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

DRAFT NEW REPORT ITU-R F.[IMT-FS 470-694/698 MHz SHARING]

Sharing and compatibility between international mobile telecommunication systems and fixed service systems in the 470-694/698 MHz frequency range

Introduction

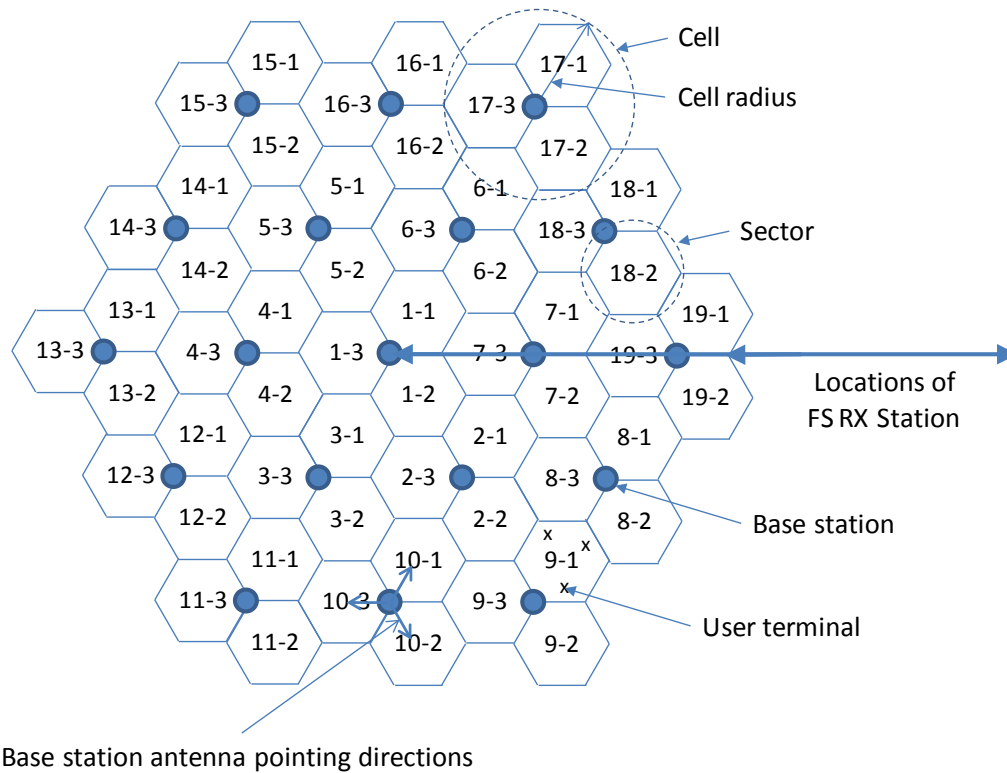
This study examines the compatibility of proposed international mobile telecommunication (IMT) systems and fixed service (FS) systems operating in the 470-694/698 MHz frequency range.

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 mobile station into FS receive station. Three deployment environments for IMT systems are considered: macro urban, macro suburban, and macro rural. 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.

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 or mobile station 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.

