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Recommendation ITU-R M.2082-0
(11/2015)

Methodology and technical example to assist coordination of the mobile-satellite service and the radiodetermination-satellite service with the fixed service based on the power flux-density coordination trigger levels in the 2 483.5-2 500 MHz band

M Series

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Note: *This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

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RECOMMENDATION ITU-R M.2082-0

Methodology and technical example to assist coordination of the mobile-satellite service and the radiodetermination-satellite service with the fixed service based on the power flux-density coordination trigger levels in the 2 483.5-2 500 MHz band

(2015)

Scope

This Recommendation provides information on coordination of the fixed service with mobile-satellite and radiodetermination-satellite service systems operating in the 2 483.5-2 500 MHz frequency band. An estimation of the level of interference that may be caused by mobile-satellite and radiodetermination-satellite service systems is included. This Recommendation examines the impact of the relaxation of the power flux-density level that triggers coordination with the fixed service that was agreed at WRC-12 under agenda item 1.18.

This Recommendation may assist when performing coordination under Radio Regulations No. **9.14** with administrations requesting to operate their RDSS or MSS systems at pfd levels in excess of the thresholds defined in RR Appendix **5**.

Keywords

RDSS, MSS, FS, MS, coordination trigger

Abbreviations/Glossary

FDP fractional degradation of performance

pfd power flux-density

Related ITU Recommendations, Reports

Recommendation ITU-R F.758-6	System parameters and considerations in the development of criteria for sharing or compatibility between digital fixed wireless systems in the fixed service and systems in other services and other sources of interference
Recommendation ITU-R F.1108-4	Determination of the criteria to protect fixed service receivers from the emissions of space stations operating in non-geostationary orbits in shared frequency bands
Recommendation ITU-R M.1143-3	System specific methodology for coordination of non-geostationary space stations (space-to-Earth) operating in the mobile-satellite service with the fixed service
Recommendation ITU-R M.1787-2	Description of systems and networks in the radionavigation-satellite service (space-to-Earth and space-to-space) and technical characteristics of transmitting space stations operating in the bands 1 164-1 215 MHz, 1 215-1 300 MHz and 1 559-1 610 MHz

The ITU Radiocommunication Assembly,

considering

a) that the band 2 483.5-2 500 MHz is allocated to the mobile-satellite service (MSS), the radiodetermination-satellite service (RDSS), the fixed service (FS) and the mobile service (MS) on a worldwide co-primary basis;

b) that the use of this band for the MSS is for downlink (space-to-Earth) transmissions to user terminals;

c) that the necessity to coordinate space systems with administrations using the FS is determined through the use of appropriate power flux-density (pfd) values given in RR Appendix **5**;

d) that the pfd is one of the technical parameters used for the determination of criteria which facilitate sharing between the MSS and terrestrial services;

e) that FS networks use digital modulation techniques,

noting

a) that in the frequency band 2 483.5-2 500 MHz shared between systems in the non-geostationary MSS, and systems in the FS, Table 5-2 of RR Appendix **5** establishes the following pfd thresholds:

-126 dB(W/(m^2 · MHz)) for $0° \le \theta \le 5°$

$-126 + 0.65\ (\theta - 5)$ dB(W/(m^2 · MHz)) for $5° \le \theta \le 25°$

-113 dB(W/(m^2 · MHz)) for $\theta > 25°$

where θ is the angle of arrival (degrees) on the surface of the Earth of the radio-frequency wave;

b) that for the countries in Region 2, 43 countries in Region 1, in Australia and in Israel, in the frequency band 2 483.5-2 500 MHz shared between systems in the non-geostationary MSS and systems in the FS, Note 9 to Table 5-2 of RR Appendix **5** establishes the following pfd thresholds:

-124.5 dB(W/(m^2 · MHz)) for $0° \le \theta \le 5°$

$-124.5 + 0.65\ (\theta - 5)$ dB(W/(m^2 · MHz)) for $5° \le \theta \le 25°$

-111.5 dB(W/(m^2 · MHz)) for $\theta > 25°$

c) that in the frequency band 2 483.5-2 500 MHz shared between systems in the non-geostationary RDSS, and systems in the FS, Table 5-2 of RR Appendix **5** establishes the following pfd threshold:

-129 dB(W/(m^2 · MHz)) for $0° \le \theta \le 90°$

d) that for the countries in Region 2, 43 countries in Region 1, in Australia and in Israel, in the frequency band 2 483.5-2 500 MHz, shared between systems in the non-geostationary RDSS and systems in the FS, Note 9 to Table 5-2 of RR Appendix **5** establishes the following pfd threshold:

-128 dB(W/(m^2 · MHz)) for $0° \le \theta \le 90°$

e) that the above values relate to the pfd and angles of arrival which would be obtained under free-space propagation conditions;

f) that, in Region 1, the provisions of RR No. **5.398A** shall be taken into account, *recommends*

1 that, subject to mutual agreement between administrations concerned, the methodology presented in Annex 1 may be used for coordination between FS and MSS and RDSS systems as a means for determining the impact on FS systems when the threshold pfd levels contained in Table 5-2 of RR Appendix **5** are exceeded;

2 that any ambiguity in specific parameters of the methodology contained in Annex 1 should be resolved through mutual agreement.

