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WINNER II Spectrum Sharing Studies

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Abstract: This report provides the results of spectrum sharing studies performed between IMT-Advanced and FSS systems, as well as between WINNER and FSS systems in the candidate bands 3 400-4 200 and 4 500-4 800 MHz. The studies cover both co-channel and adjacent band scenarios. The work is based on predicted WINNER system characteristics and sharing related technical parameters, ITU agreed sharing parameters for a generic IMT-Advanced technology and FSS parameters contained in ITU-R Recommendations. The simulations have partly been conducted with an updated version of CEPT tool SEAMCAT 3. Updates were done related to the implementation of propagation model in Recommendation ITU-R P.452. The results provided in these studies show that frequency sharing between FSS and WINNER or IMT-Advanced systems in 3 400-4 200 and 4 500-4 800 MHz bands is feasible under certain conditions.

Keyword list: Spectrum Sharing, FSS, 3 400-4 200 and 4 500-4 800 MHz bands, ITU, IMT, WRC,

Disclaimer:

Executive Summary

This deliverable describes the work done by WINNER Work Package 5, Subtask 10.3. The target was to conduct technical sharing studies that would support the ITU-R WP 8F (Working Party 8F of the International Telecommunication Union, Radiocommunication Sector) in its preparatory work towards the WRC-07.This was done when possible by contributing to the ITU-R WP 8F via the European process, through ECC PT1 (Electronic Communication Committee Project Team 1). Further, Subtask 10.3 was to work within CEPT and ITU-R to define commonly accepted IMT-Advanced sharing parameters that are sufficiently generic but able to describe the characteristics of IMT-Advanced technologies, including WINNER.

At the time of the writing of the deliverable, the WP8F had already finished its work on the CPM text and the preliminary results of the sharing studies are summarised in the CPM text. However, the sharing study activity needs to continue in the ITU-R WP 8F and the final results are required by the WRC07. Therefore the Work Package 5 Subtask 10.3 continues to work on sharing and focuses especially on possible mitigation techniques mentioned in the chapter 7 of this Deliverable.

The sharing results contained in this Deliverable are based both on ITU-R WP 8F generic sharing parameters and methodology as well as WINNER specific parameters. As typical, the ITU-R WP 8F sharing parameters and sharing scenarios correspond to the worst situation in terms of interference effects on fixed satellites systems operating in candidate bands. WINNER specific sharing parameters and dedicated mitigation techniques show less interference and therefore better geographical sharing situation results in terms of protection distance requirement.

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Abbreviations

Term	Description
ACI	Adjacent Channel Interference
ACPR	Adjacent-Channel Power Ratio
AP	Access Point
BS	Base Station (=Access Point)
CDMA	Code Division Multiple Access
CPM	Conference Preparatory Meeting
CSI	Channel State Information
FDMA	Frequency Division Multiple Access
FSS	Fixed Satellite Service
GSO	Geostationary Satellite Orbital
IMT	International Mobile Telecommunications
ITU	International Telecommunications Union
MA	Multiple Access
MAI	Multiple Access Interference
MC-CDMA (OFDM-CDMA)	Multi Carrier CDMA
MC-DS-CDMA	Multi Carrier Direct Sequence CDMA
MT	Mobile Terminal
MS	Mobile Station (=UT=MT)
NB	Narrow Bandwidth
OFDM(A)	Orthogonal Frequency Division Multiplexing (Access)
RX	Reception (radio)
SDMA	Space Division Multiple Access
SFN	Single Frequency Network
SISO	Single Input Single Output
SS-MC-MA (OFDMA-CDM)	Spread Spectrum Multi Carrier Multiple Access
TDMA	Time Division Multiple Access
TX	Transmission (radio)
WINNER	Wireless World Initiative New Radio
WB	Wide Bandwidth

Mathematical Symbols and Notation

Symbol	Description
d	Distance between IMT-Advanced and FSS earth station (km)
d intersite	Intersite distance (km)
d protection	Protection distance (km)
FL:	base station feeder loss (dB)
G_{it}	BS antenna gain in the earth station direction (dB).
G_{vr}	Earth station antenna gain in the BS direction (dB).
G(θ)	gain relative to an isotropic antenna (dBi) parameter which accounts for increased side-lobe levels above what would be expected for an antenna with improved side-lobe performance
G_0	the maximum gain in or near the horizontal plane (dBi)
h1	FSS Earth station height (km)
h2	IMT-Advanced base station height (km)
I	Received power in the earth station due to the BS (dBm).
k	Parameter which accounts for increased side-lobe levels above what would be expected for an antenna with improved side-lobe performance
P	Time percentage (%)
P_{it}	Power level distribution of the BS (dBm)
PL	Path loss between the BS and the earth station (dB).
θ	absolute value of the elevation angle relative to the angle of maximum gain (degrees)
θ_3:	The 3 dB beam width in the vertical plane (degrees)

1 Introduction

WINNER project which belongs to the 6th Framework Research Programme of the EU aims for a new radio system design that can fulfill the demanding requirements of the future mobile services and usage, such as those of the ITU-R for IMT-Advanced. Such technologies are expected to emerge within a time frame of about 10 years. WINNER will develop a system concept for ubiquitous wireless radio communication, covering the full range of scenarios from short-range to wide-area coverage. WINNER will use advanced and flexible network topologies, physical layer and MAC technologies and frequency sharing methods. The new ubiquitous radio system concept will make efficient use of the radio spectrum to minimise the cost-per-bit. The WINNER system concept will support higher data rates than today's technologies as well as and will be capable to operate also on higher carrier frequencies than existing mobile systems as wider bandwidths are expected to become available only in those frequencies. This set demanding challenges both to the radio network solutions and radio interface techniques. Despite of the technical challenges, the overall system development also needs to result in acceptable solutions from the viewpoints of economics as well as standardisation and regulatory processes. In particular, the WINNER system needs to be capable of efficient and flexible use of spectrum. Efficient spectrum use is one of the crucial design targets of the WINNER system concept that is taken into account from the beginning of the design process.

Spectrum is an essential but scarce resource in wireless communications. The continuous increase in number and popularity of wireless communication systems has led to an increased demand for more spectrum. Particularly in the telecom sector, an explosive growth of demand for spectrum was noted since the introduction of digital cellular mobile communication networks.

During the preparatory work performed within ITU-R WP 8F[1] for the WRC-07, where the need for new bands will be addressed, the frequency bands 3 400-4 200 and 4 400-4990 MHz have been identified as two of the candidate bands for the future development of IMT-2000 and IMT-advanced. A part of the bandwidth that is necessary for the full deployment of WINNER could be in these bands. From these bands the bands 3 400-4 200 and 4 500-4 800 MHz have a primary allocation for Fixed-Satellite Service, FSS, and are used for the provision of fixed satellite services in several of the countries around the world. If these bands are identified for IMT-Advanced WINNER systems need to coexist with FSS systems without interfering them.

This document aims at assessing the sharing situation and coordination conditions as protection distances may need to be set up to limit the interference levels when both systems share the spectrum bands.

This document deals with sharing studies between Fixed Satellite Systems and IMT-Advanced or WINNER systems based on generic parameters scaled to typical bandwidths technically envisaged at 4 GHz frequency range. The study provides the results of sharing studies between Fixed Satellite Systems earth stations and WINNER base stations as well as mobile stations in suburban and urban environments[2]. Three analyses have been performed:

- a deterministic analysis based on MCL interference budget calculation for effects of WINNER base stations on Fixed Satellite Systems earth stations;
- a Monte Carlo analysis conducted with SEAMCAT 3[3] tool for WINNER mobile stations effects;
- the impact of Fixed Satellite Systems space stations pfd limits on WINNER base stations

[1] WP8F: Study group of ITU-R related to issues on Mobile, radio determination, amateur and related satellite services

[2] Rural environment full coverage is considered more suitable in lower bands than the bands addressed by this document.

[3] SEAMCAT is CEPT tool currently used for spectrum sharing and compatibility studies. This statistical tool is based on Monte Carlo methodology. In the up link scenarios, SEAMCAT is the most suitable for such scenarios.

Table 1-1: Existing frequency allocations in the preferred WINNER frequency range in Europe

2700.0 - 2900.0 MHz	AERONAUTICAL RADIONAVIGATION Radiolocation	Aeronautical navigation Radiolocation (civil) Radiolocation (military) Weather radar
2900.0 - 3100.0 MHz	RADIOLOCATION RADIONAVIGATION	Aeronautical navigation Radiolocation (civil) Radiolocation (military) (2900.0 - 3500.0 MHz)
3100.0 - 3300.0 MHz	RADIOLOCATION Earth Exploration-Satellite (active) Space Research (active)	Radiolocation (military) (2900.0 - 3500.0 MHz) Active sensors (satellite)
3300.0 - 3400.0 MHz	RADIOLOCATION	Radiolocation (military) (2900.0 - 3500.0 MHz)
3400.0 - 3500.0 MHz	FIXED FIXED-SATELLITE (space-to-Earth) MOBILE Amateur Radiolocation	Radiolocation (military) (2900.0 - 3500.0 MHz) Amateur Fixed links SAP/SAB and ENG/OB (3400.0 - 3600.0 MHz) Point-to-Multipoint (3400.0 - 3800.0 MHz)
3500.0 - 3600.0 MHz	FIXED FIXED-SATELLITE (space-to-Earth) MOBILE	SAP/SAB and ENG/OB (3400.0 - 3600.0 MHz) Point-to-Multipoint (3400.0 - 3800.0 MHz) Fixed links
3600.0 - 4200.0 MHz	FIXED FIXED-SATELLITE (space-to-Earth)	Point-to-Multipoint (3400.0 - 3800.0 MHz) FSS Earth stations Point-to-Point
4200.0 - 4400.0 MHz	AERONAUTICAL RADIONAVIGATION	Altimeters Earth exploration-satellite
4400.0 - 4500.0 MHz	FIXED MOBILE	Point-to-Point (4400.0 - 4800.0 MHz) Defence systems (4400.0 - 5000.0 MHz) SAP/SAB and ENG/OB (4400.0 - 5000.0 MHz)
4500.0 - 4800.0 MHz	FIXED FIXED-SATELLITE (space-to-Earth) MOBILE	Point-to-Point (4400.0 - 4800.0 MHz) Defence systems (4400.0 - 5000.0 MHz) SAP/SAB and ENG/OB (4400.0 - 5000.0 MHz) FSS Earth stations
4800.0 - 4990.0 MHz	FIXED MOBILE except aeronautical mobile Radio Astronomy	Defence systems (4400.0 - 5000.0 MHz) SAP/SAB and ENG/OB (4400.0 - 5000.0 MHz) Passive sensors (satellite) Continuum measurements (4800.0 - 5000.0 MHz) VLBI observations (4800.0 - 5030.0 MHz)
4990.0 - 5000.0 MHz	FIXED MOBILE except aeronautical mobile RADIO ASTRONOMY	Defence systems (4400.0 - 5000.0 MHz) SAP/SAB and ENG/OB (4400.0 - 5000.0 MHz) Continuum measurements (4800.0 - 5000.0 MHz) VLBI observations (4800.0 - 5030.0 MHz)

2 General information about FSS systems

2.1 Types of deployment

Earth stations of Fixed Satellite Service, FSS, are deployed in a variety of environments in the 4 GHz frequency range,. Among them, three cases can be highlighted as the most representative:

- VSATs networks in rural, sub-urban[4] and even urban[5] areas (e.g. corporate network),
- “Small” gateways in rural and sub-urban4 environment (small to medium-size antennas often used to connect remote areas to the Internet backbone and other telecommunications networks),
- “Large” gateways in rural environment (medium-size to large antennas used to provide international connectivity with other countries or territories).

The bands examined in this document are used for the Downlink communication, in the Space-to-Earth direction of FSS, therefore the earth stations are more or less sensitive to the interference generated by transmitters in the neighbourhood, on the ground.

In addition to the FSS main use cases mentioned above, the 4 GHz frequency range is also used by feeder links of the mobile-satellite service. Though the required quality of service of such feeder links may vary from other FSS usage, their characteristics are similar to those of the “large” gateways.

2.2 System parameters

Table 2-1: Typical downlink FSS parameters in the 4 GHz band

Parameter	Typical value						
Range of operating frequencies	3 400-4 200 MHz, 4 500-4 800 MHz						
Earth station off-axis gain towards the local horizon (dBi)[1]	Elev. angle[2]	5°	10°	20°	30°	48°	>85°
	Off-axis gain	14.5	7.0	–0.5	–4.9	–10	0
Antenna reference pattern	Recommendation ITU-R S.465 (up to 85°)						
Range of emission bandwidths	40 kHz - 72 MHz						
Receiving system noise temperature	100 K						
Earth station deployment	All regions, in all locations (rural, semi-urban, urban)[3]						

[1] The values were derived by assuming a local horizon at 0° of elevation.

[2] 5° is considered as the minimum operational elevation angle.

[3] FSS antennas in this band may be deployed in a variety of environments. Smaller antennas (1.8 m-3.8 m) are commonly deployed on the roofs of buildings or on the ground in urban, semi-urban or rural locations, whereas larger antennas are typically mounted on the ground and deployed in semi-urban or rural locations.

NOTE – Parameters of fixed-satellite service stations in the 4/6 GHz part of Appendix 30B Plan may be modified under Agenda item 1.10 of WRC-07.

[4] Sub-urban area corresponds to Wide Area in WINNER concept.

[5] Urban area corresponds to Metropolitan and Local Area in WINNER concept.

3 Interference criteria

The ITU-R reference for this criterion is the recommendation ITU-R S.1432. Two cases of long term interference criteria have been considered, depending on the status of the sharing services allocated to the band 3400-4200 MHz, or 4500-4800 MHz, or part of them:

- I/N=-12.2 dB (ΔT/T = 6%) corresponding to the aggregate interference from other systems having co-primary status, for 100% of the time
- I/N=-20 dB (ΔT/T = 1%) corresponding to the aggregate interference from all other sources of interference, for 100% of the time

4 Assumptions on systems parameters

4.1 FSS earth station parameters

Table 4-1: FSS earth station parameters

Antenna pattern	Recommendation ITU-R S.465	
Short-term and long-term maximum permissible Interference level (dBW/MHz)	Recommendation ITU-R SF.1006	
Protection criteria I/N(dB)	Long term analysis	
Receiving system noise temperature (K)	100	
Environment	Sub-urban4	Urban 5
Antenna height (m)	15	25
Antenna diameter (m)	5,5	2,4
Antenna peak gain (dBi)	44,4	37,2
Antenna elevation (°)	5-45	
Reception bandwidth (MHz)	50	100
Noise floor: N (dBm)	–101.6	–98,6

All the characteristics are scaled to typical bandwidths[6] and given for macro cell as well as micro cell.

