Radiocommunication Study Groups

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Annex 16 to Joint Task Group 4-5-6-7 Chairman's Report

DRAFT NEW REPORT ITU-R F.[IMT-FS 3 400-4 200 MHz SHARING]

Sharing and compatibility between international mobile telecommunication systems and fixed service systems in the 3 400-4 200 MHz frequency range

Introduction

This study examines the compatibility of proposed international mobile telecommunication (IMT) systems and fixed service (FS) systems operating in the 3 400-4 200 MHz frequency range.

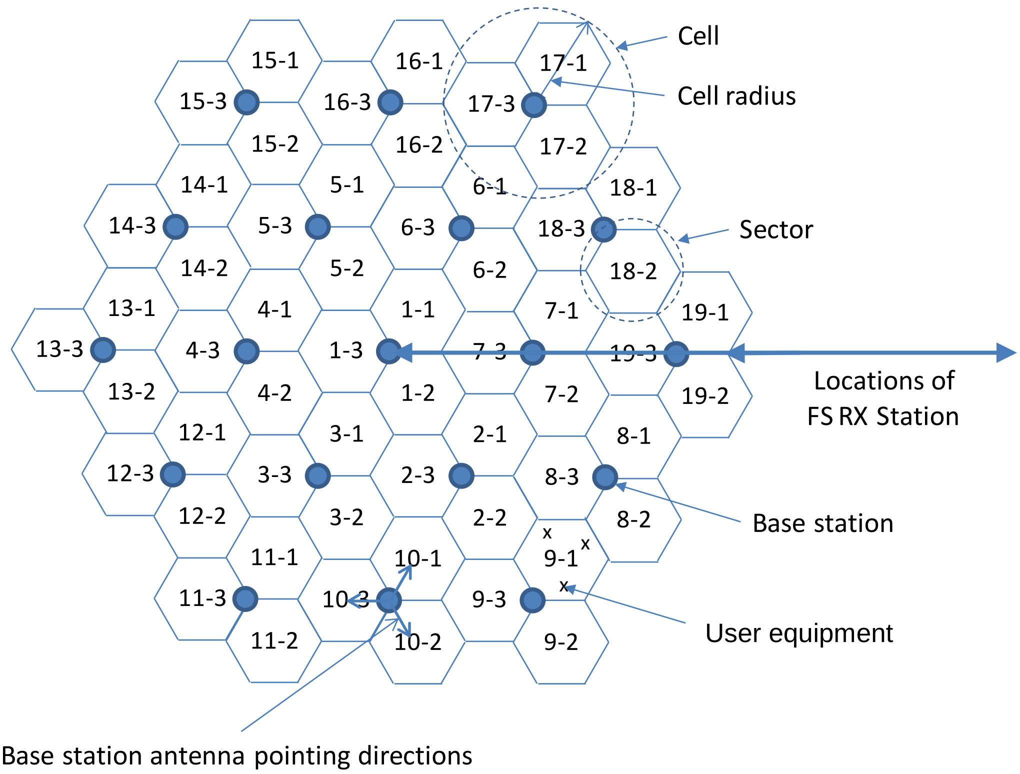
Methodology

This analysis examines the required frequency rejection as a function of separation distance for compatible operation of IMT and FS systems. Two interference scenarios are considered: IMT base station into FS receive station and IMT user equipment (UE) into FS receive station. Four deployment environments for IMT systems are considered: macro suburban, macro urban, small cell outdoor and small cell indoor. Propagation loss is calculated using Recommendation ITU-R P.452-14.

The IMT network layout is illustrated in Figure 1. Nineteen cells are arranged in a hexagonal pattern with each cell consisting of three sectors. An IMT base station is located at the centre of each cell and operates with a 3-sector antenna. Each antenna serves a single sector covering 120 degrees of the cell. For the small cell deployment scenarios, the base station antenna is omni-directional in azimuth and the cell contains only one sector.

FIGURE 1

IMT Network Layout



The interference calculation methodology used depends on the interference scenario considered:

IMT base station into FS receive station

Both co-channel and adjacent channel scenarios are addressed.

For the co-channel scenario, the interference from a single IMT base station or UE pointing in azimuth toward the FS receive station is computed over a range of azimuths and distances. The result is presented as a plot of the required separation distance around the FS receive station.

For the adjacent channel scenario, the FS receive station is positioned adjacent to the IMT network base stations. The aggregate interference into the FS station is computed assuming varying separation distances. At each distance, the required rejection is determined based on a specified protection requirement. The result is presented as a plot of the required rejection as a function of separation distance. The required frequency separation between the two systems is then determined based on the out-of-band emission characteristics of the IMT base station signal and the adjacent channel selectivity of the FS receiver.

