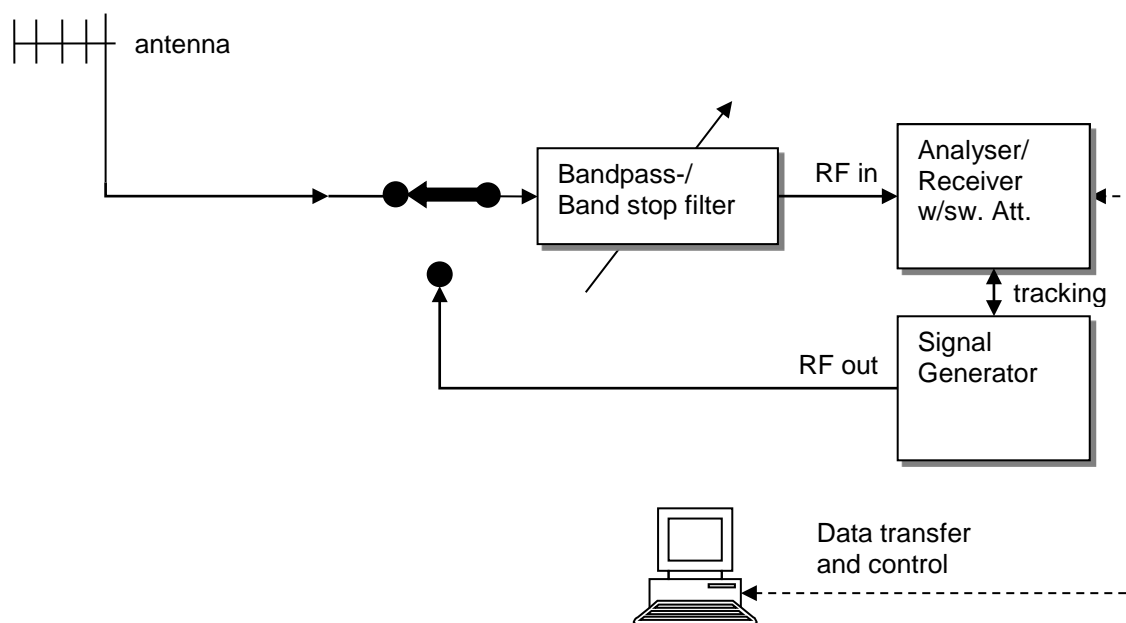


Figure 11: BEM Measurement setup

If the measurement is done off-air, a high gain directional antenna has to be used. If a conducted measurement is performed, the antenna in Figure 10: is replaced by the test output of the LTE transmitter, after the final stage of the amplifier.

The measurement receiver or spectrum analyser has to be computer-controlled. A computer programme has to step sequentially through the required frequency range, dynamically applying the necessary attenuation to avoid overloading the receiver, collecting level data on each frequency and store the results to memory.

If no strong emissions from other transmitters are present, a notch filter tuned to the centre of the LTE channel to be measured may be used. This has the advantage that the whole range of the BEM can be measured in one step. If strong signals from other transmitters are present that may overload the receiver, a band pass filter tuned to a certain section of the BEM has to be used. With this setup, only the BEM section inside the passband range of the filter can be measured in one step. To assess the whole range of the BEM, multiple sections have to be measured sequentially while always re-tuning the filter accordingly.

Tuneable 3-cavity or 5-cavity filters may be used. Steeper filter response curves enable measurements with higher dynamic range.

If a spectrum analyser is used, the following settings apply:

- Span: Zero;
- RBW: 100 kHz;
- VBW: ≥ 300 kHz;
- Detector: RMS;
- Sweep time: $71.3 \mu\text{s} \times \text{horizontal display points}$;
- Trace: MaxHold over 10 sweeps or more.

The sweep time ensures that each horizontal display pixel represents the RMS value of one LTE symbol. The MaxHold function over 10 sweeps collects at least 30 LTE radio frames and holds the symbol with the highest RMS level.

If a measurement receiver is used, the following settings apply:

- IF bandwidth: 100 kHz;
- Detector: RMS;
- Measurement time: 400 ms;
- Store the maximum measured RMS level.

The step width to the next frequency to be measured is 50 kHz (half of the RBW or IF-bandwidth, respectively).