4.1.1 Earth station antenna pattern

The following reference radiation patterns should be adopted for angles between the direction considered and the axis of the main beam at least for frequencies in the range 2-30 GHz:

$$G = 32 - 25 \log \varphi \quad \text{dBi} \quad \text{for } \varphi_{min} \leq \varphi < 48°$$

$$= -10 \quad \text{dBi} \quad \text{for } 48° \leq \varphi \leq 180°$$

where $\varphi_{min} = 1°$ or 100 λ/D degrees, whichever is the greater.

4.2 IMT-Advanced parameters

4.2.1 ITU-R WP8F parameters

Within the ITU-R, a number of generic IMT-Advanced sharing parameters have been defined to represent IMT-Advanced technologies. It is noted that WINNER parameters are reflected in these parameters as a part of the defined density range.

The following IMT-Advanced parameters values were agreed at 19th WP8F meeting (Doc. 8F/899, Attachment 5.20).

Table 4-2: Base station parameters

Parameter	Value to be considered in the simulations
EIRP density range: macro base station scaled to 1 MHz bandwidth	46 dBm/MHz
EIRP density range: micro base station scaled to 1 MHz bandwidth	22 dBm/MHz
Antenna type (Tx/Rx) (the gain is assumed to be flat within one sector)	Sectored for macrocell omni for microcell

6 Typically 50 MHz for suburban and 100 MHz for urban coverage.

Receiver thermal noise (including noise figure)	–109 dBm/MHz
Protection criteria (*I*/*N*) interference to individual BS	–10 dB
Protection criteria (*I*/*N*) vs satellite systems	–10 dB

Table 4-3: Mobile station parameters

Parameter	Value to be considered in the simulations
Maximum Tx PSD range output power[7]	7.5[8] dBm/MHz
Receiver thermal noise (dBm/MHz) (Including noise figure)	–109 dBm/MHz
Protection criteria (*I*/*N*)	–6 dB

[7] With reference signal bandwidth between 20 and 100 MHz.

[8] A median value is selected considering the effect of ATPC (pending further confirmation)

Table 4-4: Network parameters

Parameter	Value to be considered in the simulations
Macro cell antenna gain	20 dBi
Micro cell antenna gain	5 dBi
Macro cell feeder loss	4 dB
Micro cell feeder loss	0 dB
Antenna pattern for vertical sharing	ITU-R 1336-1
Mobile station antenna gain	0 dBi
BS Antenna downtilt (Macro)	2 degrees
BS antenna height (Micro)	5 m
BS antenna height (Macro)	30 m
MS antenna height (macro and micro)	1.5 m
Intersite distance (Micro)	600 m
Intersite distance (Macro)	5 km
[Intersite distance (Macro) for urban case]	1,5 km

4.2.2 WINNER parameters [1], [2], [3],[4]

The following parameters are based on WINNER parameters commonly used within system capacity simulations. According to sharing studies requirements, they are calculated for a given bandwidth and a given radio environment. These parameters correspond also to a certain scaled value of the generic density range defined within WP8F (see previous section).

4.2.2.1 Stations characteristics

Tableau 4-5: Characteristics in suburban environment

SUBURBAN MACRO CELL		
Bandwidth (MHz)	50 MHz	
	Base station BS/AP	**Mobile station MS**
Thermal noise floor including noise figure (dBm)	–92	–88
Tx output power(dBm)	43	24
Antenna gain (dBi)	20	0
Antenna down tilt (°)	2	0
Antenna height (m)	30	1.5

Tableau 4-6: Characteristics in urban environment

URBAN MICRO CELL		
Bandwidth (MHz)	100 MHz	
	Base station BS/AP	**Mobile station MS**
Thermal noise floor N (dBm)	–89	–85

Tx output power(dBm)	30	24
Noise figure (dB)	5	9
Antenna gain (dBi)	5	0
Antenna down tilt (°)	0	0
Antenna height (m)	5	1.5

4.2.2.2 Base station antenna pattern

The Base station vertical antenna pattern assumed in this contribution is based on Recommendation ITU-R F.1336-1

The following equations should be used for elevation angles that range from 0° to 90°.

$$G(\theta) = \max\left[G_1(\theta), G_2(\theta)\right]$$

$$G_1(\theta) = G_0 - 12\left(\frac{\theta}{\theta_3}\right)^2$$

$$G_2(\theta) = G_0 - 12 + 10\log\left[\left(\max\left\{\frac{|\theta|}{\theta_3}, 1\right\}\right)^{-1.5} + k\right]$$

$$\theta_3 = 107.6 \times 10^{-0.1 G_0}$$

Where:

$G(\theta)$: gain relative to an isotropic antenna (dBi)

G_0: the maximum gain in or near the horizontal plane (dBi)

θ : absolute value of the elevation angle relative to the angle of maximum gain (degrees)

θ_3: the 3 dB beamwidth in the vertical plane (degrees)

k: parameter which accounts for increased side-lobe levels above what would be expected for an antenna with improved side-lobe performance

For frequencies above 3 GHz, k=0.

4.2.2.3 WINNER adjacent band characteristics

4.2.2.3.1 Spectrum Mask [2]

Spectrum masks have been defined for the WINNER system in [2]. The masks are based on the noise floor and the Adjacent Channel Power Ratio (ACPR). The far-limit points follow from the noise floor, bandwidth and maximum Tx power, and because of this they are different for the base stations and the terminals. The transition part of the mask is formed according to non linear effects of the transmitter (mainly Power Amplifier non-linearities), while satisfying requirements from the ACPR and the noise floor. The power spectrum mask as derived in WINNER Phase I is illustrated in Figure 4-1.

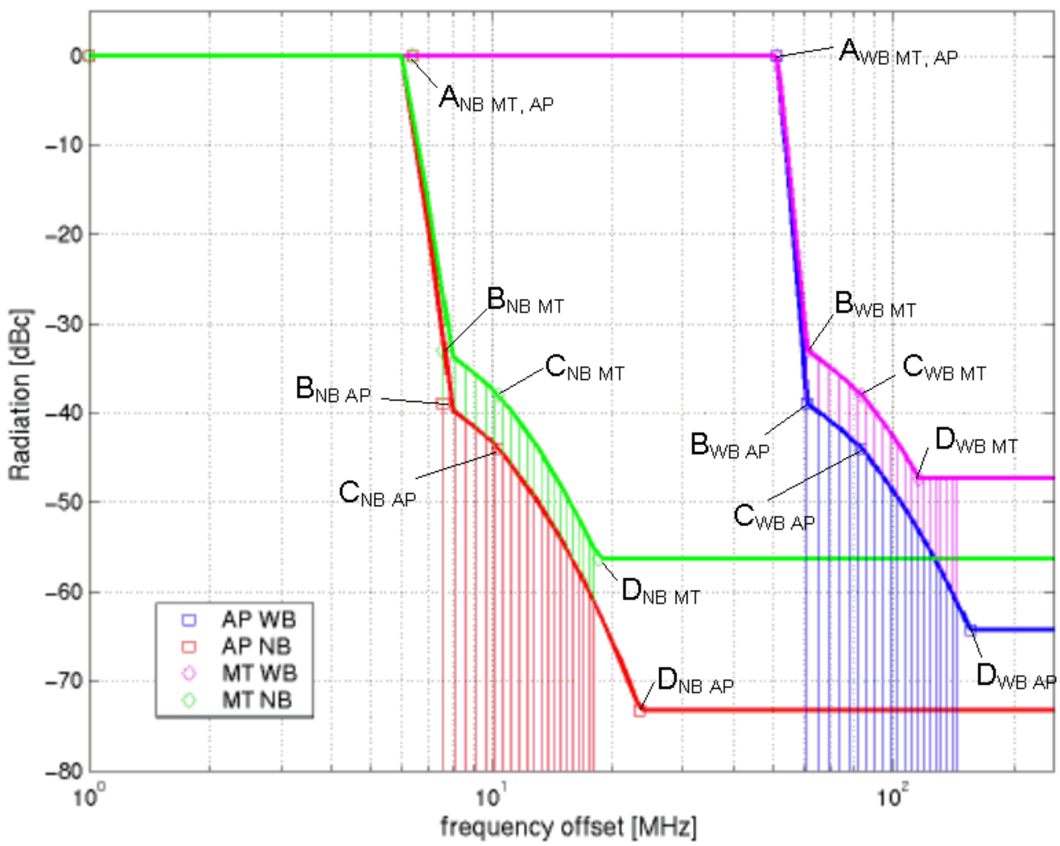


Figure 4-1: TX power spectrum mask (NB Narrow Band, WB Wide Band, MT Mobile Terminal, and AP Access Point)

In Figure 4-1 the spectrum mask is characterized by four different points: A – half the bandwidth, B – beginning of the adjacent channel, C – the spectrum slope transition point, and D – the point where the simulated PA profile crosses the noise floor. Before point C the slope of the spectrum mask is assumed to be 15 dB/bandwidth, after that point it becomes approximately 19 dB/bandwidth.

4.2.2.3.2 Noise floor

The requirements for noise floor of the AP transmitter follows from that the transmitter must not prevent a closely located MS from receiving a weak signal from another AP in the adjacent channel. The MS sees the noise floor from the close-by AP as interference on the wanted channel. In the most extreme case, the MT is at minimum coupling distance and the wanted signal is at sensitivity level. To push the TX noise below the thermal noise floor by some margin,

(AP TX noise floor [dBm/Hz]) ≤ (MT RX noise floor [dBm/Hz])

+ (minimum AP-MT coupling loss [dB]) – (multiple interference margin [dB]).

In [2] it was derived that with MT RX noise floor = thermal noise floor + noise figure = -165 dBm / Hz, and multiple interference margin = 7 dB, one obtains: AP TX noise floor ≤ -100.3 dBm/Hz (for synchronous network). The requirement is the same for WB and NB modes. For a MT transmitter a similar reasoning results in a MT TX noise floor ≤ -103.3 dBm/Hz for a synchronous system. In an asynchronous system there will also be AP-AP interference resulting a much stricter requirement on the noise floor [2].

4.2.2.3.3 Adjacent Channel Power Ratio

The requirements for AP and MT TX adjacent-channel power ratio (ACPR) follow from the same argumentation as the requirements for the noise floor. They can be obtained as the ratio between the maximum output power and maximum allowed noise floor integrated over one channel [2]

For analysing the RF requirements due to adjacent-channel interference, a multiple interference margin of 3 dB is used. For AP, this yields maximum adjacent-channel power –96.3 dBm/Hz, corresponding to –17.1 dBm in WB mode and –26.1 dBm in NB mode. With maximum output power +43 dBm, the ACPR requirements are then 60 dB in WB mode and 69 dB in NB mode.

For MT, the maximum adjacent-channel power is –99.3 dBm/Hz, giving integrated power –20.1 dBm in WB mode and –29.1 dBm in NB mode. With maximum output power +23 dBm, the ratio is 43 dB in WB mode and 52 dB in NB mode.

Table 4-7 : AP and MT TX ACPR requirements

	AP WB	AP NB	MT WB	MT NB
Calculated requirement	60	69	43	52
Relaxed specification	45	45	39	39

In [2] a maximum linearity of 30 dB of the PA is assumed to be viable. As a reference, the value for 802.11a is 25 dB and WCDMA 33 dB. The difference to 802.11a is due to WLAN not being a cellular system. The WCDMA value also results from relaxing the strictly calculated specification

5 Methodology

One way to ensure frequency sharing between FSS systems and WINNER technology is to set up protection area around the FSS earth stations.

The size of this area is calculated in this analysis as the minimum distance in each direction from a given earth station towards the base stations or mobile stations of WINNER systems that produce an interference that should not exceed required interference criterion.

The effect of single as well as aggregate WINNER stations on FSS earth station is calculated, both are done considering protection distance between WINNER stations and FSS stations in function of the earth station elevation angle and azimuth position between WINNER and FSS earth stations so that protection criterion is met. The same scenarios are performed employing multi-carrier schemes in downlink or power control in uplink.

On the hand, calculations are made in the case of co-channel scenarios with 4 GHz as co-frequency, on the other hand, adjacent channel scenarios are performed regarding the 1st adjacent channel.

5.1 MCL Interference budget calculation

The following equations are used for the interference calculation.

$$I = P_{it} + G_{it} - PL + G_{vr} - \mathrm{FL}$$

I : Received power in the earth station due to the BS (in dBm).

P_{it} : Power level distribution of the BS (in dBm).

G_{it} : BS antenna gain in the earth station direction (in dB).

G_{vr} : Earth station antenna gain in the BS direction (dB).

PL : Path loss between the BS and the earth station (dB).

FL: base station feeder loss (dB)

The following angles are used for antenna patterns calculation (see figure 1):

$$\tan a = \frac{h1 - h2}{d}$$

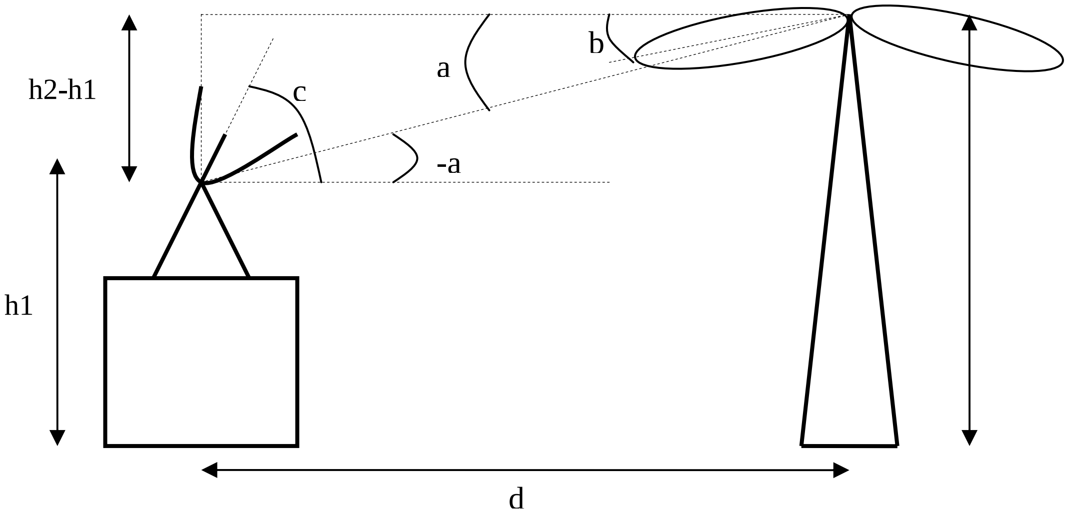
a is the vision angle seen from the base station.

The vision angle seen from the base station **-** *a* is the opposite.

b is the antenna tilt for the BS and *c* is the antenna tilt for the earth station.