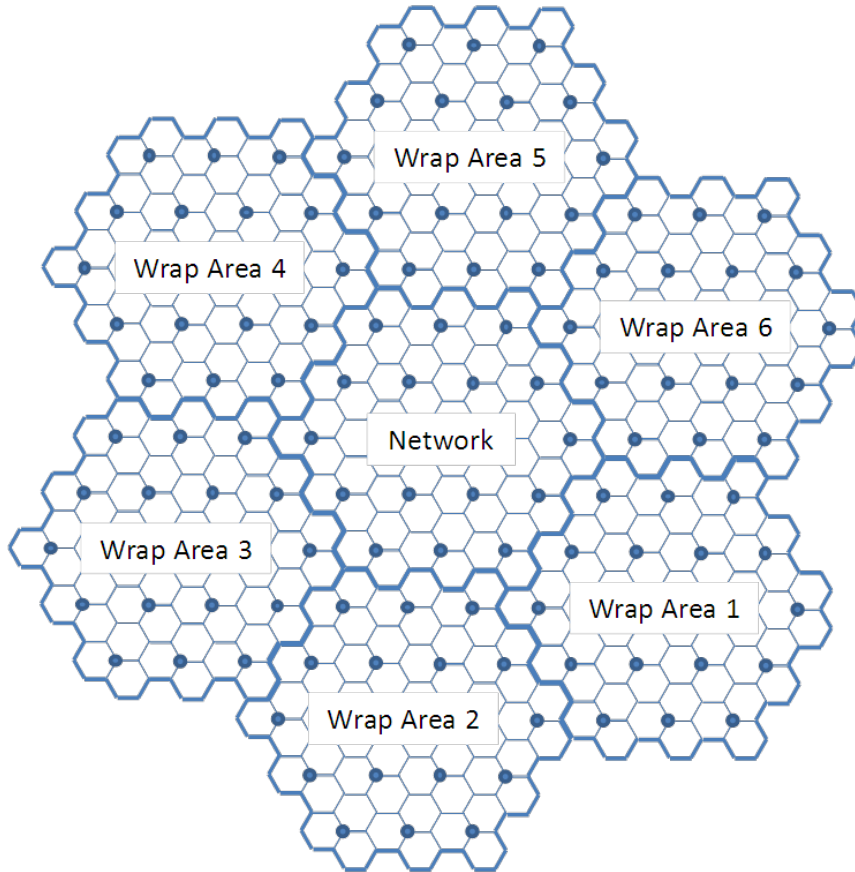
For the adjacent channel scenario, the FS receive station is positioned adjacent to the IMT network base stations. The aggregate interference into the FS station is computed assuming varying separation distances. At each distance, the required rejection is determined based on a specified protection requirement. 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 mobile station into FS receive station

Aggregate interference from IMT mobile stations is modelled based on the Monte Carlo methodology to model IMT networks. The methodology consists of 1) randomly positioning IMT mobile stations throughout the IMT network area, 2) randomly assigning these mobile stations to an IMT base station based on the propagation loss and a specified “handover margin”, 3) randomly locating the mobile stations either indoors or outdoors based on a specified percentage of indoor devices, and 4) applying a power control algorithm to the mobile stations based on their path loss distribution. The calculations are repeated for a number of “snapshots”, from which statistics are extracted. 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 user equipment (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 P_t 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 BS and PL_{x-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-ile} will transmit at P_{max} . Finally, $0 < \gamma \leq 1$ is the balancing factor for UE with bad channel and UE with good channel.

The analysis assumes that there are a sufficient number of IMT mobile stations 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 hand-held mobile stations), 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 hand-held mobile stations), 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. IMT system characteristics are provided in Report ITU-R M.2292. FS system characteristics are provided in Recommendations ITU-R F.758 and ITU-R F.1777. Note that 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 Urban	Macro Suburban	Macro Rural
Deployment			
Number of cells	19	19	19
Number of sectors per cell	3	3	3
Cell radius	2 km	2 km	8 km
Percent indoor	0%	0%	0%
Base Station			
Antenna			
Height	30 m	30 m	30 m
Frequency range	470-698 MHz	470-698 MHz	470-698 MHz
Peak gain	15 dBi	15 dBi	15 dBi
Gain pattern	F.1336 Annex 10	F.1336 Annex 10	F.1336 Annex 10
ka	0.7	0.7	0.7
kp	0.7	0.7	0.7
kh	0.7	0.7	0.7
kv	0.3	0.3	0.3
k	n/a	n/a	n/a
Horizontal beamwidth	65 degrees	65 degrees	65 degrees
Downtilt	-3 degrees	-3 degrees	-3 degrees
Transmitter			
Power	16 dBW	16 dBW	16 dBW
Activity factor	3 dB	3 dB	3 dB
Signal bandwidth	10.0 MHz	10.0 MHz	10.0 MHz
Channel spacing	10.0 MHz	10.0 MHz	10.0 MHz
Feeder loss	3 dB	3 dB	3 dB
ACLR			
1st adjacent	45 dB	45 dB	45 dB
2nd adjacent	45 dB	45 dB	45 dB
Spurious	54 dB	54 dB	54 dB