A3.5.3.4 Filter measurement

The signal from the antenna is replaced by the signal from a tracking generator (either built-in to the receiver or external). Then, the measurement described in Section A3.5.3.3 above is repeated for the same frequency range and with the same settings and the filter attenuation is stored in memory.

A3.5.3.5 Measurement of the system noise level

The antenna port of the measurement setup is terminated with 50 Ohm. Using the same receiver/analyser settings as described in A3.5.3.3 above, the indicated noise level on one frequency inside the measured range is noted.

A3.5.4 Result evaluation

First, all level values measured in Section A3.5.3.3 are corrected by the filter attenuation measured in A3.5.3.4 on the same frequency.

Then, all corrected samples inside a section of the BEM (see Figure 6:) have to be linearly integrated over the respective reference bandwidth (see Table 1:). The result is a series of average power density values, which can be compared to the relative BEM that was prepared as in Table 2:.

The result may be displayed in a graph like in Figure 12:

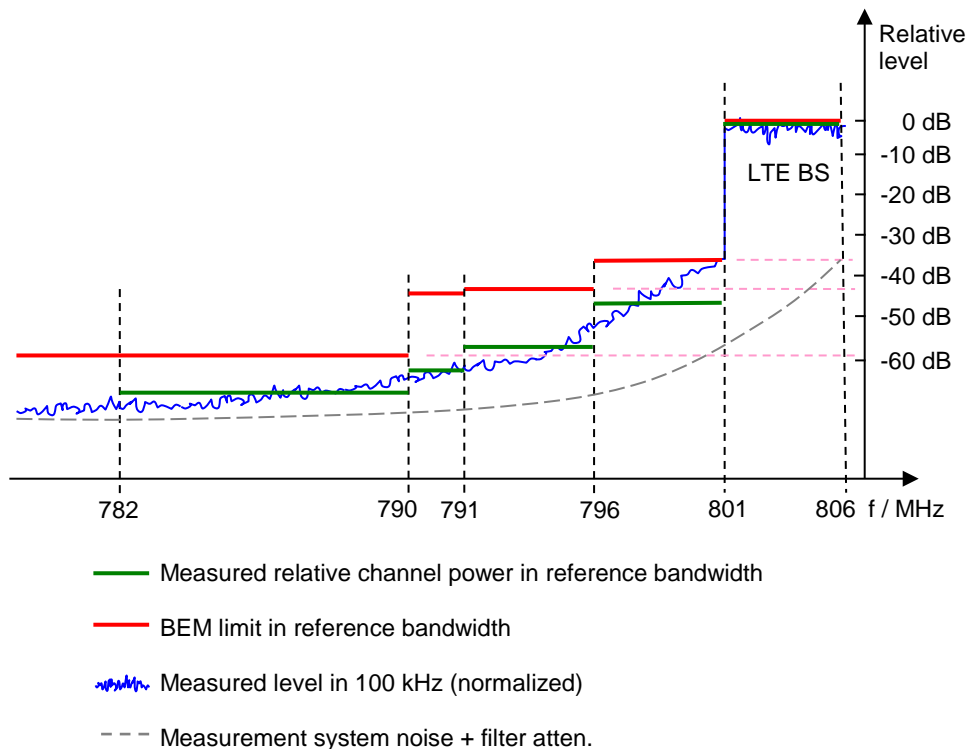


Figure 12: Sample result of BEM measurement

The line “Measurement system noise + filter attenuation” should be shown to assess whether the measured signal originated from the LTE transmitter or is in fact already receiver noise. The value of the sensitivity line is calculated by the noise level measured in Section A3.5.3.5 plus the filter attenuation on each frequency measured in Section A3.5.3.4.

The trace with the measured sideband spectrum should be shown to have a comparison with the system sensitivity line. For better readability, both lines may be normalised so that the maximum measured in-band spectral density is in line with the 0 dB reference point of the BEM in-channel

The necessary bandwidth correction is done according to

$$P_{RBW} = P_{BEM} - 10 * \log\left(\frac{\text{reference bandwidth}}{\text{measurement bandwidth}}\right) \quad (2)$$

with

P_{RBW} = level in measurement bandwidth (100 kHz)

P_{BEM} = level in reference bandwidth of the BEM (e. g. 1 MHz).