FIGURE 1

Angle of vision for the BS and the earth station



5.2 Propagation model

The propagation models to be considered in spectrum sharing studies require being suitable both for interference calculations and long range distances. When dealing with coordination distances between FSS earth stations and WINNER stations, extending WINNER path loss model to the long range is difficult, therefore the propagation model of Recommendation ITU-R P.452-12[9] is used instead.

In these studies, P.452 propagation model is used with a flat terrain model in suburban and urban environments.

Figure 5-1: Input parameters used for the P.452-12 propagation model

P (%)	Water density:	Clutter category
20%	$3 g/m^3$	Suburban and urban environments

It should be noted that generic studies are provided using Recommendation ITU-R P.452 with no terrain model (a terrain model will reduce the separation distances due to the presence of obstacles). Recommendation ITU-R P.452 with a flat terrain profile comes down to free space model below 40 km (for ranges above 40 km, Earth radius impacts the path loss).

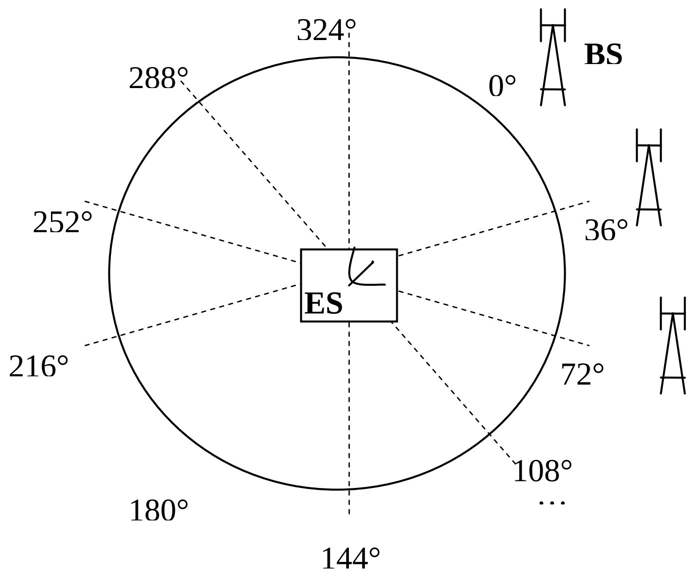
5.3 Assessment of WINNER stations on FSS earth stations effect

5.3.1 Single BS

For each environment, results are expressed in terms of required protection distance between WINNER BS and FSS earth station to meet the long term protection criteria on FSS earth station. These protection distances are assessed regarding the FSS ES elevation angle and additionally azimuth[10] between earth station and single base station as illustrated in the following figure:

[9] This model has been implemented into SEAMCAT 3 tool by WINNER.

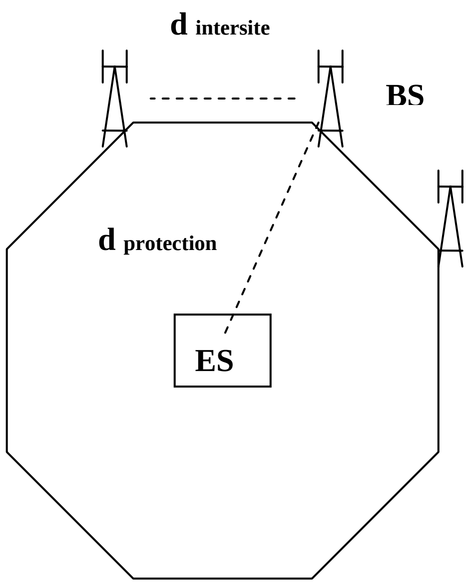
[10] Azimuth = 0° corresponds to the maximum gain of the earth station.



5.3.2 Aggregate BS

5.3.2.1 ITU-R WP8F model[11]

For the aggregate case, the effect of all the IMT-Advanced BS is taken into account i.e. a certain number of BS have been uniformly (equi-spaced) located on a circle around the FSS earth station The radius is the result of the required protection distance meeting the interference criterion. The number of IMT-Advanced BS is assessed according to the protection distance and the BS intersite distance range. All the calculations are based on ITU-R WP8F meeting IMT-Advanced parameters.



The number aggregate BS assessed is as following:

11 This model has been discussed during the 20th ITU-R WP8F meeting.

Number of aggregate BS = pi / [arc sin (d $_{intersite}$/ (2*d $_{protection}$))]

5.3.2.2 A simplified model

Another way to model the interference effects for the aggregate case, is to considerer the effect of 10 BS that are 36° equi-spaced and uniformly located on a circle around the FSS earth station with a radius equal to the protection distance.

This simplified model is used to calculate several values between the maximum and minimum required separation distance, the detailed calculations are provided in Appendix 3.

5.3.3 MS density distribution

For the Uplink case (WINNER MS on an FSS earth station) the power control implemented in Seamcat is used with the following parameters

– Power control step size: 1 dB

– Dynamic range: 120 dB

– Minimum threshold = Sensitivity [dBm/Hz] + BWimt [dBHz] + Mf [dB]

Mf is set equal to standard deviation of slow fading, here about 8 dB

Min threshold = –90 dB.

Moreover, a random distribution of mobile stations around the FSS earth station is assumed. The user density ranges from 10 to 50 users/ km².

5.3.3.1 Implementation of multi carrier multiplexing schemes[12]

Implementation of multi carrier multiplexing schemes is an application case studied in this report as mitigation technique. WINNER system is based on generalised multi-carrier (GMC) technique used for modulation as it is essential for providing the flexibility needed for the efficient delivery of the wide range of services. It enables to accommodate a plurality of multi-carrier modulation/multiple access schemes, such as different flavours of OFDM (CP-OFDM, IOTA-OFDM, PRP-OFDM), FMT, and MC-CDMA, as well as the following serial modulation schemes: single carrier, single carrier DS-CDMA, and IFDMA. This is done by selection of an appropriate mapping strategy (data symbols to sub-carriers), guard interval design, and (frequency domain) filtering. The GMC approach is also extremely useful in generating multi-band signals, for spectrum flexibility [4].

To emulate these mechanisms, a scenario with the transmitter carrier subdivided into 10 sub-bands has been performed. Each sub-band is been assigned a certain individual central frequency, bandwidth and power so that cumulative powers reach the maximum output power level.

The sum of maximal power assigned to sub-bands cannot exceed the total BS power.

Multi-carrier schemes in WINNER reduce the required maximum output power. Multi-carrier attenuation margin depends on cell coverage range and propagation model. Furthermore the decrease on effective base station power due to the use of multi-carrier power allocation must be included, in this scenario; the attenuation margin is about 5 dB according to P452 path loss.

5.3.3.2 Mitigation techniques under investigation [5]

The use advanced antenna technologies for the IMT systems is one potential component of the solution for the FSS-IMT coexistence problem.

The most obvious procedure is to place attenuation poles in the direction of the FSS main lobe into all beam patterns to decrease the aggregate receive power because the angle of high attenuation around a pole is relatively wide, especially far away from the main lobe. In general, advanced procedures could reduce the interference even further taking simultaneously all beams of all BS and the exact antenna pattern of the ES into account. The design techniques are well known and the tapering is fixed during the operation, i.e. reliability and operability are no issues.

A more basic, possible mitigation technique could be to reduce the transmitting output power of base stations that are close to the protection distance into the direction of the FSS earth station.

[12] Multi-carrier power schemes are only assumed in downlink. The schemes considered here are based on OFDM schemes.

5.3.4 Assessment of FSS satellites pfd limits on WINNER stations effect

Studies on interference from FSS space stations to WINNER are based simply on GSO satellites located every 10 degrees of longitude transmitting an EIRP of 11 dBW per 4 kHz, with all such satellites operating co-frequency and with overlapping coverage. Such scenario was agreed at 20th ITU-R WP8F meeting based on Liaison statement from ITU-R WP4A[13]. This value is scaled to given WINNER bandwidth.

For each location, the effect of several equi-spaced GSO has been assessed, for all possible orbital location of the equi-spaced GSO satellites.

The number of aggregate GSO satellites to be considered depends on the latitude of WINNER BS location as following:

Table 5-1: Number of GSO satellites with respect to WINNER base station location

Location of WINNER BS	Helsinki	Paris	Malaga	Abu Dhabi
Number of GSO to be considered	15	16	16	17

The results are expressed in terms of I/N level. Required I/Nth criterion is –10 dB on WINNER BS and –6 dB on MS.

6 Results [5]

13 WP4A is a working party of ITU-R related to issues on Efficient orbit and/or spectrum utilization

Concerning WINNER transmissions in the down link scenarios, the results are given considering protection areas around the FSS earth stations so that I/N criterion is met.

The results are given considering the mean value of I/N achieved on earth station when WINNER mobile stations are randomly distributed around the earth station. The random distribution is run with a mobile density range from 10 to 50/km².

With regards to FSS space stations pfd limits, the results are also given considering the maximum and values of I/N achieved on WINNER stations.

6.1 Impact of IMT-Advanced stations on FSS earth stations

All the results contained in the section 6.1 are based on IMT-advanced generic parameters and ITU-R WP8F model for the aggregate base station case.

6.1.1 Co-channel scenarios

	–12.2 dB criterion		**–20 dB criterion**	
IMT-Advanced Station	**Min separation distance (km)**	**Max separation distance (km)**	**Min separation distance (km)**	**Max separation distance (km)**
Single macro[14] BS	47	60.5	59	69
Single micro[15] BS	39	49.5	43	51
Aggregate macro BS	56	87	64	99
Aggregate micro BS	49	58	62	72

Density of IMT-Advanced MS (1/km²)	**10**	**20**	**30**	**40**	**50**
I/N (dB) Suburban	–16.8	–15.7	–15.1	–14.8	–14.7
I/N (dB) Urban	–26.6	–25.8	–25.3	–25.2	–25.1

In the case of IMT-Advanced Mobile stations, I/N does not exceed –14.7 dB showing that no protection distance is required with regards to –12.2 dB criterion.

6.1.2 Adjacent channel scenarios

	–12.2 dB criterion		**–20 dB criterion**	
IMT-Advanced Station	**Min separation distance (km)**	**Max separation distance (km)**	**Min separation distance (km)**	**Max separation distance (km)**
Single macro BS	3.5	33.5	10	42,5

[14] Suburban FSS earth stations characteristics are considered in the case of macro IMT-Advanced BS.

[15] Urban FSS earth stations characteristics are considered in the case of micro IMT-Advanced BS

Single micro BS in urban	0,5	7	2	14
Aggregate macro BS	10	41	27	45,5
Aggregate micro BS	0.5	19	11	35

Density of IMT-Advanced MS (1/km²)	**10**	**20**	**30**	**40**	**50**
I/N (dB) Suburban	–19.8	–18.7	–18.3	–18.0	–17.8
I/N (dB) Urban	–28.6	–27.8	–27.5	–27.1	–26,8

6.1.3 Example of protection distances if multi-carrier schemes are implemented

6.1.3.1 Co-channel scenarios

	–12.2 dB criterion		**–20 dB criterion**	
IMT-Advanced Station	**Min separation distance (km)**	**Max separation distance (km)**	**Min separation distance (km)**	**Max separation distance (km)**
Single macro BS	43.5	55	51	66
Single micro BS in urban	29.9	47	38	49
Aggregate macro BS	51	61	61	72
Aggregate micro BS	46	53	51	59

When multi-carrier schemes are implemented, protection distances decrease approximately 10%.

6.1.3.2 Adjacent channel scenarios

	–12.2 dB criterion		–20 dB criterion	
IMT-Advanced Station	**Min separation distance (km)**	**Max separation distance (km)**	**Min separation distance (km)**	**Max separation distance (km)**
Single macro BS	1.7	19.5	5	29
Single micro BS in urban	0.2	3	2.4	8.7
Aggregate macro BS	2	30.5	15	41
Aggregate micro BS	0.2	3	4	8.5

In the adjacent channel scenario, protection distance range down 0.2 km in certain cases.

6.2 Impact of WINNER stations on FSS earth stations

All the results contained in the section 6.2 are based on WINNER parameters and the simplified model for the aggregate base station case.

6.2.1 Co-channel scenarios

	–12.2 dB criterion		–20 dB criterion	
WINNER Station	**Min separation distance (km)**	**Max separation distance (km)**	**Min separation distance (km)**	**Max separation distance (km)**
Single macro[16] BS	46	59	50	66
Single micro[17] BS	32	48	41	52
Aggregate macro BS	52	61	56	74
Aggregate micro BS	42	49	45	53

The protection distance for the aggregate BS does not significantly change from the case of single BS because only the base station located in the main lobe area of the earth station creates strong interferences compared to the base stations located elsewhere.

Density of WINNER MS (1/km²)	**10**	**20**	**30**	**40**	**50**
I/N (dB) Suburban	–20,8	–19,7	–19,1	–18,8	–18,7
I/N (dB) Urban	–33,6	–32,8	–32,3	–32,2	–32,1

[16] Suburban FSS earth stations characteristics are considered in the case of macro WINNER BS.

[17] Urban FSS earth stations characteristics are considered in the case of micro WINNER BS

In the case of WINNER Mobile stations, I/N does not exceed –18.7 dB showing that no protection distance is required with regards to –12.2 dB criterion.

5.1.2 Adjacent channel scenarios

	–12.2 dB criterion		–20 dB criterion	
WINNER Station	**Min separation distance (km)**	**Max separation distance (km)**	**Min separation distance (km)**	**Max separation distance (km)**
Single macro BS	3	31	6	41
Single micro BS in urban	0.3	4	0.6	10
Aggregate macro BS	8	32	18	41
Aggregate micro BS	5	23	11	35

Density of WINNER MS (1/km²)	**10**	**20**	**30**	**40**	**50**
I/N (dB) Suburban	–23,8	–22,7	–22,3	–22,0	–21,8
I/N (dB) Urban	–35,6	–34,8	–34,5	–34,1	–33,8

6.2.2 Example of protection distances if multi-carrier schemes are implemented

6.2.2.1 Co-channel scenarios

	–12.2 dB criterion		–20 dB criterion	
WINNER Station	**Min separation distance (km)**	**Max separation distance (km)**	**Min separation distance (km)**	**Max separation distance (km)**
Single macro BS	44	56	47	61
Single micro BS in urban	23	44	36	47
Aggregate macro BS	48	56	52	61
Aggregate micro BS	33	45	42	48

When multi-carrier schemes are implemented, protection distances decrease approximately 10%.

6.2.2.2 Adjacent channel scenarios

	–12.2 dB criterion		–20 dB criterion	
WINNER Station	**Min separation distance (km)**	**Max separation distance (km)**	**Min separation distance (km)**	**Max separation distance (km)**
Single macro BS	1.7	22	3.5	35
Single micro BS in urban	0.2	2.1	0.3	5.1
Aggregate macro BS	5	23	11	35
Aggregate micro BS	0.4	2.2	1	6

In the adjacent channel scenario, protection distance range down 0.4 km in certain cases.