NOTE – Annex 2 provides a technical example of application of the methodology contained in Annex 1.

Annex 1

Determining the fractional degradation of performance of fixed service systems due to power flux-density coordination trigger levels in the 2 483.5-2 500 MHz band

1 Scope

The methodology described in this Annex draws on existing ITU-R Recommendations and references a general methodology for computing the aggregate interference from RDSS and MSS spacecraft as seen by a terrestrial station in the FS.

Examples of the aggregate level of interference to the FS from the HIBLEO-X/HIBLEO-4 MSS and Galileo RDSS constellations are provided in the Attachment to Annex 2.

2 Methodology[1]

The methodology used in Recommendation ITU-R F.1108, for digital radio relay systems, is used along with Recommendation ITU-R M.1143. Recommendation ITU-R F.1108 uses the concept of fractional degradation of performance (FDP) for digital FS stations. The FDP is the fractional increase in the percentage of time that the controlling performance criterion will not be met because of the presence of interference. It has been suggested in Recommendation ITU-R F.758-6 that an FDP of 25% is suitable for systems operating in the 2 483.5-2 500 MHz frequency range.

The program simulates the interference into the FS network from the non-GSO satellite constellation(s) as follows.

2.1 Calculation loop

The program calculates the position and velocity vectors of the satellites of the non-GSO satellite system and stations of FS system at each time instance.

At each time sample the program calculates the total interfering power at each fixed service (FS) station from all active spots from all visible and appropriately selected MSS and RDSS satellites. If the FS receiver bandwidth does not completely overlap the MSS or RDSS signal the interfering

[1] This text is adapted from Recommendation ITU-R M.1143.

power is then scaled by the bandwidth factor. In the digital case, this interfering power is scaled to 1 MHz.

The aggregate interference power from all active spot beams of all visible satellites visible to the FS station is determined using the following equation:

$$I = \sum_{i=1}^{N}\sum_{j=1}^{S}\frac{E_{ij}}{L_i} \quad G^3(\alpha_{ij})G^4(\theta_i)\frac{B_w}{B_{ij}}\frac{1}{F}\frac{1}{P_{ij}}$$

where:

I :	interference power (W)
i :	1 of N satellites being considered in the interference calculation for the FS station
j :	1 of S active spot beams on the visible selected MSS (or RDSS) satellite with frequency overlap to the current FS station receiver, taking account of the satellite spot beam frequency reuse pattern
E_{ij} :	maximum e.i.r.p. density per reference bandwidth input to the antenna for the j^{th} active spot beam in its boresight direction of the i^{th} visible selected satellite (W/reference bandwidth)
B_{ij} :	reference bandwidth for the interfering signal from the j^{th} active spot beam of the i^{th} visible selected satellite (kHz)
$G^3(\alpha_{ij})$:	antenna discrimination of the j^{th} active spot beam of the i^{th} visible selected satellite towards the FS station
α_{ij} :	angle between the boresight pointing vector j^{th} active spot beam of the i^{th} visible selected satellite to the FS station (degrees)
L_i :	free space loss at the given reference frequency from the i^{th} visible selected satellite to the FS station
$G^4(\theta_i)$:	the FS station's antenna gain in the direction of the i^{th} visible selected satellite
θ_{ik} :	angle between the FS station's antenna pointing vector and the range vector from the FS station and the i^{th} visible selected satellite (degrees)
B_W :	receiver bandwidth of the affected FS station (1 MHz)
F :	feed loss for the FS station
P_{ij} :	polarization advantage factor between j^{th} spot beam of the i^{th} MSS (or RDSS) satellite and the FS station.

The polarization advantage P_{ij} is to be used only if the i^{th} MSS (or RDSS) satellite is within the 3 dB beamwidth of the FS station antenna and the FS station is within the 3 dB beamwidth of the j^{th} spot beam of the i^{th} MSS (or RDSS) satellite. P_{ij} can be calculated according to the formula of Note 7 of Recommendation ITU-R F.1245.

2.2 Size and number of steps in the calculation loop

It is necessary to have enough samples at appropriate time intervals to have accurate results, taking into account all the interference received at the receiver of the fixed station.

2.2.1 Time increment

The following formulae are used, and the derivation of the formulae is fully detailed in RR Appendix **4**. As the satellite speed is about the same at the equator and at higher latitudes, the calculation of simulation time step Δt is made for a satellite at the equator taking into account the Earth's rotation, satellite inclination and FS station antenna elevation. The worst azimuth for FDP or the azimuth of horizontal movement is not used in calculation of Δt.

$$\omega = \sqrt{(\omega_s \cos I - \omega_e)^2 + (\omega_s \sin I)^2}$$

$$\theta_\varepsilon = \arccos\left(\frac{R}{R + h}\cos\varepsilon\right) - \varepsilon$$

$$\Delta t = \frac{\varphi_{3dB}}{N_{hits}\,\omega}\,\frac{\sin\theta_\varepsilon}{\cos\varepsilon}$$

where:

ω:	satellite angular velocity in Earth fixed coordinates (geocentric geosynchronous reference coordinate system)
ω_S :	satellite angular velocity in space fixed coordinates (geocentric heliosynchronous reference coordinate system)
ω_e :	Earth rotation angular velocity at the equator
I :	satellite orbit inclination
$\theta\varepsilon$:	geocentric angle between FS station and satellite
R :	Earth radius
h :	satellite altitude
ε :	FS antenna elevation angle
φ_{3dB} :	FS station 3 dB beamwidth
N_{hits} :	number of hits in FS station 3 dB beamwidth
Δt :	simulation time step.

