Electronic Communications Committee (ECC)
within the European Conference of Postal and Telecommunications Administrations (CEPT)

IMMUNITY OF 24 GHZ AUTOMOTIVE SRRS OPERATING ON A NON INTERFERENCE AND NON-PROTECTED BASIS FROM EMISSIONS OF THE PRIMARY FIXED SERVICE OPERATING IN THE 23 GHZ AND 26 GHZ FREQUENCY BANDS

Galati, May 2004

EXECUTIVE SUMMARY

This report considers the impact of Fixed Service (FS) systems in the 23 and 26 GHz bands into the 24 GHz Automotive Short Range Radars (SRRs).

It gives the interference situations in which 24 GHz SRR would be likely to operate in the vicinity of FS systems, both Point-to-Point (P-P) and Point-to-Multipoint (P-MP) and elaborates on the means that such SRR are expected to implement in order to endure these situations.

The analysis has been done following different scenarios, recognising that while FS systems can co-exist in a close-by environment thanks to a high level of discrimination, due to frequency separation and/or angular separation, all FS systems operating in the 23 and 26 GHz bands would fall into the SRR receiver bandwidth.

The calculations of interference from FS to SRR operating at 24 GHz show that SRR will have to operate in a high level of interference in the vicinity of FS transmitters, presenting in particular I/N levels above **+20 dB** along the FS path.

The ability of SRR to operate in such an environment mainly depends on the design of the SRR and the resulting processing gain (see section 2.1 that estimates a minimum processing gain of 67 dB).

As SRR will operate on non-interference and non-protected basis, it is therefore the responsibility of SRR manufacturers to carefully design their systems so as to minimize the effect of interference from radiocommunication services (in particular FS) as well as from other SRR devices by implementing adequate mitigation techniques, such as the spread spectrum technique (that can provide processing gain above 50 dB) and further interference suppression techniques (see section 2.2).

Based on the information provided by the industry (see section 2.2), while noting however the lack of details, it can be assumed that adequately designed SRR would be able to restore to a high degree the signals distorted by strong interference. Where the level of interference would be detrimental to the 24 GHz SRR operation, as could occur from the operation of FS, it can be assumed that the SRR devices would be temporarily disabled. This report shows that the protection of 24 GHz SRR from interference can not be guaranteed.

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1 INTRODUCTION

This report only considers the impact of FS systems in the 23 and 26 GHz bands into the 24 GHz SRRs.

It gives the interference situations in which 24 GHz SRR would be likely to operate in the vicinity of FS systems (P-P and P-MP) and elaborates on the means that such SRR are expected to implement in order to endure these situations.

The analysis has been done following different scenarios, recognising that while FS systems can co-exist in a close-by environment thanks to a high level of discrimination, due to frequency separation and/or angular separation, all FS systems operating in the 23 and 26 GHz bands would fall into the SRR receiver bandwidth.

These scenarios are the following:

- **Scenario 1** : similarly to the scenario used for calculating interference from SRR to FS, developed in ECC report 23, this scenario calculates the level of interference that a SRR will experience when operating on a road, in the vicinity of a single FS transmitter when direction of FS antenna beam parallel to the road (the same FS characteristics in terms of antenna height and offset has been used),
- **Scenario 2** : calculating the level of interference that a SRR will experience when operating at different positions around a single FS transmitter (P-P, P-MP central station or P-MP terminal station), producing hence a panoramic interference map ,
- **Scenario 3** : calculating the level of interference that a SRR will experience when operating at different positions in the vicinity of a complete FS system, also presenting resulting interference maps. The considered FS systems encompass single FS link (i.e. 2 transmitters), multiple FS links transmitting from a single node and P-MP systems (i.e. Central stations and associated terminal stations).

2 SRR 24 GHZ CHARACTERISTICS

2.1 SRR link budget

Typical SRR parameters are given below:

Output EIRP:	20 dBm
Antenna gain:	14 dBi
Bandwidth:	4000 MHz
Antenna pattern:	according to ETSI Report TR102 982
Bumper losses:	3 dB
Detection range:	30 m
Noise floor:	-69 dBm/4GHz (incl. Noise figure (3dB) and mixer losses (6 dB))
Peak noise floor:	-57 dBm/4GHz
Signal threshold:	-47 dBm/4GHz (assumed to be representative of the maximum distance detection)

On this basis, a simplified SRR link budget is given as follows (assuming a car equivalent Radar Cross Section equal to 10 dB(m^2)):

EIRP density	=20 dBm/4GHz
Antenna gain	=+14 dBi
Bumper losses (in and out)	=-6 dB
Radar losses	=-120 dB
Received level	=-92 dBm/4GHz.

Therefore, in order to comply with the signal threshold (-47 dBm/4 GHz), the processing gain of the SRR should be, at a minimum, 45 dB.

In a case of interference (when I/N > 10 dB), the necessary processing gain (PG) can be estimated by:

$$PG = 45 + (I+N)/N \cong 45 + I/N$$

In addition, the typical level of harmful interference of SRR is assumed to be I/N = 22 dB. Above this value, there is a graceful degradation of the operation of SRR devices until the interference detection function generates an unavailability signal for the SRR application. The application is hence disabled. It has to be noted that both maximum level of I/N and behaviour of the SRR device above this value up to its switch-off are likely to depend on the design of the SRR by a specific manufacturer.

It hence means that the necessary typical processing gain of the SRR should be 67 dB to be able to operate at the expected level of interference.

Finally, it can also be noted that blocking of the SRR receiver would occur at level of interference at 70 dB above the noise.

2.2 SRR processing gain

In order to achieve the above mentioned 67 dB processing gain, the following features can be implemented by SRR.

As an example, for SRRs implementing Direct Sequence Spread Spectrum (DSSS), the processing gain is defined as the ratio between the SNR_{out} at the output of the spread spectrum demodulator and the SNR_{in} at the input.

$$G_p = \frac{SNR_{out}}{SNR_{in}} = \frac{B_{SS}}{B_D}$$

where :

B_{SS}: Bandwidth of Transmission
B_D: Information Bandwidth

Short Range Radar does not transmit information. Therefore, theoretically the information bandwidth B_D could be infinitely small. Practically, for SRR, $B_D = B_{IF}$ = bandwidth of intermediate frequency defined by the IF-filter bandwidth.

B_{IF} is typically well below 100 kHz. Consequently with a transmission bandwidth B_{SS} = 4 GHz the processing gain is Gp >> 46 dB.

The principle of processing gain of spread spectrum systems is depicted in Figure 1 below.

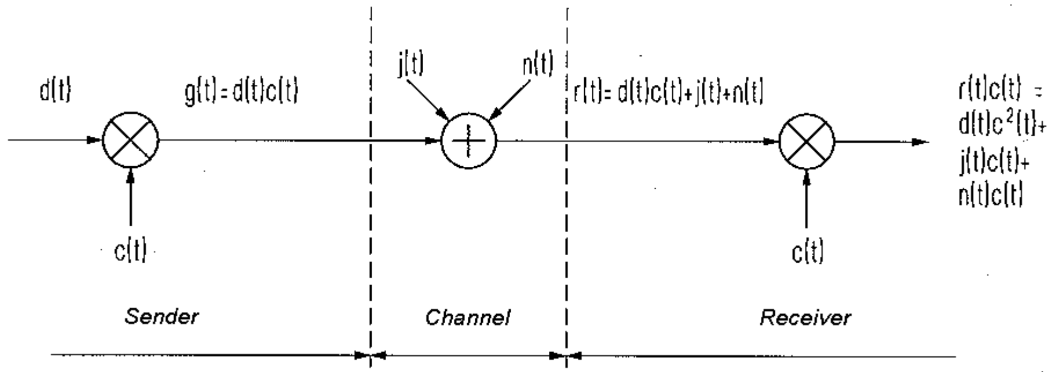


Figure 1: Baseband model for spread spectrum system.
("Handbook on Spread Spectrum Techniques", A. Goiser, 1998)

The received signal *r(t)* is multiplied in the demodulator with spreading code *c(t)*.

- The wanted signal *d(t)* is multiplied twice with spreading code
- The interference *j(t)* is multiplied only once with spreading code

$$r(t)c(t) = \underbrace{d(t)\overbrace{c^2(t)}^{\equiv 1}}_{\text{compressed to } B_{IF}} + \underbrace{n(t)c(t)}_{\text{spreaded over } B_{SS}} + \underbrace{j(t)c(t)}_{\text{spreaded over } B_{SS}}$$

Due to the multiplication with the spreading code the power of narrow band interference is spread over the entire transmission bandwidth and only a part of the interference signal is received within the IF-pass-band.

Besides the interference suppression by the spreading effect, automotive SRR apply sophisticated signal processing techniques to reduce significantly the influence of interfering signals or even produce short blocking intervals, e.g.:

- Detection and blanking of deterministic interference signals
- Plausibility check for received signal
- Tracking of targets over several time cycles
- Plausibility checks of signals from several sensors.

It is to be noted that, due to Intellectual Property related reasons, technical implementation details could not be provided when writing this report.

Consequently, based on the above information provided by the industry, while noting the lack of details, it can be assumed that an adequately designed SRR would be able to restore to a high degree the signals distorted by strong interference provided the receiver is not “blinded” by very strong signals (blocking).

In any case, it is the responsibility of SRR manufacturers to design their systems so that they function correctly in the interference environment, as predicted and described below in this report.

3 FS CHARACTERISTICS

Typical FS parameters needed for the interference analysis are:

- Frequency band
- Antenna gain
- Antenna height
- Antenna radiation pattern
- Antenna angular sector (only for P-MP Central stations)
- Elevation
- Bandwidth
- Power
- Feeder losses
- Availability.

Depending on the considered FS equipment and application, the following Table 1 gives the adequate figures for each of these parameters.

