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Radiocommunication Sector of ITU

Recommendation ITU-R F.1191-3
(05/2011)

**Necessary and occupied bandwidths
and unwanted emissions of digital
fixed service systems**

F Series
Fixed service

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Note: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.

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RECOMMENDATION ITU-R F.1191-3*

**Necessary and occupied bandwidths and unwanted emissions
of digital fixed service systems**

(1995-1997-2001-2011)

Scope

This Recommendation gives an explanation of basic terms relating to unwanted emissions and bandwidths of digital fixed service systems to clarify the application of definitions in the Radio Regulations and Recommendations ITU-R SM.328 and ITU-R SM.329, as well as guidance consideration on these subjects for use for system or equipment designer of fixed service systems.

Considerations are also made on the occupied bandwidth of multi-carrier systems and requirements for out-of-band emissions for systems used in the block-based assignment.

The ITU Radiocommunication Assembly,

considering

- a) that it is necessary for designers of digital fixed service systems (DFSS) to give guidance for the application of the terms relating to bandwidths and unwanted emissions;
- b) that it is relatively unlikely that out-of-band (OoB) emissions from DFSS will cause significant interference into systems operating in adjacent bands, because:
 - the power spectrum of a DFSS decays rapidly outside the occupied bandwidth;
 - the e.i.r.p. of line-of-sight DFSS is low or medium;
 - trans-horizon DFSS employing a high e.i.r.p. are not widely used;
- c) that from the viewpoint of interference into other systems sharing the same frequency band, interference due to OoB emissions will be, in general, less significant than that due to emissions within the necessary bandwidth;
- d) that intra-system interference related problems, which may be caused by unwanted emissions, are normally taken into account by DFSS designers;
- e) that at the allocated band edges, RF band edge guardband ZS, as defined in Recommendation ITU-R F.746, is given by the relevant ITU-R Recommendations in order to control power spill-over into adjacent allocated bands;
- f) that it is not always possible or convenient to make the occupied bandwidth of DFSS smaller than or equal to the bandwidth of the RF channel provided by the relevant RF channel arrangement established for the allocated band by ITU-R or by a national regulatory authority;
- g) that in most bands allocated to fixed services on a primary basis, a radio-frequency (RF) channel arrangement is usually established by a relevant ITU-R Recommendation or by a national regulatory authority;

* This Recommendation should be brought to the attention of Radiocommunication Study Group 1.

h) that, within the allocated band, coordination between various fixed service systems, based on the use of a RF channel arrangement, is covered by a spectrum-efficient concept summarized by Recommendation ITU-R F.746 and by the statistical propagation behaviour reported in Recommendation ITU-R P.530 and Recommendation ITU-R F.1093;

j) that DFSS, with suitable scrambling applied, have in general a transmitted spectral density and unwanted emissions with power peak factors that may be conservatively considered noise-like;

k) that DFSS generate unwanted emissions, composed of both noise-like and discrete components, in both out-of-band and spurious emissions domains;

l) that single or multi-carrier systems are widely used in DFSS,

noting

a) that Recommendation ITU-R SM.328 gives information on the evaluation of OoB spectral emission for various modulation formats;

b) that Recommendation ITU-R SM.329 gives the limits and the reference bandwidth for unwanted emissions in the spurious domain of all services, including the fixed service;

c) that Recommendation ITU-R SM.1541 gives generic limits for unwanted emissions in the OoB domain for most of the services, including the fixed service (see Note 1);

d) that Recommendation ITU-R SM.1539 gives guidance on the variation of the boundary between OoB and spurious domains for very narrow-band and very wideband emissions,

recommends

1 that the following terms should be applied to DFSS:

1.1 Allocated frequency band

For DFSS the allocated frequency band may be considered as the overall frequency band allocated to the fixed service on a primary or co-primary basis.

1.2 Assigned frequency band

For the purpose of this Recommendation this term may be considered to apply also to a block of spectrum assigned to one or more stations of an operator under a single exclusive licence (block-assignment, see examples in Recommendations ITU-R F.1488, ITU-R F.748 and ITU-R F.749).

