RECOMMENDATION ITU-R F.746-3

RADIO-FREQUENCY CHANNEL ARRANGEMENTS FOR RADIO-RELAY SYSTEMS

(Questions ITU-R 108/9 and ITU-R 136/9)

(1991-1994-1995-1997)

The ITU Radiocommunication Assembly,

considering

a) that according to Article 8 of the Radio Regulations several frequency bands are allocated to the fixed service (FS) on a worldwide basis;

b) that other frequency bands are also allocated to the FS on a regional basis;

c) that systems are already in use and expected to be used more extensively in the future;

d) that it may be desirable to interconnect radio-relay systems on international circuits in these frequency bands;

e) that in studies carried out so far, some bands have not been the subject of Recommendations for specific radio-frequency channel arrangements which might be fitted into an international pattern as has already been done in other parts of the frequency spectrum;

f) that an index of recommended radio-frequency channel arrangements would be of assistance to the ITU-R;

g) that single- and multi-carrier digital radio-relay systems are both useful concepts to achieve the best technical and economic trade-off in system design,

recommends

1 that homogeneous patterns are preferred as the basis for radio-frequency channel arrangements;

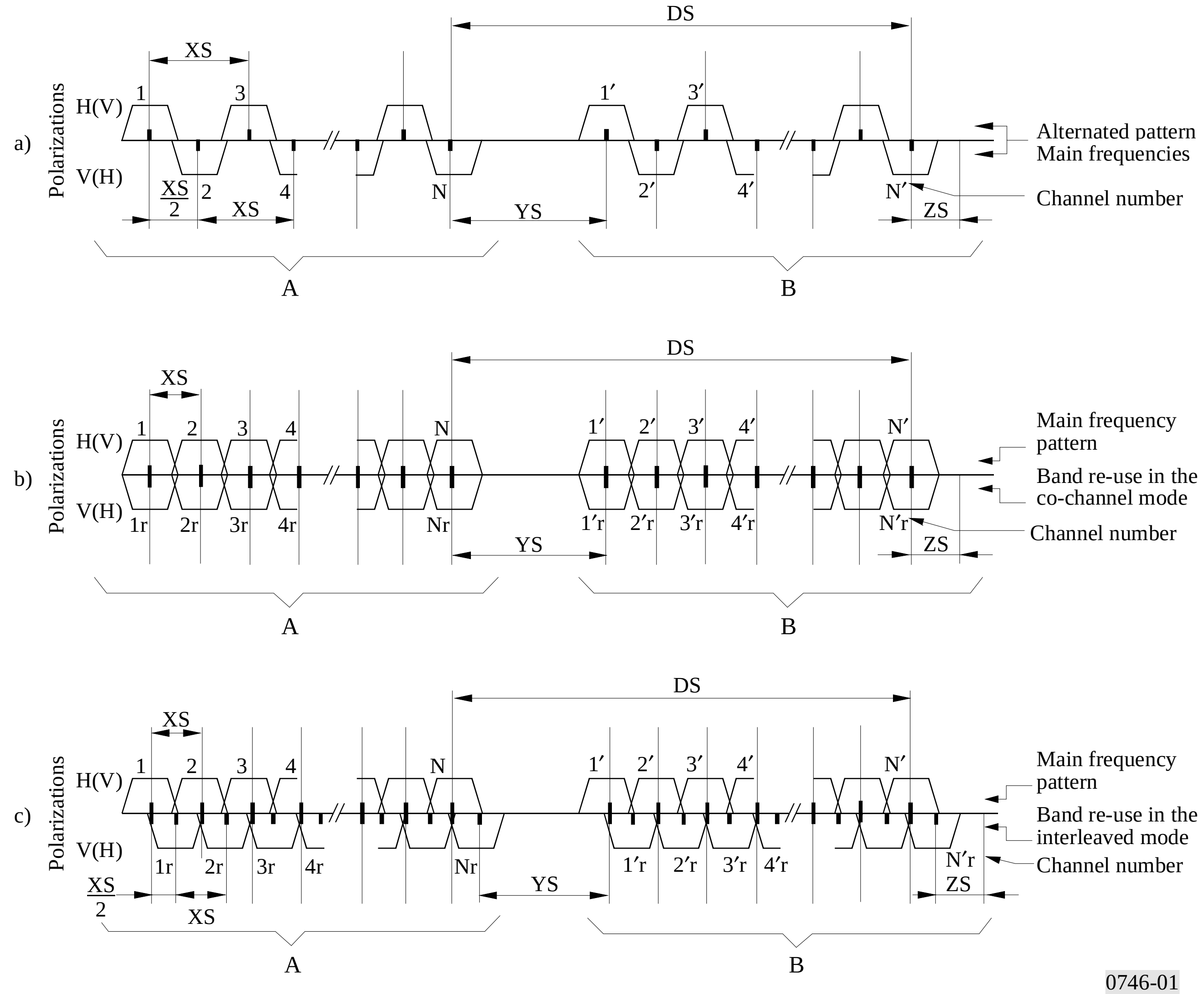
2 that the preferred radio-frequency channel arrangements should be developed from the homogeneous pattern in accordance with the alternated, co-channel band re-use, or interleaved band re-use radio-frequency channel arrangements (see Note 1) as shown in Figs. 1a), 1b) and 1c) respectively.