2.3 Applicable interference criteria – Digital FS system

For the digital FS case the program calculates the FDP for the digital station as in Annex 3 of Recommendation ITU-R F.1108:

$$FDP = \sum_{I_i = min}^{max} \frac{I_i \; f_i}{N_T}$$

where:

I :	interference power in FS receiver bandwidth B_W
f_i :	the fractional period of time that the interference power equals I
N_T :	station receiving system noise power level.

$$N_T = k\,T\,B_W$$

where:

k : Boltzmann's constant

T : FS station equivalent receiving system noise temperature (K)

B_W : FS receiver bandwidth (usually FDP is calculated in a 1 MHz reference bandwidth).

In order to assess if coordination is triggered or not with respect to digital FS systems, the computed FDP is compared with respect to the applicable criterion of 25%.

Annex 2

Technical example interference analyses

1 Characteristics of MSS, RDSS and FS systems

1.1 Characteristics of MSS systems in the band 2 483.5-2 500 MHz

For the non-GSO MSS system considered in the analyses, the characteristics shown in Table 1 have been used.

TABLE 1

Typical mobile-satellite service system parameters

System name	HIBLEO-4/HIBLEO-X
Altitude	1 414 km
Inclination	52 degrees
Number of orbital planes	8
Number of satellites per plane	6 spaced every 60 degrees
Phasing*	7.5 degrees
Antenna type	Multi-beam
Average gain	15.0 dBi
Average 3 dB beamwidth	25.3 degrees
Polarization	Left hand circular
Signal bandwidth	13 × 1.23 MHz = 16.5 MHz
Signal centre frequency	2 491.75 MHz
User terminal receiver noise temperature	300 K
User terminal receiver antenna gain	2.7 dBi
User terminal receiver antenna beamwidth	126 degrees

* The initial phase angle (ω_i) of the i-th satellite in its orbital plane at reference time t = 0, measured from the point of the ascending node ($0° \leq \omega_i < 360°$).

1.2 Assumed RDSS system characteristics

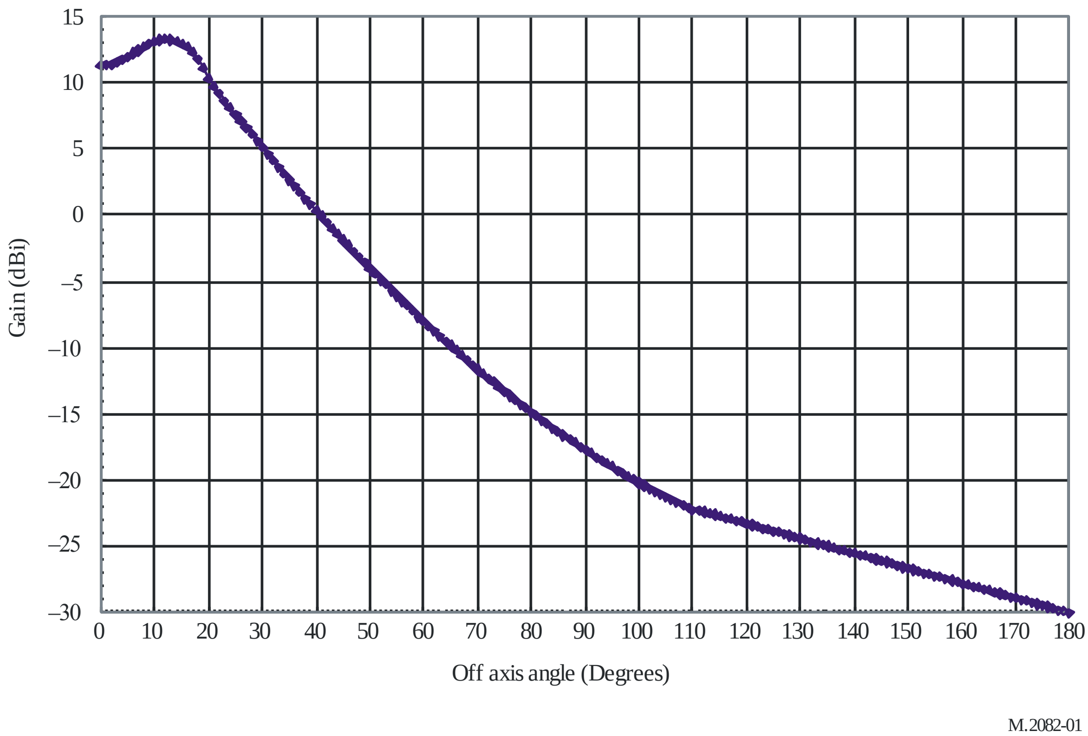
It has been noted that the Galileo system intends to provide an RDSS application with its constellation. However, no firm set of specifications has yet been published for this application.

