

RECOMMENDATION ITU-R M.1039-3

Co-frequency sharing between stations in the mobile service below 1 GHz and mobile earth stations of non-geostationary mobile-satellite systems (Earth-space) using frequency division multiple access (FDMA)

(Questions ITU-R 83/8, ITU-R 84/8 and ITU-R 201/8)

(1994-1997-2000-2006)

Scope

This Recommendation presents calculation methodologies to deal with the co-frequency sharing between stations in the mobile services below 1 GHz and mobile earth stations of non-geostationary mobile-satellite systems. A quick methodology to give an approximation of the interference is given as well as more precise calculations using detailed statistical methods.

The ITU Radiocommunication Assembly,

considering

- a) that the spectrum allocated by the World Radiocommunication Conferences WARC-92, WRC-95 and WRC-97 for low-Earth orbit (LEO) mobile-satellite services (MSS) below 1 GHz, if shared with mobile services, must provide adequate protection from harmful interference;
- b) that LEO MSS can provide beneficial radio-based services, including emergency alerting (see Note 1);

NOTE 1 – However, these services will not be identified as safety services as defined by the Radio Regulations.

- c) that the use of LEO enables practical use of frequencies below 1 GHz by space stations;
- d) that some coordination and channelization techniques used in fixed and mobile radio systems in bands below 1 GHz can lead to low Erlang loading on individual channels;
- e) that dynamic channel assignment techniques are technically feasible and may provide a means of spectrum sharing between mobile services and low power, low duty cycle MSS;
- f) that the non-GSO MSS users would operate throughout large geographic areas;
- g) that the transmission of the mobile earth station (MES) are short bursts;
- h) that the signal characteristics in the MSS below 1 GHz may allow co-channel sharing with mobile services;
- j) that there is a need to determine MSS and MS sharing possibilities while considering the impact of MS transmissions into MSS satellite receivers;
- k) that statistical modelling techniques can estimate the probability of interference to the MS from the MSS,

further considering

- a) that, in many countries, the allocations to the mobile services are extensively used, and in some cases with periods of high traffic loading;

b) that a propagation model using scattering model for VHF band is provided by Recommendation ITU-R P.1546,

noting

- a) that additional studies are required to determine whether the statistical models are fully applicable to maritime and aeronautical mobile services;
- b) that the distribution of MES users may be concentrated into a specific area within the footprint of one satellite, taking into consideration geographical restriction;
- c) that Recommendation ITU-R M.1184 provides technical characteristics of non-GSO MSS networks below 1 GHz that are considered appropriate for modelling and analysing sharing and potential interference between MES and stations in the mobile services,

recommends

- 1 that the analytic methodology described in Annex 1 can be used to provide a first approximation to the interference probability from non-GSO MSS MES to land mobile stations (LMS) generally in the same frequency band;
- 2 that a more precise calculation of the interference probability can be performed using the detailed statistical methods of either Annex 2 or Annex 3 to evaluate sharing between stations in the mobile services and FDMA non-GSO MES with primary allocations (Earth-to-space) in the same frequency band below 1 GHz;
- 3 that types of dynamic channel assignment techniques such as that described in Annex 4 could be used by non-GSO MSS systems (narrow-band) operating in MSS allocations below 1 GHz in bands to promote compatibility with terrestrial services.

Annex 1

An analytical methodology for calculating interference probability from non-GSO MSS earth station to LMS operating below 1 GHz

1 Introduction

This Annex describes an analytical methodology for calculating interference probability, considering potential interference from MES to base stations of the existing LMS station, and using a propagation model derived from the latest version of Recommendation ITU-R P.1546 (previously ITU-R P.370).