The main parameters affecting the choice of radio-frequency channel arrangements are:

- *XS* defined as the radio-frequency separation between the centre frequencies of adjacent radio-frequency channels on the same polarization and in the same direction of transmission;
- *YS* defined as the radio-frequency separation between the centre frequencies of the go and return radio-frequency channels which are nearest to each other. In the case where go and return frequency sub-bands are not contiguous, such that there is a (are) band(s) allocated for (an)other service(s) in the gap between, *YS* shall be considered to include the band separation (*BS*) equal to the total width of the allocated band(s) used by this (these) service(s).
- *ZS* defined as the radio-frequency separation between the centre frequencies of the outermost radio-frequency channels and the edge of the frequency band. In the case where the lower and upper separations differ in value, Z_1S refers to the lower separation and Z_2S refers to the upper separation. In the case where go and return frequency sub-bands are not contiguous, such that there is a (are) band(s) allocated for (an)other service(s) in the gap between, ZS_i will be defined for the innermost edges of both sub-bands and will be included in *YS*.
- *DS* Tx/Rx duplex spacing, defined as the radio-frequency separation between corresponding go and return channels, constant for each couple of *i* th and *i'* th frequencies, within a given channel arrangement.

FIGURE 1

Channel arrangements for the three possible schemes considered in the text



A: “go” channels B: “return” channels

The choice of radio-frequency channel arrangement depends on the values of cross-polar discrimination (XPD) and on the net filter discrimination (NFD) where these parameters are defined as:

$$XPD_{H(V)} = \frac{\text{Power received on polarization } H(V) \text{ transmitted on polarization } H(V)}{\text{Power received on opposite polarization } V(H) \text{ transmitted on polarization } H(V)} \quad \text{(See Note 2)}$$

$$NFD = \frac{\text{Adjacent channel received power}}{\text{Adjacent channel power received by the main receiver after RF, IF and BB filters}} \quad \text{(See Note 3)}$$

The *XPD* and *NFD* parameters (dB) contribute to the value of carrier-to-interference ratio.

If XPD_{min} is the minimum value reached for the percentage time required, from this value and from the adjacent channel *NFD*, the total amount of interfering power can be evaluated, and this result must be compared with the minimum value of carrier-to-interference $(C/I)_{min}$ acceptable to the modulation adopted (see Note 4).