A3.5.5 Enhancing the measurement sensitivity

To ensure correct measurements of the out-of-block emissions, the measured level should be at least 10 dB above the level of the sensitivity line. Because the nature of the sideband emissions can be assumed to have a noise-like character in the frequency domain, the measurement sensitivity may be increased by linearly subtracting the system noise level determined under A3.5.3.5 from each measured out-of-block level.

However, the measurement uncertainty of this method increases considerably if applied to out-of-block levels that are below the system noise. Therefore it is recommended to apply this correction only to measured values down to the system noise using the following formula:

$$\text{if } P_{\text{meas}} > P_o, \text{ then } P_{\text{corr}} = \left\{ 10 * \log\left(10^{\frac{P_{\text{meas}}}{10}} - 10^{\frac{P_o}{10}} \right) \right\}, \text{ else } P_{\text{corr}} = P_o \quad (3)$$

with

P_{corr} = Corrected out-of-block level in dBm

P_{meas} = measured out-of-block level in dBm

P_o = measured system noise level in dB

when the above method is used, the measurement is valid as long as the corrected level is above the sensitivity line. This provides an enhancement of the measurement sensitivity by about 7 dB.

A3.6 CONDUCTED MEASUREMENT USING A TEST SIGNAL AT THE LTE BASE STATION

A3.6.1 References for the test procedure and provisions

Procedures for measuring Base Station conducted emissions in test modes are described in detail in the LTE (E-UTRA) Base Station harmonised European standard ETSI EN 301 908-14 [9], with support in terms of test models and other detailed conditions in ETSI TS 136 141 [10]. A BEM sets out-of-block limits, which are normally defined as e.i.r.p. These are related to the unwanted emissions from the BS. Some BEM provisions may in addition be set as in-block limits, which are defined as e.i.r.p. for frequencies inside the operator's license block. In-block emissions are intended emissions from the BS and are related to the BS output power.

The relevant test suites that can be found in EN 301 908-14 [9]:

- The test suite for operating band unwanted emissions in clause 5.3.1 of EN 301 908-14 [9] covers conducted measurements of out-of-block emissions within the supported operating band, and for the 10 MHz immediately above and the 10 MHz immediately below the operating band.
- The test suite for spurious emissions in clause 5.3.3 of EN 301 908-14 [9] covers conducted measurements of emissions for the remaining frequencies in the spurious domain.
- The test suite for Base Station maximum output power in clause 5.3.4 of EN 301 908-14 [9] covers conducted measurements of the transmitted power of an in-block LTE carrier.

The test suites in EN 301 908-14 [9] define the test environment, describe how to set up the initial conditions for the test and provide a step-wise test procedure. A fundamental part of the test procedure is to set up a pre-defined set of channels for the BS transmitted signal, in order to provide a consistent test condition where the out-of-block emissions are assumed to be at maximum. These so-called “test models” to use in the measurements are described in detail in clauses 6.1.1.1 and 6.1.1.2 of ETSI TS 136 141 [10]. These test models basically configure the Base Station to continuously transmit all OFDM carriers with full power which is assumed to stimulate the maximum sideband emissions.

The measurement procedures apply for a number of different Base Station configurations. Annex B of EN 301 908-14 [9] describes how to apply the test suites for a BS with duplexer, different power supply options, ancillary amplifiers, antenna arrays, transmit diversity, MIMO operation and integrated modem for Remote Electrical Tilting of antennas (RET).

The resolution bandwidth (RBW) of the conducted measurement may be smaller than the reference BW for the BEM, in order to improve measurement accuracy, sensitivity, efficiency or to avoid carrier leakage. The measurements then need to be normalised to the reference BW using the principles in Section A3.5.3.4 of the present document.

A3.6.2 Result evaluation

The immediate results of conducted measurement can only be referenced to the transmitter output while the BEM limits are referenced to e.i.r.p. If it can be assumed that all elements after the transmitter output such as duplexer, feeder cable and antenna have the same properties for both the in-block and out-of-block frequency ranges, the BEM can be converted into relative levels as described in Section A3.5.1 which allows direct comparison of the measured levels with the BEM limits.

Alternatively, the measured levels can be converted into radiated power using information about the Base Station setup.

In a typical deployment example as shown in Figure 13:, a Base Station is connected to an antenna with a certain antenna gain G_{Ant} by means of a feeder, where the total feeder losses are L_{Feeder} including cable and connector losses.

