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Recommendation ITU-R F.1191-2

(05/2001)

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.1191-2

Bandwidths and unwanted emissions of digital fixed service systems*

(Question ITU-R 119/9)

(1995-1997-2001)

The ITU Radiocommunication Assembly,

considering

a) that the definitions of necessary and occupied bandwidth and allocated band are reported in Nos. 1.152, 1.153 and 1.16 of the Radio Regulations (RR) respectively;

b) that the definitions of unwanted, out-of-band and spurious emissions are reported in RR Nos. 1.146, 1.144 and 1.145 respectively;

c) that it is necessary to give guidance for the application of these definitions to digital fixed service systems (DFSS);

d) that it is relatively unlikely that out-of-band 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;

e) that from the viewpoint of interference into other systems sharing the same frequency band, interference due to out-of-band emissions will be, in general, less significant than that due to emissions within the necessary bandwidth;

f) that intra-system interference related problems, which may be caused by unwanted emissions, are normally taken into account by DFSS designers;

g) that bands are allocated to fixed services on a primary or co-primary basis, where a radio-frequency (RF) channel arrangement has been established by a relevant ITU-R Recommendation or by a national regulatory authority;

h) that transmitter frequencies should be determined so that out-of-band emissions do not cause harmful interference outside the allocated band in accordance with RR No. 4.5; the transmitters on the RF channels at the allocated band edges should comply with the general necessary bandwidth and assignment criteria required by RR No. 1.147;

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

j) that at the allocated band edges, RF bands *ZS*, as defined in Recommendation ITU-R F.746, are given by the relevant ITU-R Recommendations in order to control power spill-over into adjacent allocated bands;

k) 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;

l) that within the allocated band, coordination between various fixed service systems used on the basis of a RF channel arrangement is covered by an 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;

m) 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;

n) that DFSS have unwanted emissions composed of both noise-like and discrete components, made up of out-of-band and spurious emissions, which are not easy to distinguish one from the other;

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

p) that Recommendation ITU-R SM.329 defines the frequency boundary between spurious and out-of-band emissions as ±250% of the necessary bandwidth; however allowance is given for different definitions, and this frequency boundary may be dependent on the type of modulation used, the maximum bit rate in the case of digital modulation, the type of transmitter, and frequency coordination factors. For example, in the case of some digital systems, the frequency boundary may need to differ from the ±250% factor (see Note 4);

q) that, in fixed service applications, different emissions with different modulation formats and necessary bandwidth may co-exist in the same channel separation; it is therefore convenient, for ease of frequency coordination and for regulatory purposes, to consider the 250% of the constant channel separation as the boundary between out-of-band and spurious emissions, instead of the various different necessary bandwidths of any specific system (see Note 4);

r) that Recommendation ITU-R SM.1541 gives safety net out-of-band limits for most of the services, including the fixed service (see Note 1);

s) that on regional or national bases more tighter limits than those given by Recommendation ITU-R SM.1541 are commonly applied if such opportunities can be found;

t) that single or multi-carrier systems are widely used in DFSS;

u) that the studies required by Question ITU-R 222/1, approved by the Radiocommunication Assembly, 2000 (RA-2000), could have formal and substantial impact to basic definitions used in this Recommendation. It may be necessary to revise this Recommendation in the future to reflect the results of these studies,

noting

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

b) that RR Appendix 3 depicts tables of spurious emission limits,

recommends

1 that the following general definitions apply to DFSS:

1.1 Occupied bandwidth

The width of a frequency band such that, below the lower and above the upper frequency limits, the mean powers emitted are each equal to a specified percentage $\beta/2$ of the total mean power of a given emission (RR No. 1.153).

1.2 Necessary bandwidth

For a given class of emission, the width of the frequency band which is just sufficient to ensure the transmission of information at the rate and with the quality required under specified conditions (RR No. 1.152).

1.3 Allocated frequency band

Allocation (of a frequency band): entry in the Table of Frequency Allocations of a given frequency band for the purpose of its use by one or more terrestrial or space radiocommunication services or the radioastronomy service under specific conditions. This term shall also be applied to the frequency band concerned (RR No. 1.16).