Alternated channel arrangements can be used (neglecting the co-polar adjacent channel interference contribution) if:

$$XPD_{min} + (NFD - 3) \geq (C/I)_{min} \qquad \text{dB}$$

Co-channel arrangements can be used if:

$$10 \log \frac{1}{\dfrac{1}{10^{\frac{XPD + XIF}{10}}} + \dfrac{1}{10^{\frac{NFD_a - 3}{10}}}} \geq (C/I)_{min} \qquad \text{dB}$$

Interleaved channel arrangements can be used if:

$$10 \log \frac{1}{\dfrac{1}{10^{\frac{XPD + (NFD_b - 3)}{10}}} + \dfrac{1}{10^{\frac{NFD_a - 3}{10}}}} \geq (C/I)_{min} \qquad \text{dB}$$

where:

NFD_a : net filter discrimination evaluated at *XS* frequency spacing

NFD_b : net filter discrimination evaluated at $XS/2$ frequency spacing

XIF : *XPD* improvement factor of any cross-polar interference countermeasure, if implemented in the interfered receiver;

3 that the channel arrangements reported in Fig. 1 may be used for digital radio-relay systems either with single carrier or multi-carrier transmission (see Note 5);

4 that when multi-carrier transmission is employed, the overall number of carriers will be regarded as a single channel whose centre frequency and channel spacing will be that defined according to Fig. 1 disregarding the actual centre frequency of the carriers, which may vary, for technical reasons, according to practical implementations;

5 that where practicable (e.g. in newly exploited or rearranged bands with comparable width) it is useful to have the same duplex separation in different nearby frequency bands;

6 that Tables 1 and 2 report the summary of presently ITU-R defined radio-frequency channel arrangements with reference to the relevant Recommendation. Some radio-frequency channel arrangements in bands that are not covered by a specific Recommendation, and which are nevertheless used by administrations, are reported in Annexes 1 to 8 for due regard.

TABLE 1

Radio-frequency channel arrangement for radio-relay systems in frequency bands below about 17 GHz

(Question ITU-R 136/9)

Band (GHz)	Frequency range (GHz)	Recommendations ITU-R F-Series	Channel spacing (MHz)
1.4	1.35-1.53	1242	0.25; 0.5; 1; 2; 3.5
2	1.427-2.69 1.7-2.1; 1.9-2.3 1.7-2.3 1.9-2.3 1.9-2.3 1.9-2.3 2.3-2.5 2.29-2.67 2.5-2.7	701 382 283 1098 1098, Annexes 1, 2 1098, Annex 3 746, Annex 1 1243 283	0.5 (pattern) 29 14 3.5; 2.5 (patterns) 14 10 1; 2; 4; 14; 28 0.25; 0.5; 1; 1.75; 2; 3.5; 7; 14; 2.5 (pattern) 14
4	3.8-4.2 3.6-4.2 3.6-4.2	382 635 635, Annex 1	29 10 (pattern) 90; 80; 60; 40
5	4.4-5.0 4.4-5.0 4.4-5.0 4.54-4.9	746, Annex 2 1099 1099, Annex 1 1099, Annex 2	28 10 (pattern) 40; 60; 80 40; 20
L6	5.925-6.425 5.85-6.425	383 383, Annex 1	29.65 90; 80; 60
U6	6.425-7.11 6.425-7.11	384 384, Annex 1	40; 20 80
7	7.425-7.725 7.425-7.725 7.435-7.75 7.11-7.75	385 385, Annex 1 385, Annex 2 385, Annex 3	7 28 5 28
8	8.2-8.5 7.725-8.275 7.725-8.275 8.275-8.5	386 386, Annex 1 386, Annex 2 386, Annex 3	11.662 29.65 40.74 14; 7
10	10.3-10.68 10.5-10.68 10.55-10.68	746, Annex 3 747, Annex 1 747, Annex 2	20; 5; 2 7; 3.5 (patterns) 5; 2.5; 1.25 (patterns)
11	10.7-11.7 10.7-11.7 10.7-11.7 10.7-11.7	387, Annexes 1 and 2 387, Annex 3 387, Annex 4 387, Annex 5	40 67 60 80
12	11.7-12.5 12.2-12.7	746, Annex 4, § 3 746, Annex 4, § 2	19.18 20 (pattern)
13	12.75-13.25 12.75-13.25 12.7-13.25	497 497, Annex 1 746, Annex 4, § 1	28; 7; 3.5 35 25; 12.5
14	14.25-14.5 14.25-14.5	746, Annex 5 746, Annex 6	28; 14; 7; 3.5 20
15	14.4-15.35 14.5-15.35 14.5-15.35	636 636, Annex 1 636, Annex 2	28; 14; 7; 3.5 2.5 (pattern) 2.5