Inside a single block-assignment, the system designer may, in general, subdivide the block into suitable smaller sub-blocks in order to deploy a radio network in the geographical area where the assignment has been made, within conditions specified above (see Recommendation ITU-R F.1399).

1.3 Radio-frequency channel separation

Bandwidth equal to the frequency separation, defined in Recommendation ITU-R F.746, of adjacent channels of the relevant RF channel arrangement established within the allocated frequency band.

1.4 Guardband

Bandwidth equal to the frequency separation, defined in Recommendation ITU-R F.746 as *ZS*, between the nominal centre frequency of the outermost channel of a RF channel arrangement and the limit of the allocated band.

1.5 Multicarrier system

Systems where multiple sub-carriers may be transmitted simultaneously from a final output amplifier or an active antenna within an assigned channel of the relevant channel arrangement or a specifically dedicated spectrum slot;

2 that the following specific design objectives and terms should be used for DFSS; an illustration of those objectives and definitions can be found in Fig. 1;

2.1 that, for DFSS, the value of percentage $\beta/2$ should be taken as 0.5%; this percentage is assumed for single carrier transmitters; when multicarrier systems are concerned, this percentage, with respect to the total power of the whole set of sub-carriers should be reduced as a function of the sub-carriers number and bandwidth (see § 3 of Annex 1 for details);

2.2 that, for DFSS, the necessary bandwidth should be considered to have the same value as the occupied bandwidth;

2.3 that, according to the type of the utilized RF channel arrangement (see Note 2), the capacity and the modulation format of the transmitted signal, similar DFSS may have a necessary bandwidth which is no more than 20% wider than the radio-frequency channel separation (see Note 2); however, since dissimilar systems operating in the same band may give rise to certain incompatibilities, the relationship between the RF channel separation and the necessary bandwidth requires further study;

2.4 that the determination of occupied bandwidth should be done with a spectrum analyser method described in Recommendation ITU-R SM.328 or, whenever possible, by numerical evaluation or integration of the actual emitted spectrum as reported in Annex 1;

2.5 that when burst transmission is used (e.g. for time-division multiple access (TDMA) DFSS) the evaluation of bandwidths and emissions should be done averaging the power over burst duration;

2.6 that DFSS should use suitable scrambling circuitry in order to maintain all the spectral emissions (both wanted and unwanted) independent from the input data stream;

2.7 that any unwanted emission which falls at frequencies separated from the centre frequency of the RF channel by less than 250% of the relevant channel separation, where the system is intended to be used, should generally be considered unwanted emission in the OoB domain (see Note 4); when DFSS is intended for use in a frequency band where an RF channel arrangement has not been established, the necessary bandwidth should be used, instead of channel separation, in evaluating the 250% boundary;

2.8 that any unwanted emission which falls at frequencies separated from the centre frequency of the RF channel by 250% or more of the relevant channel separation, where the system is intended to be used, should generally be considered unwanted emission in the spurious domain (see Note 4); when DFSS is intended for use in a frequency band where an RF channel arrangement has not been established, the necessary bandwidth should be used, instead of channel separation, in evaluating the 250% boundary;

2.9 that, above and below the limits of the necessary bandwidth, the permissible mean power level of unwanted emission should be less than or equal to 0.5% of the total transmitted mean power taken at the radio antenna port (see Note 3); in case of multicarrier systems this rule is intended to be applied to the outermost sub-carriers;

2.10 that, from the viewpoint of the international regulations, it may not be necessary to establish any additional limitation on the spectral shape of unwanted emissions from DFSS;

2.11 that the levels of spurious emissions, the frequency range for their measurement and the reference bandwidth in which levels are specified should be those defined by Recommendation ITU-R SM.329 (see Note 4). Where exclusive block assignments are made, transmitters operating on sub-channels devised by the licensed operator may, in principle, be exempted, within the block, by the unwanted emissions limit required to be met outside the block; however at country borders this should require agreement between the administration concerned due to the fact that they may have licensed the band in a different way;

2.12 that any safety net limits for unwanted emissions in the OoB domain developed by ITU-R should be considered as an absolute worst-case limit to which any new DFSS design should conform;

2.13 that, without other specific agreement between administrations sharing the same band edge, the digital fixed radio transmitters operating on the outermost channel frequencies of a RF channel arrangement should have an occupied bandwidth so that the outermost part of it with respect to the centre frequency of the channel, when added to the absolute value of the frequency tolerance (see Note 5), results in a bandwidth smaller than or equal to the value of ZS as defined in § 1.4.