Note: "F.1336 Annex 10" in Table 1 should read "F.1336 recommends 3.1"

TABLE 2
IMT mobile station characteristics

Parameter	Macro Urban	Macro Suburban	Macro Rural
Deployment			
Percent indoor	70%	70%	50%
Mobile Station			
Antenna			
Height	1.5 m	1.5 m	1.5 m
Frequency range	470-698 MHz	470-698 MHz	470-698 MHz
Peak gain	-3 dBi	-3 dBi	-3 dBi
Gain pattern	ND	ND	ND
Transmitter			
Maximum power	-7 dBW	-7 dBW	-7 dBW
Minimum power	-39 dBW	-39 dBW	-28 dBW
Signal bandwidth	10.0 MHz	10.0 MHz	10.0 MHz
Channel spacing	10.0 MHz	10.0 MHz	10.0 MHz
Feeder loss	0 dB	0 dB	0 dB
Power control			
Handover margin	3 dB	3 dB	3 dB
Balancing factor (gamma)	1.0	1.0	1.0
Percent at maximum power	10%	10%	10%
ACLR			
1st adjacent	30 dB	30 dB	30 dB
2nd adjacent	33 dB	33 dB	33 dB
Spurious	53 dB	53 dB	53 dB

TABLE 3
Fixed service station characteristics

Parameter	Value
Fixed Station	
Antenna	
Height	30 m
Peak gain	25 dBi
Gain pattern	F.699
Downtilt	0 degrees
Receiver	
Signal bandwidth	3.5MHz
Channel spacing	4.0 MHz
Feeder loss	2 dB
Noise figure	3.5 dB
I/N requirement	-6 dB
ACS	
1st adjacent	45 dB
2nd adjacent	50 dB
> 2nd adjacent	55 dB

Propagation loss is based on Recommendation ITU-R P.452-14. The analysis takes a conservative approach by assuming a smooth Earth terrain profile, which may overestimate interference to fixed service systems in environments other than flat plain regions. The propagation characteristics used in this analysis are shown in Table 4.

TABLE 4
Propagation characteristics

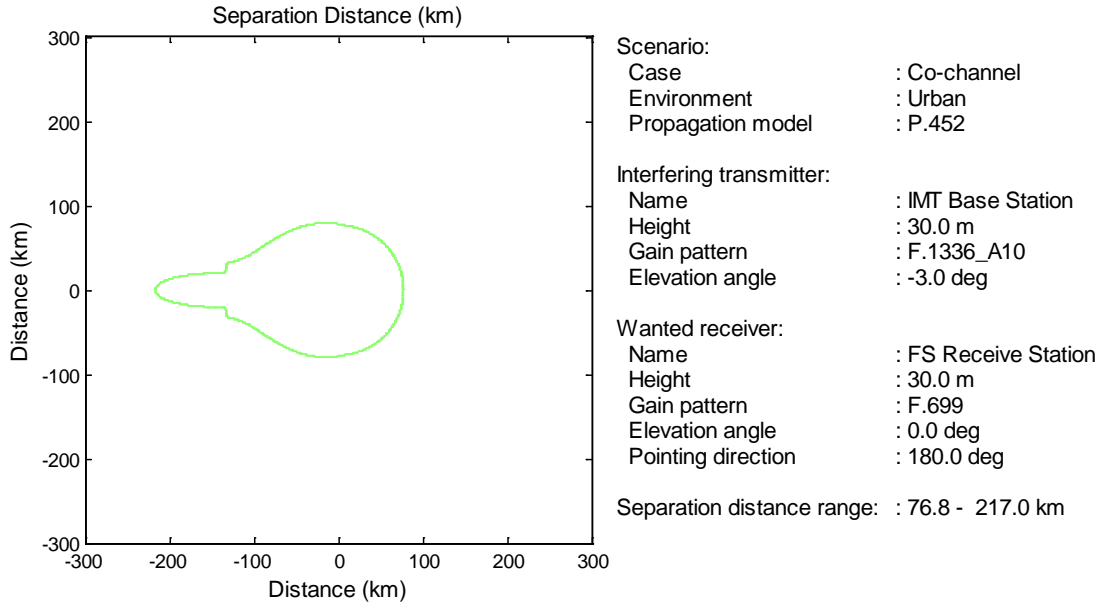
Parameter	Macro Urban	Macro Suburban	Macro Rural
Propagation			
Model	P.452-14	P.452-14	P.452-14
Percentage of time basic loss is not exceeded	20%	20%	20%
Average radio-refractive index lapse rate	45 N-units/km	45 N-units/km	45 N-units/km
Sea-level surface refractivity	330 N-units	330 N-units	330 N-units
Path center latitude	40 N	40 N	40 N
Clutter height	20 m	9 m	4 m
Clutter distance	0.02 km	0.025 km	0.1 km
Polarization discrimination			
IMT base station	3 dB	3 dB	3 dB
IMT mobile station	0 dB	0 dB	0 dB
Other propagation effects			
Building penetration loss (indoor stations only)	20 dB	20 dB	15 dB
IMT mobile station body loss	4 dB	4 dB	4 dB