6.3 Impact of FSS satellites pfd limits on WINNER stations (co-channel scenarios)

	Macro BS		Micro BS		MS	
	Min I/N	**Max I/N**	**Min I/N**	**Max I/N**	**Min I/N**	**Max I/N**
Single GSO satellite	–38.6	–20.3	–23,5	–17,8	–26.9	–25.8
10° equi-spaced aggregated GSO satellite	–21.8	–14.9	–6,2	–8,1	–14.6	–14.1

Required protection criterion on WINNER stations is exceeded only on micro base stations for the aggregate case.

7 Conclusion

The results provided by these studies show that frequency sharing between FSS and WINNER systems in 3 400-4 200 and 4 500-4 800 MHz bands is feasible under certain conditions. Protection areas are required and some mitigation techniques are desirable. WINNER spectrum functionalities as multi-carrier usage basically related to OFDM schemes are helpful in achieving the necessary implementation flexibility.

In addition of implementing multi-carrier multiplexing schemes in downlink that decrease the exclusion area range about 10%, some other future mitigation techniques that are under investigation are envisaged in order to reduce more these protection distances and then to improve sharing situation.

The methods that could be envisaged:

– Generally, base stations have tri-sectorial antennas: a way to reduce this transmitting output power level could be to disable the antenna sector that points towards the FSS earth station. It is noted that disabling one sector could weak the cell capacity
– More sectors will decrease the exclusion area.
– Use of alternative frequencies in bands outside 3 400-4 200 and 4 500- 4 800 MHz by WINNER system in the considered protection areas. Base stations and terminals located in an FSS protection area could be monitored to ensure the usage of other frequencies;
– Frequency segmentation between FSS earth stations and WINNER systems in a FSS protection area could also be investigated even if it would reduce the operational flexibility of both systems.
– Finding sub bands unused by FSS in particular geographic locations would allow operation of WINNER without a protection area in the vicinity of FSS earth station

8 References

[1] IST-2003-507581 WINNER D7.8 V1.0 "Performance Assessment of the WINNER System Concept"

[2] IST-20003-507581 WINNER D2.5 V1.0 "Duplex arrangements for future broadband radio interface"

[3] IST-2003-507581 WINNER D7.7 v. 1.0 "Winner System Concept Complexity Estimates"

[4] IST-2003-507581 WINNER D2.10 v1.0 “Final report on identified RI key technologies, system concept, and their assessment”

[5] R03-WP8F-C-1015 " SHARING STUDIES BETWEEN FSS AND IMT-ADVANCED SYSTEMS IN THE 3 400-4 200 AND 4 500-4 800 MHz BANDS"

9 Appendix

9.1 Appendix1

9.1.1 Considerations when assigning powers in the simulation scenario: Mean base station power for a uniform user distribution within the cell

If it is assumed that users are spread uniformly within a cell of radius R, even though the complex power assignment algorithms were not addressed in the simulations, it is still possible to define a metric that accounts for the power emissions over the whole cell and large time periods: i.e. the mean power emitted by the BS.

Mean BS power per user i-th is defined as:

$$\overline{P_{BS\,i}}(R) = \int_0^R P_i(r) \cdot \Pr_r(r) \cdot dr$$

* $P_i(r)$: power emitted to the i-th user, as function of the user distance ‘r’ to BS.

* $\Pr_r(r)$: probability of distance ‘r’, assuming uniformly spread users within cell, it equals to R^{-1}.

$P_i(r)$ must hold the following in order to have a correct reception (noise-limited cell):

$$P_i(r) = S + L_1(r) - (G_T + G_R) + M_F$$

* S : is the sensitivity of receiver.

* G_T , G_T : are respectively the Tx and Rx antenna gains.

* M_F : fading margin.

* $L_1(r)$: function of the path loss $L_0(r)$. $L_0(r)$ depends on distance and channel model.

Besides uplink power control, WINNER technology is supposed to implement also downlink power control, just assigning less power to carriers corresponding to near MS and more power to carriers corresponding to MS far apart. However, due to dynamic range limitation effects of physical devices, both in Tx and Rx, e.g. intermodulation on amplifiers, selectivity of filters, etc. is not possible assigning very disparate power levels to adjacent carriers. A dynamic range between the highest and lowest powers assigned to different MS on adjacent bands must be defined to that end. Regarding the mean BS power metric, was found by simulation -evaluation of the integral K1(R) below- that a dynamic range of about 18 dB was enough as to full benefit from downlink power control. This value is also quite affordable from the technology point of view and therefore doesn’t compromise to any technological option.

Thus $L_1(r)$ will be function of the dynamic range, $L_0(r)$ and the maximum possible attenuation:

$$L_1(r) = \max(L_0(r), L_0(R) - DynamicRange)$$

The sensitivity of the receiver [per Hz] is calculated as -notice than in this simple model guard bands or times and other inefficiencies are not considered-:

$$S = 10\log K \cdot T_0 + F + \frac{S}{N}$$

* $10\log K \cdot T_0$: Noise power density per Hertz: the well-known –174 dBm/ Hz.

* F : Receiver noise figure: assumed 5 dB.

* $\frac{S}{N}$: Assumed equal to 0 dB for the lowest modulation & coding configurations.

$$S = -174 + 5 = -169 \text{ dBm / Hz}$$

Will be assumed same sensitivity at BS and MS, though due to the higher quality components and computational effort available at BS, its sensitivity is slightly lower.

Then,

$$\overline{P_{BS\,i}}(R) = \int_0^R BW_i \cdot \frac{S \cdot M_F}{G_T G_R} \cdot L_1(r) \cdot \Pr_r(r) \cdot dr = BW_i \cdot \frac{S \cdot M_F}{G_T G_R} \cdot \frac{1}{R} \int_0^R L_1(r) \cdot dr$$

* BW_i : bandwith assigned to the i-th user.

* S : sensitivity of the receiver [per Hz].

The integral will be renamed: $K_1(R) = \frac{1}{R} \int_0^R L_1(r) \cdot dr$

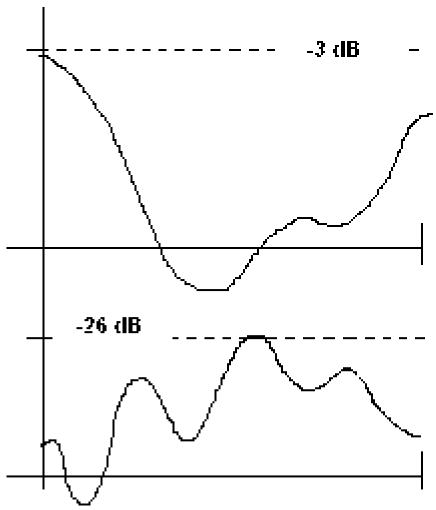
And the total mean BS power will be:

$$\overline{P_{BS}}(R) = \sum_i^N \overline{P_{BS\,i}}(R) = BW \cdot \frac{S \cdot M_F}{G_T G_R} \cdot K_1(R)$$

It is plotted the evaluations of the integral for radius values up to 6 km, and for different channel models. Since the evaluation of the integral aims at determining the mean value emitted by BS, any instantaneous fluctuations on the path loss, not depending on the distance, as e.g. slow fading, have not been considered.

9.1.2 Power control in multi-carrier adaptive systems

An example snapshot of a frequency selective channel is provided below. The x-axis segments represent the whole contiguous bandwidth spanned by the multicarrier system. Curves show the experienced channel over the working bandwidth for two mobile terminals, A and B.



Channels experienced by a MS exhibits strong frequency dependency. Channels experienced by different MS are independent each other, both in overall attenuation (e.g. –3 dB against –26 dB) as well as in their actual shape.

An adaptive system has the following features for dealing with frequency selective channels within a multi-user environment:

– Adaptive resource partitioning.

– Adaptive/ non-adaptive transmission.

Further, takes into consideration following factors when performing resource partitioning:

– Cell throughput maximization.
– Inter-cell interference avoidance.
– Fairness among users.
– Individual user targets.

Application of these schemes and criteria results in a set of non-overlapping sub-bands, pieces of the whole contiguous bandwidth, quantized to the minimum time-frequency unit, i.e. the chunk. Each sub-band is assigned a certain individual central frequency, bandwidth and power.

Even given an individual sub-band serving a user, sub-carrier power allocation within that sub-band is performed by means of e.g. bit-loading or water-filling algorithms, aiming at capacity maximization.

Thus power assigned to a given user remains being transparent to these power allocation schemes, power control still plays a role. Depending on dynamic range of these, basically performed in digital-domain, power allocation algorithms, the only way to stick to link budget requirements is by means of power control. Also the traditional mean to compensate for slow fading is power control.

To emulate these mechanisms, a scenario with the transmitter carrier subdivided into 10 sub-bands has been performed. Each sub-band is been assigned a certain individual central frequency, bandwidth and power so that cumulative powers reach the maximum output power level.

The sum of maximal power assigned to sub-bands cannot exceed the total BS power.

When implementing multi-carrier schemes in WINNER frequency allocation, a reduction of maximum output power is resulted. Multi-carrier attenuation factor depends on cell coverage range and propagation model. Furthermore the decrease on effective base station power due to the use of multi-carrier power allocation must be included, i.e. about 5 dB according to P.452 path loss.

A simplified figure provides an assessment of this attenuation factor for cell range up to 6 km for such distance range.

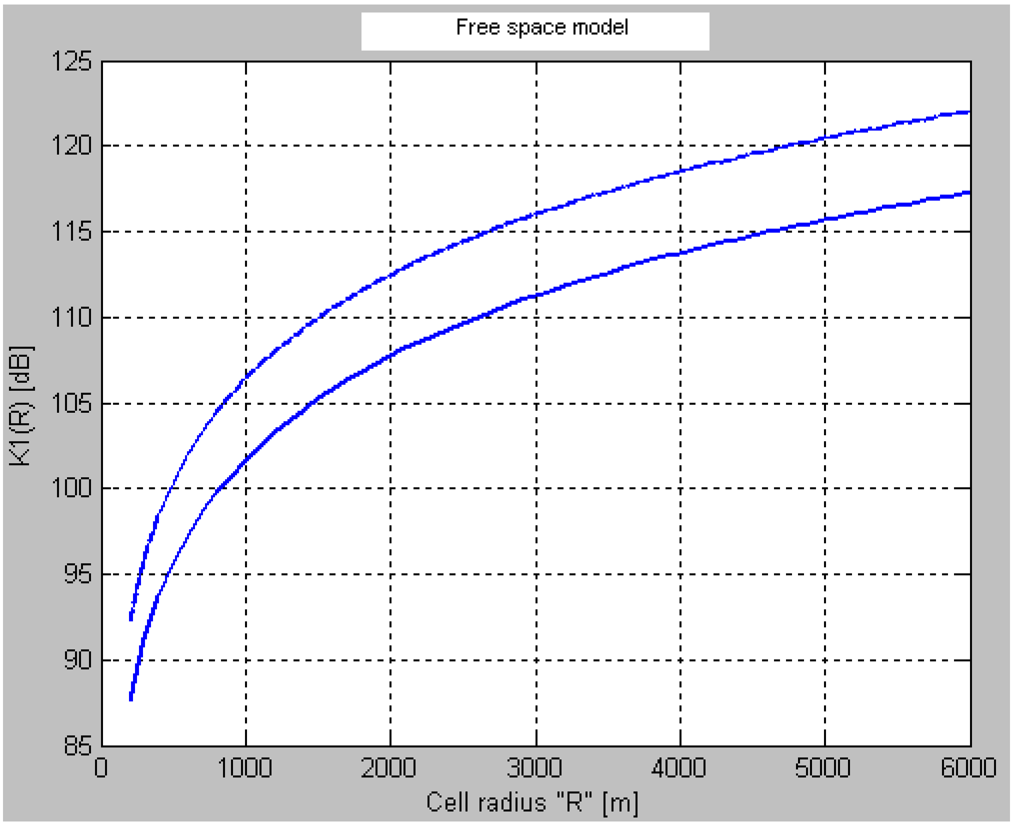


Figure 9-1: Measure of the reduction on necessary base station emitted power for a given cell radius

There are plotted the results for both enabled and disabled power control. The difference between both setups give a measure of the reduction on necessary emitted power at base station for a given cell radius.

9.2 Appendix 2: ITU-R P.452-12 loss

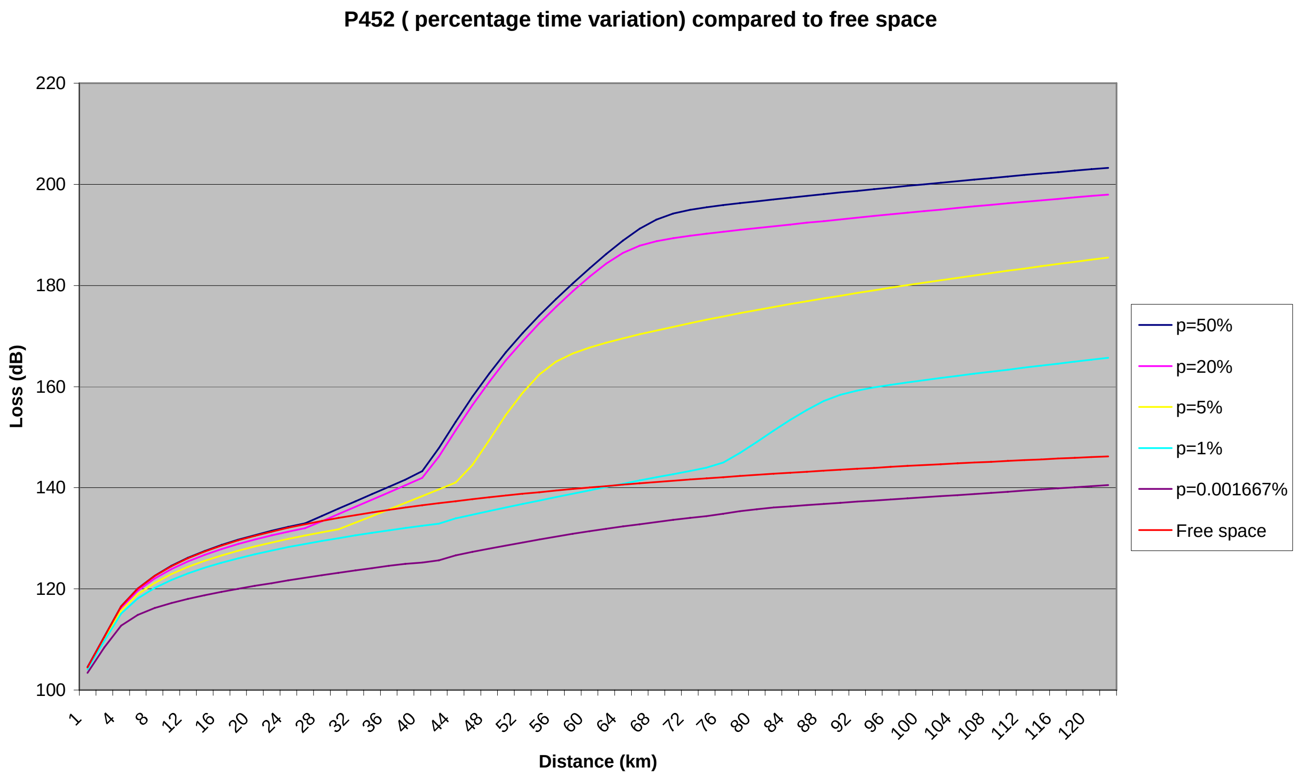


Figure 9-2: Path loss attenuation with respect to percentage time

The above curves are given for information so that losses can be compared according to percentage time variation and referred to free space model losses.