Parameter	P-P	P-MP (CS)	P-MP (TS)
Frequency band	22-23.6 GHz	24.5-26.5 GHz	24.5-26.5 GHz
Antenna gain (dBi)	34, 41, 47 and 50	18	32 and 35
Antenna height (m)	10, 18 and 25	30	5 and 10
Antenna pattern	Rec ITU-R 699	Rec ITU-R 1336	Rec ITU-R 699
Antenna sector (°)	N/A	45 and 90	N/A
Elevation (°)	0	-2	>0 (1° assumed)
Hop length (km)	3, 7 and 10	Max 3 km	Max 3 km
Bandwidth	28 and 56	28 and 56	28 and 56
Power (dBm)	30	30	30
Feeder losses (dB)	0	0	0
Availability (%)	99.99 – 99.999	99.99	99.99

Table 1: Considered interference parameters of FS

4 CALCULATIONS

4.1 General issues

In all scenarios, the interference level produced at the SRR receiver input by one single FS station is:

$$I = P + G_{discriFS} - L + G_{discriSRR} - L_{bump}$$

where:

P = FS transmitter power
$G_{discri\ FS}$ = FS relative antenna gain in the direction of the SRR
L = free space losses
$G_{discri\ SRR}$ = SRR relative antenna gain in the direction of the FS
L_{bump} = Bumper losses.

Note 1: the calculated interference from FS to SRR is the total level of interference power transmitted in the SRR bandwidth and then, to calculate the interference level (I, in dBm/4GHz) or the I/N, no bandwidth factor has to be taken into consideration.

Note 2: the calculations below do not take into account potential attenuation by clutter (buildings, vegetation, etc.), nor shielding due to preceding cars and can hence be considered as a worst case. On the other hand, these attenuations were not considered in this report since they will not occur in a number of situations that can raise concerns in case of immunity.

4.2 Scenario 1

Scenario 1 is similar to the scenario used for calculating interference from SRR to FS as presented in ECC Report 23. It allows calculating the level of interference that a SRR will experience when operating on a road, in the vicinity of a single FS transmitter pointing parallel to the road up to 3 kilometres (the same FS characteristics in terms of antenna height and offset has been used).

The interference from FS to SRR is calculated with the FS parameters as in Table 1 above with the following values of antenna height and antenna off-set:

- antenna height = 10, 18 and 25 meters
- antenna off-set = 10 and 30 meters.

The results of these calculations are presented in figures 2-7 below.

It can be noted that depending on the considered rain rate zone and availability objective, the calculations performed for a single transmitter may represent different hop length links. On this basis, the probability of occurrence of certain combinations (antenna height, EIRP, hop length) may vary on a geographical basis.

Figure 2 : (10h-10off)

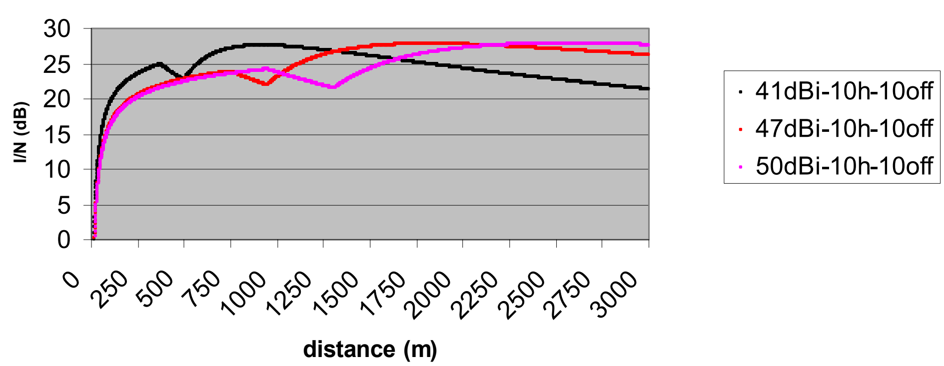
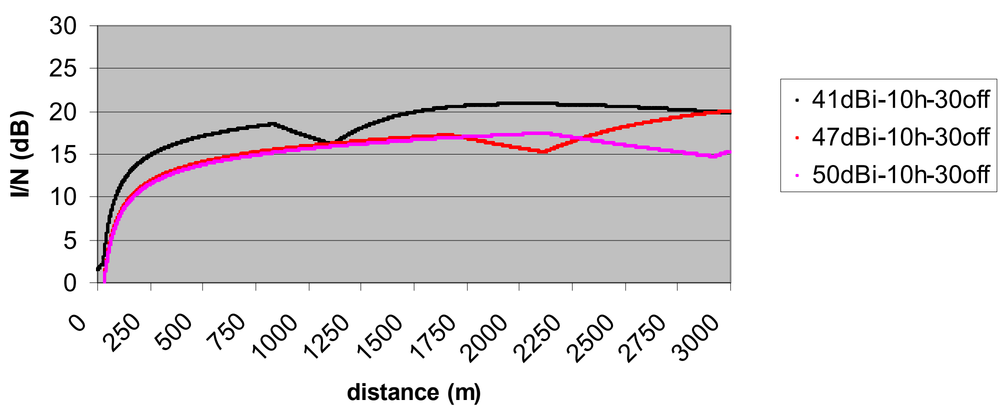


Figure 3 : (10h-30off)



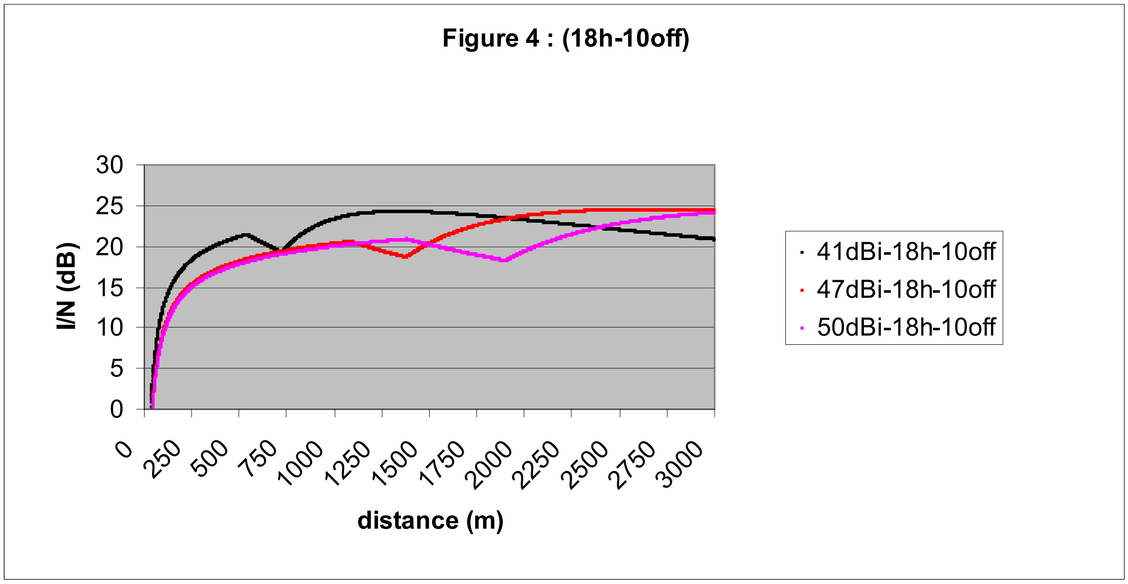


Figure 4 : (18h-10off)
I/N (dB)
30
25
20
15
10
5
0
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
distance (m)
41dBi-18h-10off
47dBi-18h-10off
50dBi-18h-10off