TABLE 2

Radio-frequency channel arrangements for radio-relay systems in frequency bands above about 17 GHz

(Question ITU-R 108/9)

Band (GHz)	Frequency range (GHz)	Recommendations ITU-R F-Series	Channel spacing (MHz)
18	17.7-19.7	595	220; 110; 55; 27.5
	17.7-21.2	595, Annex 1	160
	17.7-19.7	595, Annex 2	220; 80; 40; 20; 10; 6
	17.7-19.7	595, Annex 3	3.5
	17.7-19.7	595, Annex 4	13.75; 27.5
23	21.2-23.6	637	3.5; 2.5 (patterns)
	21.2-23.6	637, Annex 1	112 to 3.5
	21.2-23.6	637, Annex 2	28; 3.5
	21.2-23.6	637, Annex 3	28; 14; 7; 3.5
	21.2-23.6	637, Annex 4	50
	21.2-23.6	637, Annex 5	112 to 3.5
	22.0-23.6	637, Annex 1	112 to 3.5
27	24.25-25.25	748	3.5; 2.5 (patterns)
	24.25-25.25	748, Annex 3	56; 28
	25.25-27.5	748	3.5; 2.5 (patterns)
	25.25-27.5	748, Annex 1	112 to 3.5
	27.5-29.5	748	3.5; 2.5 (patterns)
	27.5-29.5	748, Annex 2	112 to 3.5
	27.5-29.5	748, Annex 3	112; 56; 28
31	31.0-31.3	746, Annex 7	25; 50
38	36.0-40.5	749	3.5; 2.5 (patterns)
	36.0-37.0	749, Annex 3	112 to 3.5
	37.0-39.5	749, Annex 1	140; 56; 28; 14; 7; 3.5
	38.6-40.0	749, Annex 2	50
	39.5-40.5	749, Annex 3	112 to 3.5
55	54.25-58.2	1100	3.5; 2.5 (patterns)
	54.25-57.2	1100, Annex 1	140; 56; 28; 14
	57.2-58.2	1100, Annex 2	100

NOTE 1 – A given frequency channel arrangement can be regarded as either alternated or interleaved as a consequence of the symbol rate transmitted by the radio systems. Alternated frequency channel arrangements may be, in principle, further implemented with co-channel band re-use.

NOTE 2 – The definition and application of XPD is different from that of cross-polarization isolation (XPI) as defined in Recommendation ITU-R P.310.

NOTE 3 – In the definition of *NFD* the following assumptions are made:

– adjacent channels *XPD*, if any, has not been taken into account,

– a single side interfering channel only is considered; for double side like-modulated interferences a NFD value 3 dB lower should be taken into account.

NOTE 4 – This argument is covered by the outage and propagation behaviour prediction methods covered by Recommendations ITU-R F.1093 and ITU-R P.530.

NOTE 5 – A multi-carrier system is a system with n (where $n > 1$) digitally modulated carrier signals simultaneously transmitted (or received) by the same radio-frequency equipment. The centre frequency should be regarded as the arithmetic average of the n individual carrier frequencies of the multi-carrier system. When applying a multi-carrier system in an already existing radio-frequency channel arrangement, it may be convenient to shift the centre frequency of the multi-carrier system to the middle of two adjacent channels of the basic arrangement.