Calculations are based on a flat terrain model and following input parameters:

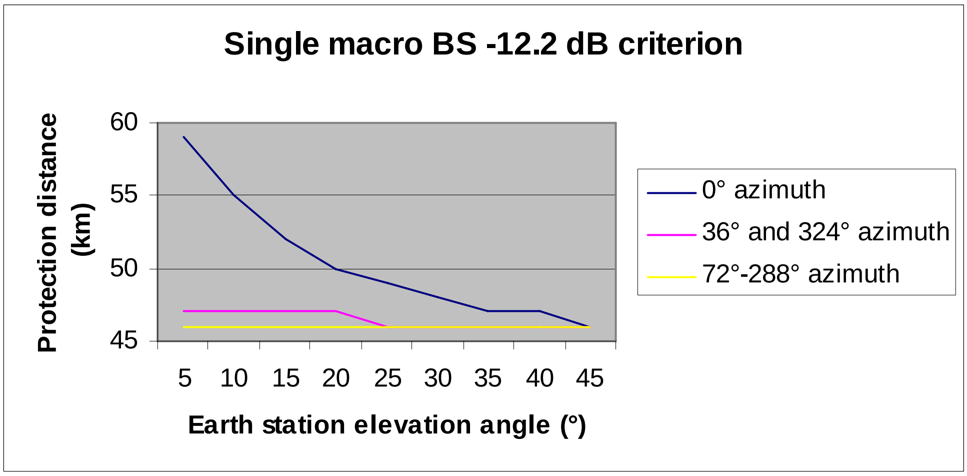
Tx Height (m)	Rx Height (m)	Frequency (GHz)
30	15	4

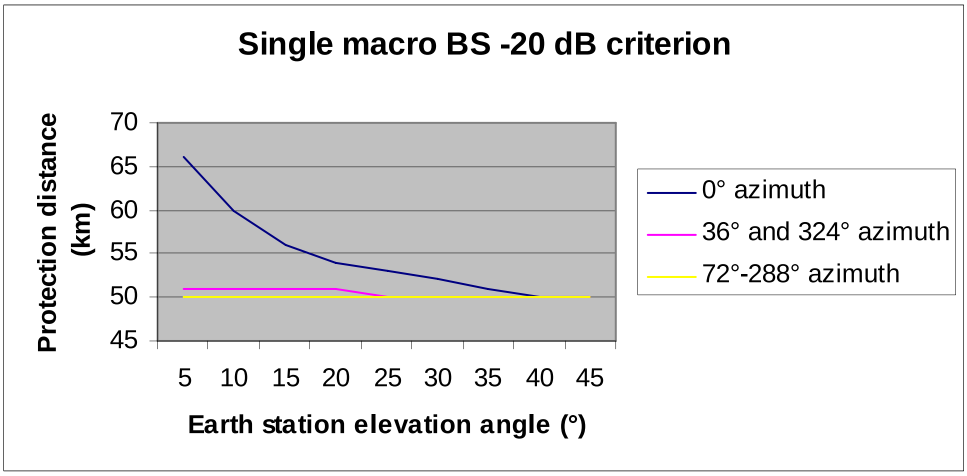
9.3 Appendix 3: Detailed results

9.3.1 Impact of WINNER stations on FSS earth stations

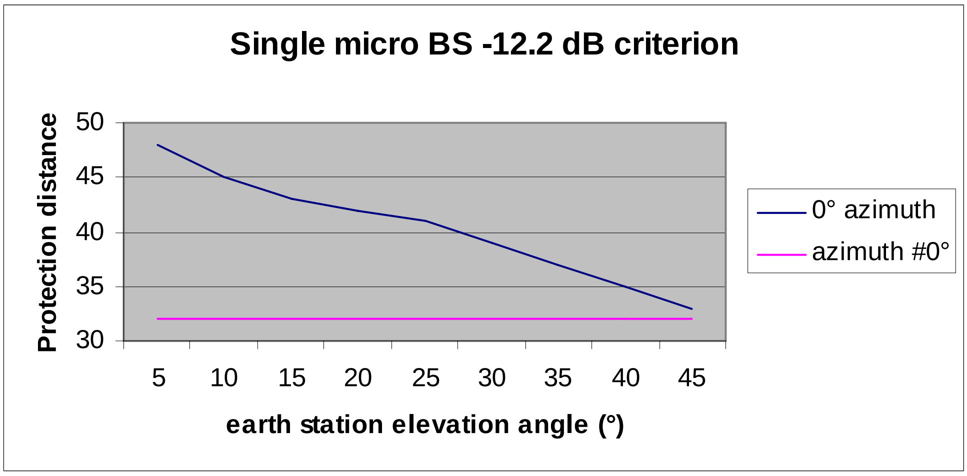
9.3.1.1 Co-channel scenarios

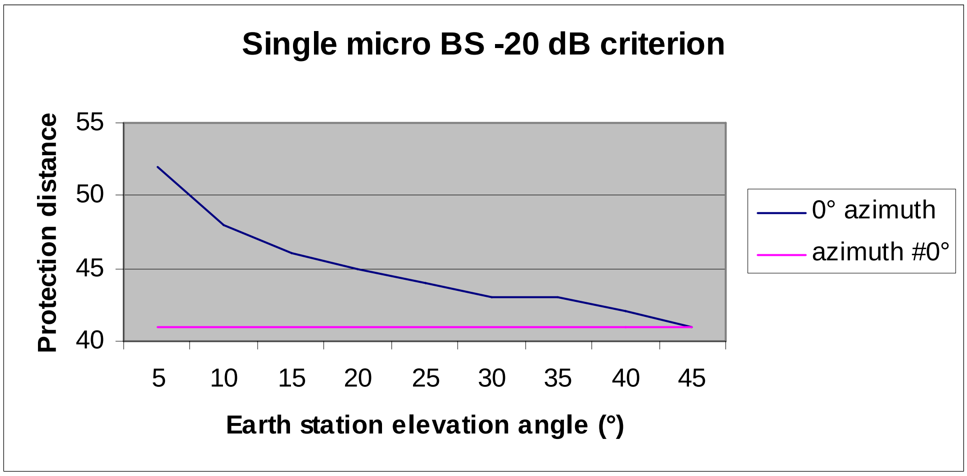
9.3.1.1.1 Single BS





In the case of a single macro WINNER base station impact on FSS earth station, the MCL results show that required protection distances range from 46 km to 59 km to meet –12.2 dB criterion and range from 50 to 66 km to meet –20 dB criterion.


Single micro BS -12.2 dB criterion
Protection distance
50
45
40
35
30
5 10 15 20 25 30 35 40 45
earth station elevation angle (°)
0° azimuth
azimuth #0°

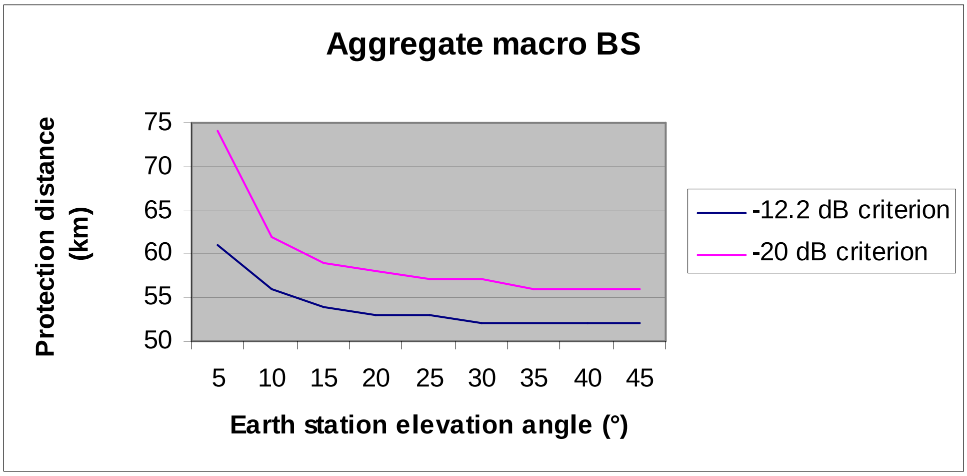

Single micro BS -20 dB criterion
Protection distance
55
50
45
40
5 10 15 20 25 30 35 40 45
Earth station elevation angle (°)
0° azimuth
azimuth #0°

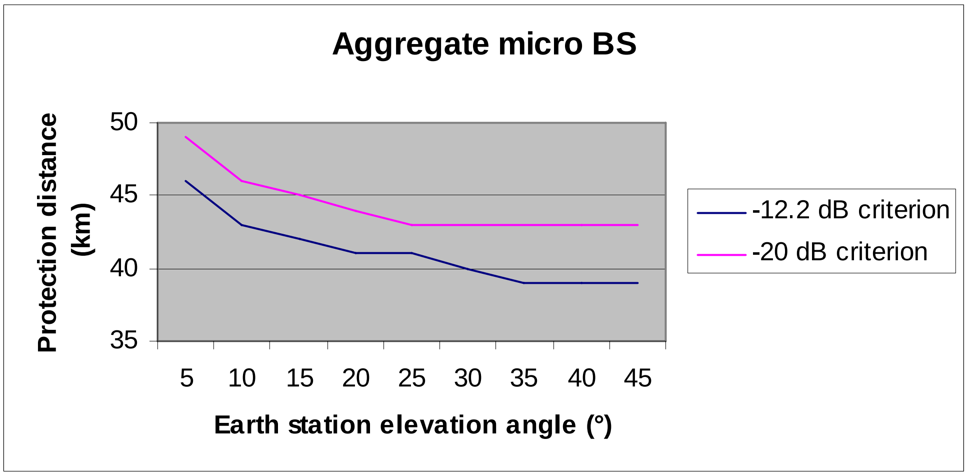
9.3.1.1.2 Aggregate case

9.3.1.1.2.1 WINNER BS

FIGURE 3

Aggregate macro WINNER BS on FSS earth station



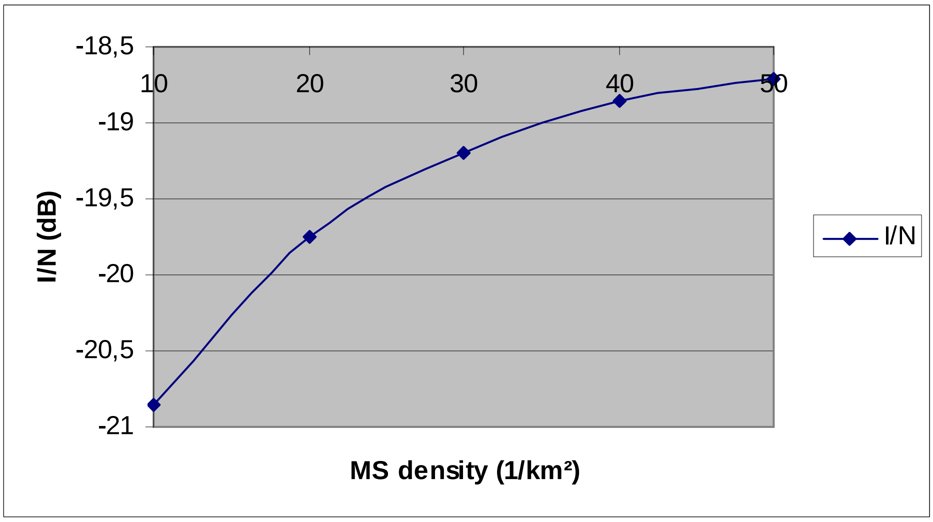


9.3.1.1.2.2 WINNER MS

9.3.1.1.2.2.1 Suburban environment

FIGURE 7

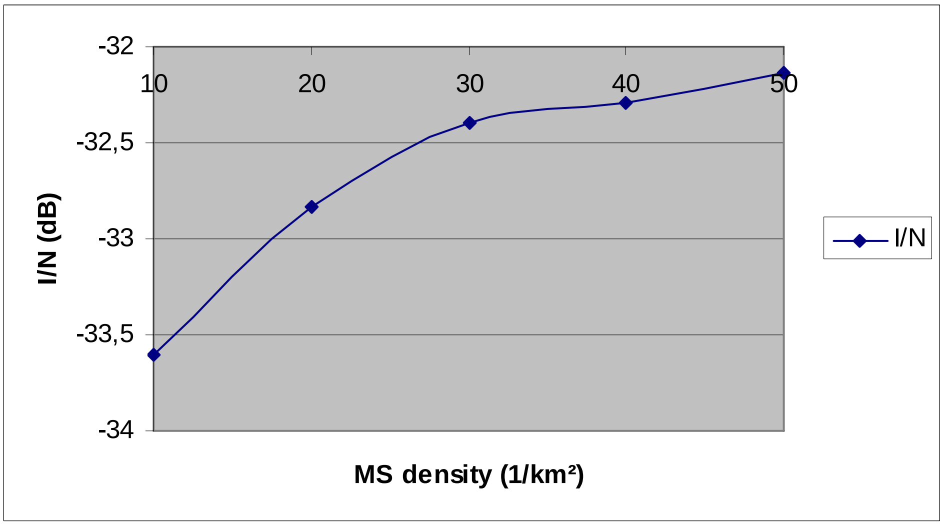
I/N for aggregate MS interferers on FSS earth station (suburban)