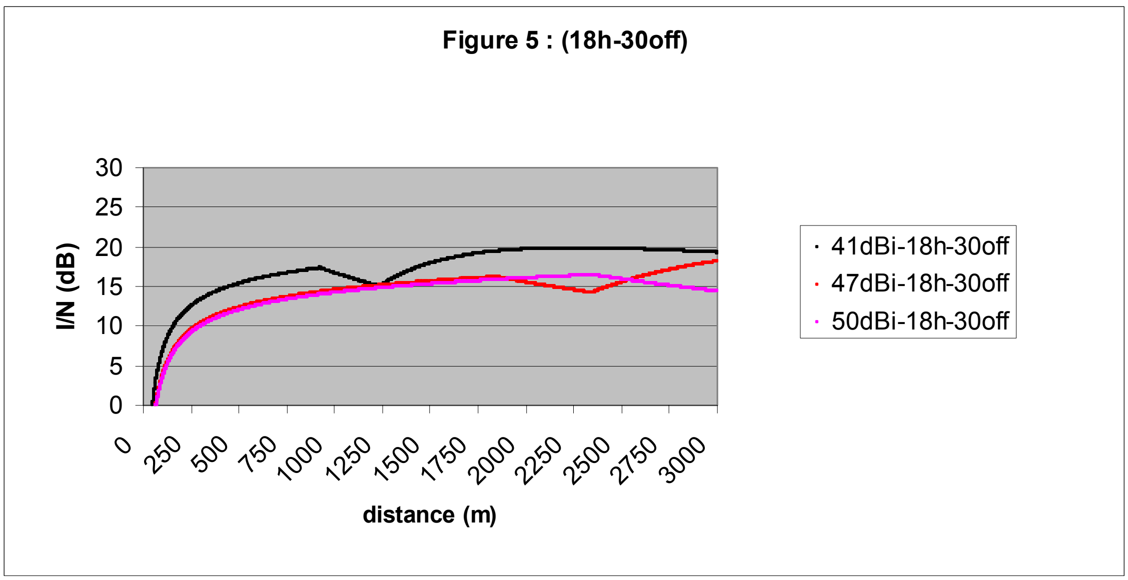
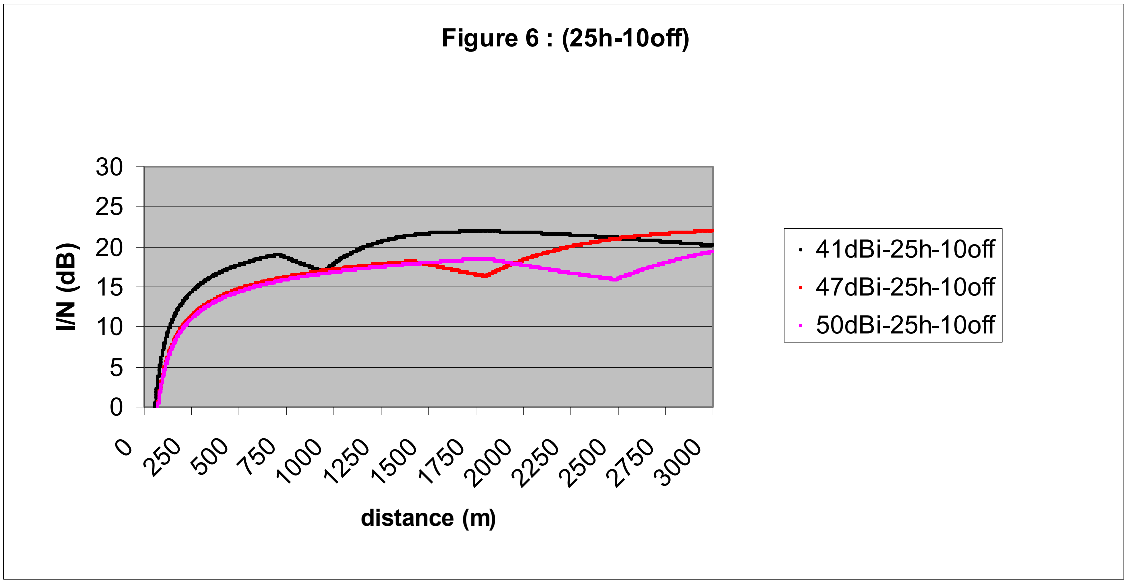
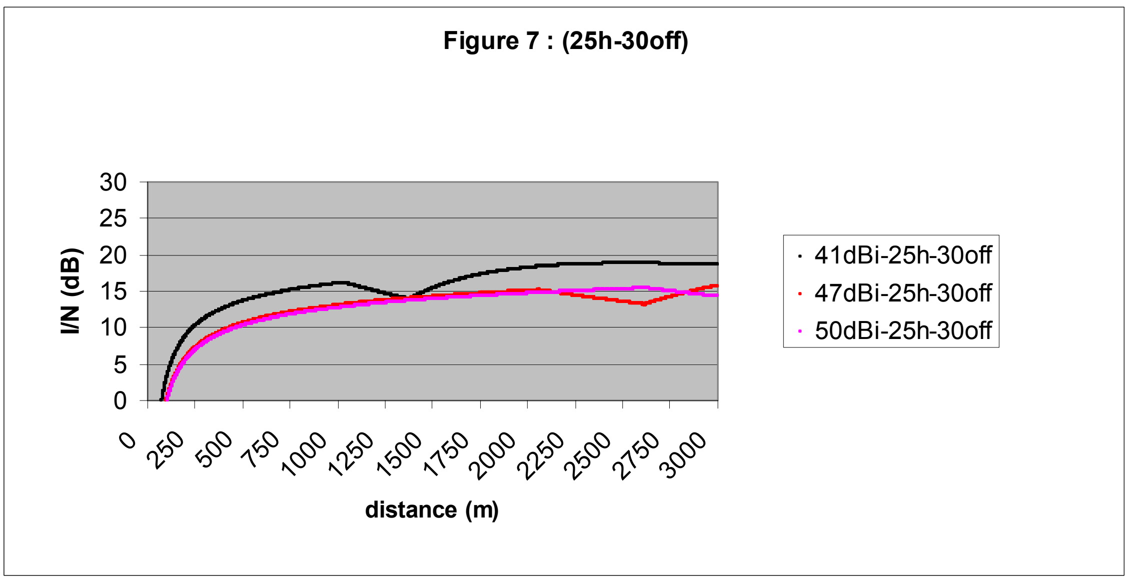


Figure 5 : (18h-30off)
I/N (dB)
30
25
20
15
10
5
0
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
distance (m)
41dBi-18h-30off
47dBi-18h-30off
50dBi-18h-30off





4.3 Scenario 2

Scenario 2 allows calculating the level of interference that a SRR will experience when operating at different points around a single FS transmitter (P-P, P-MP central station or P-MP terminal station). The results are given as interference map for each type of FS station and a graph of the impacted area for each I/N level.

For P-P stations (see section 4.3.1 below), the interference from FS to SRR was calculated based on the FS parameters as given in Table 1 above with different values of antenna height and antenna gain (with 0° elevation):

- antenna height = 10, 18 and 25 m
- antenna gain = 34, 41 and 47 dBi.

For P-MP terminal stations (see section 4.3.2 below), the interference from FS to SRR was calculated with different values of antenna height and antenna gain (with 1° elevation):

- antenna height = 5 and 10 m
- antenna gain = 32 and 35 dBi.

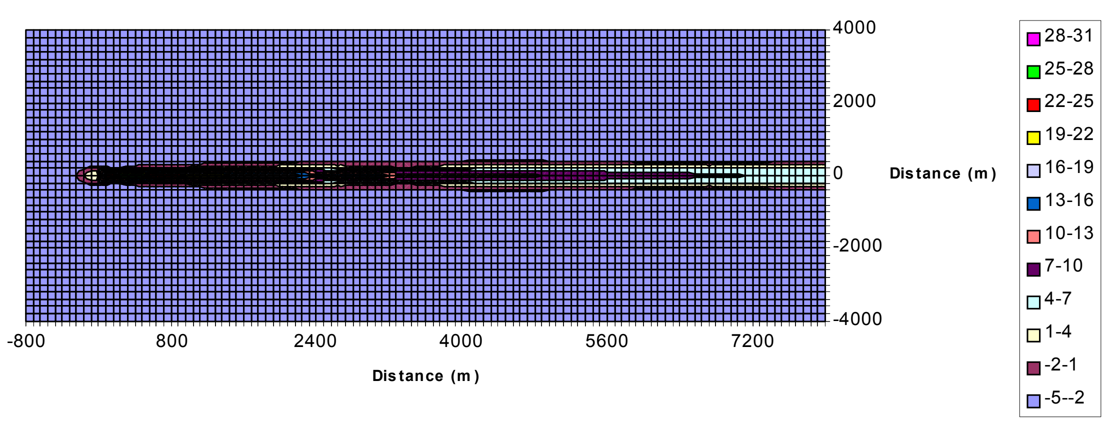
For P-MP central stations (see section 4.3.3 below), the interference from FS to SRR was calculated with 45° (20 dBi antenna gain) and 90° (18 dBi antenna gain) sector antennas and with 2° down-tilt.

4.3.1 P-P stations

The representation of I/N calculations with a square scale (same scale for X-axis and Y axis) as in Figure 8 below reflects the interference situation, but obviously lacks clarity since levels of interference are difficult to see.

Therefore, for all type of P-P stations, I/N calculations have been performed over an area of 8800m x 400m (3.52 km²). Hence, in the following figures, the scale of the abscissa is different from the scale of the ordinates (Y-axis).

Figure 8 : I/N produced by one P-P station (34 dBi-10m) (square scale)

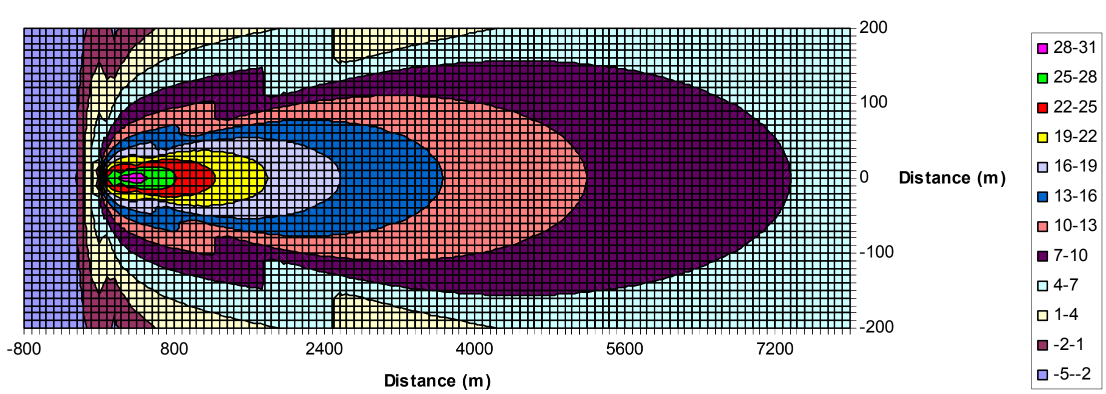


(Scale of Figure 8 : X = 8800 m ; Y = 8000 m)

a) 34 dBi antenna gain.

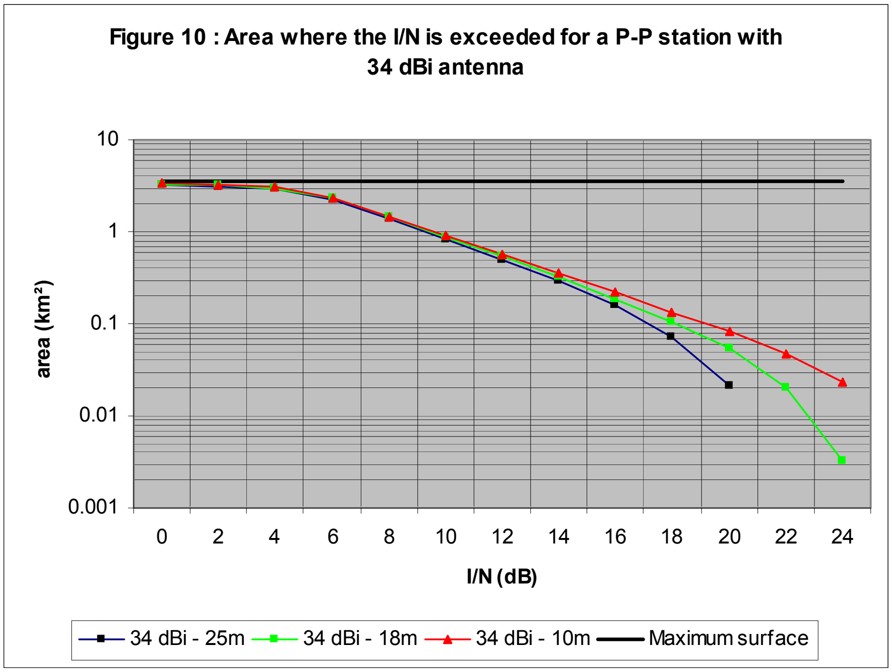
The following Figure 9 describes the I/N levels that would be produced by one P-P station with 34 dBi antenna gain and 10 m antenna height.