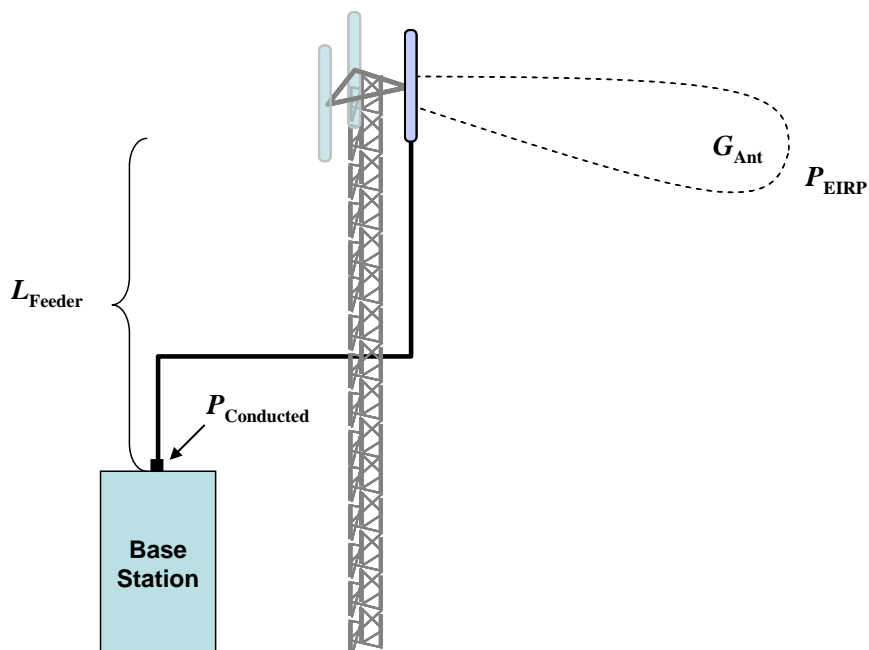


Figure 13: Typical LTE800 Base Station setup

The emissions in the BEM frequency ranges are measured as conducted emissions at the BS antenna connector according to Section A3.6.1 as $P_{\text{Conducted}}$. The corresponding radiated emissions for evaluation against the BEM requirements, expressed as P_{EIRP} are:

$$P_{\text{EIRP}} = P_{\text{Conducted}} + G_{\text{Ant}} - L_{\text{Feeder}} \quad (4)$$

The resulting in-block and out-of-block levels can then directly be compared with the BEM limits and presented in a graph similar to the example shown in Figure 12:.

For measurement uncertainty calculations, the methods stated in ETSI TR 100 028 v.1.4.1 [8] should be applied.

ANNEX 4: ASSESSMENT OF THE BLOCK EDGE FOR LTE BASE STATIONS WITHIN THE FREQUENCY BAND 738-791 MHz

A4.1 INTRODUCTION

This Annex describes the assessment of block edge masks for LTE base station (BS) transmitters within the frequency band 758-788 MHz, also referred to as LTE700. The measurement principles are identical to the ones described in Annex 3 on LTE800 base stations. The current Annex therefore only describes major differences of LTE700.

In addition, ECC/DEC/(16)02 [14] defines technical conditions and frequency bands for the implementation of Broadband Public Protection and Disaster Relief (BB-PPDR) systems in 698-703 MHz (uplink) / 753-758 MHz (downlink), in 703-733 MHz (uplink) / 758-788 MHz (downlink) those specified in ECC/DEC/(15)01 [13] (see section A4.2 for requirements), and 733-736 MHz (uplink) / 788-791 MHz (downlink). For the downlinks in 753-758 MHz as well as 788-791 MHz, this Annex can also be applied, see section A4.4 for BB-PPDR applicable requirements.

A4.2 BLOCK EDGE MASK FOR LTE700 MFCN BASE STATIONS

ECC/DEC/(15)01 defines the technical conditions, including the relevant BEM for the LTE700 system also called Mobile/Fixed Communication Networks (MFCN). The transmit frequency range of FDD base stations is 758 to 788 MHz with a corresponding uplink band between 703 and 733 MHz. It is recommended to use continuous blocks of 5 MHz bandwidth. Guard bands to protect digital terrestrial television (DTT) and LTE800 are defined from 694 to 703 MHz and from 788 to 791 MHz.

