Recommendation T/R 25-03 (Stockholm 1976 and 1977)

CO-ORDINATION OF FREQUENCIES FOR THE LAND MOBILE SERVICE IN THE 80, 160 AND 460 MHz BANDS AND THE METHODS TO BE USED FOR ASSESSING INTERFERENCE

Recommendation proposed by "Radiocommunications" Working Group T/WG 3 (R)

Text of the Recommendation adopted by the "Telecommunications" Commission.
"The European Conference of Posts and Telecommunications Administrations,

considering

(a) that it is necessary to harmonise procedures for the co-ordination of frequencies for the land mobile service in frontier regions,
(b) that it is important that a simple method of co-ordination be established which Administrations will be able to implement as widely as possible,
(c) that it is a matter of utmost necessity that the available spectrum be used with maximum efficiency, in particular avoiding according land mobile service radio stations greater protection than justified by operating requirements,
(d) that exceptionally some stations require increased protection, for example stations of the public land mobile radio telephone service,
(e) that in practice it is advantageous both for determining the field strength of the wanted signal and for determining that of the interfering signal to use the same propagation curves,
(f) that it may be very useful to determine a maximum permissible value for the field strength of the interfering signal,
(g) that account needs to be taken of the variable nature of propagation phenomena, which depend on location and time,
(h) that the use of certain selective calling devices can to a certain extent improve the quality of the service by eliminating a large amount of interference,

recommends

that in co-ordinating frequencies in frontier regions for the land mobile service Administrations should be guided by the following provisions:

1.- for determining field strength, the CCIR propagation curves valid for 50% of locations and 50% of the time shall be used in every case.
2. calculations shall be made following the procedure set out in part A of the Annex to this Recommendation,
3. the parameters contained in part B of the Annex shall be used to determine the need for co-ordination and for dealing with practical cases of co-ordination,
4. Administrations shall divide stations into 3 groups:
   Group l : stations requiring an exceptional quality of service and consequently a high level of protection;
   Group 2: stations requiring a normal quality of service;
   Group 3: stations requiring no protection,
5. Administrations shall classify under group 2 the largest possible number of stations not classified under group 3. For this purpose users may, for example, be invited to use, as appropriate, selective calling devices and effective methods of coding so as to reduce the effects of interference in the absence of the wanted signal."

Annex

A. CALCULATION OF FIELD STRENGTH

1. PRINCIPLE

The sensitivity of a receiver is determined by the electromotive force which enables a given value for the output signal to noise ratio to be obtained; if the gain of the antenna and the feed line losses are known, the minimum value C_o of the electrical field can be deduced from this.

The electrical field produced at a distance by a radio-electrical transmitter of known characteristics is subject to propagation variations and its strength varies with time and according to the location. It is accepted that, according to the laws of probability, its value will follow a normal distribution in dB.

In that case, if the value of the standard deviation is known, it is possible to determine the median value of the field so as to obtain the value C_o with a given probability P.

The median value must be

$C_m = C_o + x\sigma$

where σ is the value of the standard deviation and x a coefficient. The relationship between P and x is given by tables or curves.

Given the random nature of the distribution of the field, a service quality may be characterised by the percentage of locations where, in a given zone, the field exceeds the value C_o.

However, this is inadequate if unwanted transmissions reach the receiver, thus causing interference.

If reception of the wanted signal is not to be disturbed by the interfering signal, the ratio between their values at any given time must be sufficiently high.

The minimum value of this ratio is the protection ratio (R_o).

Given that the variations in the interfering field obey the same statistical laws as those affecting the wanted field, the ratio between them also varies according to a statistical law of the same kind, in accordance with the following rules:

— the median value of the ratio between the wanted field and the interfering signal, expressed in dB, is equal to the difference between the median values of these fields;

— the value of the standard deviation for the statistical distribution of this ratio is:

$\sigma' = \sqrt{\sigma_u^2 + \sigma_b^2}$

where

σ_u = standard deviation for the wanted field

σ_b = standard deviation for the interfering field

Since the nature of the two fields is the same, $\sigma_u = \sigma_b = \sigma$

and $\sigma' = \sqrt{2} \cdot \sigma$

In order to arrive at a complete definition of a quality of service it is therefore necessary not only to define the percentage of locations in which the zone to be served must be covered, but also at what percentage of locations protection against interference must be provided, in other words, for what percentage of locations the ratio between the wanted field and the interfering field must be greater than R_o in dB.