Figure 9 : I/N produced by one P-P station (34 dBi-10m)



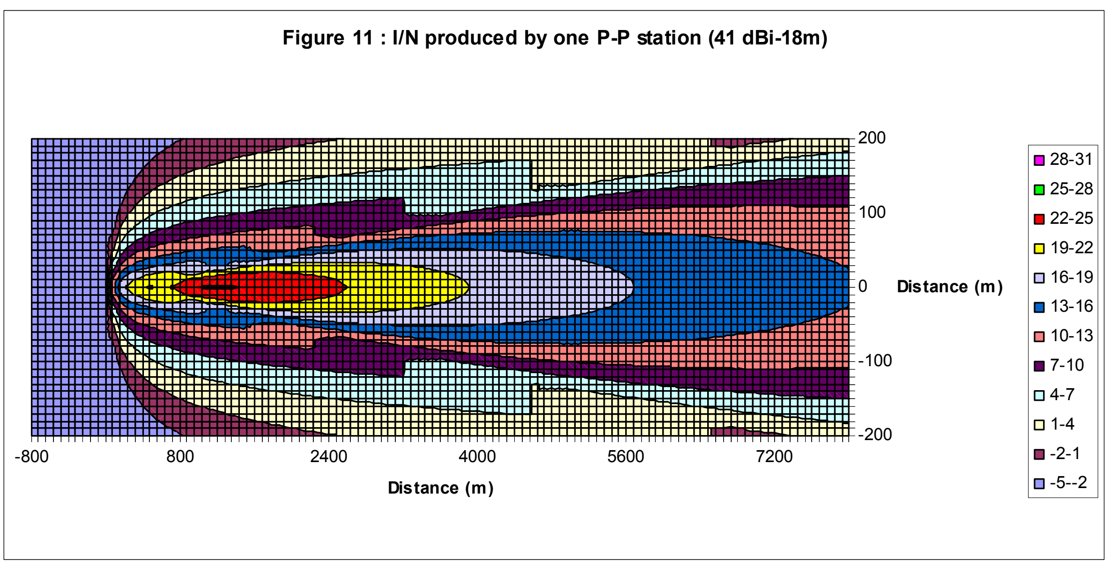
(Scale of Figure 9 : X = 8800 m ; Y = 400 m)

Based on Figure 9 and similar calculations for other antenna heights (18 and 25 m), the following Figure 10 below gives the respective area where given I/N levels are exceeded. (It is interesting to note that 0.01 km² represents the area of a football field).



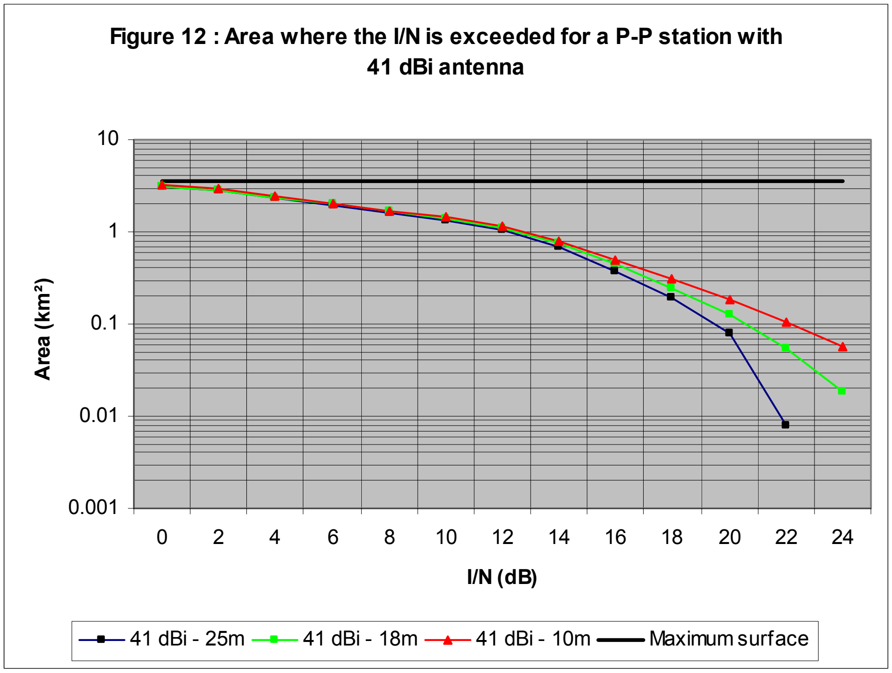
b) 41 dBi antenna gain

The following Figure 11 describes the I/N levels that would be produced by one P-P station with 41 dBi antenna gain and 18 m antenna height.



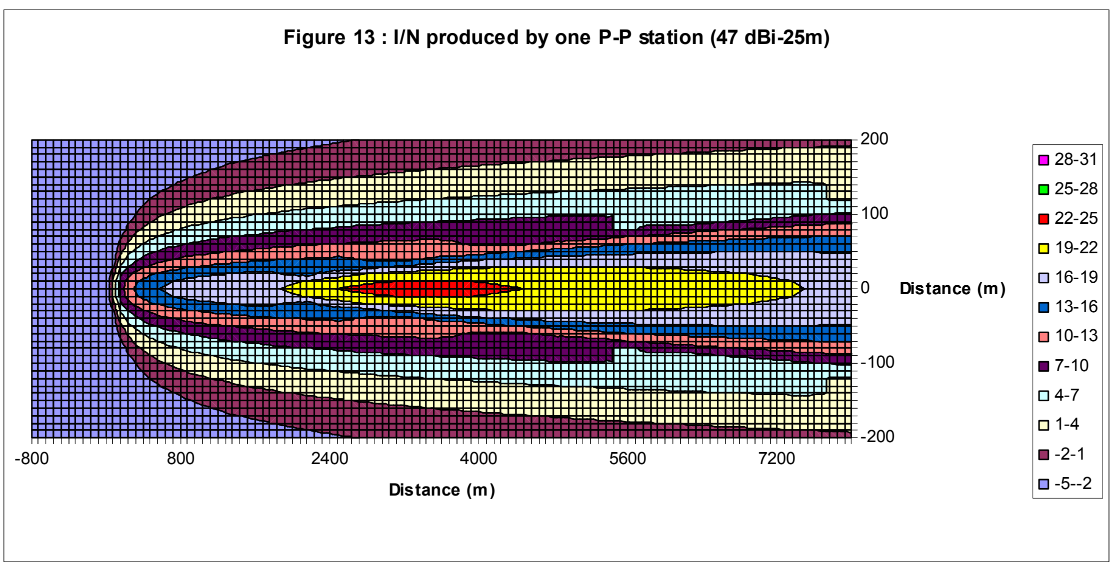
(Scale of Figure 11 : X = 8800 m ; Y = 400 m)

Based on Figure 11 and similar calculations for other antenna heights (10 and 25 m), the Figure 12 below gives the respective area where given I/N levels are exceeded.



c) 47 dBi antenna gain

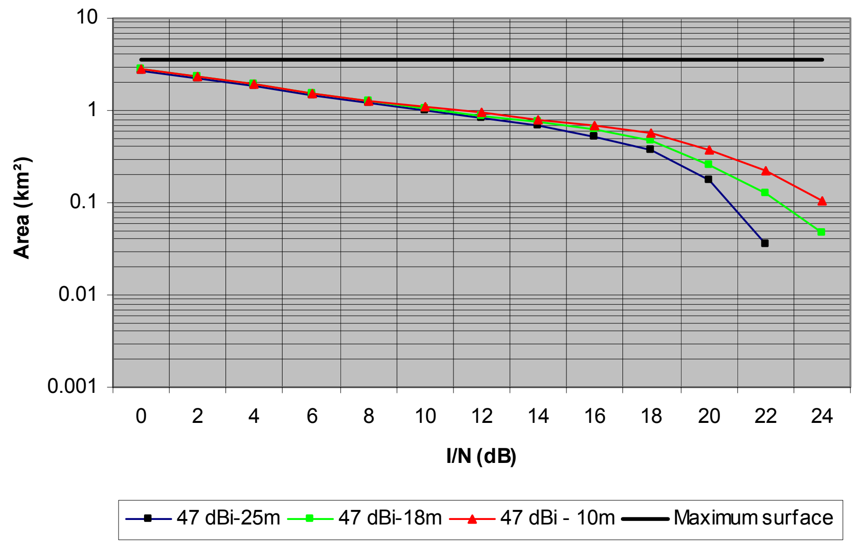
The following Figure 13 describes the I/N levels that would be produced by one P-P station with 47 dBi antenna gain and 25 m antenna height.



(Scale of Figure 13 : X = 8800 m ; Y = 400 m)

Based on Figure 13 and similar calculations for other antenna heights (10 and 18 m), the Figure 14 below gives the respective area where given I/N levels are exceeded.