The frequency range from 738 to 758 MHz in the FDD duplex gap may be used on a national basis for:

- Additional unpaired supplemental LTE downlink blocks (SDL) (738-758 MHz);
- Programme Making and Special Events (PMSE);
- Broadband Public Protection and Disaster Relief (PPDR) (UL: 733-736 MHz / DL: 753-758 MHz);
- Machine to Machine (M2M) (733-736MHz).

Block edge masks for LTE700 are more complex than for LTE800 because the levels of unwanted emissions depend not only on absolute and relative frequencies but also on the intended usage of the frequency band concerned. The LTE700 BEM consists of the following elements:

Table 5: LTE700 BS BEM elements according to ECC/DEC(15)01

| Element | Description |
|---------------------|--|
| In-block | Block for which the BEM is derived. |
| Baseline | Spectrum used for MFCN UL and DL (including SDL, if applicable), for DTT, for MFCN above 790 MHz (UL and DL), for BB-PPDR or M2M UL or DL |
| Transitional region | The transitional region applies from 0 to 10 MHz below and above the block assigned to the operator, except from in the uplink region of MFCN (703-733 MHz), BB-PPDR or M2M. |
| Guard bands | <ul style="list-style-type: none"> - Spectrum between the DTT allocation below 694 MHz and the lower edge of the MFCN uplink (694-703 MHz); - Spectrum between the upper edge of MFCN downlink below 788 MHz and the lower edge of MFCN downlink above 790 MHz (if applicable) (788-791 MHz). In case of overlap between transitional regions and guard bands, transitional power limits are used. When spectrum is used by BB-PPDR or M2M baseline or transitional power limits are used. |

| | |
|------------|--|
| Duplex Gap | Spectrum in the FDD duplex gap which is not used by SDL, BB-PPDR or M2M. In case of overlap between transitional regions and the part of the FDD duplex gap not used by SDL, BB-PPDR or M2M, transitional power limits are used. |
|------------|--|

The maximum in-block power is defined as 64 dBm per antenna in 5 MHz reference bandwidth.

The baseline limits are as follows:

Table 6: LTE700 BS baseline requirements

| Frequency range | Bandwidth of protected block | Maximum mean e.i.r.p. | Reference bandwidth |
|--|------------------------------|---------------------------------|------------------------|
| DTT frequencies below 694 MHz | 8 MHz | -23 dBm per cell ⁽¹⁾ | 8 MHz |
| Uplink frequencies in the range 698-743 MHz ⁽²⁾ | ≥ 5 MHz | -50 dBm per cell ⁽¹⁾ | 5 MHz |
| | 3 MHz | -52 dBm per cell ⁽¹⁾ | 3 MHz ⁽²⁾ |
| | ≤ 3 MHz | -64 dBm per cell ⁽¹⁾ | 200 kHz ⁽²⁾ |
| Uplink frequencies in the range 832-862 MHz | ≥ 5 MHz | -49 dBm per cell ⁽¹⁾ | 5 MHz |
| Downlink frequencies in the range 738-791 MHz | ≥ 5 MHz | 16 dBm per antenna | 5 MHz |
| | 3 MHz | 14 dBm per antenna | 3 MHz |
| | < 3 MHz | 2 dBm per antenna | 200 kHz |
| Downlink frequencies in the range 791-821 MHz | ≥ 5 MHz | 16 dBm per antenna | 5 MHz |

⁽¹⁾ In a multi sector site "cell" refers to one of the sectors.

⁽²⁾ Administrations may select a measurement bandwidth of 3 MHz or 200 kHz for protection of block size 3 MHz depending on national options implemented.

The limits for the transition frequency bands are as follows:

Table 7: LTE700 BS transition requirements in the range 733-788 MHz

| Frequency range | Maximum mean e.i.r.p. | Reference bandwidth |
|-------------------------------------|-----------------------|---------------------|
| -10 to -5 MHz from lower block edge | 18 dBm per antenna | 5 MHz |
| -5 to 0 MHz from lower block edge | 22 dBm per antenna | 5 MHz |
| 0 to +5 MHz from upper block edge | 22 dBm per antenna | 5 MHz |
| +5 to +10 MHz from upper block edge | 18 dBm per antenna | 5 MHz |