ANNEX 1

Radio-frequency channel arrangement in the band 2 300-2 500 MHz
(Table 1)

1 The radio-frequency channel arrangement for the above radio-relay systems is based on an adjacent-channel spacing of 1 MHz, and is derived as follows:

Let f_0 be the reference frequency of the frequency pattern (MHz),

f_n be the centre frequency of one radio-frequency channel in the lower half of the band (MHz),

f'_n be the centre frequency of one radio-frequency channel in the upper half of the band (MHz),

then the centre frequencies of the individual channels can be expressed by the following relationships:

lower half of the band: $f_n = f_0 - 87 + n$

upper half of the band: $f'_n = f_0 + 7 + n$

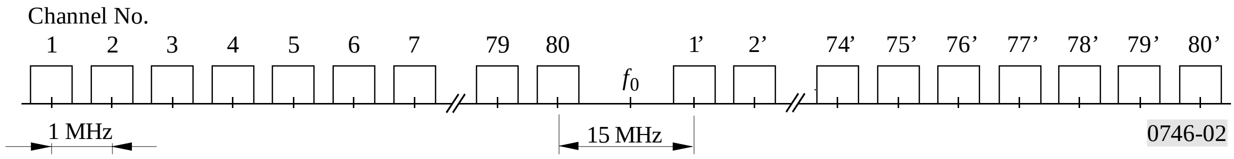
where:

$n = 1, 2, 3, ..., 80.$

This is illustrated in Fig. 2.

FIGURE 2

Radio-frequency channel arrangement for up to 300 telephone channel radio-relay systems operating in the 2 300-2 500 MHz band



2 The reference frequency should preferably be $f_0 = 2\,394$ MHz.

3 In a section over which an international or rural connection is arranged, as well as in a network node, all the go channels should be in one half of the radio-frequency band, and all the return channels in the other half.

4 The preferred adjacent co-polar channel separations for various channel capacities are listed in Table 3.

TABLE 3

Channel capacity	RF channel separation (MHz)	n
12 FDM	1	1, 2, 3, 4, ...
24 FDM	2	1, 3, 5, 7, ...
60 FDM	4	1, 5, 9, 13, ...
120 FDM	14	1, 15, 29, 43, ...
300 FDM	28	1, 29, 57
24 PCM	2	1, 3, 5, 7, ...
30 PCM	2	1, 3, 5, 7, ...
48 PCM	4	1, 5, 9, 13, ...
60 PCM	4	1, 5, 9, 13, ...
30 PCM(1)	1	1, 2, 3, 4, ...
60 PCM(1)	2	1, 3, 5, 7, ...

(1) Using multi-state modulation (e.g. 16-QAM).

5 When, for example, either at a nodal point or within an artery (using cross-polar discrimination), and for capacities of 24 telephone channels or more, additional radio-frequency channels are required, the channel numbers should be as follows:

24 telephone channels:	$n = 2, 4, 6, 8, ...$	$(n \leq 80)$
60 telephone channels:	$n = 3, 7, 11, 15, ...$	$(n \leq 79)$
120 telephone channels:	$n = 8, 22, 36, 50, ...$	$(n \leq 78)$
300 telephone channels:	$n = 15, 43, 71.$	

6 For capacities of 60 telephone channels or more, additional frequencies with channel number:

$n = 2, 4, 6, 8, ...$	for 60 telephone channels
$n = 5, 12, 19, 26, ...$	for 120 telephone channels
$n = 8, 22, 36, 50, ...$	for 300 telephone channels

are available for use as offset frequencies. Use of these frequencies may help to reduce interference along a route due to over-reach, or to reduce the requirements for antenna discrimination in a network node.

NOTE 1 – Further studies are required to evaluate interference problems caused by intermodulation products between different systems working on the same route.

ANNEX 2

Radio-frequency channel arrangement in the band 4 400-5 000 MHz
(Table 1)

This Annex describes a radio-frequency channelling plan for digital systems in the band 4 400-5 000 MHz. The arrangement provides for up to 10 go and 10 return channels, each accommodating either 4 × 34 Mbit/s or 1 × 139 368 kbit/s.

A 64-QAM modulation scheme allows for system operation at those bit rates.