To enable computer simulations, it has been assumed that the Galileo RDSS application will have characteristics similar to those being used for its radionavigation-satellite service (RNSS) application as published in Recommendation ITU-R M.1787.

It has further been assumed that the spacecraft antenna for the RDSS application would also have an iso-flux antenna characteristic. The peak gain of the assumed antenna is 13.3 dBi. The antenna pattern used in the computer simulation is shown in Fig. 1. The results of WRC-12 provide that a pfd level of −128 dBW/m² MHz, for all angles of arrival at the surface of the Earth be used as a coordination trigger for the RDSS allocation in the 2 483.5-2 500 MHz frequency band. Based on the pfd level and that the assumed antenna has relative gain maxima at ±9 degrees, which corresponds to a slant range of 25 239 km between the RDSS spacecraft and the surface of the Earth, a RDSS e.i.r.p of 40.46 dBW or an e.i.r.p density of 30.16 dBW/MHz was assumed.

FIGURE 1

Galileo S-band antenna pattern



The other characteristics assumed for the Galileo RDSS application and used in the computer simulation are shown in Table 2.

TABLE 2

Proposed typical RDSS system characteristics

System name	Galileo RDSS
Altitude	23 616 km
Inclination	56 degrees
Number of orbital planes	3
Number of satellites per plane	Total of 9, each separated by 40 degrees
Phasing*	13 1/3 degrees
Antenna type	Iso-flux
Peak gain	13.3 dBi
3 dB beamwidth	40 degrees peak-to-peak
Polarization	Right-hand circular (RHCP)
Signal bandwidth	16.5 MHz
Signal centre frequency	2 491.75 MHz
Power flux-density level	–128 dB (W/m^2. MHz)
Implied e.i.r.p. per spacecraft	40.5 dBW

* The initial phase angle (ω_i) of the *i*-th satellite in its orbital plane at reference time $t = 0$, measured from the point of the ascending node ($0° \leq \omega_i < 360°$).

1.3 Point-to-point fixed service characteristics

The parameters for the fixed service stations were chosen consistent with those in Recommendation ITU-R F.758 and are given in Table 3.

TABLE 3

Point-to-point digital fixed service average parameters

Average path length	29.45 kilometres
Average e.i.r.p.	29.5 dBW
Average antenna gain	25 dBi Rec. ITU-R F.1245-1
3 dB beamwidth	9.1 degrees
Average antenna height	50.3 m
Elevation angle	0 degree
Carrier center frequency	2 491 MHz
Carrier bandwidth	14 MHz
System noise temperature	438 K
Feeder loss	4 dB

The terrain below the point-to-point path was assumed a flat surface. The propagation along the FS path conformed to Recommendations ITU-R P.525 and ITU-R P.530 with the propagation of the interference conforming to Recommendation ITU-R P.452.

2 Determination of interference levels into FS systems

2.1 Fixed service point-to-point interference simulation

Computer simulations, as shown in the Attachment below, were conducted using commercial software to evaluate the potential interference from the composite of RDSS and MSS downlinks into FS links using the parameters given above in Table 3. The MSS parameters used are those shown in Table 1 and the RDSS parameters are those shown in Table 2. The spacecraft antennas and power outputs were chosen so that the power flux-densities (pfds) produced at the surface of the Earth were identical to the coordination trigger pfd levels given in RR Appendix **5**. The locations of the fixed service stations selected for the simulations were in Nigeria. The simulation included the effects of the climate of the region and of multi-path fading.

The power for each MSS spacecraft was set to produce a downlink pfd in the 2 483.5-2 500 MHz frequency band of −124.5 dBW/m² MHz. Correspondingly, the power of each RDSS spacecraft was set to produce a pfd of −128 dBW/m² MHz.

The interference was computed at each 20 second time increment for a period of 10 days. The time interval between repetition of the ground tracks of the Galileo RDSS and HIBLEO-4/HIBLEO-X systems are 10 days and 2 days, respectively. The simulated time period thus included an integral numbers of ground track repetitions for both satellite systems. The analysis of interference was carried out on the basis of the FDP of the fixed service link.