NOTE 1 – In general terms the generic limit is considered to be a generally worst-case envelope based on the least restrictive OoB emission limits successfully used as national or regional regulations in areas having a high radiocommunication density and representing a significant portion of the radiocommunication manufacturing base. The word “generally” is intended to cover exceptional cases where a particularly unrestrictive mask may have been used, e.g. to encourage equipment development in an unattractive band (see *noting c*)).

2.14 that the following Notes 2 to 5 should be considered as part of this Recommendation.

NOTE 2 – See Recommendation ITU-R F.746 for definitions of alternated, co-channel mode band reuse and interleaved mode band reuse RF channel arrangements. Channel separation is defined as $XS/2$ for alternated frequency channel arrangements and XS for co-channel and interleaved frequency channel arrangements.

NOTE 3 – Due to possible compatibility problems, caution should be exercised when applying this Recommendation to high capacity systems, bands which have dissimilar systems in adjacent channels, and bands which are shared with other services.

NOTE 4 – Recommendation ITU-R SM.1539 also gives guidance on boundary variations where very narrow-band or very wideband emissions are concerned. In addition, as Recommendation ITU-R SM.329 allows for boundary values different than $\pm 250\%$, the following is provisionally recommended for DFSS operating above 1 GHz with channel separation less than 2 MHz:

- that the boundary between the spurious and out-of-band emissions is established as $\pm 500\%$ of the channel separation;
- that the reference bandwidth is 100 kHz in the frequency range between this boundary and ± 20 MHz of the nominal centre frequency;

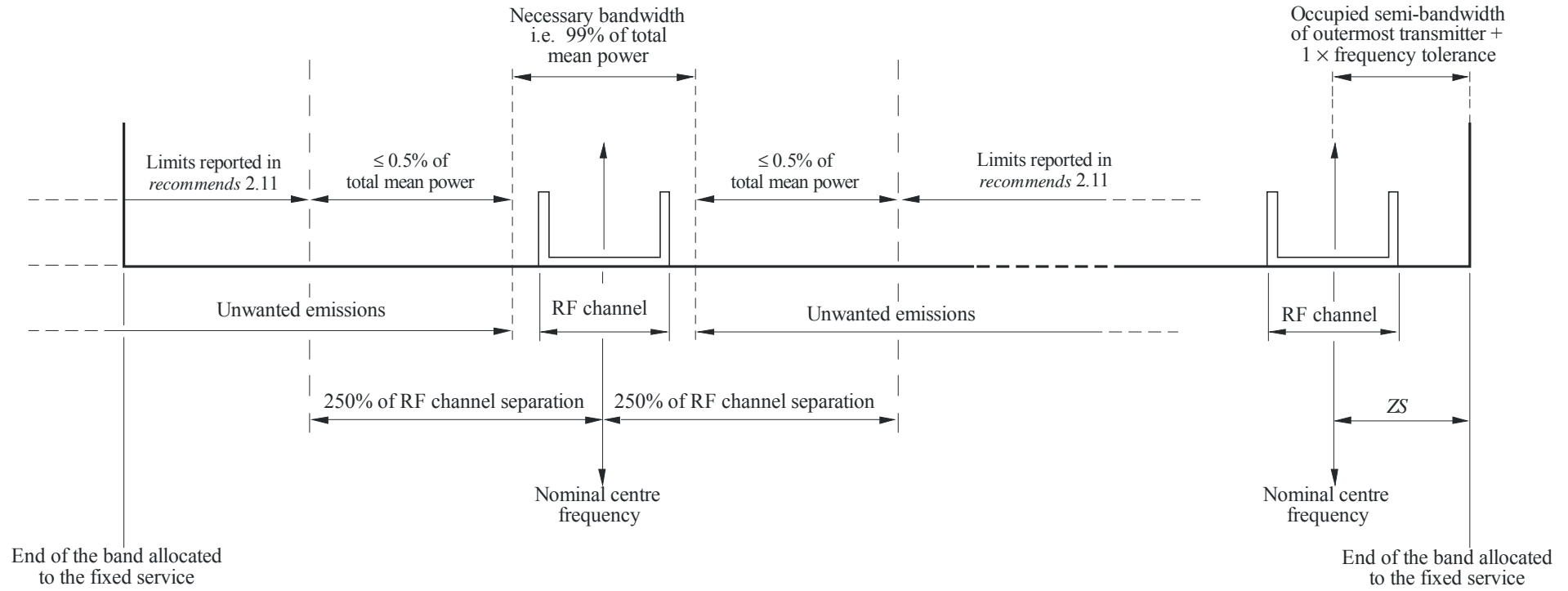
and also for DFSS operating above 1 GHz with transmitter power 20 W or more and with channel separation between 2 MHz and 14 MHz:

- that the boundary between the spurious and OoB emissions is established as $\pm 250\%$ of the channel separation;
- that the reference bandwidth is 100 kHz in the frequency range between this boundary and ± 70 MHz of the nominal centre frequency.

NOTE 5 – The precise frequency tolerance values are left to the national regulatory authorities.

FIGURE 1

Unwanted emission attenuation objectives and bandwidth of DFSS

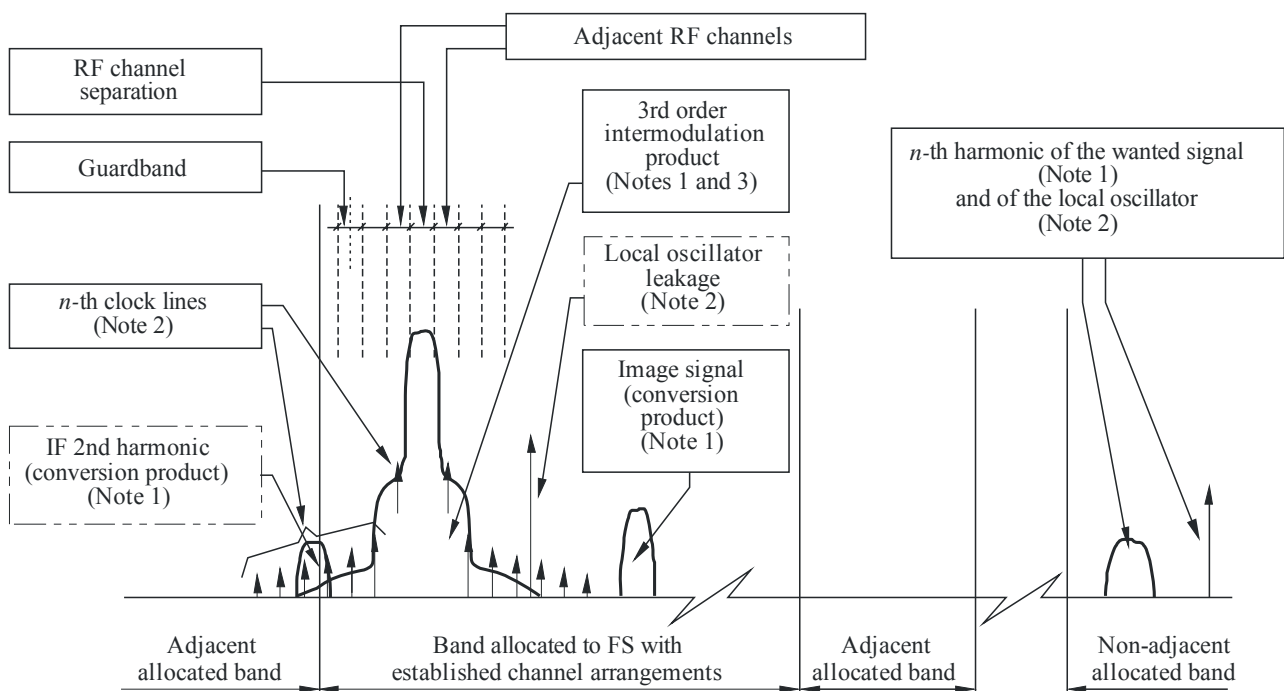


Annex 1

1 Typical emission scenario of a DFSS

Figure 2 shows the typical scenario based on typical and most important emissions of a heterodyne digital radio transmitter. Other emissions (e.g. other conversion products and residual components of the carrier generation) are not shown. For directly modulated RF transmitters, some unwanted emissions (e.g. conversion products and local oscillator leakage) are not applicable.

FIGURE 2
Frequency bands and unwanted emissions of a DFSS (typical scenario)



Note 1 – Example of noise-like component of unwanted emissions.

Note 2 – Example of discrete component of unwanted emissions.

Note 3 – Non-linearity due to transmitter results in out-of-band emission which is immediately adjacent to the necessary bandwidth, due to odd order intermodulation products.

2 Calculation of occupied bandwidth

Generally, a normalized power spectrum $W(f)$ of a modulated carrier of a DFSS can be expressed as follows:

$$W(f) = S(f) \left(\frac{\sin(\pi f T)}{\pi f T} \right)^2 \quad (1)$$

where:

$S(f)$: frequency response of the shaping filter located in the transmitter

f : frequency separation from the carrier

T : pulse width.

Therefore, the occupied bandwidth, B_0 , can be calculated as follows:

$$\int_{-B_0/2}^{+B_0/2} W(f) df = 0.99 \int_{-\infty}^{+\infty} W(f) df \quad (2)$$