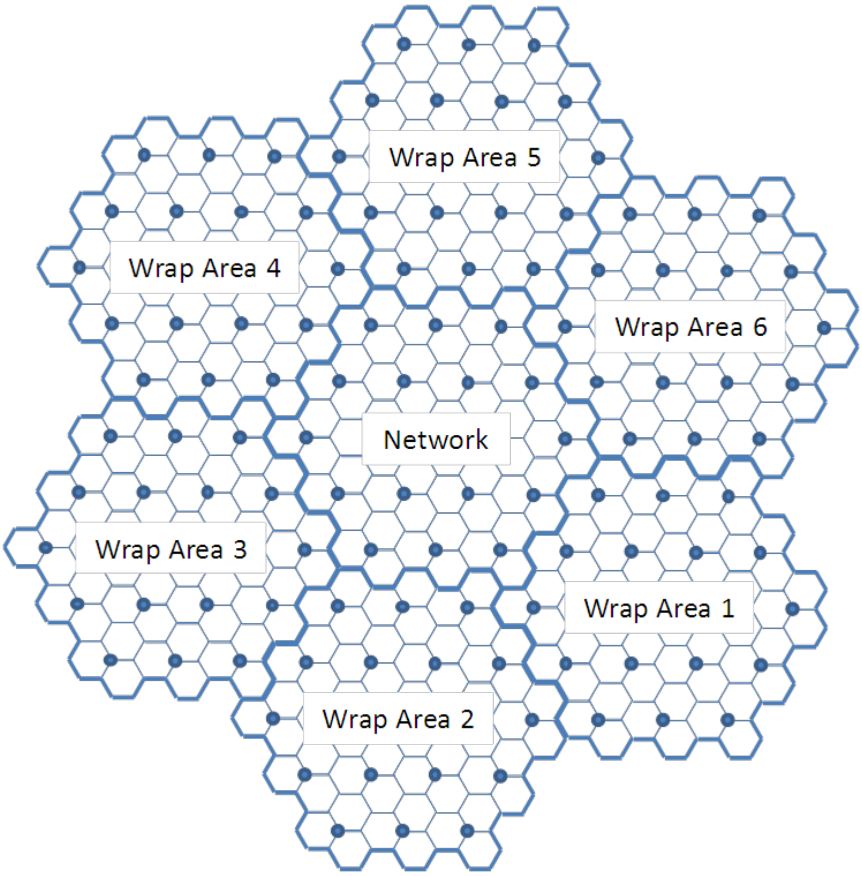
IMT UE into FS Receive Station

Aggregate interference from IMT UE is modelled based on the Monte Carlo methodology to model IMT networks. The methodology consists of 1) randomly positioning IMT UE throughout the IMT network area, 2) randomly assigning these UE to an IMT base station based on the propagation loss and a specified “handover margin”, 3) randomly locating the UE either indoors or outdoors based on a specified percentage of indoor devices, and 4) applying a power control algorithm to the UE based on their path loss distribution. The calculations are repeated for a number of “snapshots”, from which statistics are extracted. Elements from the ITU-R methodology pertinent to this analysis are presented below:

The network region relevant for simulations is the cluster of 19 cells illustrated in Figure 1. Additional clusters of 19 cells are repeated around this central cluster based on a “wrap-around” technique employed to avoid the network deployment edge effects as shown in Figure 2.

FIGURE 2

IMT Network Layout with “Wrap-around” Clusters



The simulation of interference on the IMT uplink is structured as follows:

For i=1:# of snapshots

1. Distribute sufficiently many UE randomly throughout the system area such that to each cell within the HO margin of 3 dB the same number K_{UL} of users is allocated as active UE.
   – calculate the pathloss from each UE to all cells and find the smallest pathloss;
   – link the UE randomly to a cell to which the pathloss is within the smallest pathloss plus the HO margin of 3 dB;
   – select K_{UL} UE randomly from all the UE linked to one cell as active UE. These K_{UL} active UE will be scheduled during this snapshot.
2. Perform UL power control
   – Set UE transmit power to $P_t = P_{max} \times \min\left\{1, \max\left[R_{min}, \left(\frac{PL}{PL_{x-ile}}\right)^{\gamma}\right]\right\}$

where Pt is the transmit power of the UE, P_{max} is the maximum transmit power, R_{min} is the ratio of UE minimum and maximum transmit powers P_{min}/P_{max} and determines the minimum power reduction ratio to prevent UE with good channel conditions to transmit at very low power level. PL is the path-loss for the UE from its serving base station and $PL_{x\text{-}ile}$ is the x-percentile path-loss (plus shadowing) value. With this power control scheme, the 1-x percent of UE that have a path-loss larger than $PL_{x\text{-}ile}$ will transmit at P_{max}. Finally, 0<γ<=1 is the balancing factor for UE with bad channels and UE with good channels.

The analysis assumes that there is a sufficient number of IMT UE in each sector to fully occupy the bandwidth of the FS receive station receiver. The number of "snapshots" used for the Monte Carlo simulation is set to 50.

Again, both co-channel and adjacent channel scenarios are addressed.