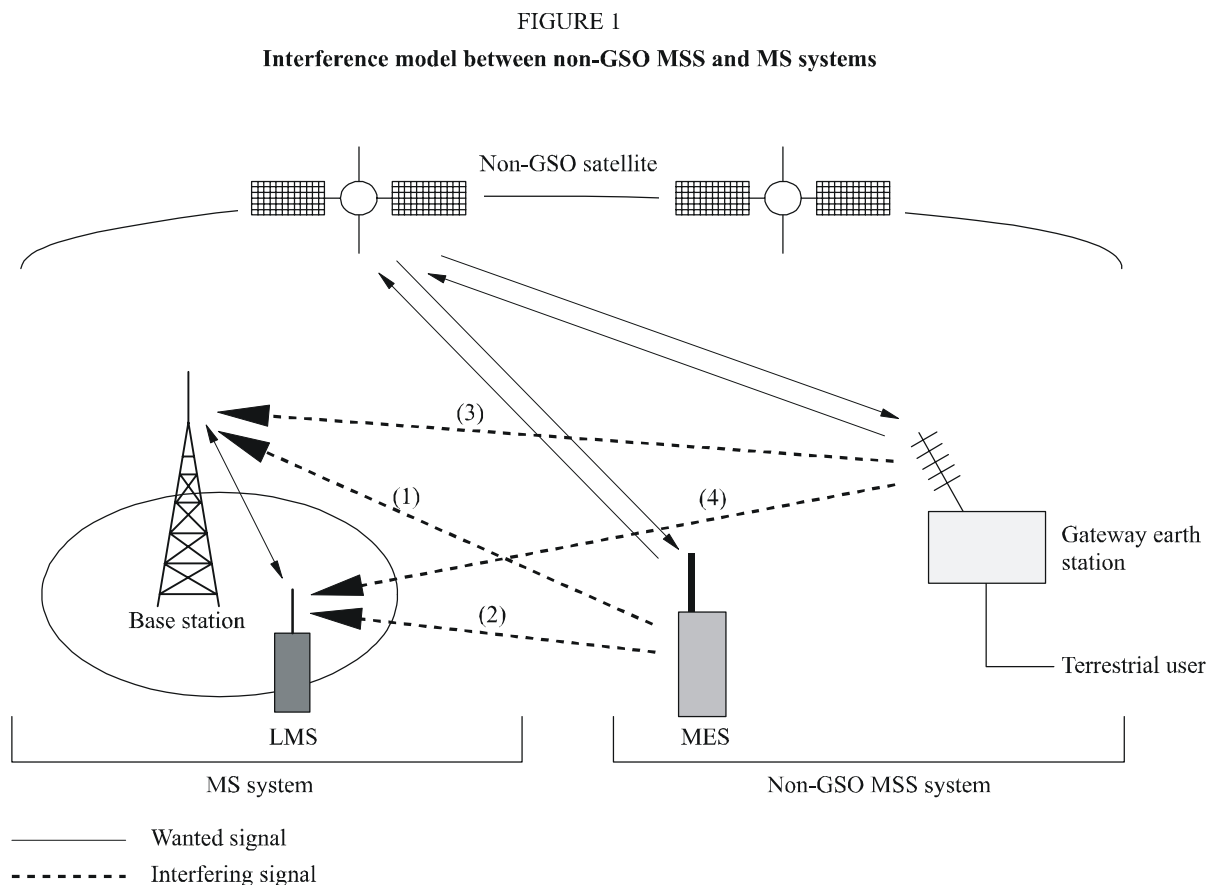
The proposed method may be used to evaluate the interference probability easily, and applies to any non-GSO MSS systems using FDMA. The employment of this method could facilitate the frequency sharing analysis between non-GSO MSS systems and the existing MS systems below 1 GHz.

2 Interference model between non-GSO MSS system and land mobile communications system

The frequency band 148-149.9 MHz allocated for Earth-to-space direction in the non-GSO MSS system is used as forward and return links in the land mobile communications systems. The operation of non-GSO MSS system in the frequency band 148-149.9 MHz could give rise to the following four interference cases between these two systems, as shown in Fig. 1:

- (1) interference from MES of non-GSO MSS system to base station of the existing MS system;
- (2) interference from MES to LMS of the existing MS system;
- (3) interference from gateway earth station of non-GSO MSS system to base station;
- (4) interference from gateway earth station to LMS.

Among these four interference cases, (1) and (2) are the interference paths from MES to the existing MS systems.



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This Annex describes the methodology for evaluating the interference probability in the interference paths (1) and (2).

For the interference paths (1) and (2), it is necessary to make an assessment of the existing systems in both of the following operation modes:

- the communications mode,
- the waiting mode.

The waiting mode is the case that no information is being exchanged between two stations, but the MS receivers are turned on to accommodate any call or information. When the MS system is in the waiting mode, the receiver, except for the receivers with use of tone squelch techniques, will have a squelch break during burst length $+\alpha$ (max. 450 ms $+\alpha$, for example) emitted by MES with the interference probability mentioned hereunder.

The following presents the methodology for evaluating the interference probability occurring in the interference paths (1) and (2) as shown in Fig. 1, where the existing systems are both in the communications and waiting modes.