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.

1.4 Assigned frequency band

Authorization given by an administration for a radio station to use a radio frequency or radio-frequency channel under specified conditions (RR No. 1.18).

For the purpose of this Recommendation this term is 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 operator may, in general, subdivide the block into suitable smaller sub-blocks in order to deploy a radio network in the geographical area where the assign-ment has been made, within conditions specified above (see Recommendation ITU-R F.1399).

1.5 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.

1.6 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.

1.7 Unwanted emissions

Consist of spurious emissions and out-of-band emissions (RR No. 1.146).

For DFSS an example of a typical scenario is reported in Fig. 2.

1.8 Out-of-band emission

Emission on a frequency or frequencies immediately outside the necessary bandwidth which results from the modulation process, but excluding spurious emissions (RR No. 1.144).

1.9 Spurious emission

Emission on a frequency or frequencies which are outside the necessary bandwidth and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products, but exclude out-of-band emissions (RR No. 1.145).

1.10 Characteristic frequency

A frequency which can be easily identified and measured in a given emission (RR No. 1.149).

1.11 Multicarrier system

For the purpose of this Recommendation, multicarrier systems are those where multiple sub-carriers may be transmitted simultaneously from a final output amplifier or an active antenna;

2 that the following specific design objectives and definitions 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 is reduced as a function of the sub-carriers number and bandwidth (see Section 3 of Annex 1 for details);

2.2 that, for DFSS, the necessary bandwidth is to 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 could 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 could 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, will generally be considered out-of-band emission (see Notes 4 and 5);

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, will generally be considered spurious emission (see Notes 4 and 5);

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 is presently not 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 Notes 4 and 6). Where exclusive block assignments are made, transmitters operating on sub-channels devised by the licensed operator could, 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 out-of-band emissions limits developed by Radiocommunication Study Group 1 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 7), results in a bandwidth smaller than or equal to the value of *ZS* as defined in § 1.6.

NOTE 1 – In general terms the safety net is considered to be a generally worst-case envelope based on the least restrictive out-of-band emission limits successfully used as national or regional regulations in areas having a high radiocommunications density and representing a significant portion of the radiocommunications 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.

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 – As Recommendation ITU-R SM.329 allows for boundary values different than ±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 ±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 out-of-band emissions is established as ±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.