9.3.1.1.2.2.2 Urban environment

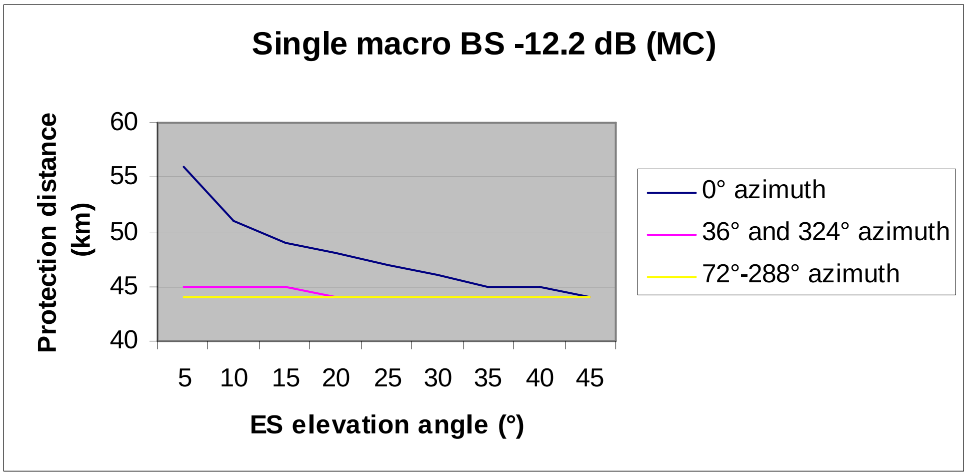
FIGURE 8

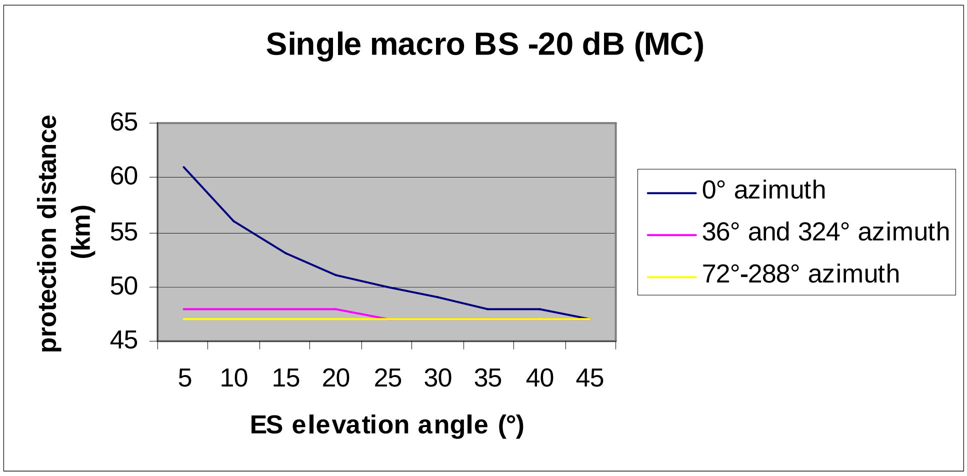
I/N for aggregate MS interferers on FSS earth station (urban)

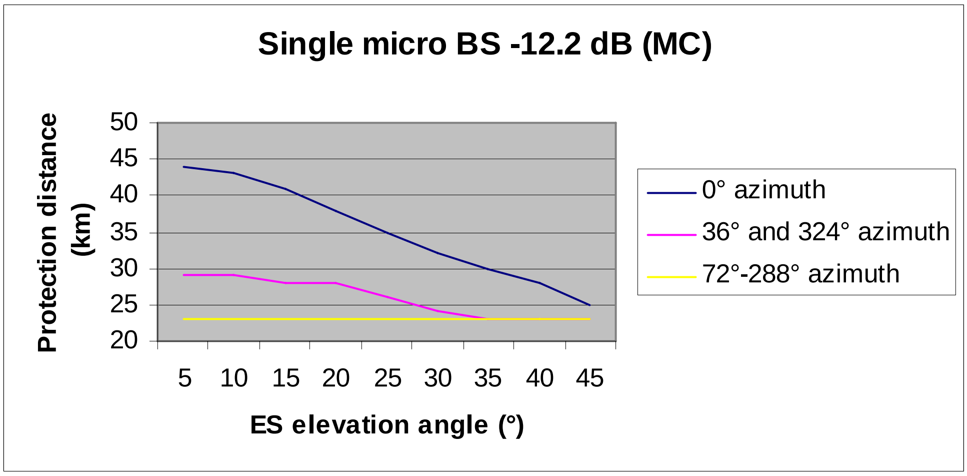


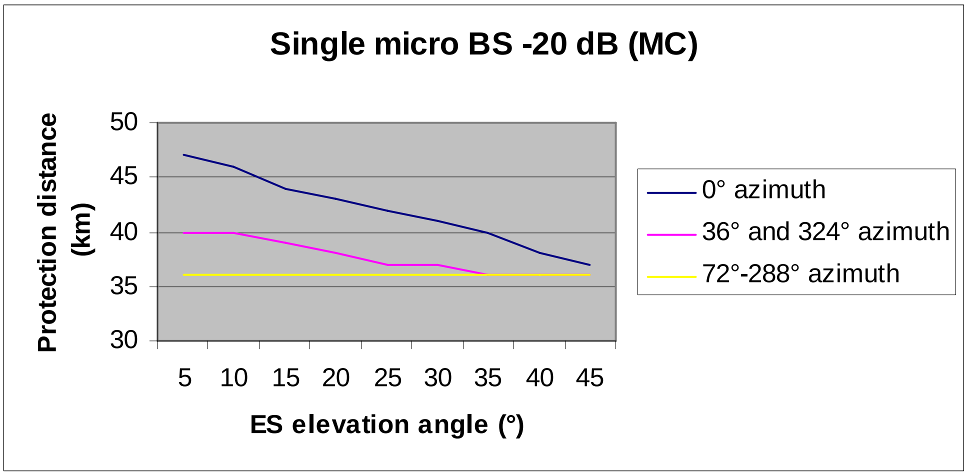
9.3.1.2 Co-channel scenarios if multi-carrier schemes are implemented