3 Propagation loss between MES and base station of MS system

Amongst the ITU-R texts, Recommendation ITU-R P.1546 describes the propagation loss in the VHF band from the antennas at high altitude. This Recommendation shows the experiments' results of the field strength of TV signals in the VHF band at the receiving station at d km away. The results are shown for various heights of antennas. For the above reasons, the propagation loss, required for obtaining the interference coordination distance between MES and the base station, is evaluated in this model on the basis of Recommendation ITU-R P.1546. Figure 2 shows the VHF propagation loss to the propagation distance for the various antenna heights obtained from the latest version of Recommendation ITU-R P.1546 (previously ITU-R P.370). In the computation of propagation loss shown in Fig. 2, 10% of the time values are used. For other frequency bands, Fig. 2 would need to be recalculated.

4 System parameters

Figure 3 shows the interference model from the MES to the base station and to the LMS of the existing MS system. The system parameters of the base station, LMS and MES used in the following consideration are summarized below. Suffix i indicates interfering system, w is interfered system, t is transmitter, and r is receiver. Also, b and m indicate base station and LMS, respectively.

4.1 MES parameter (interfering station):

- Transmission side
 - Transmission power: P_{it} (dBm)
 - Transmission antenna gain: G_{it} (dB)
 - MES antenna height: h_i (m)

4.2 Base station parameter (interfered station)

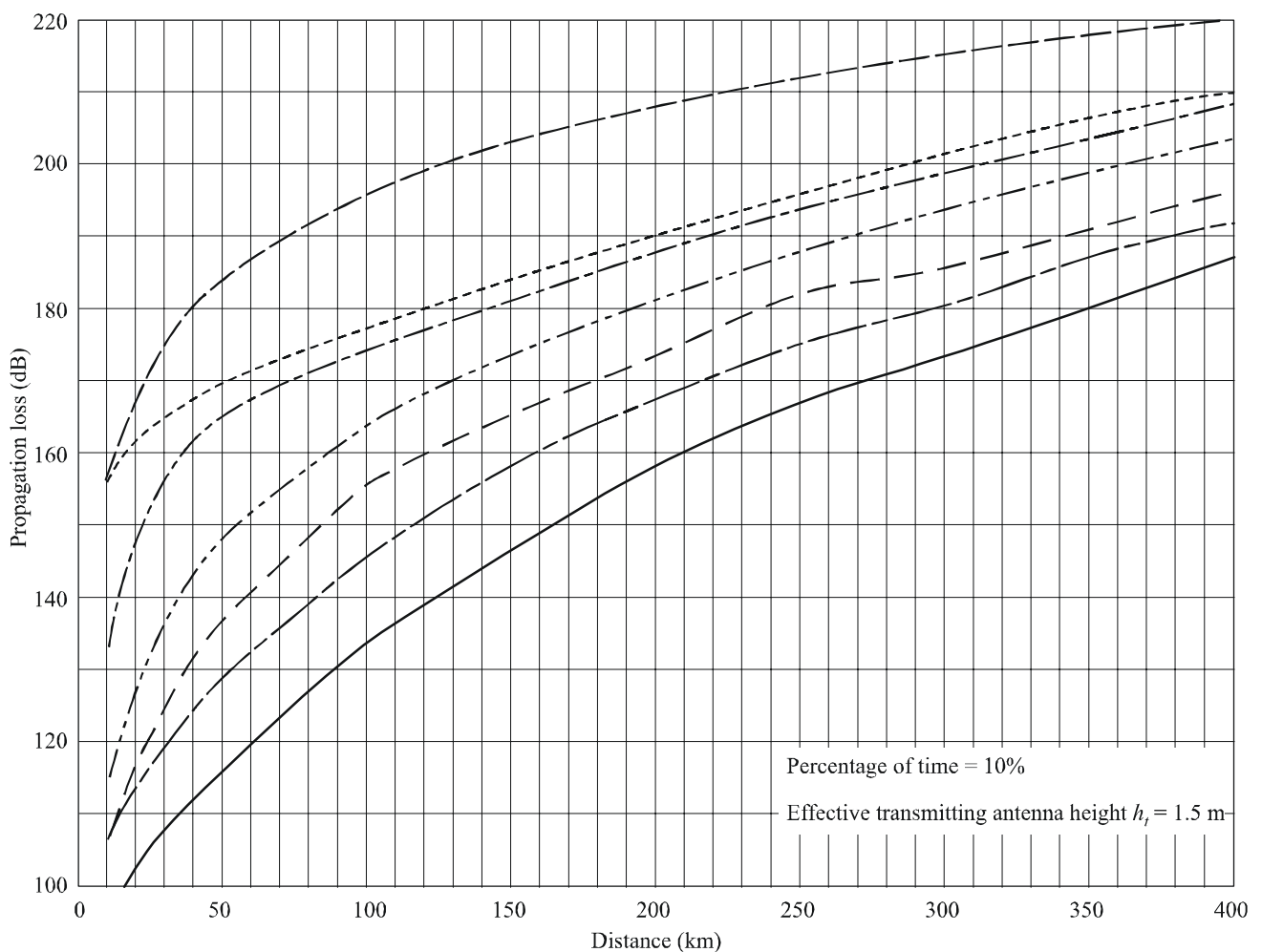
- Transmission side
 - Transmission power: P_{bwt} (dBm)
 - Transmission antenna gain: G_{bwt} (dB)
 - Transmission feeder loss: L_{bwt} (dB)
 - Base station antenna height: h_{bw} (m)