Results of interference calculations

Co-channel

The interference from a single IMT base or mobile station 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 Urban	76.8 - 217.0 km
	Macro Suburban	76.8 - 217.0 km
	Macro Rural	76.8 - 217.0 km
IMT mobile station into FS receive station	Macro Urban	< 32.0 km
	Macro Suburban	< 27.0 km
	Macro Rural	< 27.0 km

These results are based on worst-case assumptions including the pointing direction of the IMT station and the application of the propagation model.

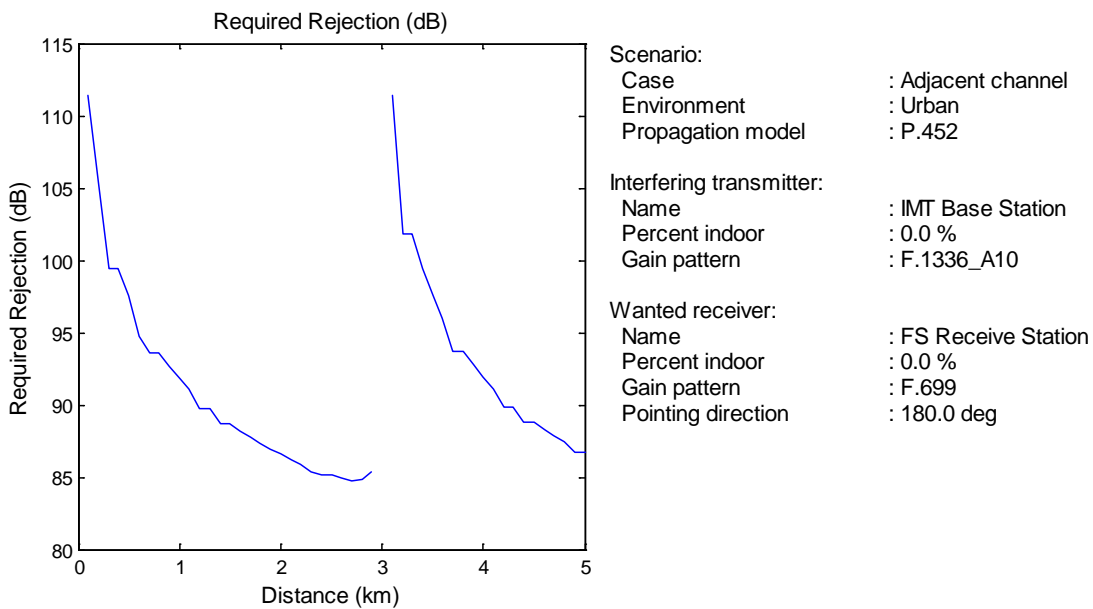
Adjacent channel

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. 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