Interference levels are calculated as follows:

$$I_0 = PD_{tx} - FL_{tx} - HL_{tx} + G_{tx}(\theta_{tx}) - BL_{tx} - PL - BL_{rx} + G_{rx}(\theta_{rx}) - FL_{rx} - HL_{rx} - PD$$

where:

I_0 = Interference power density, dBW/Hz

PD_{tx} = Transmit station signal power density, dBW/Hz

FL_{tx} = Transmit station feeder loss, dB

HL_{tx} = Transmit station head loss (applicable only to UE), dB

$G_{tx}(\theta_{tx})$ = Transmit station antenna gain in direction of receive station, dBi

BL_{tx} = Building penetration loss (applicable only to indoor transmit stations), dB

PL = Propagation loss, dB

BL_{rx} = Building penetration loss (applicable only to indoor receive stations), dB

$G_{rx}(\theta_{rx})$ = Receive station antenna gain in direction of transmit station, dBi

FL_{rx} = Receive station feeder loss, dB

HL_{rx} = Receive station head loss (applicable only to UE), dB

PD = Polarization discrimination, dB

The required rejection is determined from the interference level as follows:

$$I / N = I_0 - N_0$$

$$R = I / N - I / N_{reqt}$$

where:

N_0 = Receive station noise power density, dBW/Hz

R = Rejection needed to meet protection requirement, dB

I/N_{reqt} = I/N protection requirement, dB

System characteristics

The following tables summarize the IMT and FS characteristics considered for this analysis (see Report ITU-R M.2292). FS system characteristics are provided in Recommendations ITU-R F.758 and ITU-R F.1777. Note that the FS reference material does not address adjacent channel selectivity, and values similar to those for the IMT base station are assumed for this analysis.

TABLE 1

IMT base station characteristics

Parameter	Macro Suburban	Macro Urban	Small Cell Outdoor	Small Cell Indoor
Deployment				
Number of cells	19	19	19	19
Number of sectors per cell	3	3	1	1
Cell radius	0.6 km	0.3 km	0.3 km	0.3 km
Percent indoor	0%	0%	0%	100%
Base Station				
Antenna				
Height	25 m	20 m	6 m	3 m
Frequency range	3400 - 4200 MHz	3400 - 4200 MHz	3400 - 4200 MHz	3400 - 4200 MHz
Peak gain	18 dBi	18 dBi	5 dBi	0 dBi
Gain pattern	F.1336 Annex 10	F.1336 Annex 10	F.1336	F.1336
ka	0.7	0.7	n/a	n/a
kp	0.7	0.7	n/a	n/a
kh	0.7	0.7	n/a	n/a
kv	0.3	0.3	n/a	n/a
k	n/a	n/a	0.7	0.7
Horizontal beamwidth	65 degrees	65 degrees	n/a	n/a
Downtilt	-6 degrees	-10 degrees	0 degrees	0 degrees
Transmitter				
Power	16 dBW	16 dBW	-6 dBW	-6 dBW
Activity factor	3 dB	3 dB	3 dB	3 dB
Signal bandwidth	10.0 MHz	10.0 MHz	10.0 MHz	10.0 MHz
Channel spacing	10.0 MHz	10.0 MHz	10.0 MHz	10.0 MHz
Feeder loss	3 dB	3 dB	3 dB	3 dB
ACLR				
1st adjacent	45 dB	45 dB	45 dB	45 dB
2nd adjacent	45 dB	45 dB	45 dB	45 dB
Spurious	54 dB	54 dB	54 dB	54 dB

Note: In Table 1 above “F.1336 Annex 10” should read “F.1336 *recommends* 3.1”

TABLE 2

IMT UE characteristics

Parameter	Macro Suburban	Macro Urban	Small Cell Outdoor	Small Cell Indoor
Deployment				
Percent indoor	70%	70%	70%	100%
User equipment				
Antenna				
Height	1.5 m	1.5 m	1.5 m	1.5 m
Frequency range	3 400-4 200 MHz	3 400-4 200 MHz	3 400-4 200 MHz	3 400-4 200 MHz
Peak gain	-4 dBi	-4 dBi	-4 dBi	-4 dBi
Gain pattern	ND	ND	ND	ND
Transmitter				
Maximum power	-7 dBW	-7 dBW	-7 dBW	-7 dBW
Minimum power	-70 dBW	-70 dBW	-70 dBW	-70 dBW
Signal bandwidth	10.0 MHz	10.0 MHz	10.0 MHz	10.0 MHz
Channel spacing	10.0 MHz	10.0 MHz	10.0 MHz	10.0 MHz
Feeder loss	0 dB	0 dB	0 dB	0 dB
Power control				
Handover margin	3 dB	3 dB	3 dB	3 dB
Balancing factor (gamma)	1.0	1.0	1.0	1.0
Percent at maximum power	10%	10%	10%	10%
ACLR				
1st adjacent	30 dB	30 dB	30 dB	30 dB
2nd adjacent	33 dB	33 dB	33 dB	33 dB
Spurious	53 dB	53 dB	53 dB	53 dB

