RECOMMENDATION ITU-R S.742-1*

Spectrum utilization methodologies

(1992-1993)

The ITU Radiocommunication Assembly,

considering

a) that interference may impose a limit on the number of satellites which operate in the same frequency band in the same part of the geostationary-satellite orbit (GSO);

b) that the number of satellites using the GSO for operational purposes has grown and will continue to grow significantly in the next few years;

c) that frequency band utilization methodologies are considered as a means of reducing inhomogeneity between networks in the frequency dimension;

d) that the more heterogeneous the types of carriers concerned, the higher are the levels of internetwork interference, and the more complex is the coordination process;

e) that methods of spectrum utilization can, in some circumstances, increase the likelihood of accommodating additional users;

f) that the use of frequency band utilization methodologies will lead to the most efficient use of the radio-frequency spectrum and the GSO,

recommends

1 that in internetwork coordination one of the following spectrum utilization methodologies should be used as far as possible, depending on their individual practicalities:

1.1 Band segmentation methodologies

Spectrum segmentation can be achieved by several methods. The first method is designated as macro-segmentation, where frequency bands are segmented into large blocks, typically many transponder bandwidths wide resulting in only a few segments. Two different techniques for characterizing each of the segments can be used, the first by carrier classification and the second by parameter values. Different sets of rules can be used with each technique. The macro-segmentation method would be most effective where the proportions of different types of carrier or technical parameter values are the same in the satellite networks being coordinated.

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* Radiocommunication Study Group 4 made editorial amendments to this Recommendation in 2001 in accordance with Resolution ITU-R 44 (RA-2000).

The second method of segmentation is micro-segmentation. For this method, the segmentation is based on small blocks, typically the size of a transponder. The micro-segmentation method would be most effective where the transponder plans (bandwidths, polarization, etc.) of the satellite systems, operating in the orbital arc of coordination interest, are similar.

1.1.1 Macro-segmentation, carrier classification approach

In this technique standard types of carriers are identified and several classifications are defined. Table 1 shows how 50 different carriers can be identified and placed in one of the following three classes:

– high-density carriers: FM-TV
low-index FDM-FM

– low-capacity carriers: SCPC
low-capacity or low-power analogue and digital carriers

– average carriers: medium- to high-index FDM-FM
TDMA
wideband digital carriers.

This last type of carrier is compatible with either of the two former types as regards mutual interference. Thus only the first two types of carrier – high density and low capacity – would have to be segregated under a rational set of spectrum utilization rules: the average carriers can be placed anywhere. To accomplish this, the band allocated (generally 500 or 250 MHz wide) is divided into low-capacity and high-density sub-bands. This can be done by allotting the lower parts of the bandwidth to low-capacity carriers and the upper parts to high-density carriers and only carriers of the assigned class could use the sub-band. The optimum segmentation procedure will depend on the frequency bands in question. Figure 1 shows some of the required separation angles, obtained with the use of this method.

1.1.2 Macro-segmentation, parameter value approach

In this technique a different approach for determining sub-band segments, based on limits on particular values for parameters such as earth-station e.i.r.p., carrier bandwidth and various combinations of the WARC ORB-88 set of generalized parameters (A, B, C and D) are proposed. According to this approach the 6/4 GHz frequency band can be divided into two segments reducing the required satellites spacing to half, relative to the unsegmented case, and with the greatest improvement being achieved on the basis of carrier bandwidth, uplink e.i.r.p., and downlink e.i.r.p. (see Fig. 1).

1.1.3 Micro-segmentation

In this method, bands of the order of a transponder bandwidth are considered for sub-division. A carrier classification approach is used such that sub-bands are identified for use by high-density carriers and for avoidance by low-capacity carriers. In contrast to macro-segmentation, the sub-bands are identified relative to a transponder bandwidth (e.g. 36 MHz) instead of an entire frequency band (e.g. 500 MHz).