1 The radio-frequency channel arrangement is shown in Fig. 3 and is derived as follows:

Let f_0 be the frequency at the centre of the band:

$f_0 =$ 4 700 MHz,

f_n : frequency of one radio-frequency channel in the lower half of the band (MHz),

f'_n : frequency of one radio-frequency channel in the upper half of the band (MHz),

the centre frequencies of the individual channels are expressed by the following relationships:

lower half of the band: $f_n = f_0 - 310 + 28\ n$

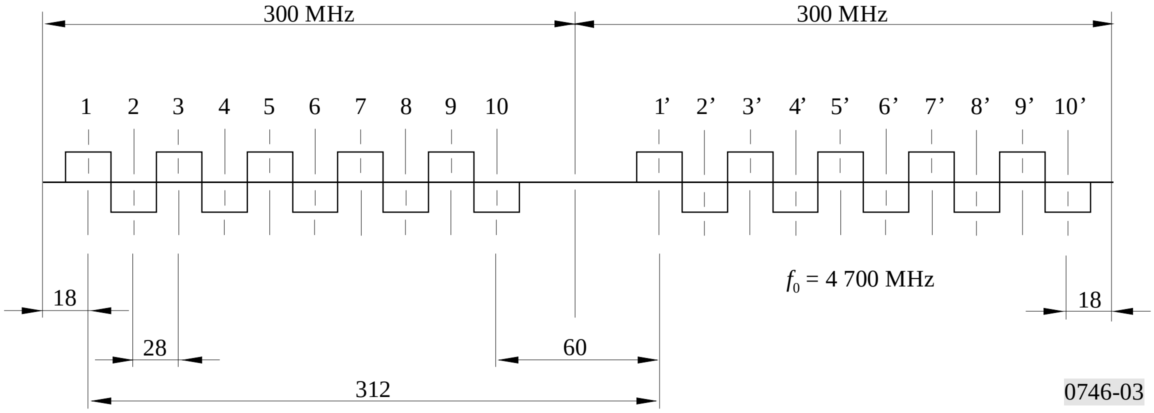
upper half of the band: $f'_n = f_0 + 2 + 28\ n$

where:

$n = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10.$

FIGURE 3

Radio-frequency channel arrangement for the band 4 400-5 000 MHz with a 28 MHz channel spacing



2 All the go channels should be in one half of the band and all the return channels should be in the other half of the band.

3 This radio-frequency channelling arrangement also allows transmission of SDH, STM-1 at 155 520 kbit/s signals, using an appropriate modulation method.

ANNEX 3

Utilization of the band 10.3-10.68 GHz
(Table 1)

Recommendation ITU-R F.747 gives radio-frequency channel arrangements for use of the band 10.5-10.68 GHz. However, some administrations use alternative arrangements, and examples are:

1 2 MHz plan in the band 10.5-10.68 GHz

In the United Kingdom the band is used for point-to-multipoint systems with a channel bandwidth of 2 MHz. To allow coexistence with existing services, different channel plans are used for different areas of the United Kingdom.

2 5 MHz plan in the bands 10.38-10.45 GHz and 10.58-10.65 GHz

In Sweden, these frequency bands are used for the transmission by radio channel of 120 telephone channels (FDM) or of 30 digital channels. The channel arrangement is based on a separation of 5 MHz.

Attention is drawn to the fact that, in Region 2, the band 10.38-10.45 GHz is not available for radio-relay systems.

3 20 MHz plan in the bands 10.3-10.45 GHz and 10.5-10.68 MHz

In Italy, these frequency bands are used for the transmission by radio channels of analogue and digital TV.

The channel arrangement is based on a separation of 20 MHz.

ANNEX 4

Utilization of the band 11.7-13.25 GHz
(Table 1)

Recommendation ITU-R F.497 gives radio-frequency channel arrangements for digital and analogue systems in the band 12.75-13.25 GHz. However, some administrations use also parts of the band 11.7-13.25 GHz. Examples are as follows:

1 12.5/25 MHz plan

In the United States of America, extensive use is being made of the 12.7-12.95 GHz range primarily for television transmission to feed wired distribution systems (cable television). These systems, often traversing distances of 100 to 500 km, are typically uni-directional, hence a frequency pattern without a guard band is used, utilizing a 25 MHz spaced main channel plan and a mid-spaced interstitial plan for coordination purposes (e.g. branch routes).