If this probability is fixed at P, the median value for this ratio must be

$R_m = R_o + x \cdot \sigma'$

Since C_m, the median value of the wanted field, has been determined by the quality of service, the level of protection enables R_m to be determined, thus giving the median value for the interfering field:

$B_m = C_m - R_m$

2. SENSITIVITY OF RECEIVERS

The sensitivity to be taken into account for co-ordination at frontiers shall be 6 dB in relation to one microvolt (e.m.f.).

3. CORRESPONDING VALUE OF THE FIELD

Power received

$$P_r = \frac{e^2}{120\,\pi} \cdot \frac{g_i \lambda^2}{4\,\pi} \qquad (1)$$

which gives

$$P_r = C + G_d - 20 \log f - 105 \qquad (2)$$

If the antenna and the receiver have the same impedance of 75 ohms the power received is therefore

$$P_r = \frac{e^2}{4\,Z} = \frac{e^2}{300} \qquad (3)$$

which gives

$$P_r = E - 145 \qquad (4)$$

It follows that

$$C = E + 20 \log f - G_d - 40 \qquad (5)$$

Account is taken of mismatching loss caused by using antennas and receivers with different input impedances by making a correction D, and of antenna inefficiency by making a correction A, depending on the type of installation. We then obtain

$$C = E + 20 \log f - G_d - 40 + D + A \qquad (6)$$

For example, in the case of an antenna $\lambda/4$ and receiver input impedance of 50 ohms, we can admit

$G_d = 3$ dB $D = 2$ dB $A = 3$ dB

from which it follows that

$C = E + 20 \log f - 38$

This gives the following values for the field C in the different frequency bands:

80 MHz	160 MHz	460 MHz
6 dB	12 dB	21 dB

p_r = power received in watts
P_r = power received in dB in relation to the watt
e = field in volts per metre
C = field in dB in relation to µV/m
g_i = isotropic gain
G_d = gain in relation to $\lambda/2$ dipole in dB
λ = wavelength in metres
f = frequency in MHz
e = electromotive force in volts
E = electromotive force in dB in relation to µV
Z = receiver input impedance
D = antenna mismatch correction
A = antenna efficiency correction

4. EFFECT OF EXTERNAL NOISE SOURCES

The effect of external noise sources is negligible in the 460 MHz band.

However, it is very considerable in the 80 MHz and 160 MHz bands in high-density urban area.

Measurements have shown that to obtain the same quality of reception as is obtained in the absence of external noise, the e.m.f. of the signal must be 10 µV at 80 MHz and 5 µV at 160 MHz.

Since these figures apply only to particular areas, no account will be taken of them below, in view of the statistical nature of the problem.

5. QUALITY OF SERVICE AND NECESSARY FIELD

In the case of group No. 1, if at 75% of locations the field must be greater than the minimum value for C_o, the corresponding value for x is 0.675.

In the view of the CCIR, the standard deviation assumes the following values:
80 and 160 MHz bands: 8 dB
460 MHz band (Δ h = 50 m): 10 dB

This gives the following median values for the wanted field:

80 MHz: $6 + 0.675 \times 8 = 11.4$ dB

160 MHz: $12 + 0.675 \times 8 = 17.4$ dB

460 MHz (Δ h = 50 m): $21 + 0.675 \times 10 = 27.7$ dB

In the case of group No. 2, where the percentage of locations is 50%, x is equal to 0 and the median values for the field are respectively:

80 MHz	160 MHz	460 MHz
6 dB	12 dB	21 dB

6. PROTECTION RATIO

Where the wanted transmission and the interference are both in class F3, which is the most usual case, an instantaneous value of 8 dB is admitted for the protection ratio.

If reception has to be protected for 75%[1]) of locations in the case of group 1, the median value must therefore be $R_m = R_o + 0.675 \cdot \sigma'$.