TABLE 1

Macro-segmentation carrier classification example

FDM-FM No.	Type		N/V	B_{oc} (MHz)	f_{min} (kHz)	f_{max} (kHz)	Δf_{st} (kHz)	Δf_m (kHz)	Categories LC	AV	HD
1	12	1.3	12	1.13	12.0	60.0	108.5	159.0	x		
2	12	2.5	12	2.2	12.0	60.0	238.9	350.0	x		
3	24	2.5	24	1.96	12.0	108.0	163.4	275.0		x	
4	60	2.5	60	2.25	12.0	252.0	136.5	276.0		x	
5	72	2.5	72	2.25	12.0	300.0	124.5	261.0		x	
6	60	5.0	60	3.96	12.0	252.0	270.1	546.0		x	
7	132	5.0	132	4.45	12.0	552.0	223.5	529.0		x	
8	192	5.0	192	4.51	12.0	804.0	180.0	459.0		x	
9	96	7.5	96	5.87	12.0	408.0	359.8	799.0		x	
10	192	7.5	192	6.40	12.0	804.0	297.2	758.0		x	
11	252	7.5	252	6.74	12.0	1 052.0	259.7	733.0		x	
12	132	10.0	132	7.50	12.0	552.0	430.0	1 020.0			x
13	252	10.0	252	8.49	12.0	1 052.0	357.4	1 009.0			x
14	312	10.0	312	8.96	12.0	1 300.0	320.0	1 005.0			x
15	252	15.0	252	12.39	12.0	1 052.0	576.4	1 627.0			x
16	432	15.0	432	12.95	12.0	1 796.0	400.2	1 479.0			x
17	432	20.0	432	17.99	12.0	1 796.0	615.8	2 276.0			x
18	612	20.0	612	17.70	12.0	2 540.0	453.7	1 996.0			x
19	432	25.0	432	20.59	12.0	1 796.0	727.3	2 688.0			x
20	792	25.0	792	22.34	12.0	3 284.0	498.4	2 494.0			x
21	972	25.0	972	25.00	12.0	4 028.0	410.0	2 274.0			x
22	972	36.0	972	35.99	12.0	4 028.0	796.7	4 417.0			x

SCPCA No.	Type		B_{oc} (kHz)	f_{min} (kHz)	f_{max} (kHz)	Δf (kHz)	Categories LC	AV	HD
23	0.020		20.0	0.3	3.4	5.8	x		
24	0.025		25.0	0.3	3.4	12.0	x		
25	0.030		30.0	0.3	3.4	8.5	x		
26	0.090		90.0	0.3	3.4	3.4	x		
27	0.180		180.0	0.3	3.4	3.3	x		

SCPCN No.	Type	N/E	B_{oc} (kHz)	Bit rate (kbit/s)	LC	AV	HD
28	0.064	4	38.0	64.0	x		
29	0.085	4	50.0	85.0	x		
30	0.128	4	150.0	128.0	x		
31	0.256	4	300.0	256.0	x		
32	0.512	4	600.0	512.0	x		

NUM-LB No.	Type	N/E	B_{oc} (MHz)	Bit rate (Mbit/s)	LC	AV	HD
33	2Q	4	1.44	2.048		x	
34	3Q	4	1.84	3.072		x	
35	4Q	4	2.25	4.096		x	
36	8Q	4	5.0	8.448		x	
37	10Q	4	5.0	10.0		x	
38	17Q	4	10.2	17.0		x	
39	25Q	4	18.0	24.6		x	
40	34Q	4	20.6	34.368		x	
41	40Q	4	20.0	40.0		x	

NUM-LB No.	Type	N/E	B_{oc} (MHz)	Bit rate (Mbit/s)	LC	AV	HD
42	50Q	4	25.6	50.0		x	
43	120Q	4	75.0	120.0		x	
44	139Q	4	82.0	139.264		x	
45	147Q	4	110.0	147.0		x	