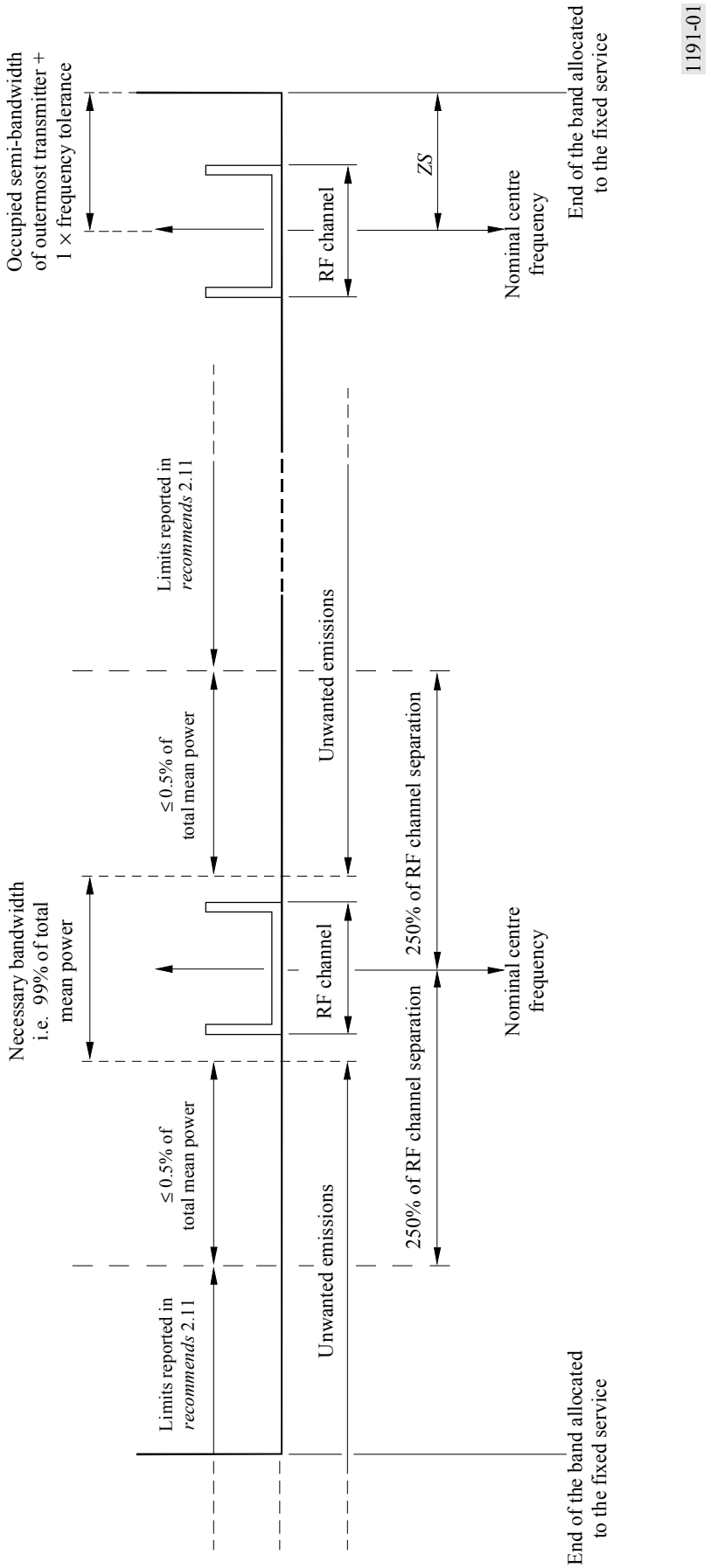
NOTE 5 – When the fixed service system is intended for use in a frequency band where an RF channel arrangement has not been established, the necessary bandwidth should be used, instead of channel separation, in evaluating the 250% boundary.

NOTE 6 – It is recognized that the reference bandwidth of 1 MHz may result in spectral density requirement of up to 24 dB more stringent than with the 4 kHz bandwidth given in the 1995 version of this Recommendation.

NOTE 7 – The precise specification of frequency tolerance values is left to the national regulatory authorities.

FIGURE 1

Unwanted emission attenuation objectives and bandwidth definitions of DFSS



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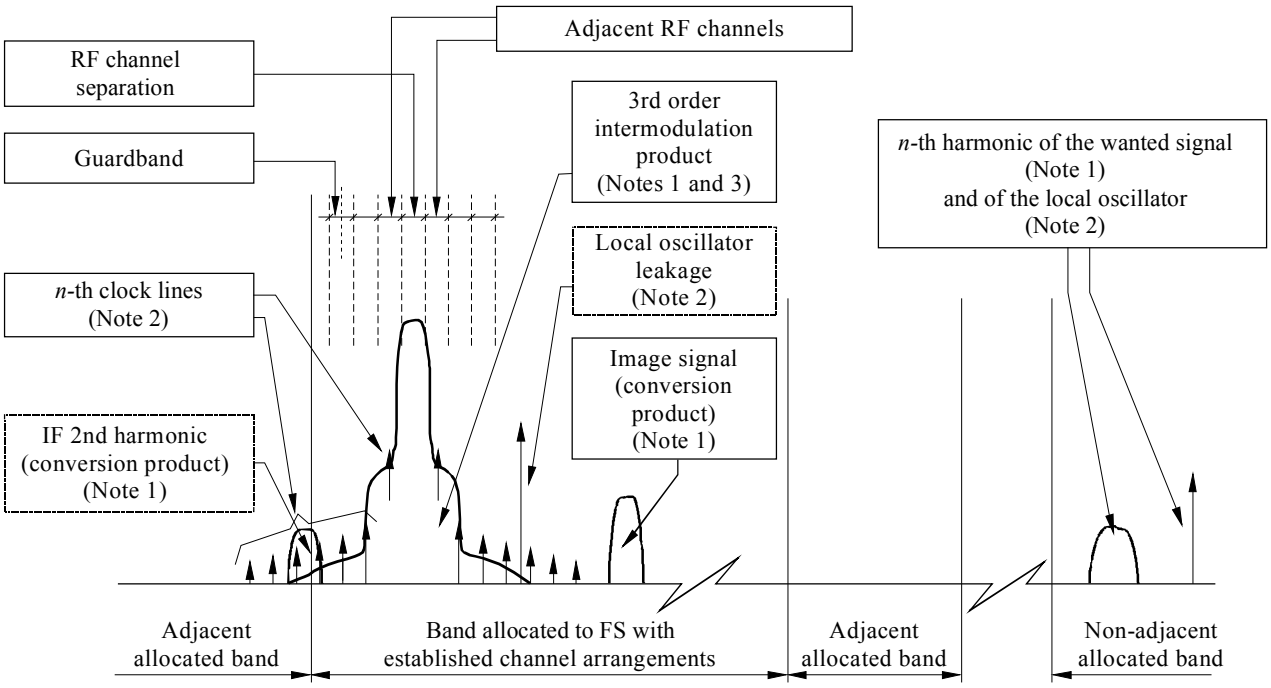
ANNEX 1