TABLE 3

Fixed service station characteristics

Parameter	Value
Fixed Station	
Antenna	
Height	30 m
Peak gain	27 dBi
Gain pattern	F.1245
Downtilt	0 degrees
Receiver	
Signal bandwidth	8.0 MHz
Channel spacing	8.0 MHz
Feeder loss	0.2 dB
Noise figure	2.5 dB
I/N requirement	-10 dB
ACS	
1st adjacent	45 dB
2nd adjacent	50 dB
> 2nd adjacent	55 dB

Propagation loss is based upon Recommendation ITU-R P.452-14. This Recommendation has been used in past studies in the 3 400-4 200 MHz frequency range. The analysis takes a conservative approach by assuming a smooth Earth terrain profile, which may overestimate interference to FS systems in environments other than flat plain regions. Other ITU-R propagation models utilized in the IMT-Advanced evaluation process (i.e. Report ITU-R M.2135) may provide a more realistic match to measured data. The propagation characteristics used in this analysis are shown in Table 4.

TABLE 4

Propagation Characteristics

Parameter	**Macro Suburban**	**Macro Urban**	**Small Cell Outdoor**	**Small Cell Indoor**
Propagation				
Model	P.452-14	P.452-14	P.452-14	P.452-14
Percentage of time basic loss is not exceeded	20%	20%	20%	20%
Average radio-refractive index lapse rate	45 N-units/km	45 N-units/km	45 N-units/km	45 N-units/km
Sea-level surface refractivity	330 N-units	330 N-units	330 N-units	330 N-units
Path center latitude	40 N	40 N	40 N	40 N
Clutter height	9 m	20 m	9 m	9 m
Clutter distance	0.025 km	0.02 km	0.025 km	0.025 km
Polarization discrimination				
IMT base station	3 dB	3 dB	3 dB	3 dB
IMT use equipment	0 dB	0 dB	0 dB	0 dB
Other propagation effects				
Building penetration loss (indoor stations only	20 dB	20 dB	20 dB	20 dB
IMT mobile station body loss	4 dB	4 dB	4 dB	4 dB

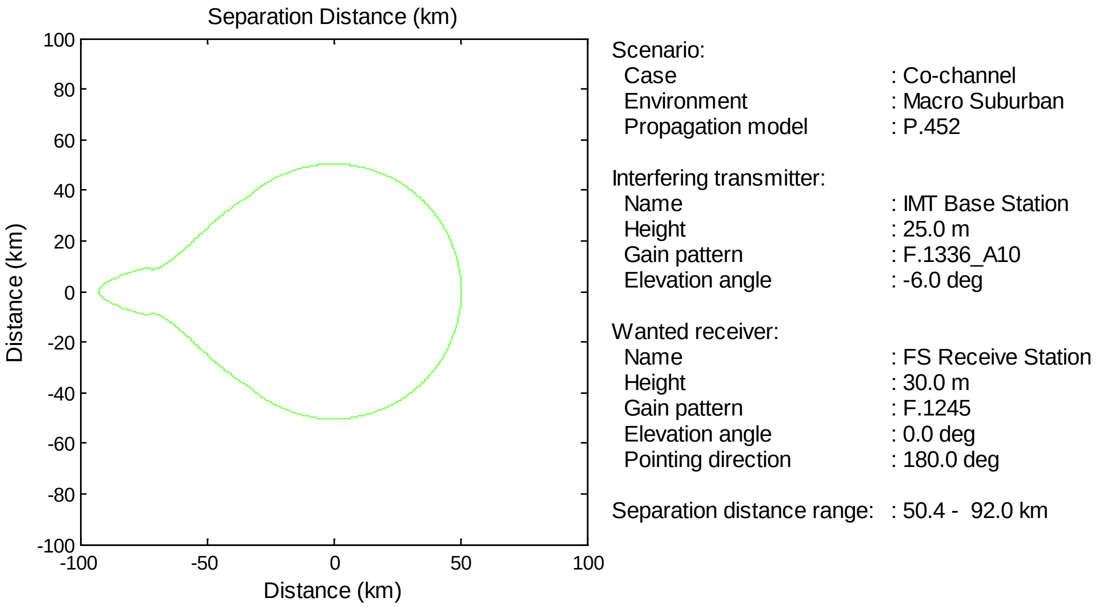
Results of Interference Calculations

Co-channel

The interference from a single IMT base station or UE pointing in azimuth toward the FS receive station is computed over a range of azimuths and distances. From this data, a contour is drawn at the locations around the FS receive station that meet interference protection requirement.