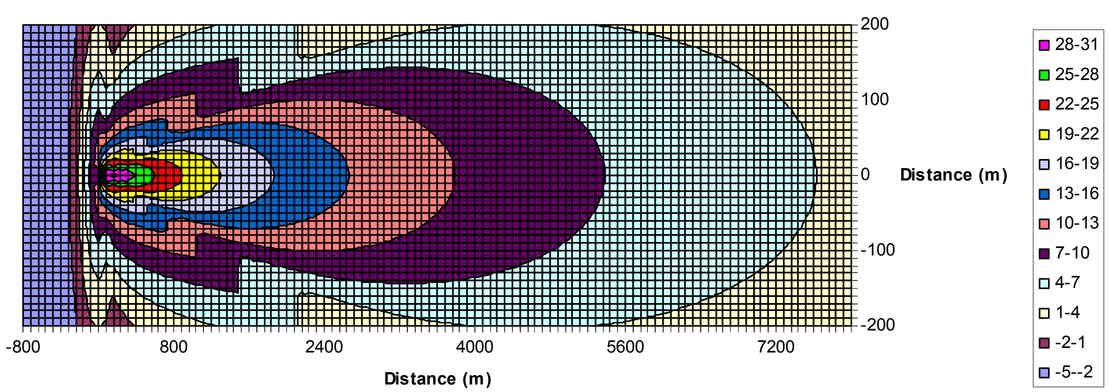
Figure 14 : Area where the I/N is exceeded for a P-P station with 47 dBi antenna



4.3.2 P-MP terminal stations

The following Figure 15 shows the I/N levels that would be produced by one P-MP terminal station with 32 dBi antenna gain, 5 m antenna height and 30 dBm transmitter power.

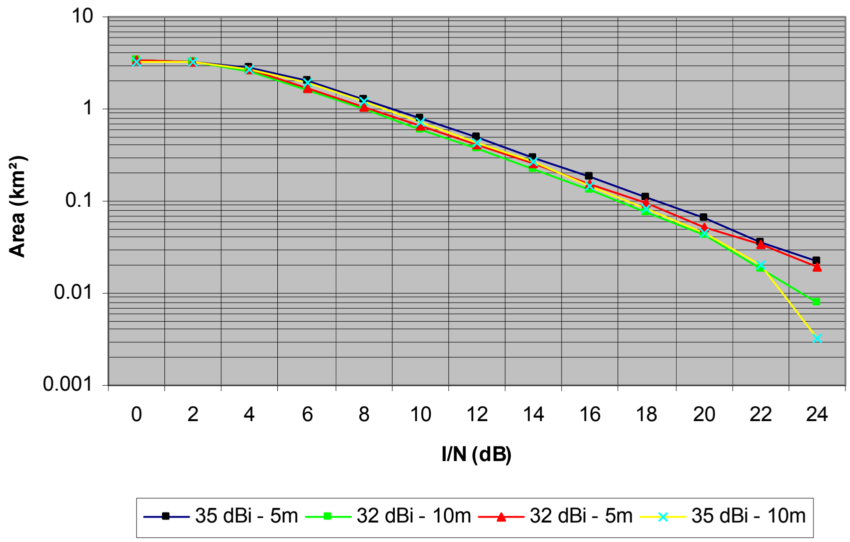
Figure 15 : I/N produced by one P-MP terminal station (32 dBi-5m)



(Scale of Figure 15 : X = 8800 m ; Y = 400 m)

Based on Figure 15 and similar calculations for other antenna heights (5 and 10 m) and /or other antenna gain (35 dBi), the Figure 16 below gives the respective area where given I/N levels are exceeded.

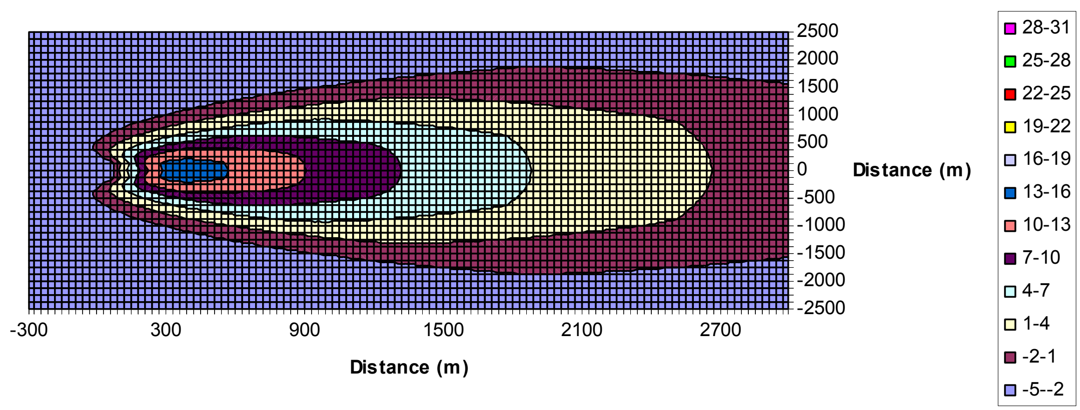
Figure 16 : Area where the I/N is exceeded for a P-MP terminal station



4.3.3 *P-MP central stations*

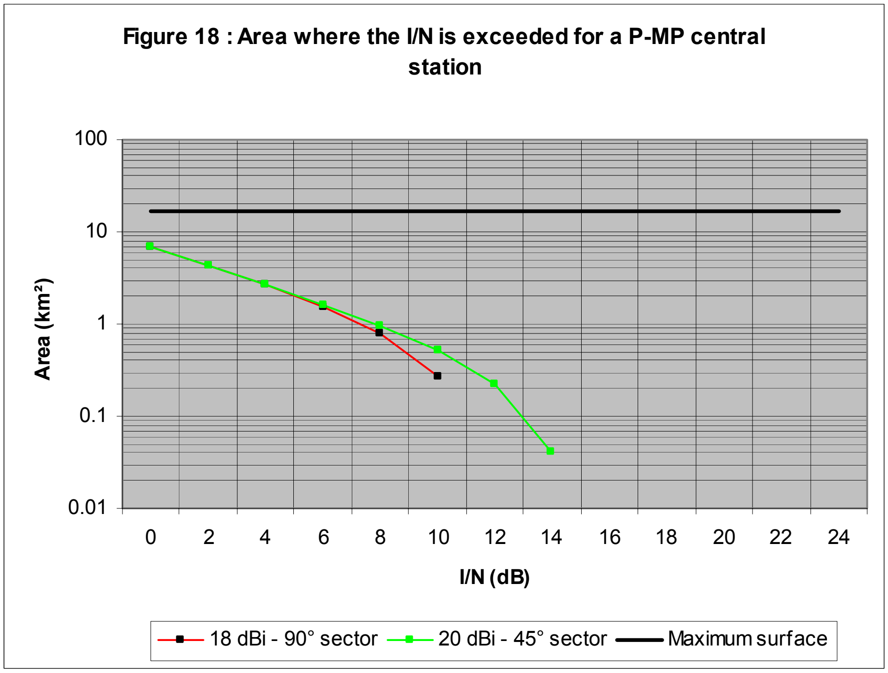
The following Figure 17 shows the I/N levels that would be produced by one P-MP central station with 20 dBi antenna gain, 45° sector, 30 m antenna height and 30 dBm transmitter power.

Figure 17 : I/N produced by one P-MP central station (20 dBi-45°)



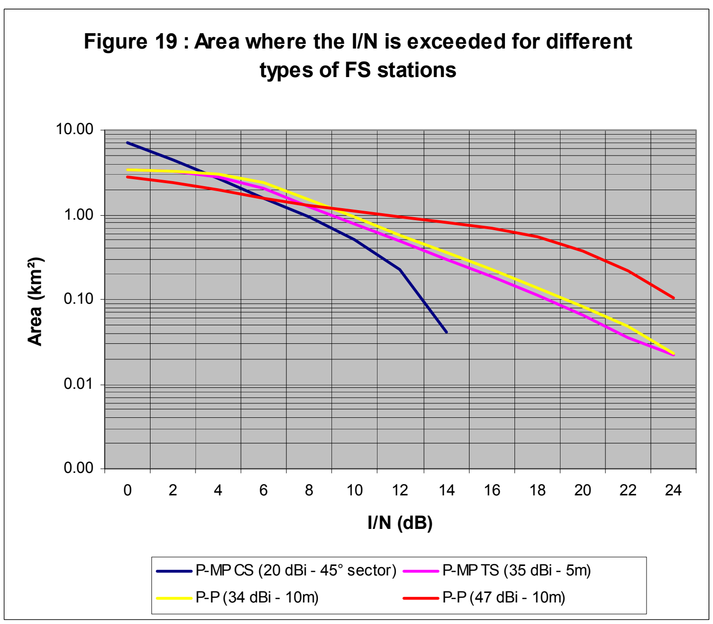
(Scale of Figure 17 : X = 3300 m ; Y = 5000 m)

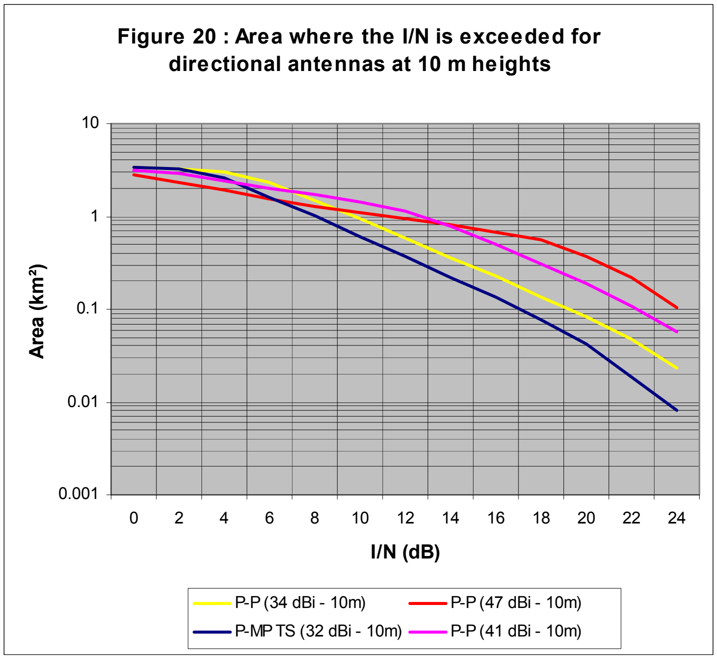
Based on Figure 17 and similar calculations for a P-MP central station with 18 dBi antenna gain and 90° sector, the Figure 18 below gives the respective area where given I/N levels are exceeded.