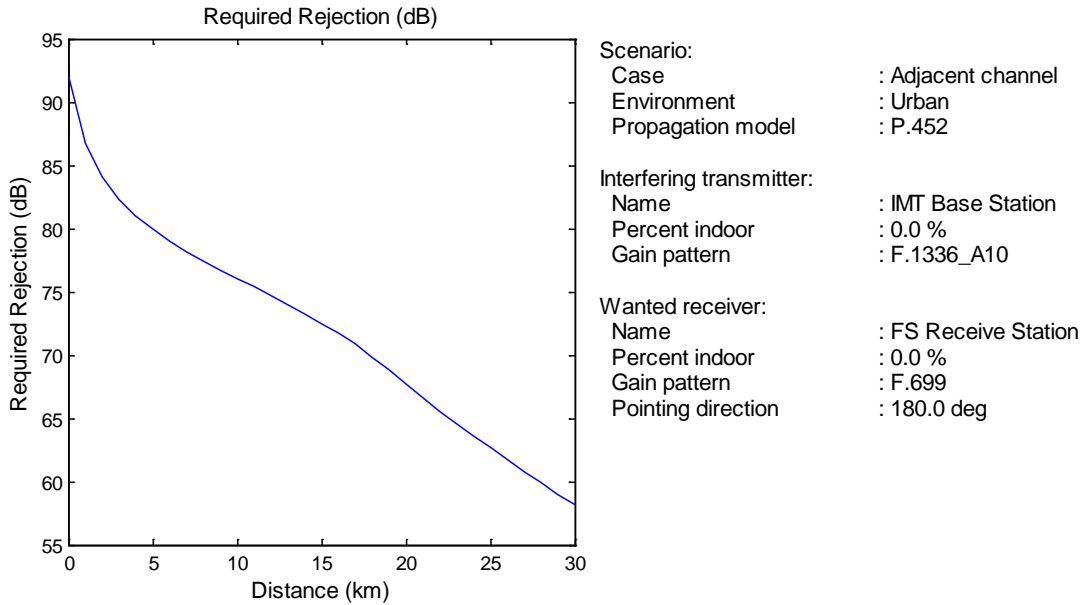
Required Rejection
IMT base station into FS receive station
FS receive station located within IMT deployment area



Note: The break in the curve shown above occurs when the FS station position coincides with the IMT base station location. Since the distance between the IMT and FS stations is zero, the propagation loss cannot be calculated resulting in no value to plot at this distance. This situation will not occur in practice.

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 mobile stations, a Monte Carlo simulation is used to determine the interference into the FS station receiver. The IMT mobile terminals 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 terminals 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 mobile terminals. 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, for brevity, plots of these results are not included here.