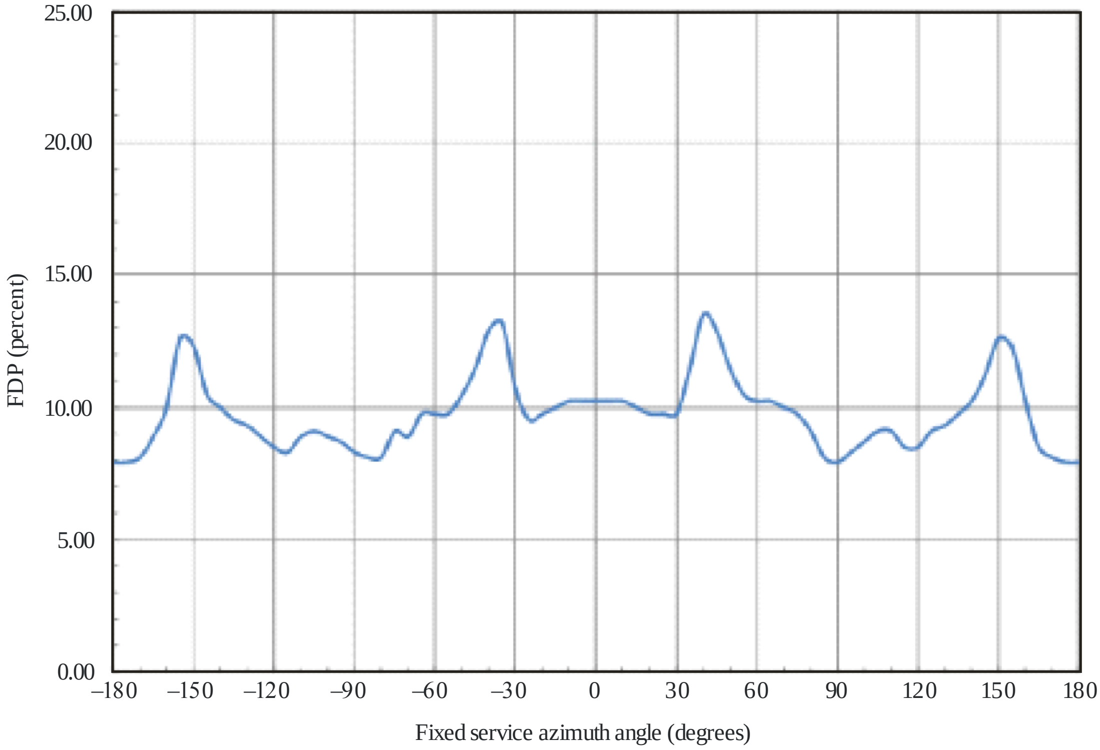
Attachment
to Annex 2

Simulation results

The results of the computer simulations are shown in Fig. 2 through Fig. 5. As discussed above, the simulation time used was sufficient to allow for the entire constellations of both satellite systems to interfere with the fixed service system. The interference caused to the fixed service link was determined at azimuth intervals of 5 degrees. The FDP was determined on the basis of an arithmetic average as opposed to an average of logarithmic values.

FIGURE 2

% FDP for simulated FS links in Nigeria
Due to interference from the composite emissions of RDSS and MSS systems



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The FDP for this link in Nigeria is always less than 14% which is well under the acceptable value of 25% for links within the 2 483.5-2 500 MHz frequency band.

Figure 3 shows the computer simulation results for a link in Senegal. The FDP for this link is always less than 22% within the 2 483.5-2 500 MHz frequency band.

FIGURE 3

% FDP for simulated FS links in Senegal
Due to interference from composite emissions of RDSS and MSS systems

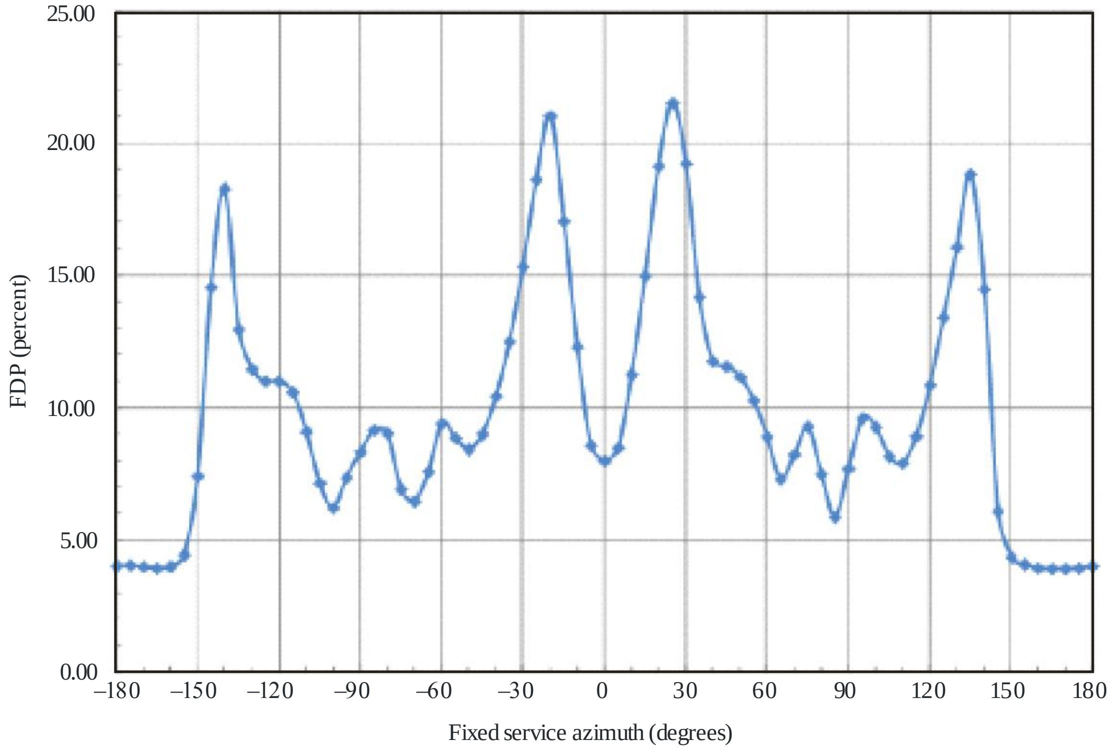

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Figure 4 shows the computer simulation results for a link in Kenya. The FDP for this link is always less than 19% within the 2 483.5-2 500 MHz frequency band.