4.3.4 Comparisons

Comparisons between different scenarios described above are given in Figures 19 and 20.





4.4 Scenario 3

Scenario 3 allows calculating the level of interference that a SRR will experience when operating in the vicinity of a complete FS system, also presenting a resulting interference map.

The considered FS systems encompass single FS link (i.e. 2 transmitters), multiple FS links transmitting from a single node and P-MP systems (i.e. central stations and associated terminal stations).

In all these situations, all transmitters from the FS systems while transmitting at different frequencies, fall into the SRR bandwidth and hence produce interference that will aggregate within the SRR receiver.

On this basis, the following situations have been simulated:

- Single 3 km P-P link,
- Single 7 km P-P link,
- FS node with 3 P-P links (3, 5 and 7 km),
- P-MP cell with 1 central station (CS) and 5 terminal stations (TS).

It can be noted that these simulations have been performed without taking into account any SRR antenna horizontal discrimination. Hence, in some cases, the aggregate I/N may represent a worst case.

4.4.1 Single 3 km P-P link

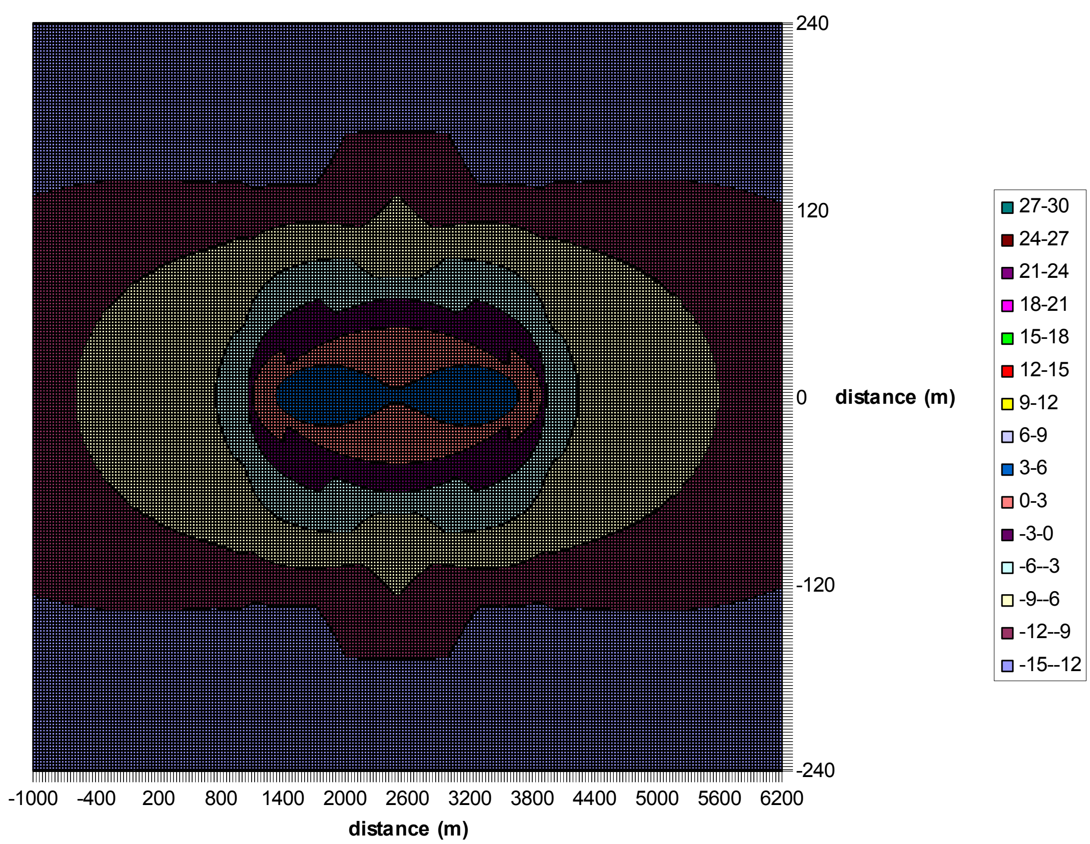
The I/N levels produced by a 3 km P-P link have been calculated with the following assumptions shown in Table 2 :

Parameter	Case 1	Case 2	Case 3	Case 4
Rain rate	32 mm/h	32 mm/h	42 mm/h	42 mm/h
Availability	99.999%	99.99%	99.999%	99.99%
Hop length	3 km	3 km	3 km	3 km
Antenna gain	34 dBi	34 dBi	34 dBi	34 dBi
Power	10 dBm	0 dBm	20 dBm	3 dBm
Antenna height	18 m	18 m	18 m	18 m
Receiver threshold level	- 73 dBm	- 73 dBm	- 73 dBm	- 73 dBm

Table 2: Considered parameters for a 3-km P-P link

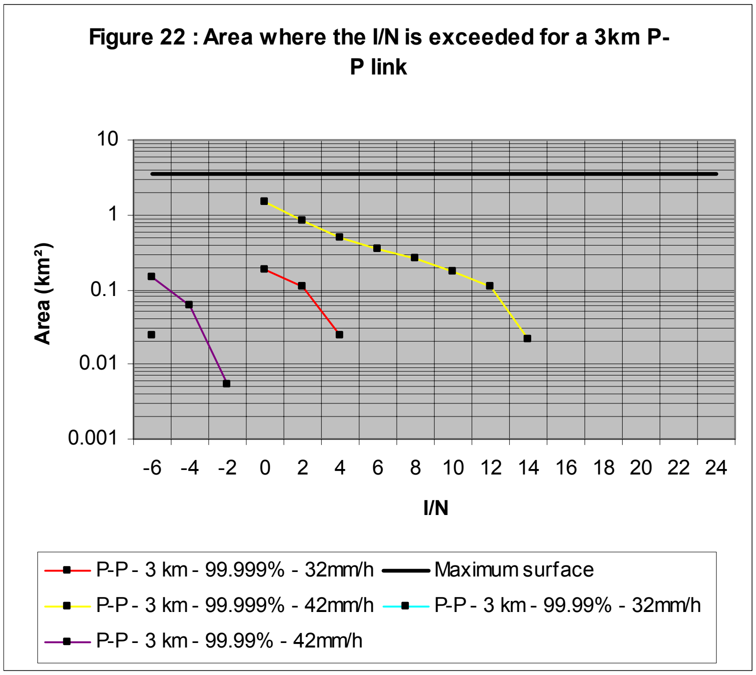
The following Figure 21 describes the I/N levels that would be produced by a 3 km P-P link with 99.999% availability in 32 mm/h rain zone (Case 1).

Figure 21 : I/N produced by one 3km P-P link (99.999% and 32 mm/h)



(Scale of Figure 21 : X = 7200 m ; Y = 480 m)

Based on Figure 21 and similar calculations for 3 km P-P link with 99.99% availability and/or 42 mm/h rain zone, the following Figure 22 below gives the respective area where given I/N levels are exceeded.



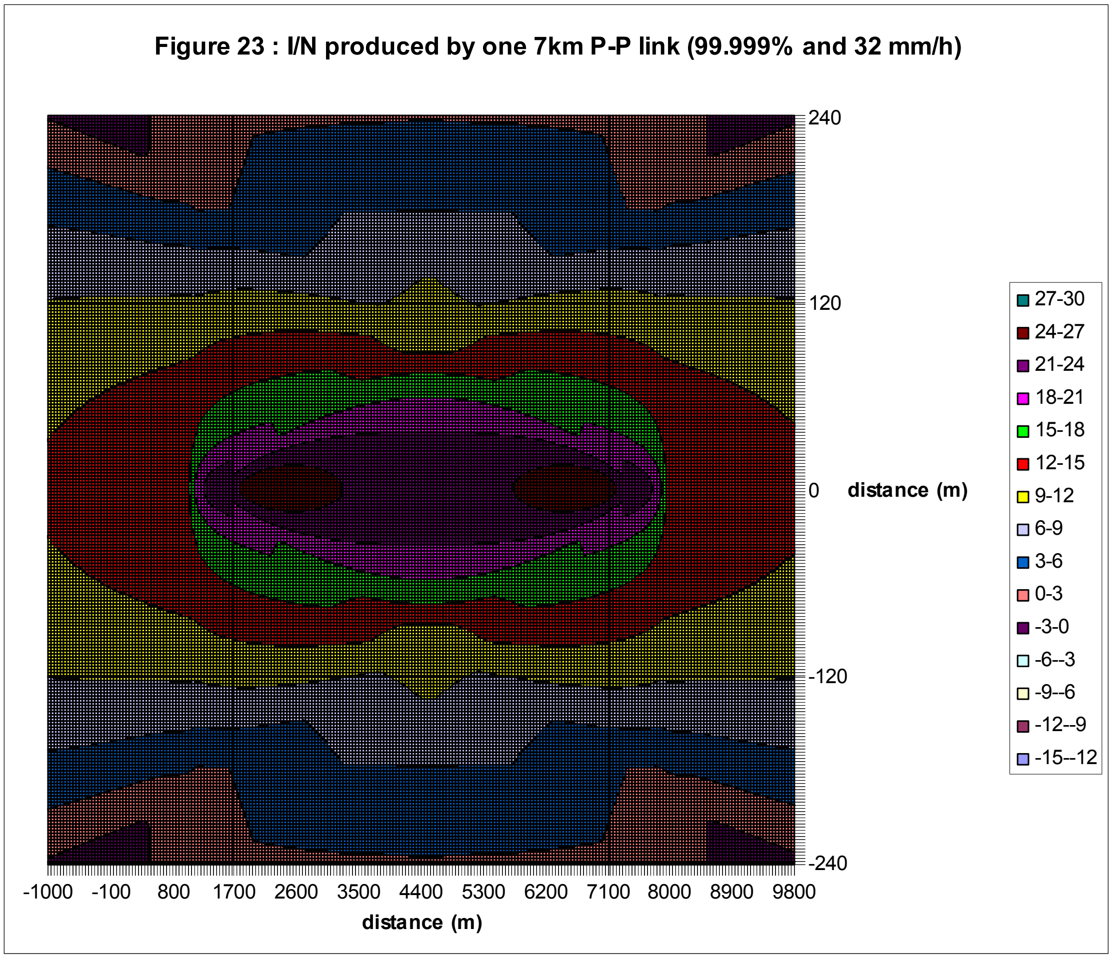
4.4.2 Single 7 km P-P link

The I/N levels produced by a 7 km P-P link have been calculated with the assumptions shown in Table 3:

Parameters	Case 1	Case 2	Case 3	Case 4
Rain rate	32 mm/h	32 mm/h	42 mm/h	42 mm/h
Availability	99.999%	99.99%	99.999%	99.99%
Hop length	7 km	7 km	7 km	7 km
Antenna gain	41 dBi	41 dBi	47 dBi	41 dBi
Power	30 dBm	6 dBm	30 dBm	10 dBm
Antenna height	18 m	18 m	18 m	18 m
Receiver threshold level	- 73 dBm	- 73 dBm	- 73 dBm	- 73 dBm

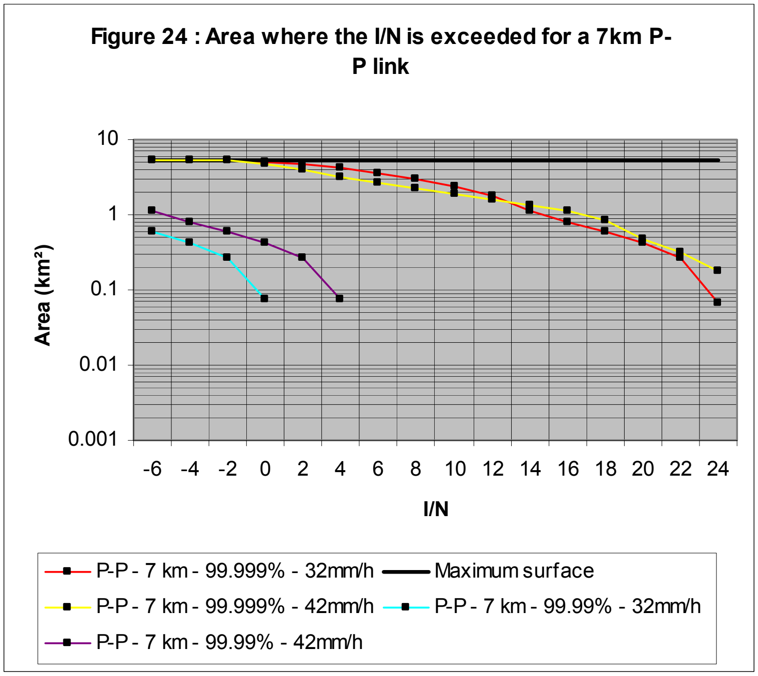
Table 3: Considered parameters for a 7-km P-P link

The following Figure 23 describes the I/N levels that would be produced by a 7 km P-P link with 99.999% availability in 32 mm/h rain zone (Case 1).



(Scale of Figure 23 : X = 7200 m ; Y = 480 m)

BFsed on figure 23 and similar calculations for 7 km P-P link with 99.99% availability and/or 42 mm/h rain zone, the Figure 24 below gives the respective area where given I/N levels are exceeded.



4.4.3 FS node with 3 P-P links

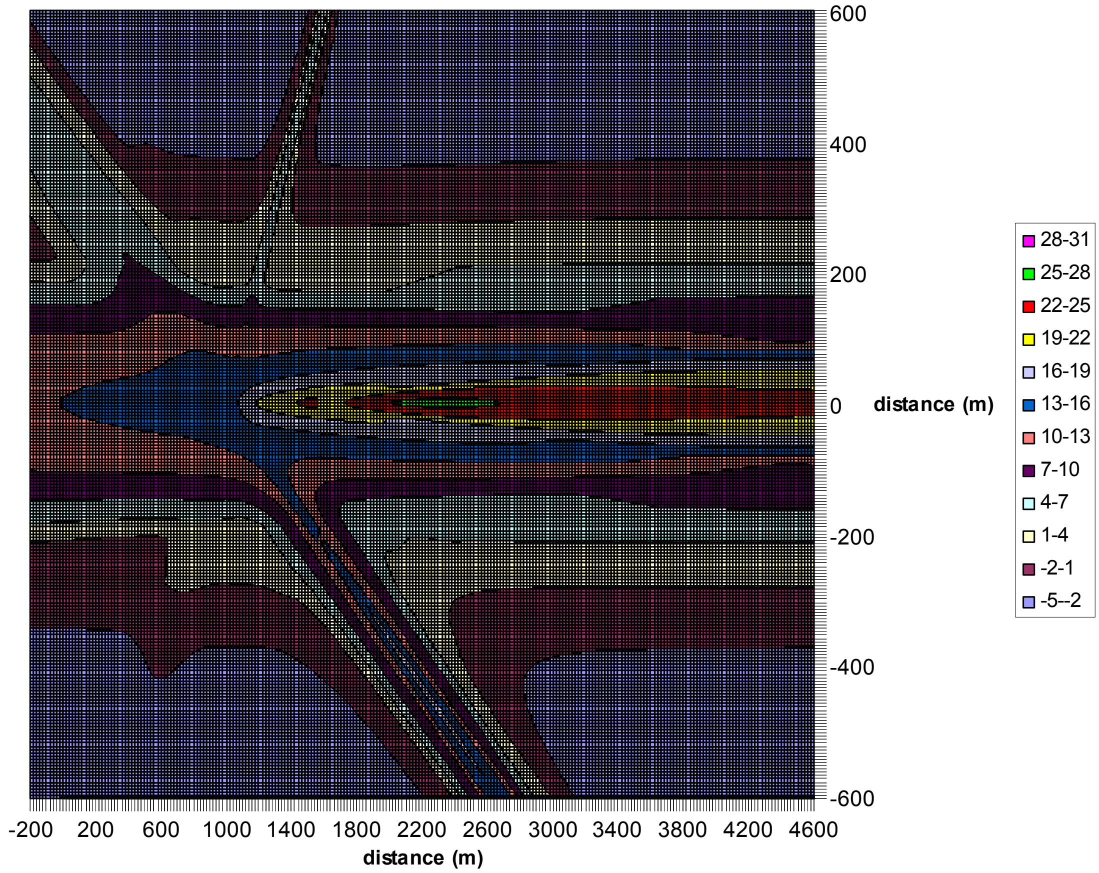
Calculations of I/N produced by three P-P links on a node (i.e. the three links have each one transmitter at the same location) have been performed with the assumptions shown in Table 4:

Parameters	Link 1	Link 2	Link 3
Hop length (km)	3	5	7
Azimuth (°)	45	-20	0
Antenna height at the node (m)	16	18	20
Antenna height of the other transmitter (m)	10	18	25
Receiver threshold level (dBm)	- 73	- 73	- 73
99.999% availability (rain zone 32 mm/h)	24 dB fade margin	40 dB fade margin	49 dB fade margin
Power (dBm)	10	20	30
Antenna gain (dBi)	34	41	41
99.999% availability (rain zone 42 mm/h)	32 dB fade margin	48 dB fade margin	62 dB fade margin
Power (dBm)	20	30	30
Antenna gain (dBi)	34	41	47

Table 4: Considered parameters for a 3-P-P links star node

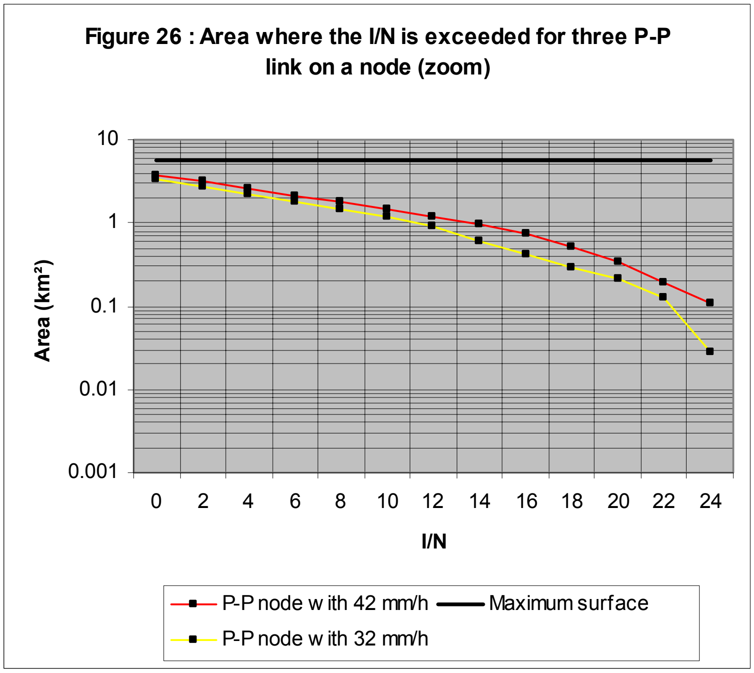
The following Figure 25 describes the I/N levels (zoomed on the node) that would be produced by three P-P links on a node with 99.999% availability in 32 mm/h rain zone.

Figure 25 : I/N produced by three P-P link on a node (99.999% and 32 mm/h)(zoom at the node)



(Scale of Figure 25 : X = 4400 m ; Y = 1200 m)

Based on Figure 25 and similar calculations for 42 mm/h rain zone, the Figure 26 below gives the respective area where given I/N levels are exceeded (for the situation around the node as described on Figure 25, which represents a total 5.76 km²).