Table 8: LTE700 BS transition requirements above 788 MHz

| Frequency range | Maximum mean e.i.r.p. | Reference bandwidth |
|---|-----------------------|---------------------|
| 791-796 MHz for block with upper edge at 788 MHz | 19 dBm per antenna | 5 MHz |
| 791-796 MHz for block with upper edge at 783 MHz | 17 dBm per antenna | 5 MHz |
| 796-801 MHz for block with upper edge at 788 MHz | 17 dBm per antenna | 5 MHz |
| 788-791 MHz for block with upper edge at 788 MHz | 21 dBm per antenna | 3 MHz |
| 788-791 MHz for block with upper edge at 783 MHz | 16 dBm per antenna | 3 MHz |
| 788-791 MHz for block with upper edge at 788 MHz for protection of systems with bandwidth < 3 MHz | 11 dBm per antenna | 200 kHz |
| 788-791 MHz for block with upper edge at 783 MHz for protection of systems with bandwidth < 3 MHz | 4 dBm per antenna | 200 kHz |

The limits for the duplex gap depend on the usage of this gap.

Table 9: LTE700 BS Requirements for the part of the FDD duplex gap not used by SDL, BB-PPDR or M2M

| Frequency range | Maximum mean e.i.r.p. | Reference bandwidth |
|---|-----------------------|---------------------|
| -10 to 0 MHz offset from DL lower band edge or lower edge of the lowest SDL block, but above uplink upper band edge | 16 dBm per antenna | 5 MHz |
| More than 10 MHz offset from DL lower band edge or lower edge of the lowest SDL block, but above uplink upper band edge | -4 dBm per antenna | 5 MHz |

Table 10: LTE700 BS Requirements for spectrum in guard bands not used by BB-PPDR or M2M

| Frequency range | Maximum mean out-of-block e.i.r.p. | Reference bandwidth |
|--|------------------------------------|---------------------|
| Spectrum between broadcasting band edge and FDD uplink lower band edge (694-703 MHz) | -32 dBm per cell ⁽¹⁾ | 1 MHz |
| Spectrum between downlink upper band edge and downlink of 800 MHz MFCN (788-791 MHz) | 14 dBm per antenna | 3 MHz |

⁽¹⁾ In a multi sector site "cell" refers to one of the sectors.

Figure 14: illustrates the BEM with the example of a 5 MHz FDD base station operating in the block at 778 – 783 MHz. It is further assumed that the duplex gap is not used by unpaired LTE700 downlinks (SDL), BB-PPDR or M2M and that the LTE700 base station uses one antenna per sector.