FIGURE 3

Separation Distance - IMT base station into FS receive station



Applying this methodology to the interference scenarios and deployment environments shown in the tables above gives the following results:

TABLE 5

Co-channel Separation Distance

Scenario	Environment	Separation distance
IMT base station into FS receive station	Macro Suburban	50.4-92.0 km
	Macro Urban	41.7-81.0 km
	Small Cell Outdoor	13.4-45.0 km
	Small Cell Indoor	1.0-10.0 km
IMT UE into FS receive station	Macro Suburban	1.0-24.0 km
	Macro Urban	1.0-31.0 km
	Small Cell Outdoor	1.0-25.0 km
	Small Cell Indoor	< 1.0 km

Furthermore, mobile operators can determine which locations are suitable for the deployment of IMT base stations, which can prove advantageous in terms of meeting any required separation distances.

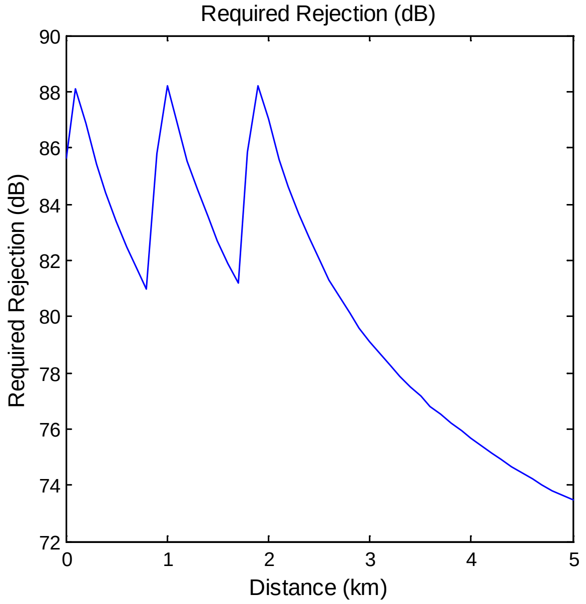
Adjacent channel

Nineteen IMT base stations are positioned over the network area as illustrated in Figure 1.
The FS receive station is initially positioned at the centre of the IMT network area. The pointing angle of the FS receive antenna is along the -x axis toward the array of IMT base stations.
(The pointing angles in the following figures are measured counter clockwise from the x-axis.)
This positioning creates the worst case scenario for receiving interference from the IMT network.

However, these pointing scenarios should be avoidable in practice, and as such, it could be expected that in reality interference is somewhat lower due to varying pointing direction of FS receive station with respect to IMT network., especially since operators make decisions about where to locate base stations. Next, the aggregate interference from the IMT base stations into the FS receive station is computed. Then the FS receive station position is moved incrementally along the x-axis and the aggregate interference is recomputed at each of these positions. This aggregate interference is compared with the FS protection requirement to determine the additional rejection needed to meet the protection requirement as a function of separation distance. The results are illustrated in the following figures:

FIGURE 4A

Required Rejection - IMT base station into FS receive station
FS receive station located within IMT deployment area



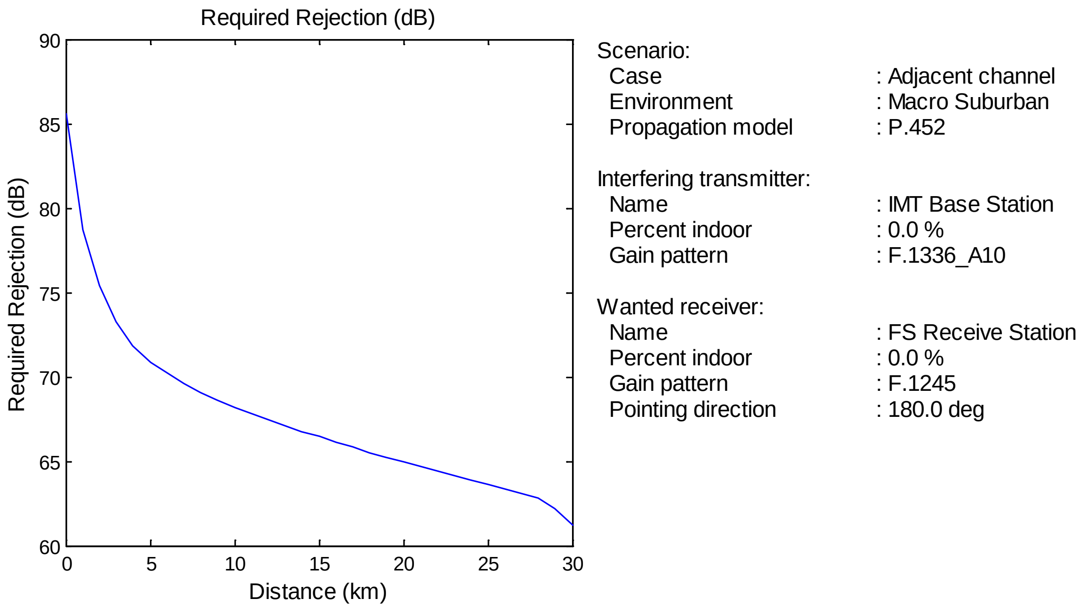
Scenario:
Case : Adjacent channel
Environment : Macro Suburban
Propagation model : P.452