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

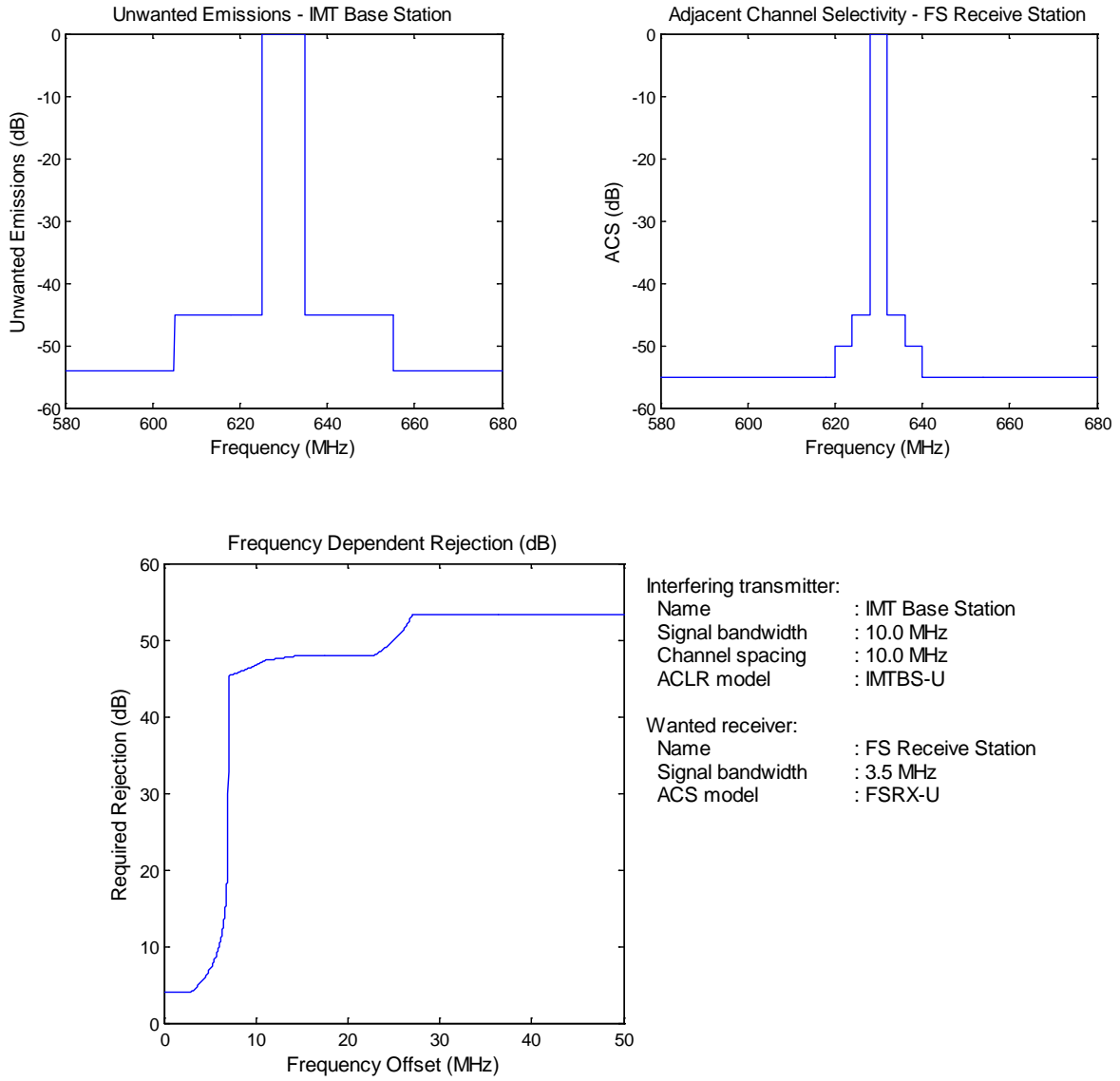
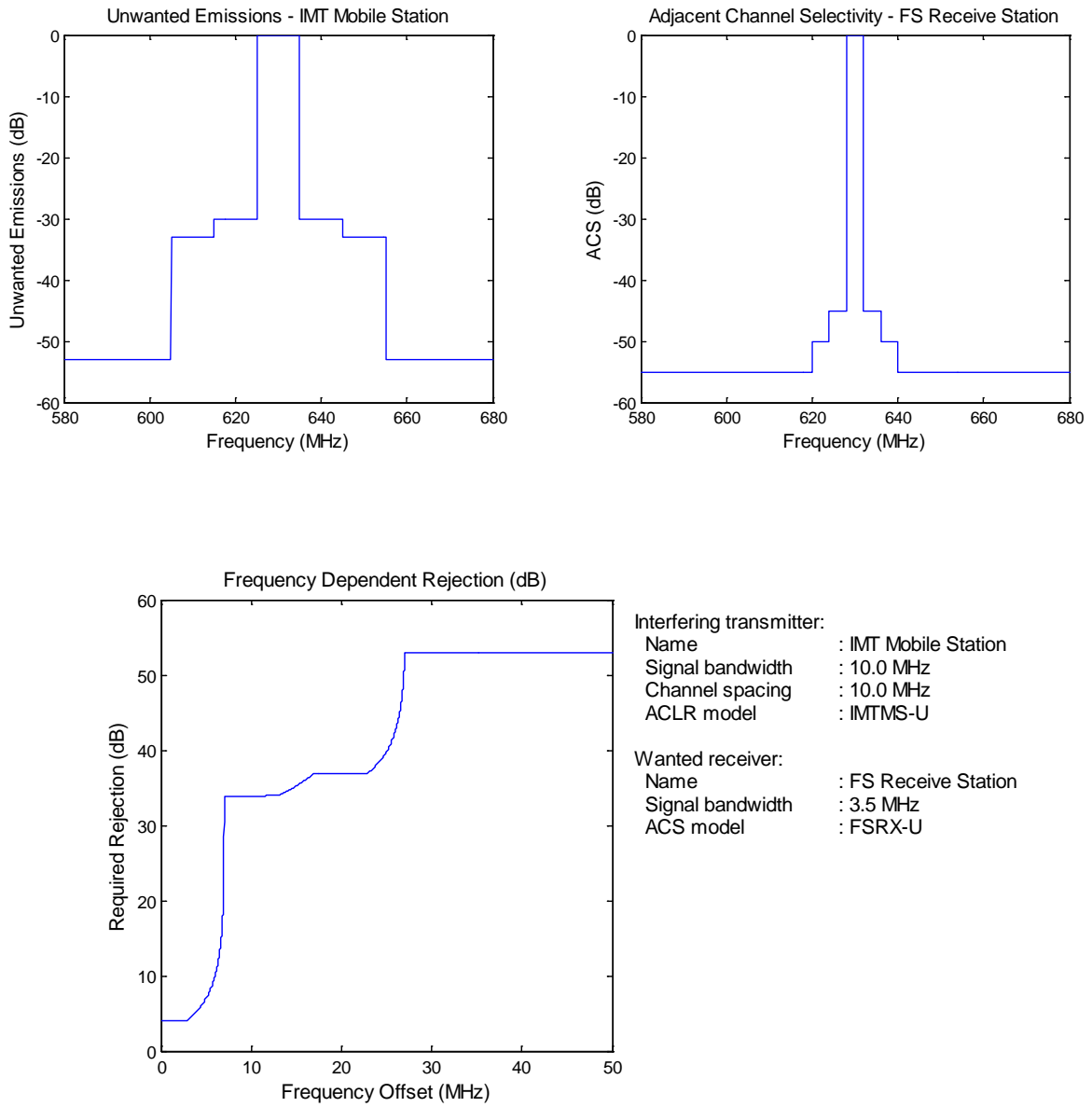