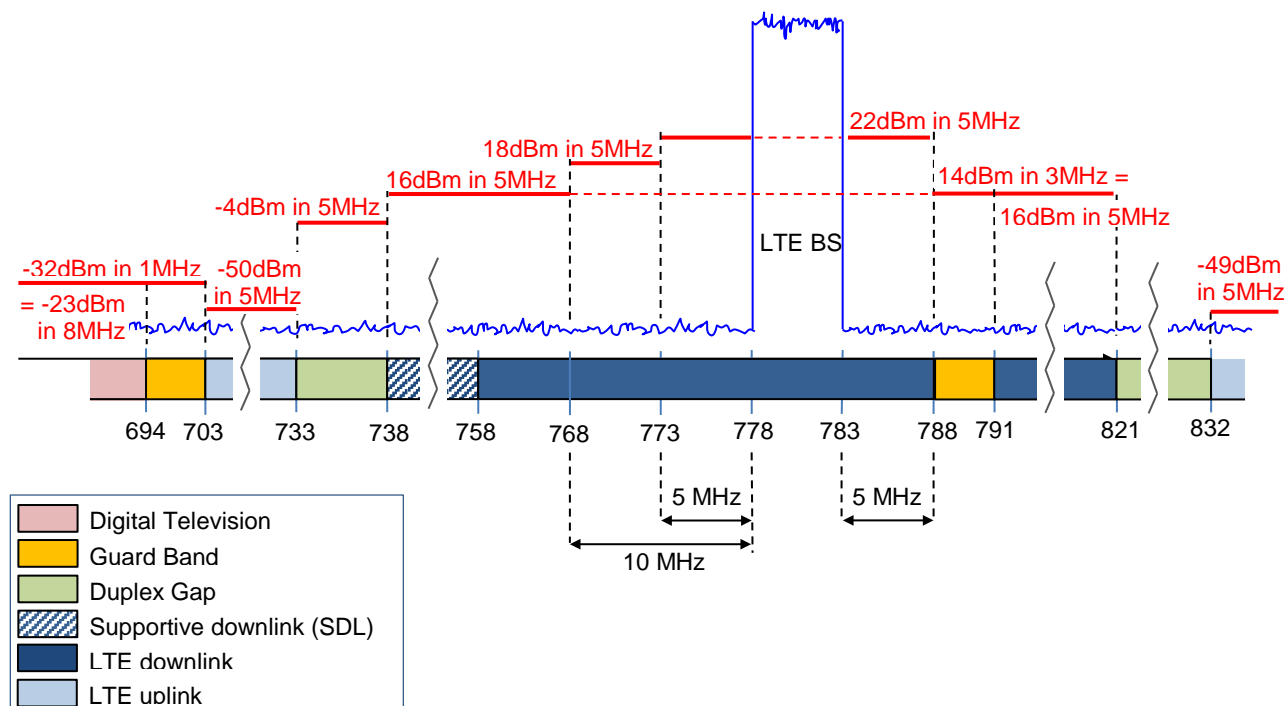


Figure 14: Example BEM for LTE700 BS according to ECC/DEC/(15)01

The BEM definitions from ECC/DEC/(15)01 [13] leave some ambiguity. For example, there are no limits in the LTE800 duplex gap between 821 and 832 MHz. In the frequency range 788-791 MHz there are two limits for our example station: In Table 8: the limit is 16 dBm in 3 MHz bandwidth and in Table 6: it is 14 dBm.

A4.3 PRACTICAL CONSIDERATIONS

ANNEX 3: of this Recommendation defines three different methods to measure BEM compliance of LTE800 base stations:

- Radiated measurement (“off-air”) under normal operating conditions of the LTE base station;
- Conducted measurement under normal operating conditions of the LTE base station;
- Conducted measurement according to ETSI EN 301908-14 [9] while the LTE base station is in a defined test mode.

One of the major advantages of the radiated measurement is that the base station can remain in service during the measurement and that it can be done independent of the operator, even without his knowledge. However, the additional spectrum for LTE700 will in most cases be used by operators also having LTE800 blocks. It is then obvious that they will co-locate LTE700 and LTE800 base stations which leads to the situation that on most transmitter sites there will be at least two LTE blocks receivable with nearly equal level. At these sites it will be difficult, if not impossible to determine which base station is responsible for the measured unwanted emissions in a certain frequency block. This difficulty applies especially for the frequency range between two LTE blocks.

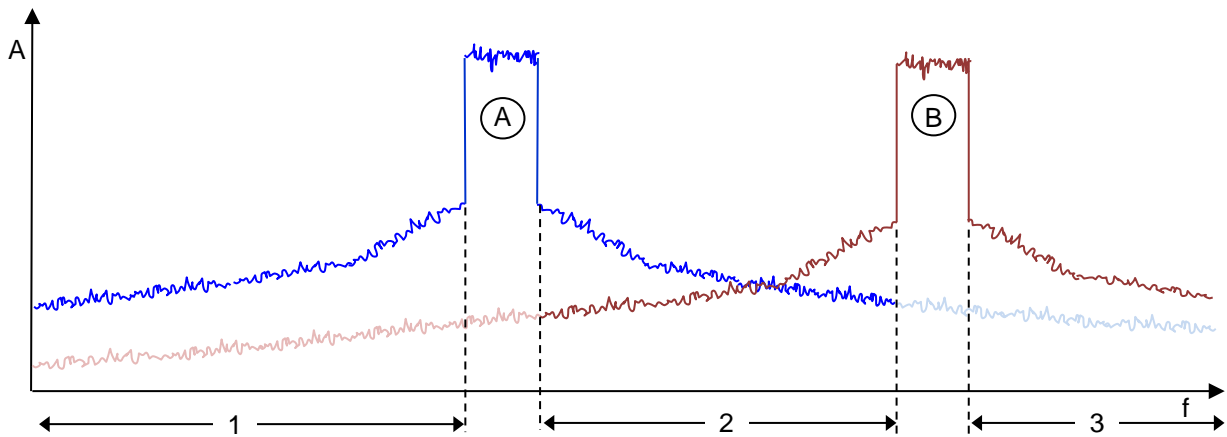


Figure 15: Unwanted emissions from two LTE base stations

If the two stations do not behave completely differently, it can be assumed with reasonable confidence that the unwanted emissions in frequency range 1 originate from station A and those in frequency range 3 from station B. In frequency range 2, however, there is a transition in the dominance of unwanted emissions between station A and B which is unknown. Overstepping of the BEM can therefore not be proven in this frequency range with a radiated measurement. In these cases a measurement at the transmitter output may be more feasible.