FIGURE 4

% FDP for simulated FS links in Kenya
Due to interference from the composite emissions of RDSS and MSS systems

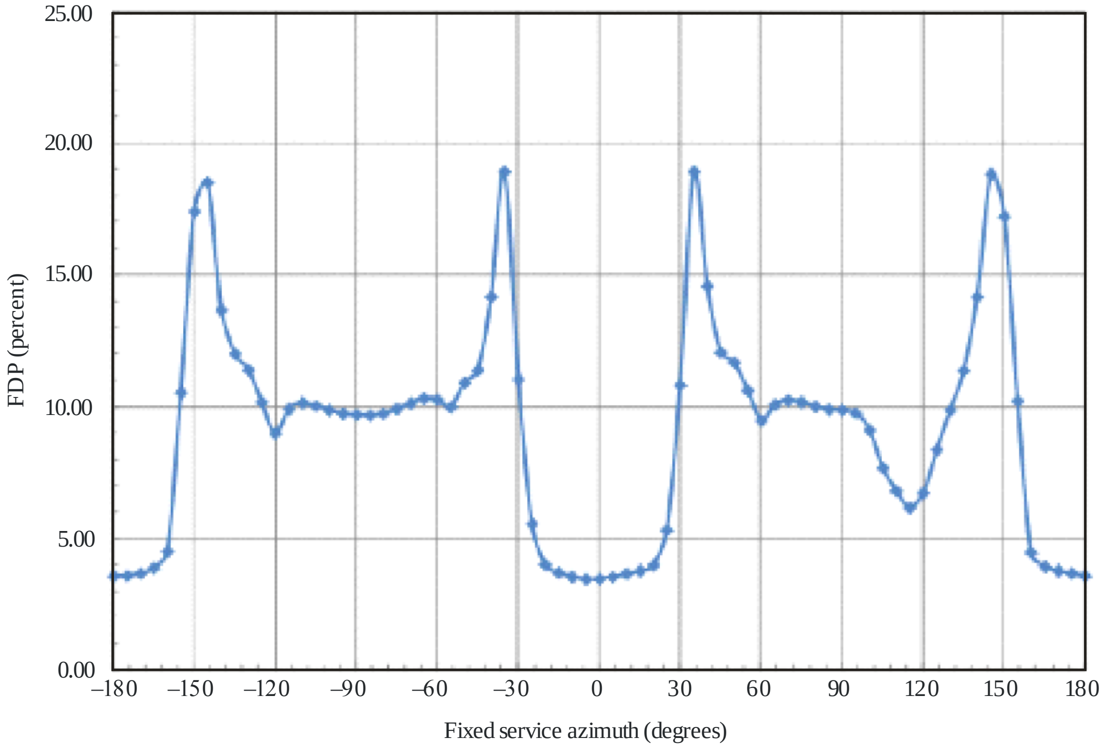

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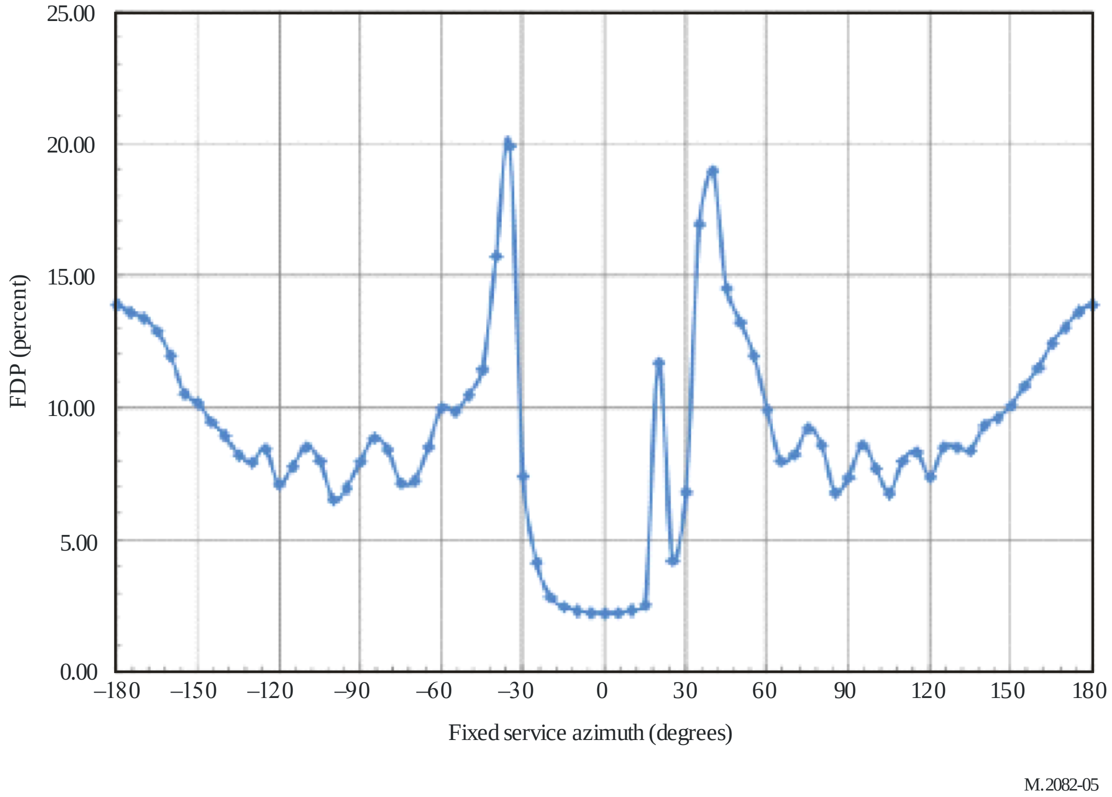
Figure 5 shows the computer simulation results for a link in South Africa. The FDP for this link is always less than 21% within the 2 483.5-2 500 MHz frequency band.

FIGURE 5

% FDP for simulated FS links in South Africa
Due to interference from the composite emissions of RDSS and MSS systems



Effect of fixed service antenna elevation