Interfering transmitter:
Name : IMT Base Station
Percent indoor : 0.0 %
Gain pattern : F.1336_A10

Wanted receiver:
Name : FS Receive Station
Percent indoor : 0.0 %
Gain pattern : F.1245
Pointing direction : 180.0 deg

FIGURE 4B

Required Rejection - IMT base station into FS receive station
FS receive station located adjacent to IMT deployment area



For the scenario of aggregate interference from IMT UE, a Monte Carlo simulation is used to determine the interference into the FS station receiver. The IMT UE are randomly positioned over each sector in sufficient numbers to ensure that the entire bandwidth of the FS receive station receiver is fully occupied by interfering signals. A specified percentage of the IMT UE are assumed to be located indoors. As described above, a power control algorithm is applied to assign path loss and transmit power levels to each of the UE. Again, the FS receive station is initially positioned just to the right of the IMT network area and its antenna is pointed along the –x axis, or directly toward the IMT service area. The aggregate interference is computed for a range of separation distances and compared with the FS protection requirement to derive the needed rejection as a function of distance. This calculation is repeated 50 times.

These methodologies are applied to the deployment environments shown in the tables above, but,

Results of frequency separation calculations

Frequency dependent rejection (FDR) is dependent on the characteristics of the interfering signal and the wanted receiver filter. FDR is calculated from the following equation:

$$FDR(\Delta f) = 10\log_{10}\left[\frac{\int_{-\infty}^{+\infty} S(f)df}{\int_{-\infty}^{+\infty} S(f)F(f+\Delta f)df}\right]$$

where:

FDR = Frequency dependent rejection, dB

S = Power spectral density of the interfering signal, W/Hz

F = Frequency response of the wanted receiver, relative power fraction

f = Frequency, Hz

Δf = Frequency offset, Hz

The interfering signal, S, is modelled as a flat spectrum within the signal bandwidth and a specified adjacent channel leakage ratio (ACLR) curve outside the signal bandwidth. Similarly, the wanted receiver filter response, F, is modelled as a flat response within the receive signal bandwidth and a specified adjacent channel selectivity (ACS) curve outside the signal bandwidth. The following figures show the interfering signal, wanted receiver frequency response, and resulting FDR for each interference scenario considered here.