FIGURE 6
Frequency Dependent Rejection
IMT mobile station into FS receive station



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 = 3.5 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 Urban	180 deg	-	-	-	-	-
		90 deg	-	-	25.9 MHz	7.0 MHz	7.0 MHz
	Macro Suburban	180 deg	-	-	-	-	-
		90 deg	-	-	25.9 MHz	7.0 MHz	7.0 MHz
	Macro Rural	180 deg	-	-	-	-	25.3 MHz
		90 deg	26.9 MHz	23.7 MHz	7.0 MHz	7.0 MHz	7.0 MHz
IMT mobile station into FS receive station	Macro Urban	180 deg	5.6 MHz	4.9 MHz	3.4 MHz	0.0 MHz	0.0 MHz
		90 deg	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz
	Macro Suburban	180 deg	5.4 MHz	3.8 MHz	0.0 MHz	0.0 MHz	0.0 MHz
		90 deg	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz
	Macro Rural	180 deg	1.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz	0.0 MHz
		90 deg	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 around 25 kilometres to nearly 220 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 interference can be mitigated with a separation distance between the FS receive station and the IMT base station on the order of 10 kilometres coupled with a frequency separation of about one to two channel bandwidths. It is important to note that the frequency separation results reflect channel centre-to-channel centre separations and not guardbands, which are usually expressed as channel edge-to-channel edge.

These results also show that the interference from the IMT mobile stations is acceptable with a geographic separation as low as one kilometre.

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.