A second set of simulations was conducted that included the effects of having an antenna elevation angle of 0.5 degrees. The simulations produced for the previous section were repeated using a receive antenna elevation of 0.5 degrees. The results of those simulations are shown in Fig. 6 through Fig. 9.

FIGURE 6

% FDP for simulated FS links in Nigeria
Due to interference from the composite emissions of RDSS and MSS systems
Fixed service receive antenna elevation angle = 0.5 degrees

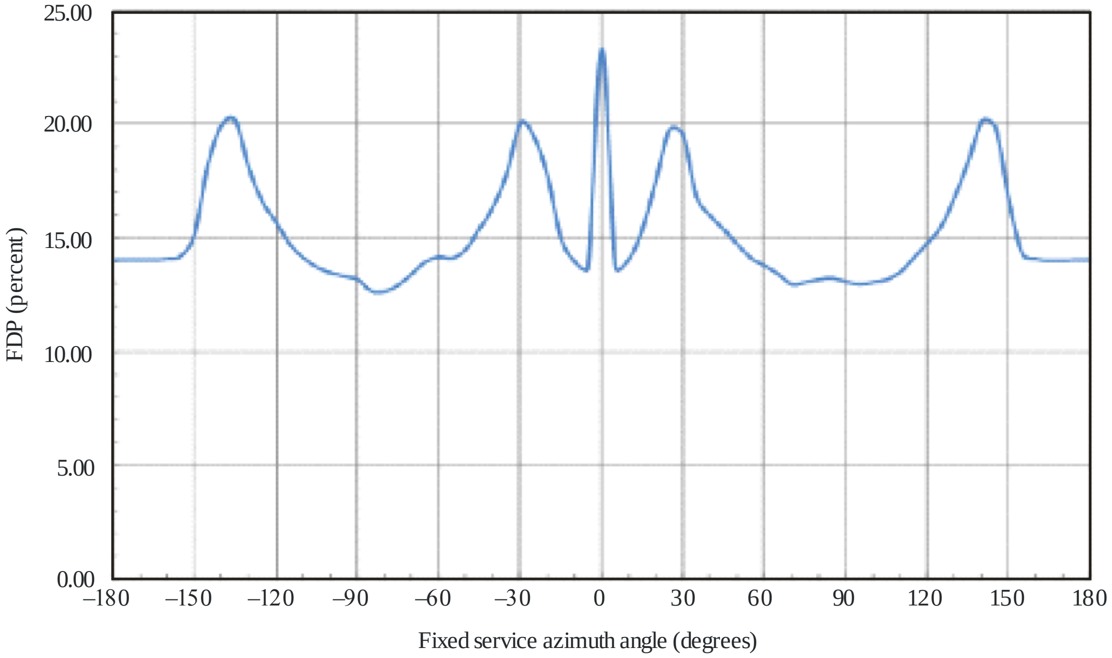


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FIGURE 7

% FDP for simulated FS links in Senegal
Due to interference from the composite emissions of RDSS and MSS systems
Fixed service receive antenna elevation angle = 0.5 degrees