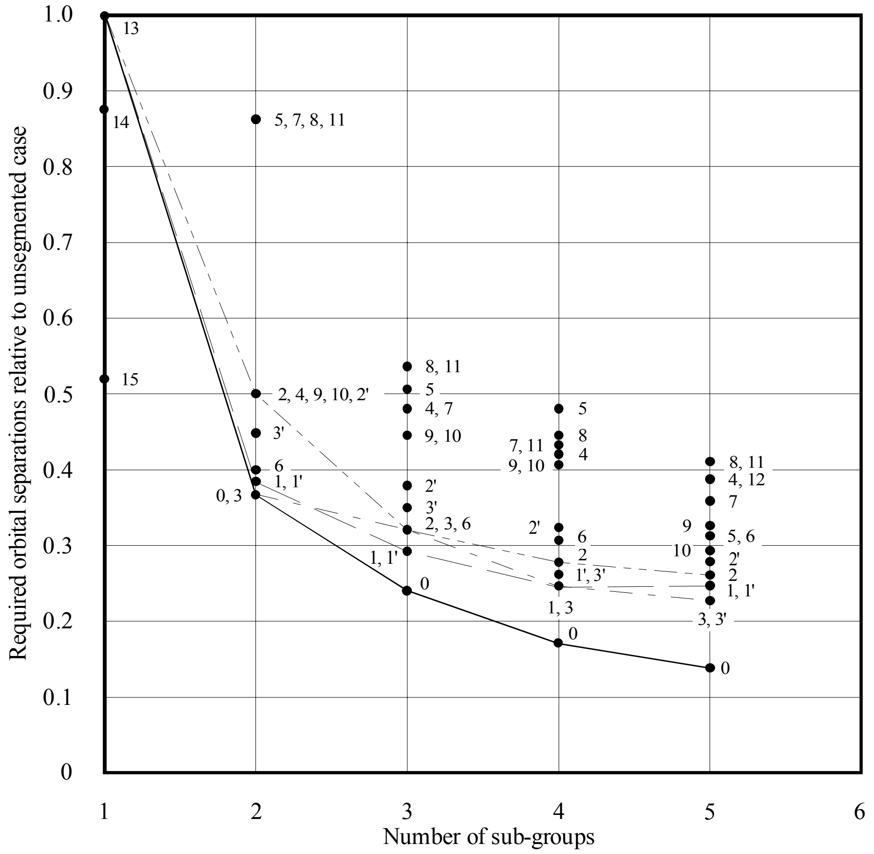
FM-TV No.	Type	Δf (MHz)	B_{oc} (MHz)	Δf_{pm} (MHz)	Δf_{pnm} (MHz)	f_{bal} (Hz)	LC	AV	HD
46	TV.17	4.75	17.5	1.0	2.0	60/30			x
47	TV.20	4.8	20.0	1.0	2.0	50			x
48	TV.30	6.2	30.0	2.0	4.0	50			x
49	TV.35	5.0	30.0	2.0	4.0	50/25			x
50	TV.36	11.0	32.0	1.0	2.0	50			x

Legend to Table 1:

SCPCA :	SCPC (analogue)
SCPCN :	SCPC (digital)
NUM-LB :	wideband (digital)
N/V :	number of channels
N/E :	number of states
B_{oc} :	occupied bandwidth
Δf :	frequency deviation
Δf_{pm} :	frequency deviation (modulated carrier)
Δf_{pnm} :	frequency deviation (unmodulated carrier)
f_{bal} :	sweep frequency
Δf_{st} :	frequency deviation (test signal)
Δf_m :	frequency deviation (multiplex signal)
LC :	low capacity
AV :	average
HD :	high density

FIGURE 1

Required satellite separations in 6/4 GHz frequency band (excludes multiple-beam considerations) using the macro-segmentation method



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0 Optimum
1 Bandwidth
2 Up-link e.i.r.p.
3 Down-link e.i.r.p.
4 Parameter A
5 Parameter B
6 Parameter C
7 Parameter D
8 A/B
9 C/D
10 Max (A/B, C/D)
11 Min (A/B, C/D)
12 Type of modulation
13 Without segmentation
14 Excluding coexistence of TV-FM and SCPC-PSK
15 Excluding coexistence of TV-FM and (SCPC-PSK and SCPC-FM)

Prime indicates that e.i.r.p.s of INTELSAT carriers are maximum.