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 DFFS (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.

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2 Calculation of occupied bandwidth

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

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

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:

$$\int_{-B_0/2}^{+B_0/2} W(f)\,\mathrm{d}f = 0.99 \int_{-\infty}^{+\infty} W(f)\,\mathrm{d}f \tag{2}$$

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:

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

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:

$$B_0 = 2\,K(\alpha)/T \tag{4}$$

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:

$$B_0 = b_0 + (m - 1)\,\Delta F \tag{5}$$

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 out-of-band 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 $0.5/m$ %.

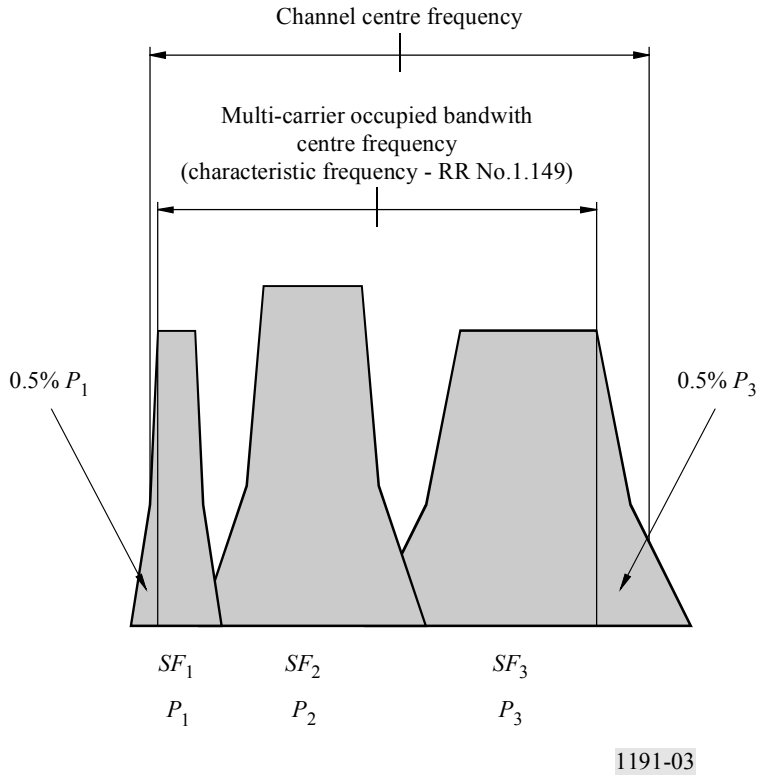
NOTE 1 – For the purpose of this Recommendation systems employing orthogonal frequency division modulation are not considered multicarrier systems; in these systems the large number of sub-carriers are not independently modulated.

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.

FIGURE 3

Generic example of a three sub-carrier system with different symbol frequency and power



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:

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

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

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.