This frequency range is also available for multiple television channel transmission – both vestigial sideband/SSB and VSB/FM. These are typically of a short-haul type (5-15 km) and feed multiple receiving points. The rest of the band (12.95-13.25 GHz) uses a similar channelling pattern, but in this case the prime use is to feed television broadcasting systems, both in fixed, as well as in mobile, configurations. In Japan, the entire frequency range of 12.7-13.25 GHz is used for television pick-up and studio transmitter links with the same 25 MHz channel separations.

2 20 MHz plan

In the United States of America and Japan, the 12.2-12.7 GHz range is used for both television and telephony data transmission. The channelling arrangement is based on a 20 MHz pattern. These channels are used for FDM telephony (to 1 200 channels) or for digital data streams up to 45 Mbit/s. Users of this band include utilities, educational entities, civil government and commerce.

3 The band 11.7-12.5 GHz

The development of a channel arrangement with a frequency spacing of 19.18 MHz (the selection of radio-frequency channels from the 19.18 MHz spacing plan should be determined by agreement between the administrations concerned) in the 11.7-12.5 GHz band will need to take into account the requirements of the broadcasting-satellite service (BSS) to which the band or parts thereof are also allocated, in accordance with the decisions of the World Administrative Radio Conference for the Planning of the Broadcasting-Satellite Service (Geneva, 1977) (WARC BS-77), the World Administrative Radio Conference (Geneva, 1979) (WARC-79) and the First Session of the World Administrative Radio Conference on the Use of the Geostationary-Satellite Orbit and the Planning of the Space Services Utilizing It (Geneva, 1985) (WARC ORB-85). For Regions 1 and 3, studies indicate that a channel arrangement should have the following basic characteristics in order to facilitate sharing between the two services:

– adjacent channel spacing should be the same as, or a multiple of, the spacing agreed for the BSS (19.18 MHz);

– channel frequencies should coincide or be interleaved with the BSS frequencies, that is:

$$f = 11\,708.3 + 19.18\, n \quad \text{MHz}$$

or $$f = 11\,717.89 + 19.18\, n \quad \text{MHz}$$

where:

$n = 1, 2, 3, ..., 40;$

– go and return channel separations should be compatible with BSS frequency grouping.

In the band 11.7-12.5 GHz, certain countries propose to use radio-relay systems with SSB modulation for the simultaneous transmission of several television and sound-broadcasting signals by one or more transmitters to a number of receiving stations. The frequencies indicating the channel to be used for an individual television plus sound signal should correspond to the centre of the modulating band of the individual signal.

ANNEX 5

Radio-frequency channel arrangement in the band 14.25-14.5 GHz using a 14/28 MHz channel spacing

(Table 1)

In the United Kingdom, the basic 14/28 MHz pattern is used in the band 14.25-14.5 GHz, as an extension of the 13 GHz band in Recommendation ITU-R F.497, to provide analogue television or medium and low capacity digital channels with channel spacings of 28, 14, 7 and 3.5 MHz.

Recommendation ITU-R F.636 shows preferred channel arrangements in the band 14.4-15.35 GHz, using the basic pattern which takes account of the differing restrictions imposed by various administrations in the centre of the band.

The basic 28 MHz channel arrangement is as follows:

lower half of the band: $f_n = f_r + 2\,534 + 28\,n$ MHz

upper half of the band: $f'_n = f_r + 2\,674 + 28\,n$ MHz

where:

f_r : reference frequency

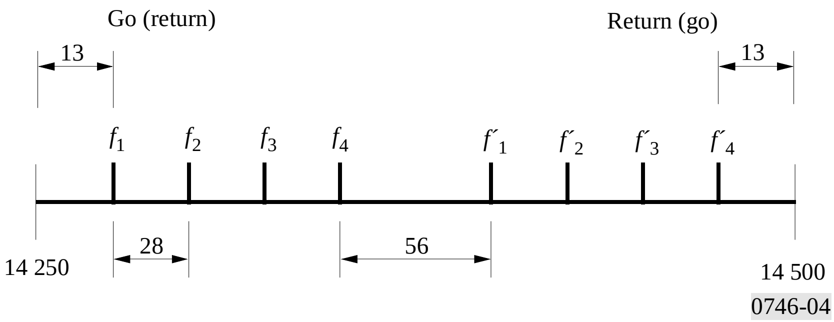
$n = 1, 2, 3, 4.$

The frequency arrangement with $f_r = 11\,701$ MHz is shown in Fig. 4.