9.3.1.2.1 Single BS

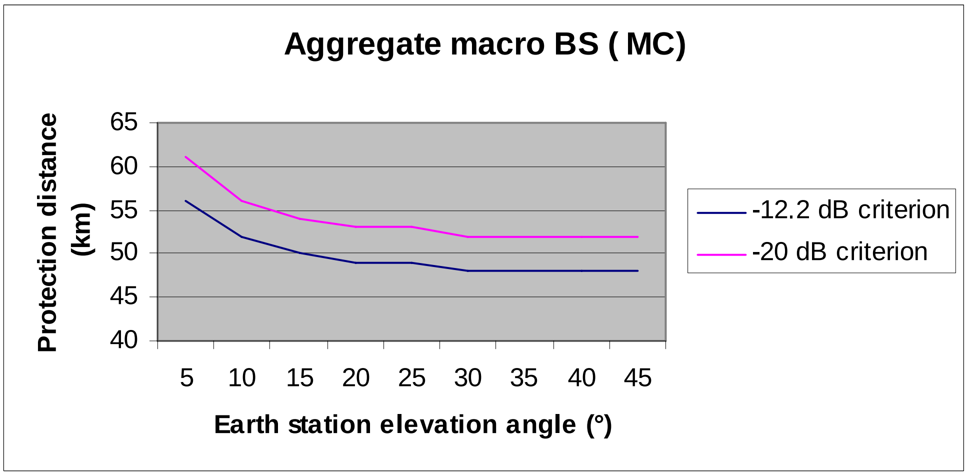


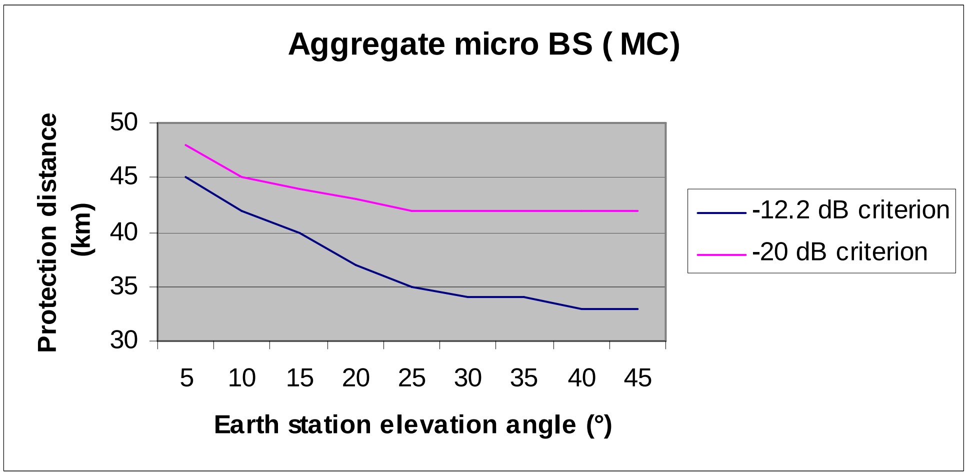






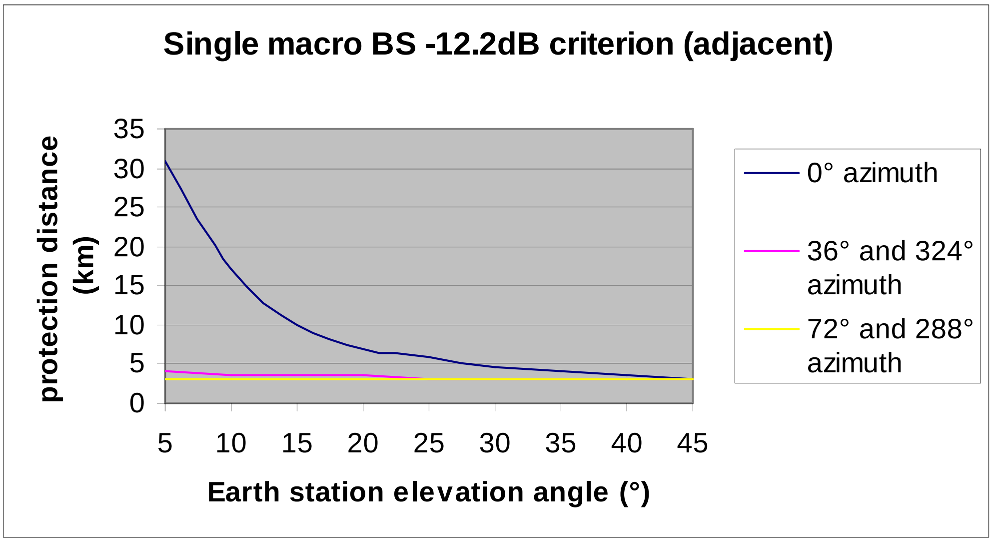
9.3.1.2.2 Aggregate BS

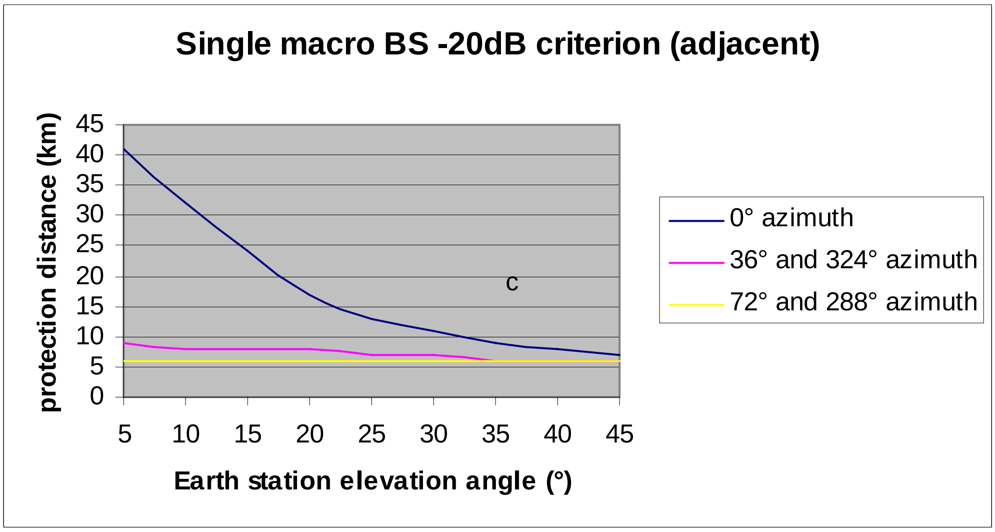


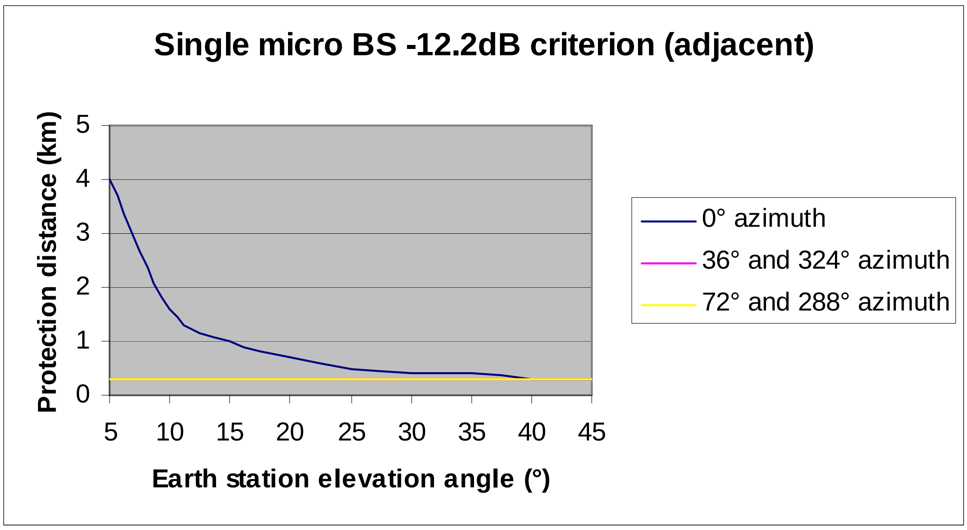


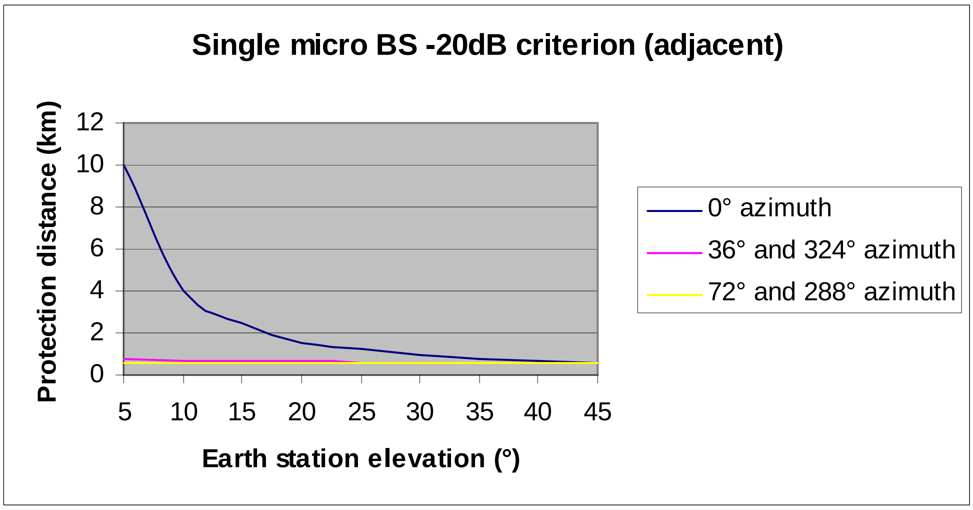
9.3.1.3 Adjacent channel scenarios

9.3.1.3.1 Single BS



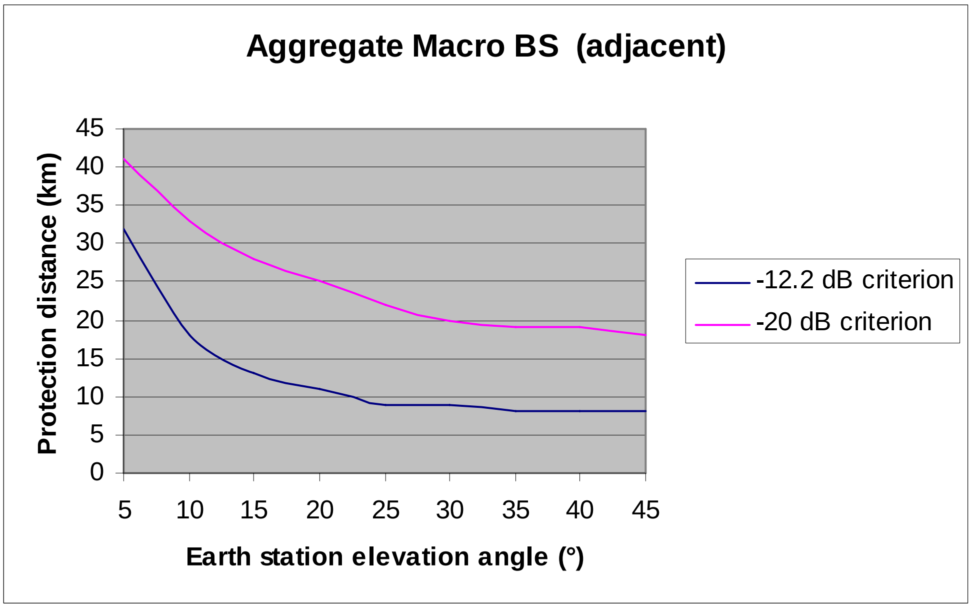


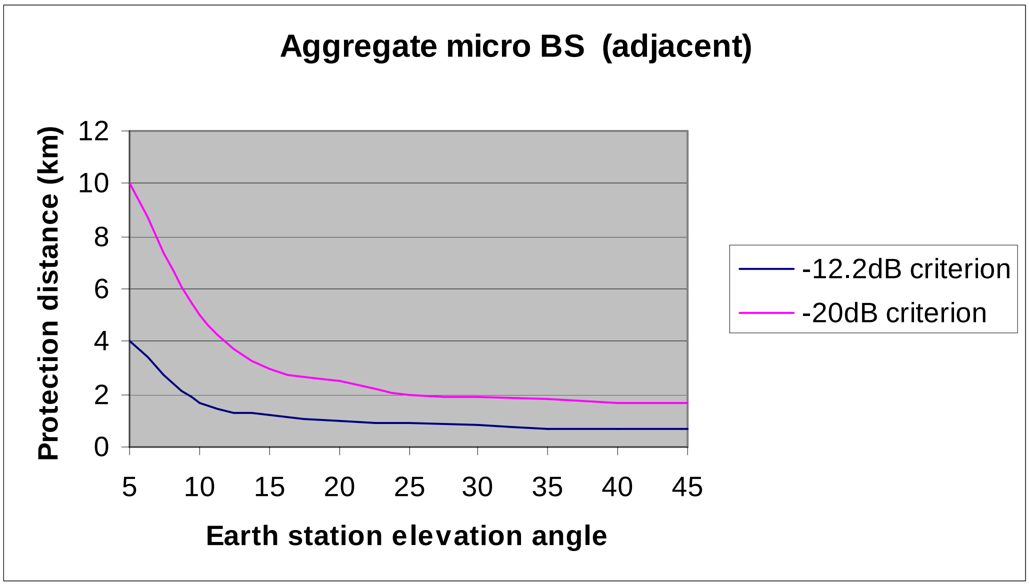




8.3.1.3.2 Aggregate case

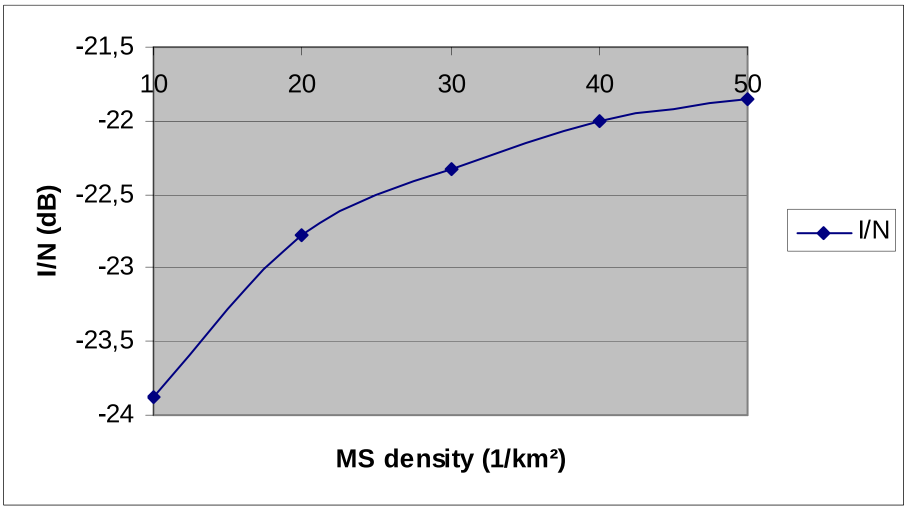
9.3.1.3.1.1 WINNER BS



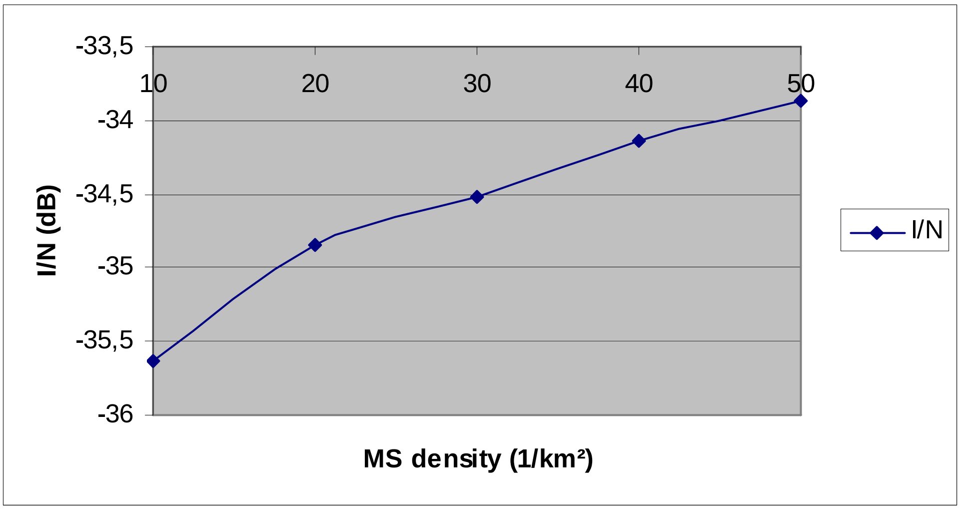


9.3.1.3.1.2 WINNER MS

9.3.1.3.1.2.1 Suburban environment

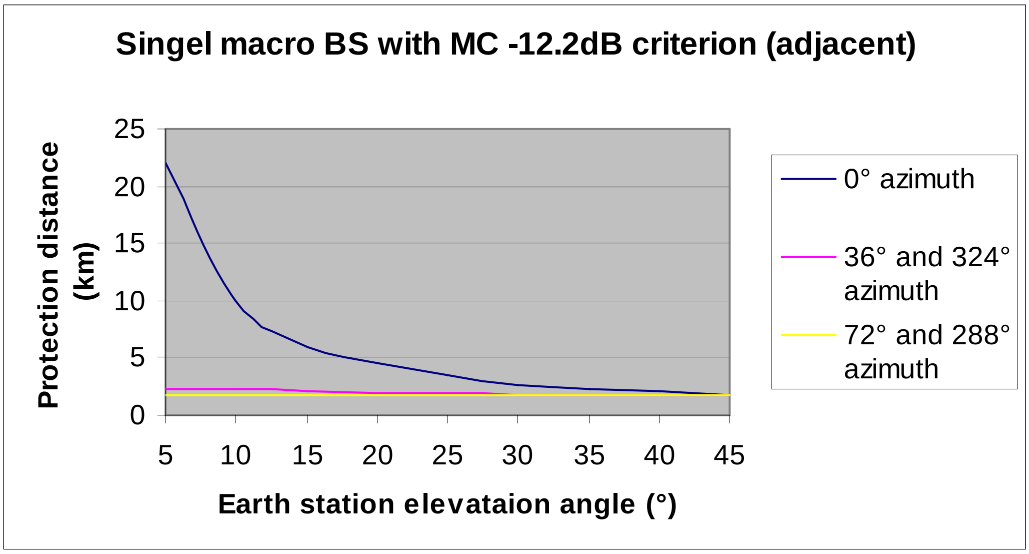


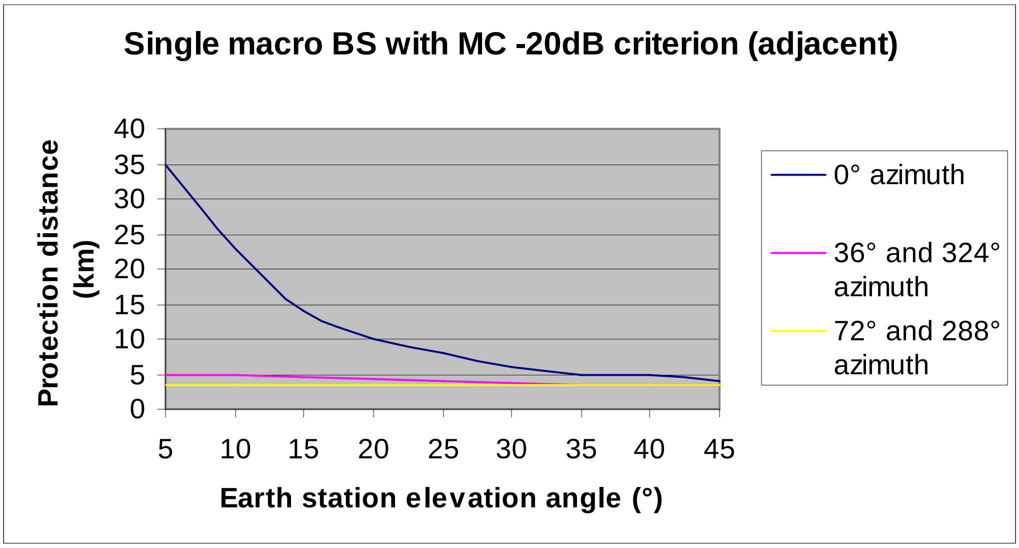
9.3.1.3.1.2.2 Urban environment

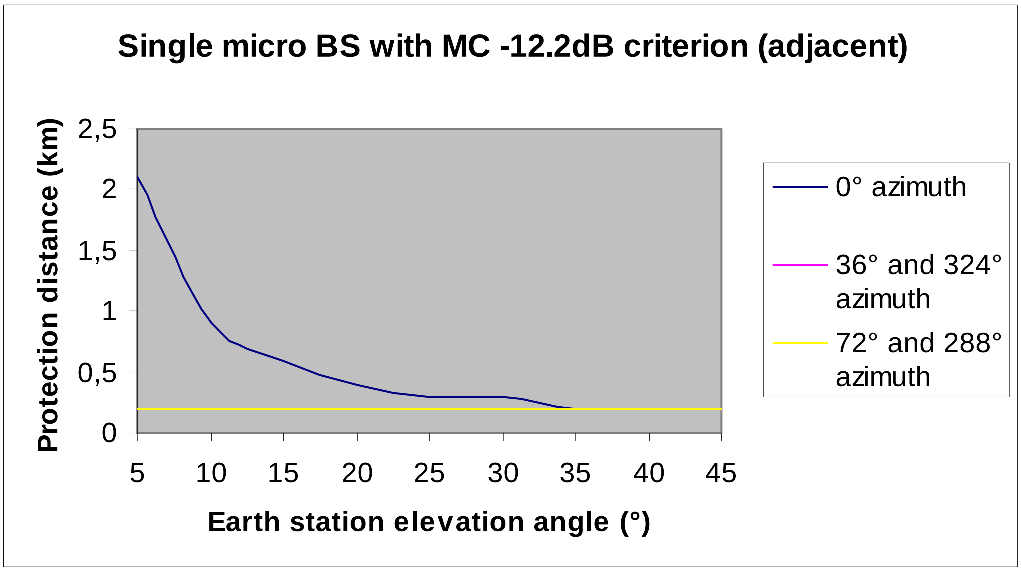


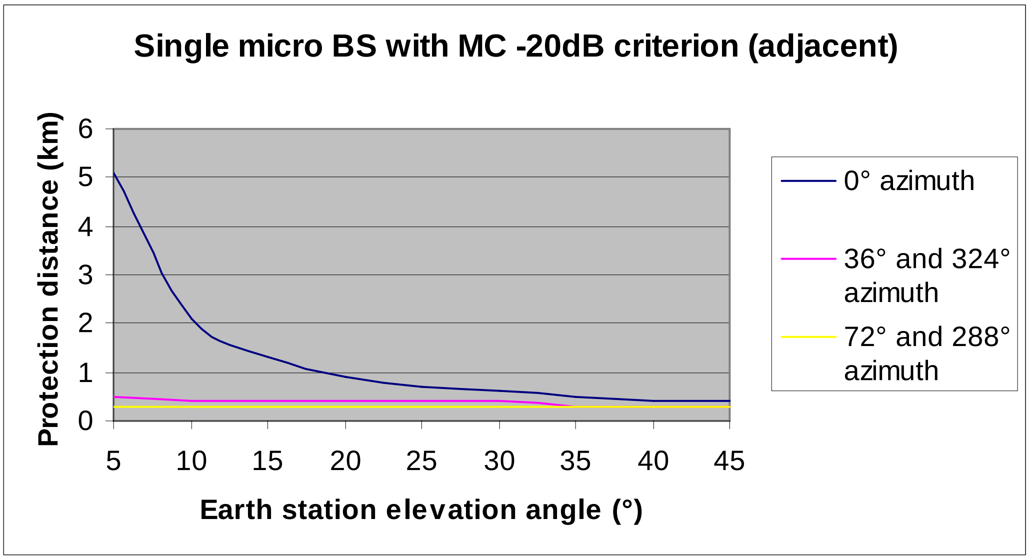
9.3.1.4 Adjacent channel scenarios if multi-carrier schemes are implemented