2.1 Case of phase and amplitude modulated signals with ideal square root cosine roll-off shaping

In many cases shaping filters of a square root cosine roll-off type are employed at the transmitter side and the ideal frequency response is given by:

$$S(f) = \begin{cases} \left(\frac{\pi f T}{\sin(\pi f T)} \right)^2 & \text{for } |f| \leq \frac{1 - \alpha}{2T} \\ \frac{1}{2} \left(1 - \sin \left[\frac{\pi T}{\alpha} \left(|f| - \frac{1}{2T} \right) \right] \right) \left(\frac{\pi f T}{\sin(\pi f T)} \right)^2 & \text{for } \frac{1 - \alpha}{2T} < |f| \leq \frac{1 + \alpha}{2T} \\ 0 & \text{for } \frac{1 + \alpha}{2T} \leq |f| \end{cases} \quad (3)$$

where α is the roll-off factor between 0 and 1.

Substitution of equation (3) into equations (1) and (2) gives the ideal occupied bandwidth as follows:

$$B_0 = 2 K(\alpha) / T \quad (4)$$

where $K(\alpha)$ is a function of α and is calculated as shown in Table 1.

Thus, the occupied bandwidth can be calculated by using equation (4) and Table 1.

TABLE 1

The values of $K(\alpha)$

α	$K(\alpha)$
0.1	0.510
0.2	0.537
0.3	0.567
0.4	0.600
0.5	0.634
0.6	0.669
0.7	0.705
0.8	0.742
0.9	0.779
1.0	0.816

2.2 Case of phase and amplitude modulated signals with other shaping filters

Different practical implementations and other types of shaping filters are sometimes used. These cases need more complex numerical evaluations of equation (2) and are under study.

2.3 Case of frequency and phase modulated signals

These cases are under study.

3 Occupied bandwidth for multiple sub-carriers operation**3.1 Case of homogeneous and equally spaced sub-carriers**

In some cases, a DFSS transmitter may carry multiple independently modulated sub-carriers amplified by a common amplifier or an active antenna. They are also commonly referred to as multicarrier systems (see Note 1).