FIGURE 5

Frequency dependent rejection - IMT base station into FS receive station

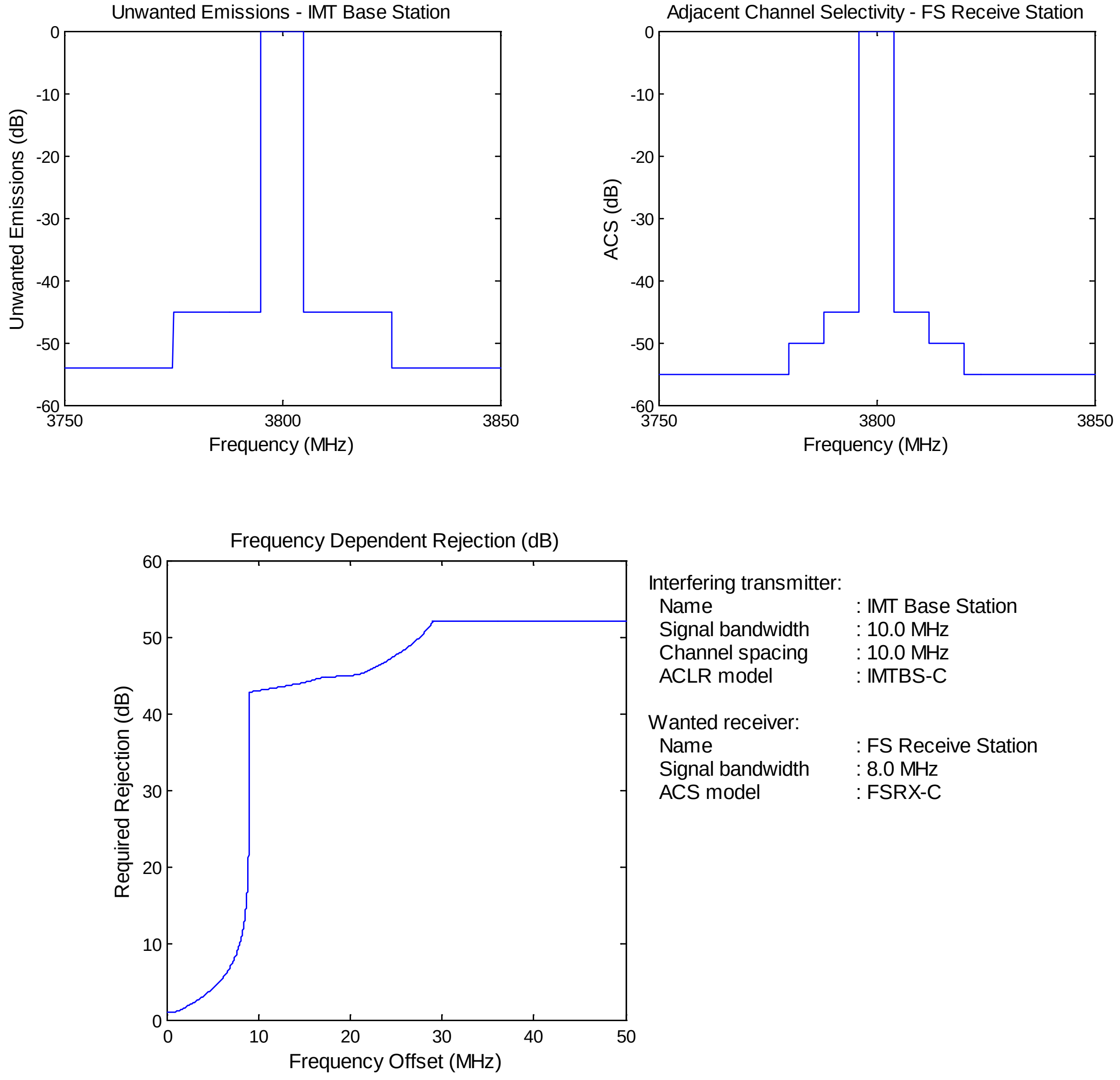
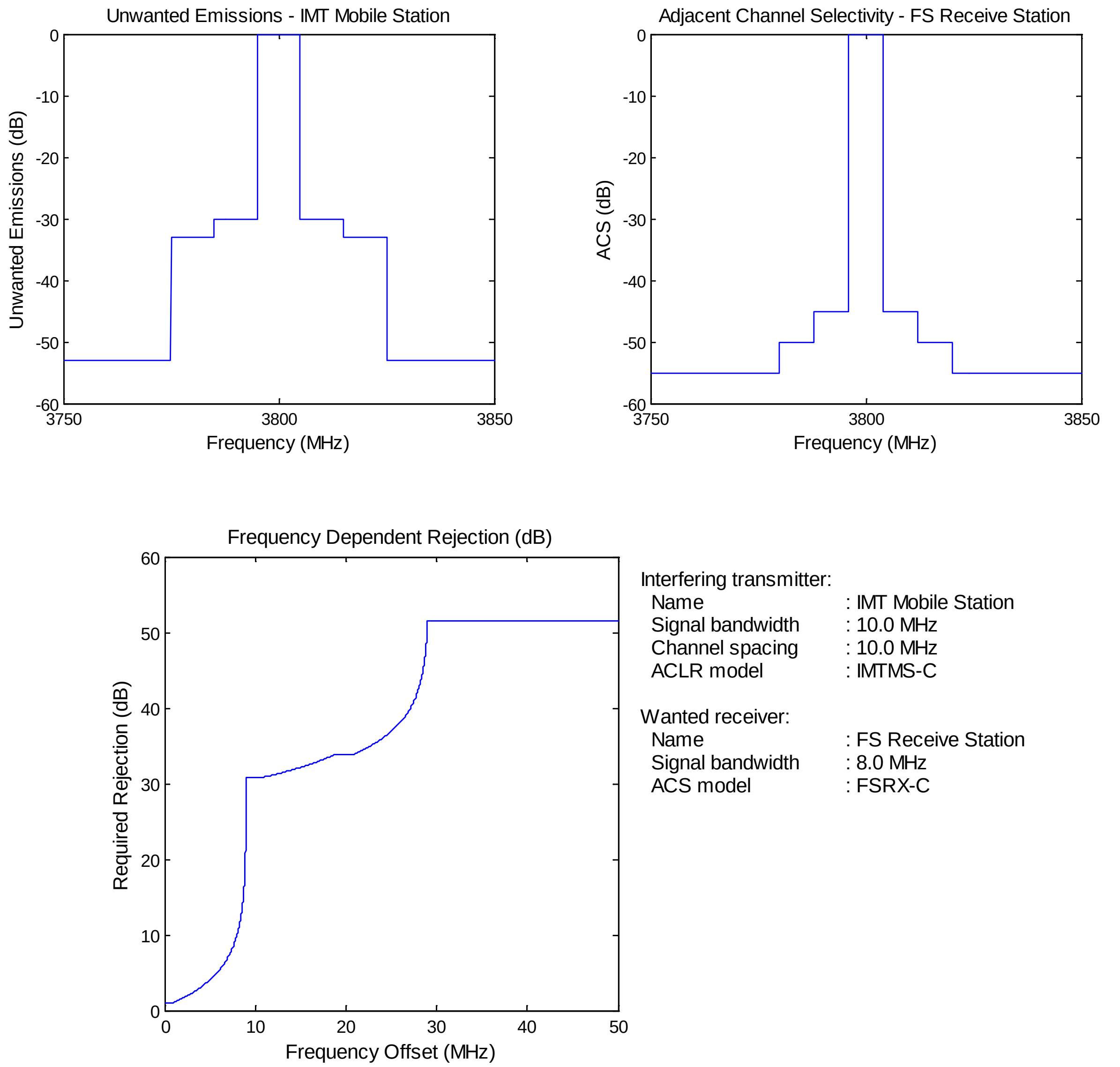