9.3.1.4.1 Single BS

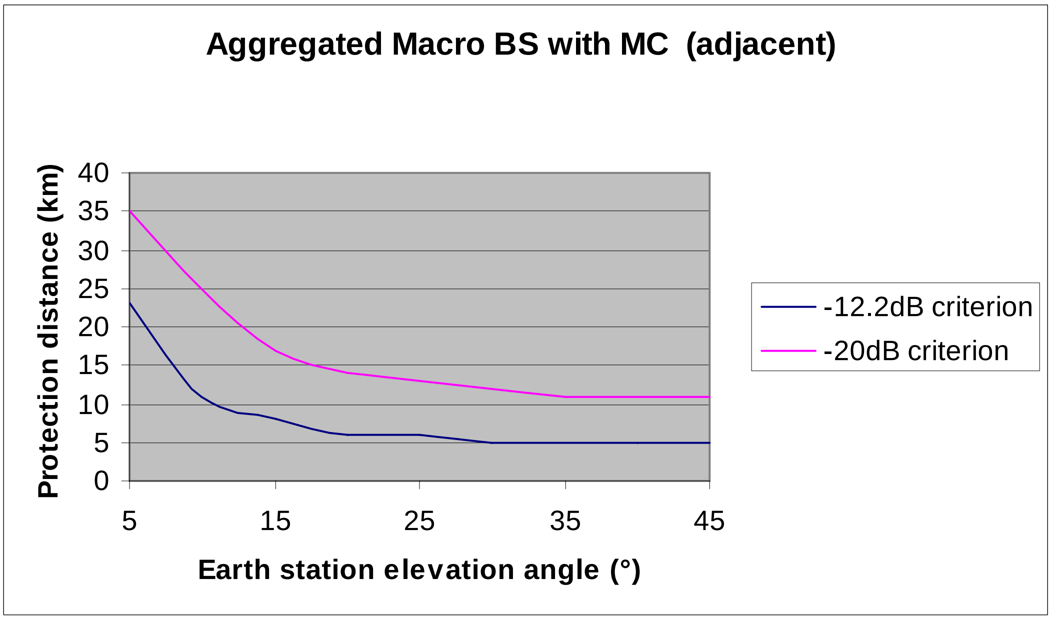


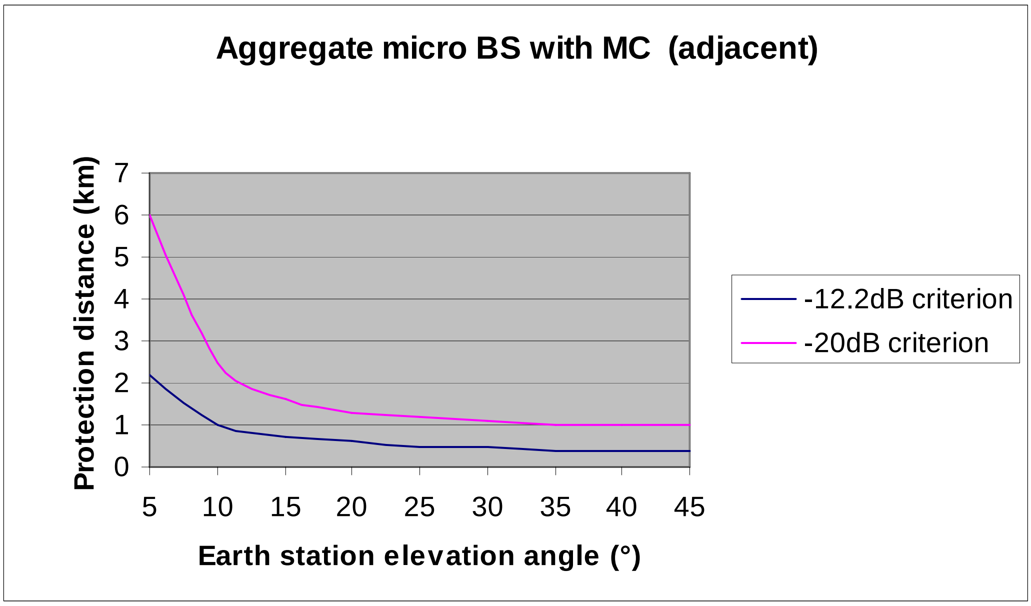






9.3.1.4.2 Aggregate BS





9.3.2 Impact of pfd limits on WINNER systems

In this part of the study, only co-channel scenarios have been considered.

9.3.2.1 Impact of pfd limits on WINNER BS

Therefore, Recommendation ITU R F.1336-1 is always used: the k parameter is set at 0 as recommended in section 2.1.2 of Recommendation ITU R F.1336-1.

9.3.2.1.1 Single GSO

9.3.2.1.1.1 Suburban macro cell environment

Table 9-1: I/N for a single GSO satellite on WINNER BS with k=0 (suburban)

Location	Helsinki			Paris			Malaga			Abu Dhabi		
Orbital location of GSO satellite (°)	I/N (dB)	Vision angle (°)	BS antenna gain (dB)	I/N (dB)	Vision angle (°)	BS antenna gain (dB)	I/N (dB)	Vision angle (°)	BS antenna gain (dB)	I/N (dB)	Vision angle (°)	BS antenna gain (dB)
0	-32.94	21.9	-6.5	-35.43	34.4	-9.2	-37.23	47.8	-11.3	-38.65	61.6	-12.9
10	-32.8	21.4	-6.3	-35.29	33.6	-9.1	-37.08	46.5	-11.1	-38.45	59.5	-12.6
20	-32.39	19.8	-5.9	-34.88	31.2	-8.6	-36.63	42.8	-10.6	-37.89	53.8	-12
30	-31.66	17.3	-5.1	-34.17	27.4	-7.8	-35.87	38.3	-9.7	-37.04	46.2	-11.1
40	-30.52	14.1	-3.9	-33.1	22.6	-6.7	-34.79	30.6	-8.5	-35.89	37.4	-9.8
50	-28.81	10.2	-2.1	-31.54	17	-5	-33.26	23.2	-6.8	-34.34	28.3	-8
60	-26.03	5.8	0.8	-29.15	10.9	-2.5	-31.01	15.4	-4.4	-32.14	18.9	-5.6
70	-20.25	1.2	6.7	-24.84	4.5	2	-27.18	7.4	-0.4	-28.52	9.6	-1.8
80				-21,86	2,02	5,1	-19,01	0,61	7,92	-17,79	0,45	9,11
-10	-32.8	21.4	-6.3	-35.29	33.6	-9.1	-37.08	46.5	-11.1	-38.45	59.5	-12.6
-20	-32.39	19.8	-5.9	-34.88	31.2	-8.6	-36.63	42.8	-10.6	-37.89	53.8	-12
-30	-31.66	17.3	-5.1	-34.17	27.4	-7.8	-35.87	38.3	-9.7	-37.04	46.2	-11.1
-40	-30.52	14.1	-3.9	-33.1	22.6	-6.7	-34.79	30.6	-8.5	-35.89	37.4	-9.8
-50	-28.81	10.2	-2.1	-31.54	17	-5	-33.26	23.2	-6.8	-34.34	28.3	-8
-60	-26.03	5.8	0.8	-29.15	10.9	-2.5	-31.01	15.4	-4.4	-32.14	18.9	-5.6
-70	-20.25	1.2	6.7	-24.84	4.5	2	-37.23	7.4	-0.4	-28.52	9.6	-1.8
-80										-17,79	0,45	9,11

9.3.2.1.1.2 Urban micro cell environment

Table 9-2: I/N for a single GSO satellite on WINNER BS with k=0 (urban)

Location	Helsinki			Paris			Malaga			Abu Dhabi		
Orbital location of GSO satellite (°)	I/N (dB)	Vision angle (°)	BS antenna gain (dB)	I/N (dB)	Vision angle (°)	BS antenna gain (dB)	I/N (dB)	Vision angle (°)	BS antenna gain (dB)	I/N (dB)	Vision angle (°)	BS antenna gain (dB)
0	**-18,25**	21,9	4,13	**-19,31**	34,43	2,86	**-21,05**	47,8	0,89	**-23,59**	61,62	-1,82
10	**-18,26**	21,37	4,17	**-19,22**	33,59	2,97	**-20,85**	46,99	1,11	**-23,15**	59,47	-1,36
20	**-18,18**	19,81	4,29	**-18,98**	31,17	3,25	**-20,32**	42,8	1,7	**-22,07**	53,84	-0,21
30	**-18,07**	17,3	4,45	**-18,66**	27,39	3,65	**-19,63**	37,32	2,49	**-20,8**	46,15	1,16
40	**-17,96**	14,07	4,64	**-18,33**	22,56	4,08	**-18,93**	30,63	3,31	**-19,64**	37,43	2,48
50	**-17,87**	10,18	4,81	**-18,05**	16,97	4,48	**-18,37**	23,21	4,03	**-18,73**	28,25	3,56
60	**-17,85**	5,83	4,93	**-17,88**	10,88	4,78	**-18**	15,39	4,57	**-18,14**	18,93	4,35
70	**-17,9**	1,17	4,99	**-17,85**	4,49	4,96	**-17,85**	7,4	4,9	**-17,87**	9,64	4,83
80				**-17,97**	2,02	4,99	**-17,93**	0,6	4,99	**-17,9**	0,45	4,99
-10	**-18,26**	21,37	4,17	**-19,22**	33,59	2,97	**-20,85**	46,99	1,11	**-23,15**	59,47	-1,36
-20	**-18,18**	19,81	4,29	**-18,98**	31,17	3,25	**-20,32**	42,8	1,7	**-22,07**	53,84	-0,21
-30	**-18,07**	17,3	4,45	**-18,66**	27,39	3,65	**-19,63**	37,32	2,49	**-20,8**	46,15	1,16
-40	**-17,96**	14,07	4,64	**-18,33**	22,56	4,08	**-18,93**	30,63	3,31	**-19,64**	37,43	2,48
-50	**-17,87**	10,18	4,81	**-18,05**	16,97	4,48	**-18,37**	23,21	4,03	**-18,73**	28,25	3,56
-60	**-17,85**	5,83	4,93	**-17,88**	10,88	4,78	**-18**	15,39	4,57	**-18,14**	18,93	4,35
-70	**-17,9**	1,17	4,99	**-17,85**	4,49	4,96	**-17,85**	7,4	4,9	**-17,87**	9,64	4,83
-80										**-17,9**	0,45	4,99

8.3.2.1.2 Aggregate GSO

Location of WINNER BS	Helsinki	Paris	Malaga	Abu Dhabi
Number of GSO to be considered	15	16	16	17

9.3.2.1.1.3 Suburban macro cell environment

Table 9-3: I/N for aggregate 10° equi-spacing GSO satellites on WINNER BS (suburban)

Location	Helsinki	Paris	Malaga	Abu Dhabi
Isat/Nth (dB)	–14.90110232	-16,94930919	-17,12424572	-14,01247837

9.3.2.1.1.4 Urban micro cell environment

Table 9-4: I/N for aggregate 10° equi-spacing GSO satellites on WINNER BS (urban)

Location	Helsinki	Paris	Malaga	Abu Dhabi

Isat/Nth (dB)	–6,264987091	-6,377995323	-6,9903936178	-7,271772277

9.3.2.2 Impact of pfd limits on WINNER MS

9.3.2.2.1 Single GSO

9.3.2.2.1.1 Suburban macro cell environment

Table 9-5: I/N for a single GSO satellite on WINNER MS (suburban)

Location	Helsinki	Paris	Malaga	Abu Dhabi
orbital location of GSO satellite (°)				
0	-26.44	-26.19	-25.96	-25.78
10	-26.45	-26.21	-25.98	-25.8
20	-26.49	-26.25	-26.04	-25.87
30	-26.54	-26.33	-26.14	-25.98
40	-26.61	-26.43	-26.26	-26.13
50	-26.7	-26.55	-26.41	-26.31
60	-26.8	-26.69	-26.58	-26.51
70	-26.91	-26.83	-26.77	-26.71
70				
-10	-26.45	-26.21	-25.98	-25.8
-20	-26.49	-26.25	-26.04	-25.87
-30	-26.54	-26.33	-26.14	-25.98
-40	-26.61	-26.43	-26.26	-26.13
-50	-26.7	-26.55	-26.41	-26.31
-60	-26.8	-26.69	-26.58	-26.51
-70	-26.91	-26.83	-26.77	-26.71
-80				

9.3.2.2.1.2 Urban micro cell environment

Table 14: I/N for a single GSO satellite on WINNER MS (urban)

Location	Helsinki	Paris	Malaga	Abu Dhabi
orbital location of GSO satellite (°)				
0	-26.43	-26.18	-25.95	-25.77
10	-26.44	-26.19	-25.97	-25.79
20	-26.48	-26.24	-26.03	-25.86
30	-26.53	-26.32	-26.13	-25.97
40	-26.61	-26.42	-26.25	-26.12
50	-26.69	-26.54	-26.41	-26.3
60	-26.79	-26.68	-26.57	-26.5
70	-26.89	-26.82	-26.75	-26.71
-10	-26.44	-26.19	-25.97	-25.79
-20	-26.48	-26.24	-26.03	-25.86
-30	-26.53	-26.32	-26.13	-25.97
-40	-26.61	-26.42	-26.25	-26.12
-50	-26.69	-26.54	-26.41	-26.3
-60	-26.79	-26.68	-26.57	-26.5
-70	-26.89	-26.82	-26.75	-26.71

9.3.2.2.2 Aggregate GSO

9.3.2.2.2.1 Suburban macro cell environment

Table 15: I/N for aggregate 10° equi-spacing GSO satellites on WINNER MS (suburban)

Location	Helsinki	Paris	Malaga	Abu Dhabi
Isat/Nth (dBm)	-14.57977116	-14.39734506	-14.22936611	-14.09644838

9.3.2.2.2.2 Urban micro cell environment

Table 16: I/N for aggregate 10° equi-spacing GSO satellites on WINNER MS (urban)

Location	Helsinki	Paris	Malaga	Abu Dhabi
Isat/Nth (dBm)	-14.56985202	-14.3860262	-14.21945973	-14.08754291