The occupied bandwidth B_0 for such operation should be calculated as follows:

$$B_0 = b_0 + (m - 1) \Delta F \quad (5)$$

where:

b_0 : occupied bandwidth of a single sub-carrier

m : number of sub-carriers

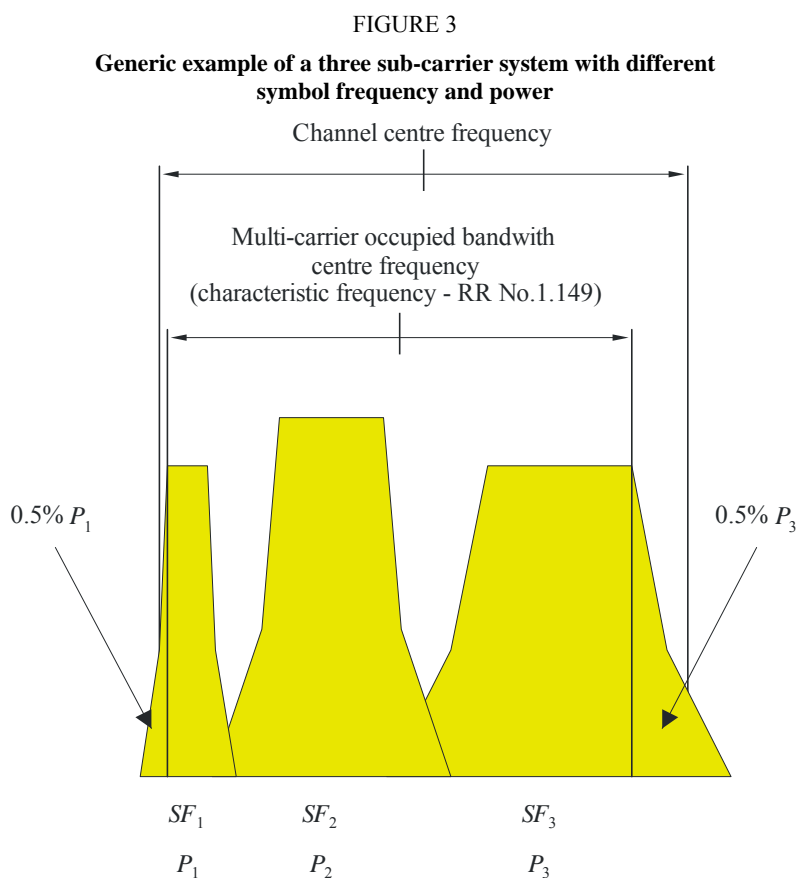
ΔF : frequency spacing between centre frequencies of adjacent sub-carriers.

Equation (5) assumes that the multiple sub-carriers are homogeneous and equally spaced and the transmitter noise is negligible in comparison to the OoB power of the outermost sub-carriers. However, it should be noted that in this case the value of percentage $\beta/2$ evaluated on the total power of all sub-carriers is $0.5/m$ %.

NOTE 1 – For the purpose of this Recommendation systems employing orthogonal frequency division modulation are not considered multicarrier systems; in these systems the large number of sub-carriers are not independently modulated.

3.2 Case of arbitrary number of sub-carriers arbitrarily spaced in frequency with different power

A generic example of this case is shown in Fig. 3.



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In Fig. 3 the generic centre frequencies and occupied bandwidth concepts for multicarrier systems with arbitrary sub-carriers are shown.

The power percentages exceeding the so defined occupied bandwidth, with respect to the total power of the system are evaluated as:

$$\text{Lower edge: } \beta/2_L = 0.5 \frac{P_1}{P_1 + P_2 + P_3} \quad \%$$

$$\text{Upper edge: } \beta/2_U = 0.5 \frac{P_3}{P_1 + P_2 + P_3} \quad \%$$

The centre of the defined occupied bandwidth may be shifted from the channel centre frequency in view of equalizing the power falling outside from both sides of the channel.