It follows that for

80 MHz

$$\sigma' = \sigma\sqrt{2} = 11.3$$

$$R_m = 8 + 0.675 \times 11 = 15.6 \text{ dB}$$

160 MHz

$$\sigma' = \sigma\sqrt{2} = 11.3$$

$$R_m = 8 + 0.675 \times 11 = 15.6 \text{ dB}$$

460 MHz

$$\sigma' = \sigma\sqrt{2} = 14.1$$

$$R_m = 8 + 0.675 \times 14 = 17.5 \text{ dB}$$

In the case of group 2, the median value of the protection ratio is 8 dB since x = 0.

7. THEORETICALLY TOLERABLE INTERFERING FIELDS (median values)

Group 1

	80 MHz	160 MHz	460 MHz
Wanted field	11.4 dB	17.4 dB	27.7 dB
Protection ratio	15.6 dB	15.6 dB	17.5 dB
Interfering field	−4.2 dB	1.8 dB	10.2 dB

Group 2

	80 MHz	160 MHz	460 MHz
Wanted field	6 dB	12 dB	21 dB
Protection ratio	8 dB	8 dB	8 dB
Interfering field	−2 dB	4 dB	13 dB

The values for the wanted field and the interfering field are expressed in dB in relation to 1 μV/m.

[1]) A protection probability of P% means that for a link operating alternately on two frequencies, the probability of interference is (100 − P)% for a call to a mobile unit at the edge of the service zone, assuming that the interfering base station is permanently on the air (1 traffic unit). If the station's traffic is t traffic units, the probability of interference will be t × (100 − P)%.

8. EFFECT OF RELIEF AND OF STATISTICAL DISTRIBUTION OVER TIME

Generally speaking, if the field has a normal distribution in relation to location and to time, with standard deviations of σ_e and σ_t respectively, the resulting standard deviation for distribution is

$\sigma = \sqrt{\sigma_e^2 + \sigma_t^2}$

It is dependent on frequency and distance. The effect of the effective antenna height is negligible for the heights involved in the land mobile service. For group 2 stations, the maximum tolerable interference field is independent of σ_t and of Δ h.

For group 1 stations, the median value of the tolerable interference field for Δ h × 50 m and $\sigma_t = 0$ is
$B_{m10} = B_{m2} - 0.675\ \sigma_{e,o}\ (\sqrt{2} - 1$.

where B_{m2} = the median value of the tolerable interference field for group 2 stations
and $\sigma_{e,o}$ = standard deviation for the distribution in relation to location for Δ h = 50 m

The reference median values for the tolerable interference field are given in paragraph 7. The effect of different types of relief (Δ h) and of the standard deviation in relation to time of the interfering signal (σ_t) are accounted for by a correction factor.

$\Delta_{e,t} = B_{m1} - B_{m10}$

where B_{m1} = median value of the tolerable interference field for group 1 stations
where $\Delta_{e,t} = x\left[\sigma_{e,o}\ (\sqrt{2} - 1) - \sqrt{\sigma_{u,e}^2 + \sigma_{b,e}^2 + \sigma_{b,t}^2} + \sigma_{u,e}\right]$

$\sigma_{u,e}$ = standard deviation of the distribution of the wanted field in relation to the locations
$\sigma_{b,e}$ = standard deviation of the distribution of the interfering field in relation to the locations
$\sigma_{b,t}$ = standard deviation of the distribution of the interfering field in relation to time

For $\sigma_{u,e} = \sigma_{b,e}$ (i.e. where the wanted field and the interfering field cross the same type of relief) and, for P = 75% (x = 0.675), the correction factors are given in the following table:

VHF (80 MHz, 160 MHz)				UHF (460 MHz)						
	land		sea and land	land					sea	
d [km]	σ_t	$\sigma_e = 8$	$\sigma_e = 0$	σ_t	Δh = 50 $\sigma_e = 10$	Δh = 150 $\sigma_e = 15$	$\sigma_e = 0$	Δh = 300 $\sigma_e = 18$	σ_t	$\sigma_e = 0$
50	3	−0.3	0.2	2	−0.1	−1.5	1.4	−2.3	9	−3.3
100	7	−1.4	−2.5	5	−0.6	−1.8	−0.6	−2.6	14	−6.7
150	9	−2.2	−3.8	7	−1.1	−2.2	−1.9	−2.9	20	−10.7
175	11	−3.0	−5.2							