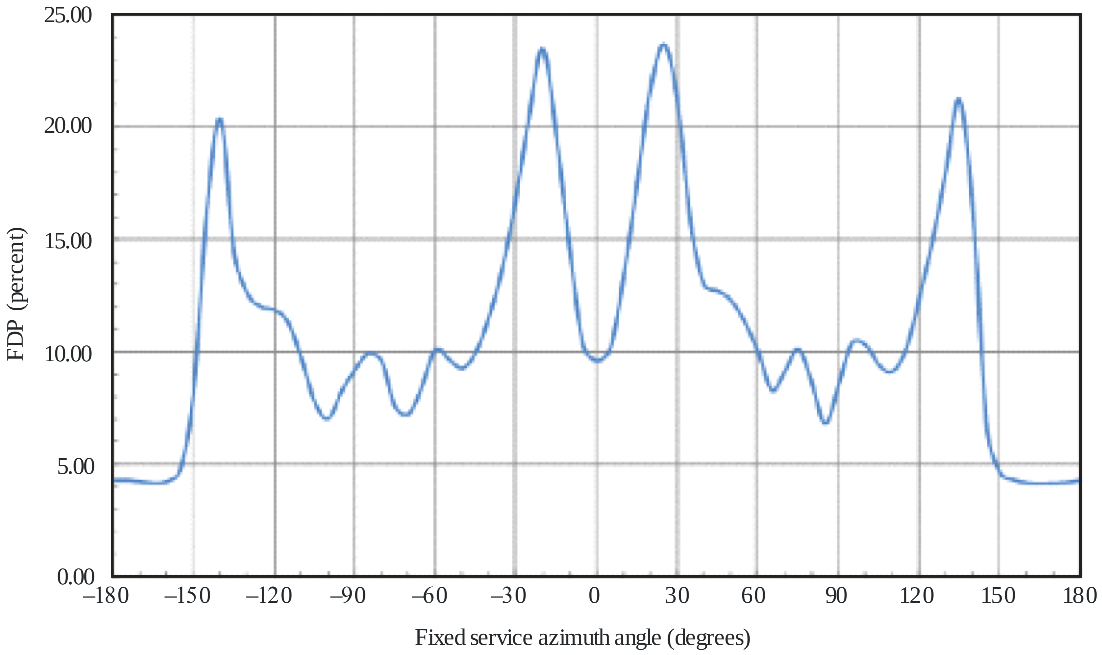

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FIGURE 8

% FDP for simulated FS links in Kenya
Due to interference from the composite emissions of RDSS and MSS systems
Fixed service receive antenna elevation angle = 0.5 degrees

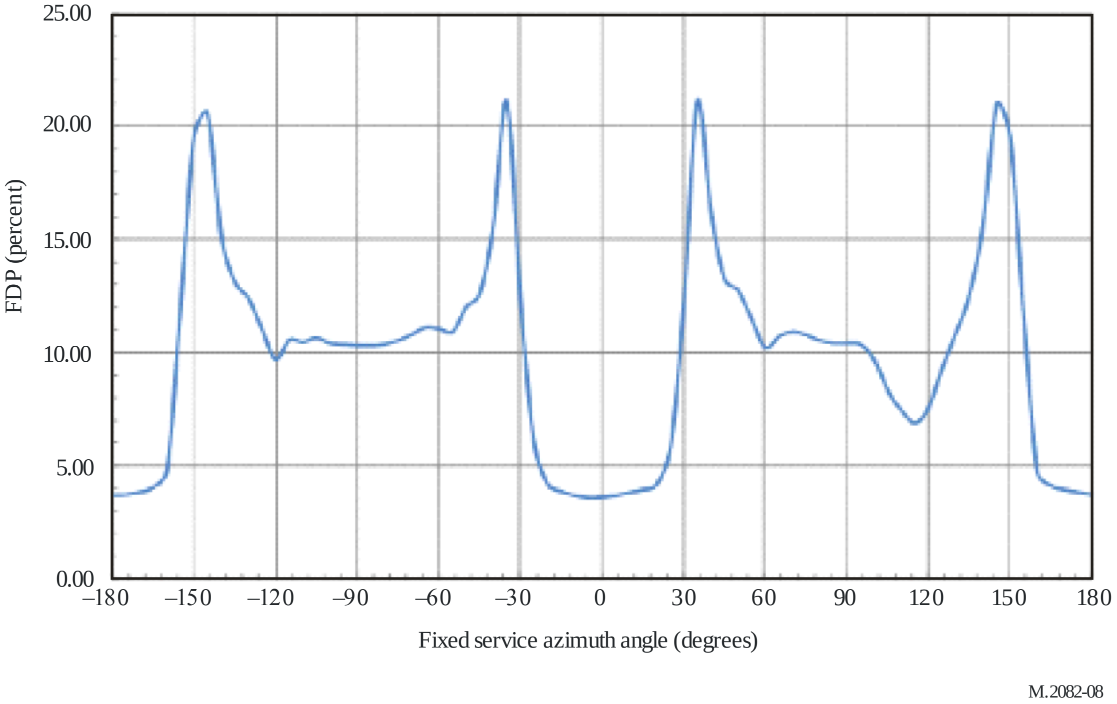

FIGURE 9

% FDP for simulated FS links in South Africa
Due to interference from the composite emissions of RDSS and MSS systems
Fixed service receive antenna elevation angle = 0.5 degrees