1.2 Harmonized and flexible spectrum utilization methodologies

1.2.1 Harmonization of spectrum utilization

In this approach, harmonious utilization of the spectrum is provided by using the following rule:

– TV and high-density carriers may occupy the frequency band allocated from the top downwards: SCPC and low-capacity carriers may occupy it from the bottom upwards, or *vice versa*, depending on the range in question. This technique alleviates the problems in many cases and avoids rigid utilization of the spectrum.

This approach is very similar to carrier classification approach described above, with the added flexibility of no fixed boundaries for different carrier types. The removal of the fixed boundaries, however, may result in conflicting carrier types to be co-frequency due to an imbalance in the proportions of different carrier types in the satellite systems being coordinated. For example, some of the narrow-band single channel per carrier (SCPC) carriers in one system might overlap with an FM-TV channel in the other system. With a need for optimal orbital utilization efficiency, and hence small orbital separation between the satellites, protecting the SCPC carriers from harmful interference from FM-TV would necessitate applying one of the guidelines as noted in § 1.2.2 or Note 1 of § 2 below.

1.2.2 Flexible utilization

Under this approach, inhomogeneities among adjacent satellite frequency plans are considered during the coordination phase, using the guideline that SCPC carriers should not be allocated at or near FM-TV carrier frequencies within the energy dispersal bandwidth.

2 that the following Notes should be regarded as part of this Recommendation:

NOTE 1 – Even without strict segmentation, very considerable improvement in orbital utilization efficiency is obtainable by the avoidance of co-frequency assignment of TV-FM and SCPC carriers. This may be achieved in practice by allocating TV and SCPC to separate segments through flexible arrangements. However, it should be noted that for administrations with only a low traffic requirement, this may lead to inefficient use of the space segment.

NOTE 2 – In the carrier classification approach of the macro-segmentation method, the use of a neutral sub-band provides for a limited amount of flexibility to accommodate small traffic imbalances within the classes. However, there is a major disadvantage in the inherent rigidity of this approach. For existing systems, if re-location of carriers to appropriate sub-bands is required, this would present a problem to some systems as there could be severe constraints from either equipment or from prior coordination agreements.

The rigidity of this approach could be alleviated by permitting networks to use any sub-band for any type of carrier but following a pattern corresponding to the classifications in use. For example, the order of use could follow increasing frequency for low-capacity carriers and decreasing frequency for high-density carriers. Where difficulties between networks result from such use, preference should be given to those carriers corresponding to the sub-band classification if the difficulty could not otherwise be resolved.

NOTE 3 – In terms of the impact of both the parameter value and carrier classification approaches to macro-segmentation on existing and planned systems, every segmentation scheme would impose a rearrangement of carriers within systems. This could be difficult to implement, particularly in complex multi-beam satellites where the location of carriers is governed by several complex considerations related to coverage and connectivity. If strict band segmentation schemes were applied in these cases the efficiency in use of the spectrum and orbit may well be reduced.

NOTE 4 – In the micro-segmentation method, the width of the sub-bands where placement of low-density carriers should be avoided is probably in the range of 2 to 10 MHz; this to be the subject of further study. These methods can be augmented in some cases by alternating the polarization of overlapping high-density carriers in transponders off-set by approximately one-half of a transponder bandwidth. Using for example a 36 MHz transponder bandwidth, the spacing between the centres of the sub-band would then be 20 MHz.