For a positive result, however, the radiated measurement method is still applicable: If the total level of unwanted emissions in all frequency ranges remains below the BEM for any of the receivable LTE stations, then all of these stations comply with their BEM requirements.

A4.4 REQUIREMENTS SPECIFIC TO BB-PPDR IN ECC/DEC/(16)02 [14]

For the BB-PPDR DL block in 788-791 MHz, the technical requirements as described in ECC/DEC/(15)01 [13] Annex 2 apply, extending the applicability of ECC/DEC/(15)01 Annex 2, Table 4 to the frequency range 733-821 MHz (BS transition requirements as in Table 7: in A4.2), and with the exception of ECC/DEC/(15)01 Annex 2 Table 5 which is not applicable for this band (this is actually MFCN BS transition requirements above 788 MHz in Table 8: in A4.2).

For the BB-PPDR DL block 753-758 MHz, the technical requirements in ECC/DEC/(15)01 Annex 2 apply.

For CEPT administrations deploying BB-PPDR radio systems in the 753-758 MHz block and within 788-791 MHz, the BS unwanted emissions level shall be in accordance with ECC/DEC/(15)01 (as in A4.2).

A4.5 MEASUREMENT PROCEDURE AND EVALUATION

The measurement procedure and evaluation of the results, including the process of converting the absolute BEM limits from ECC/DEC/(15)01 into relative levels are identical to the methods described in Annex 3 of this Recommendation for LTE800 base stations.

ANNEX 5: LIST OF REFERENCE

This annex contains the list of relevant reference documents.

- [1] ECC Recommendation (04)05: Guidelines for Accommodation and Assignment of Multipoint Fixed Wireless Systems in frequency bands 3.4-3.6 GHz and 3.6-3.8 GHz
- [2] ETSI EN 302 326-2: Fixed Radio Systems; Multipoint Equipment and Antennas; Part 2: Harmonized EN covering the essential requirements of article 3.2 of the R&TTE directive for digital multipoint radio equipment
- [3] CEPT Report 19: Report from CEPT to the European Commission in response to the Mandate to develop least restrictive technical conditions for frequency bands addressed in the context of WAPECS
- [4] CEPT Report 30: Report from CEPT to the European Commission in response to the Mandate on “The identification of common and minimal (least restrictive) technical conditions for 790 - 862 MHz for the digital dividend in the European Union”
- [5] ECC Report 131: Derivation of a block edge mask (BEM) for terminal stations in the 2.6 GHz frequency band (2500-2690 MHz)
- [6] IEEE 802.16-2009: IEEE Standard for Local and metropolitan area networks
Part 16: Air Interface for Broadband Wireless Access Systems
- [7] JCGM 100:2008: Evaluation of measurement data - Guide to the expression of uncertainty in measurement
- [8] ETSI TR 100 028-1 and TR 100 028-2: Electromagnetic and Radio spectrum Matters (ERM); Uncertainties in the measurement of mobile radio equipment characteristics (Parts 1 and 2)
- [9] ETSI EN 301 908-14, Harmonized European Standard, “IMT cellular networks; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive; Part 14: Evolved Universal Terrestrial Radio Access (E-UTRA) Base Stations (BS)”
- [10] ETSI TS 136 141, Technical Specification, “LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) conformance testing”
- [11] Commission Decision of 6 May 2010 on harmonised technical conditions of use in the 790-862 MHz frequency band for terrestrial systems capable of providing electronic communications services in the European Union
- [12] ECC Decision (09)03 of 30 October 2009 on harmonised conditions for Mobile/Fixed Communications Networks (MFCN) operating in the band 790-862 MHz
- [13] ECC Decision (15)01 of 6 March 2015 on harmonised technical conditions for mobile/fixed communications networks (MFCN) in the band 694-790 MHz including a paired frequency arrangement (Frequency Division Duplex 2x30 MHz) and an optional unpaired frequency arrangement (Supplemental Downlink)
- [14] ECC Decision (16)02 of 17 June 2016 on harmonised technical conditions and frequency bands for the implementation of Broadband Public Protection and Disaster Relief (BB-PPDR) systems