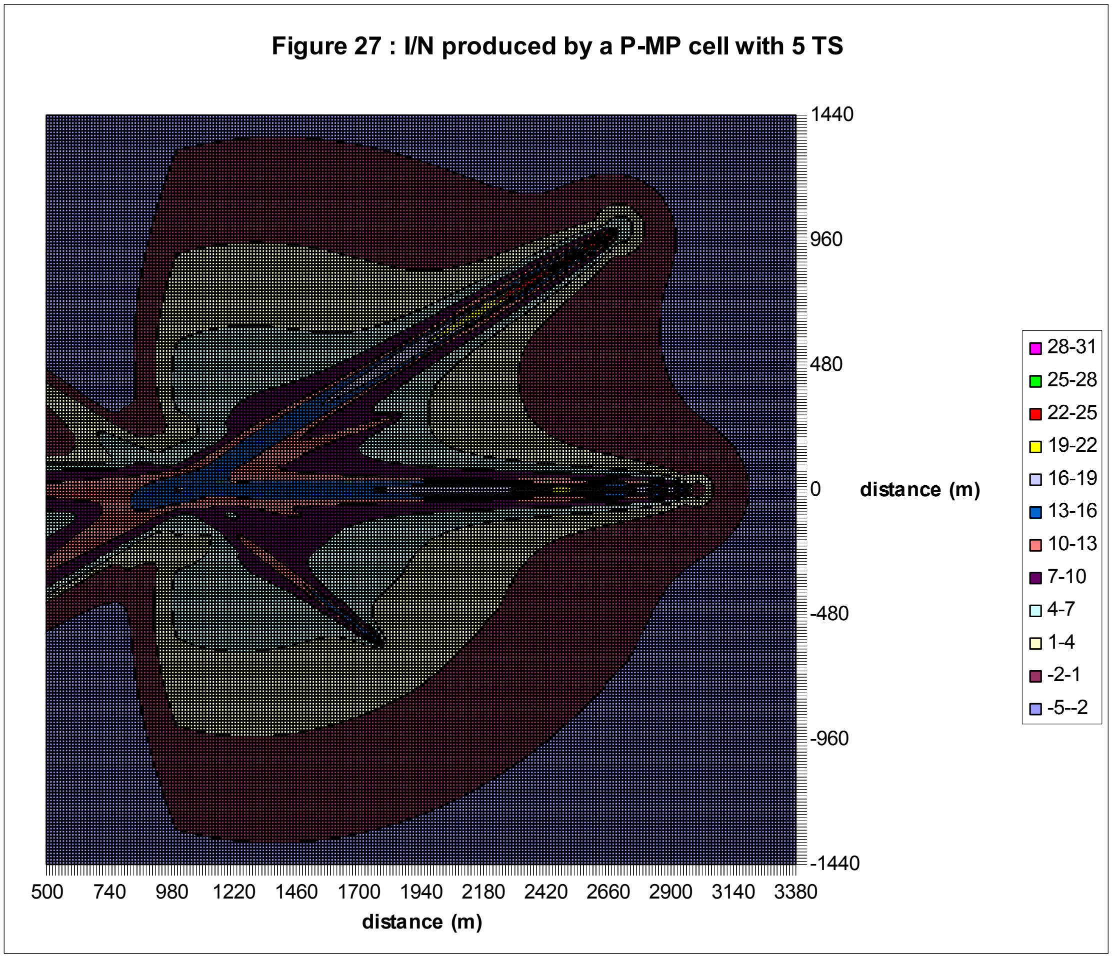
4.4.4 P-MP cell

Calculations of I/N produced by three P-MP cells (i.e. one CS and 5 TS) have been performed with the assumptions shown in the Table 5:

Parameters	CS	TS1	TS2	TS3	TS4	TS5
Distance from the CS (km)		0.5	1	1	2	2
Azimuth (°)		-10	20	-40	0	30
Antenna gain (dBi)	18	32	32	32	35	35
Sector (°)	90					
Power (dBm)	27	10	16	16	25	25
Antenna height at the node (m)	30	5	10	5	10	5
Elevation (°)	-2	2.9	1.1	1.4	0.6	0.7
99. 99% availability (32 mm/h)		3 dB fade margin	5 dB fade margin	5 dB fade margin	10 dB fade margin	10 dB fade margin

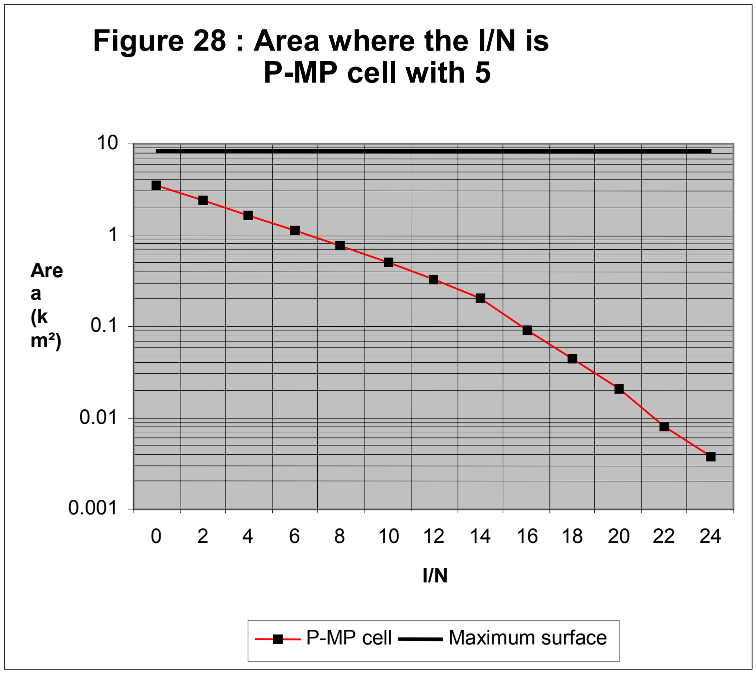
Table 5: Considered parameters for a P-MP cell

The following Figure 27 describes the I/N levels that would be produced by a P-MP cell in 32 mm/h rain zone.



(Scale of Figure 27 : X = 2880 m ; Y = 2880 m)

Based on Figure 27, the Figure 28 below gives the respective area where given I/N levels are exceeded.



4.5 Analysis of the results

All figures above show that FS stations present large areas in their vicinity where the I/N induced to SRR is positive (i.e. > 0 dB) and in many cases the induced I/N is above +20 dB (whereas, in general, protection level of non-UWB radars is taken at an I/N = -6 dB). This confirms that with such levels of interference, SRR will only be able to operate in the vicinity of an FS link by applying high levels of processing gain to balance such interference up to a certain extent, as described in section 2.

Considering a single FS station, the worst I/N case is produced, as expected, with 47 dBi antenna P-P station (see Figures 13 and 14), while P-MP central stations produce lower levels of I/N up to 14 dB but on larger areas due to their sector antennas (see Figures 17 and 18).

In operational conditions, considering FS systems such as a single FS link or a P-MP cell, the interference from all emitting stations aggregates in the SRR bandwidth and hence presents a higher potential for interference. However, the level of interference and the impacted area depend on the FS link budget and hence mainly on the distance between the corresponding FS stations as well as the required availability and the rain zone.

For a 3 km P-P link that requires less system gain, the interference to SRR is lower (in terms of I/N and impacted area) than the one produced by a 7 km P-P link, as shown respectively in Figures 21/22 and 23/24. In addition, the P-P node case as described in section 4.4.3 corresponds to a scenario that presents a high interference potential in the vicinity of the node (see Figures 25 and 26).

On the other hand, for P-MP systems which utilise shorter operating distances, Figure 27 shows that interference potential is higher due to the coverage of the central station and the high number of terminal stations. It is worth noting that Figure 27 represents the case of a P-MP cell with 5 terminal stations whereas typical cell may contain few tens terminal stations. In addition, since P-MP systems present a “cellular based topology”, it is more than likely that other central stations transmitting on adjacent cells (possibly 4 with 90° sectors) will be located at the same place and hence will result in a larger impacted area.

This latter scenario has not been considered, but the addition of few P-MP cells associated with their many terminal stations is likely to be the worst situation in which SRR would have to operate. The mitigation effect from buildings in the urban environment should however be carefully considered in such a scenario.

On a general basis, the area over which a positive level of I/N may be experienced is very large (up to several km^2 around a FS station). Therefore, considering the number of FS systems in both the 23 and 26 GHz bands that may also be aggregated since they all operate in the SRR bandwidth, the occurrence of interference situations in which SRR 24 GHz would be impacted or in some cases unable to operate can not be neglected.

5 CONCLUSIONS

The calculations of interference from FS to SRR operating at 24 GHz show that SRR will have to operate in a high level of interference in the vicinity of FS transmitters, presenting in particular I/N levels above **+20 dB** along the FS paths.

The ability of SRR to operate in such an environment mainly depends on the design of the SRR equipment and the resulting processing gain (see section 2.1 that estimates a minimum processing gain of 67 dB).

As SRR will operate on non-interference and non-protected basis, it is therefore the responsibility of SRR manufacturers to carefully design their systems so as to minimize the effect of interference from radiocommunication services (in particular Fixed Service), as well as from other SRR devices by implementing adequate mitigation techniques, such as the spread spectrum technique (that can provide processing gain above 50dB) and further interference suppression techniques (see section 2.2).

Based on the information provided by industry (see section 2.2), while noting however the lack of details, it can be assumed that adequately designed SRR would be able to restore to a high degree the signals distorted by strong interference. Where the level of interference would be detrimental to the 24 GHz SRR operation, as could occur from the operation of FS, it can be assumed that the SRR devices would be temporarily disabled. The present analysis shows that the interference protection of 24 GHz SRR can not be guaranteed.