FIGURE 4

Radio-frequency channel arrangement in the frequency band 14.25-14.5 GHz

(All frequencies in MHz)



NOTE 1 – Due to the narrow edge and centre guard bands, channels 1 and 4 are unsuitable for use at 34 Mbit/s on a 28 MHz channel spacing. These channels are, therefore, restricted to use for 625-line analogue television or low capacity digital systems, with the channels subdivided to 7 and 3.5 MHz, in a similar manner to that adopted in Recommendation ITU-R F.497, § 10, Alternatives I and III.

ANNEX 6

Radio-frequency channel arrangement in the band 14.25-14.5 GHz using a 20 MHz channel spacing
(Table 1)

20 MHz plan in the band 14.25-14.5 GHz

In Italy, the band 14.25-14.5 GHz is used for the transmission of colour TV signals with up to six sound channels, above the video band.

The specific 20 MHz channel arrangement is derived as follows:

lower half of the band: $f_n = f_r + 2\,549 + 10\,n$ MHz

upper half of the band: $f'_n = f_r + 2\,679 + 10\,n$ MHz

where:

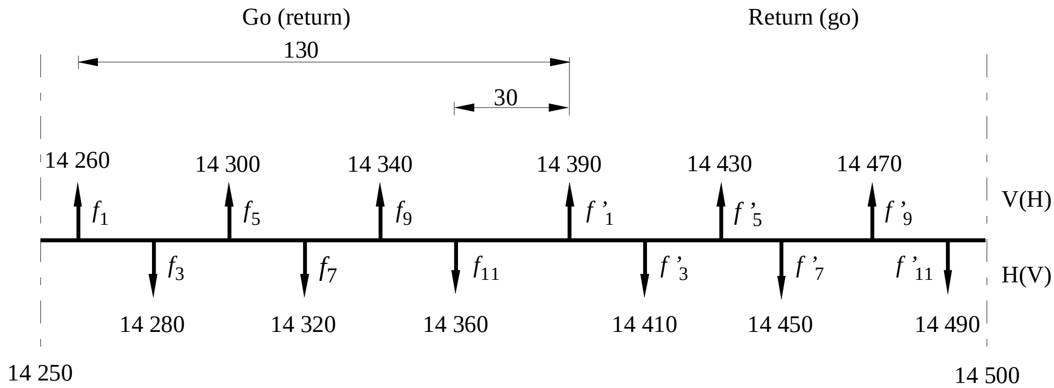
f_r : reference frequency

$n = 1, 3, 5, 7, 9, 11.$

The frequency arrangement with $f_r = 11\,701$ MHz is shown in Fig. 5.

FIGURE 5

Radio-frequency channel arrangement for radio-relay systems operating in the 14 GHz band with 20 MHz spacing
(All frequencies in MHz)



0746-05

ANNEX 7

Radio-frequency channel arrangement in the band 31.0-31.3 GHz
(Table 2)

This band is intended, in the United States of America, for use without prior frequency coordination and without protection against harmful interference. Either 25 MHz or 50 MHz channels can be used.

The radio-frequency channel arrangement with 25 MHz channels can be represented as follows:

$$f_n = f_r + 25\,n$$

where:

$n = 1, 2, 3, ..., 12$

f_r (reference frequency) = 30 087.5 MHz.

The corresponding arrangement for 50 MHz channels is as follows:

$$f_n = f_r + 50\,n$$

where:

$n = 1, 2, 3, 4, 5, 6$

f_r (reference frequency) = 30 075 MHz.

For two-way operation in either radio-frequency channel arrangement, the go-return separation is 150 MHz.