FIGURE 6

Frequency dependent rejection - IMT UE into FS receive station



The adjacent channel interference levels and FDR curves computed above are combined to derive the frequency separation (centre-to-centre) necessary to meet the stated protection requirement at various separation distances. Table 6 provides results for selected separation distances for the various interference scenarios and deployment environments considered here.

TABLE 6

Adjacent Channel Frequency/Distance Separation
IMT Signal Bandwidth = 10.0 MHz, FS Signal Bandwidth = 8.0 MHz

Scenario	Environment	FS Pointing Angle	Frequency Separation				
			1.0 km	5.0 km	10.0 km	20.0 km	30.0 km
IMT base station into FS receive station	Macro Suburban	180 deg 90 deg	- 27.7 MHz	- 9.0 MHz	- 9.0 MHz	- 9.0 MHz	- 9.0 MHz
	Macro Urban	180 deg 90 deg	- 25.4 MHz	- 9.0 MHz	- 9.0 MHz	- 9.0 MHz	- 8.9 MHz
	Small Cell Outdoor	180 deg 90 deg	- 9.0 MHz	25.8 MHz 8.8 MHz	19.8 MHz 8.3 MHz	9.0 MHz 6.2 MHz	9.0 MHz 0.9 MHz
	Small Cell Indoor	180 deg 90 deg	6.3 MHz 0.0 MHz	0.0 MHz 0.0 MHz	0.0 MHz 0.0 MHz	0.0 MHz 0.0 MHz	0.0 MHz 0.0 MHz
IMT UE into FS receive station	Macro Suburban	180 deg 90 deg	6.3 MHz 0.0 MHz	5.7 MHz 0.0 MHz	3.2 MHz 0.0 MHz	0.0 MHz 0.0 MHz	0.0 MHz 0.0 MHz
	Macro Urban	180 deg 90 deg	8.2 MHz 0.0 MHz	7.3 MHz 0.0 MHz	5.4 MHz 0.0 MHz	0.0 MHz 0.0 MHz	0.0 MHz 0.0 MHz
	Small Cell Outdoor	180 deg 90 deg	6.6 MHz 0.0 MHz	0.0 MHz 0.0 MHz	0.0 MHz 0.0 MHz	0.0 MHz 0.0 MHz	0.0 MHz 0.0 MHz
	Small Cell Indoor	180 deg 90 deg	6.0 MHz 0.0 MHz	2.2 MHz 0.0 MHz	0.0 MHz 0.0 MHz	0.0 MHz 0.0 MHz	0.0 MHz 0.0 MHz

Conclusions

The co-frequency channel results show that the required separation distance can range from less than one kilometre to nearly 100 kilometres, depending on the interference scenario and deployment environment. These results are based on worst-case assumptions including the pointing direction of the IMT station and the application of the propagation model. Furthermore, mobile operators can determine which locations are suitable for the deployment of IMT base stations, which can prove advantageous in terms of meeting any required separation distances.

The adjacent channel results show that in the worst-case scenarios (FS receive station pointing directly toward a macro deployment of IMT base stations) the separation distance needed to protect the FS station exceeds 30 kilometres. However, these pointing scenarios should be avoidable in practice, and for more realistic pointing scenarios, the interference can be mitigated through a combination of geographic separation and frequency separation. For these cases, the separation distance between macro base stations and FS receive stations is on the order of a few kilometres coupled with a frequency separation of about one or two channel bandwidths, depending on the distance separation. It is important to note that the frequency separation results reflect channel centre-to-channel centre separations and not guard bands, which are usually expressed as channel edge-to-channel edge. It should also be noted that operators decide where to deploy IMT base stations based on a variety of factors including minimizing interference near international borders in accordance with regulations.

The required geographic and frequency separations are significantly reduced for the small cell indoor base station deployment scenario. For this case, the separation distance between small cell base stations and FS receive stations is on the order of one kilometre coupled with a frequency separation of about one channel bandwidth or a few kilometres with no frequency separation, depending on the relative pointing directions of the IMT and FS stations.

These results also show that the interference from the IMT UE is relatively low. This interference can be mitigated by either a frequency separation of about one channel or a geographic separation of a few kilometres.

It should be noted that certain assumptions such as FS receive station placement and direction, use of propagation model, etc. overestimate interference from the IMT network.