If the path of the wanted field is characterised by the value $\sigma_{c,o}$ and the path of the interfering field by different values of $\sigma_{b,e}$, the correction factors are those given in the following table:

VHF (80 MHz, 160 MHz)				UHF (460 MHz)						
	land		sea and land	land				sea	
d [km]	σ_t	$\sigma_{h,e} = 8$	$\sigma_{h,e} = 0$	σ_t	$\Delta h = 50$ $\sigma_{h,e} = 10$	$\Delta h = 150$ $\sigma_{h,e} = 15$	$\Delta h = 300$ $\sigma_{h,e} = 18$	σ_t	$\sigma_{h,e} = 0$
50	3	−0.3	1.9	2	−0.1	−2.7	−4.4	9	−0.5
100	7	−1.4	0.5	5	−0.6	−3.1	−4.8	14	−2.1
150	9	−2.2	−0.5	7	−1.1	−3.5	−5.1	20	−5.6
175	11	−3.0	−1.6						

B. LIST OF VALUES TO BE TAKEN INTO ACCOUNT IN CO-ORDINATION AGREEMENTS

Administrations responsible for co-ordination will adapt the values set out below to the various cases they encounter and, in particular, to the type of station concerned (base or mobile stations operating on one or two frequencies) and to the characteristics of their antennae (gain, height above ground level, polarisation and, where appropriate, directivity diagram).

A height above ground level other than 3 metres may be used in particular co-ordination agreements where the consulting Administration is aware that the stations across the frontier likely to cause interference are base stations.

Such agreements must enable the countries concerned to be aware of the distribution of base stations and mobile stations in the different frequency sub-bands.

B.1. Interference to group 2 stations

Co-ordination between the Administrations concerned is necessary where the following field strength values are exceeded at the frontier at a height of 3 metres above ground level.

80 MHz	160 MHz	460 MHz
−2 dB	4 dB	13 dB

(Values expressed in relation to 1 μV/m.)

The values taken into account for co-ordination and which apply to cases using the antennae most frequently found are:

	80 MHz	160 MHz	460 MHz
Minimum wanted field to be protected	6 dB	12 dB	21 dB
Protection ratio	8 dB	8 dB	8 dB
Maximum tolerable interfering field	−2 dB	4 dB	13 dB

(The values of the wanted field and the interfering field are expressed in relation to 1 μV/m.)

For an antenna of $\lambda/4$: $G_d = 3$ dB D = 2 dB A = 3 dB
For an antenna of $\lambda/2$: $G_d = 0$ dB D = 2 dB A = 0 dB
(See paragraph 3. of part A.)

B.2. **Interference caused to group 1 stations**

In this case, the percentage of locations and the protection probability to be taken into account are set at 90% (x = 1.3) for a type of relief corresponding to Δ h = 50 m.

(See paragraph 6. of part A.)

For other types of relief see paragraph 8. part A.

The field strength which must not be exceeded at the frontier at a height of 3 metres above ground level is:

80 MHz	160 MHz	460 MHz
−6.2 dB	−0.2 dB	7.7 dB

(Values expressed in relation to 1 μV/m.)

The values taken into account for co-ordination and under the same conditions as for group 2 are:

	80 MHz	160 MHz	460 MHz
Wanted field to be protected	16.3 dB	22.3 dB	33.8 dB
Protection ratio	22.5 dB	22.5 dB	26.1 dB
Maximum tolerable interfering field	−6.2 dB	−0.2 dB	7.7 dB

(The values of the wanted field and the interfering field are expressed in relation to 1 μV/m.)

In order to avoid group 2 stations being too penalised by the increase in the repetition distance, it is very much to be desired that in frontier regions group networks should be operated in the same frequency sub-bands.

B.3. **Interference caused to group 3 stations**

Since these stations cannot claim any protection, there is no need for them to be taken into account in co-ordination agreements.