Receiver side

- Receiving antenna gain: G_{bwr} (dB)
- Receiving feeder loss: L_{bwr} (dB)
- Base station antenna height: h_{bw} (m)
- Receiver sensitivity: C_b (dBm)
- Required C/I : $(C/I)_{br}$ (dB)
- Permissible interference level: I_b (dBm)
- Squelch sensitivity: P_{bsd} (dBm).

FIGURE 2

Propagation loss in the VHF band (based on Recommendation ITU-R P.370)



— — — Recommendation ITU-R P.529
($h_t \times h_r$) = (1.5 m $\times$ 1.5 m)

----- Effective receiving antenna
height $h_r = 1.5$ m

----- Effective receiving antenna
height, $h_r = 37.5$ m

----- Effective receiving antenna height, $h_r = 300$ m

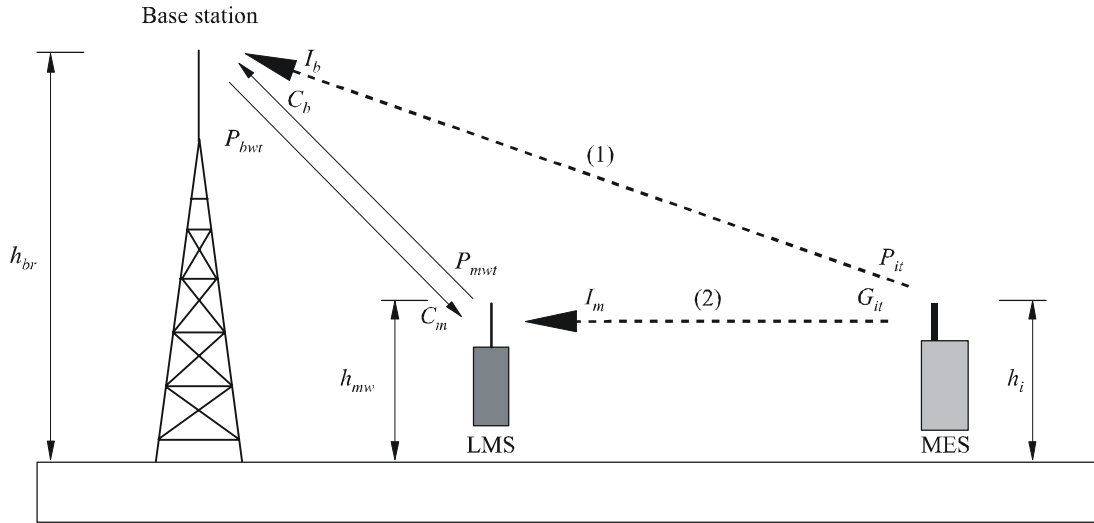
----- Effective receiving antenna height, $h_r = 500$ m

----- Effective receiving antenna height, $h_r = 1\,000$ m

----- Effective receiving antenna height, $h_r = 2\,000$ m

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FIGURE 3
Interference model between MES and existing MS system



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4.3 LMS parameter (interfered station)

- Transmission side
 - Transmission power: P_{mwt} (dBm)
 - Transmission antenna gain: G_{mwt} (dB)
 - LMS antenna height: h_{mw} (m)
- Receiver side
 - Receiving antenna gain: G_{mwr} (dB)
 - LMS antenna height: h_{mw} (m)
 - Receiver sensitivity: C_m (dBm)
 - Required C/I : $(C/I)_{mr}$ (dB)
 - Permissible interference level: I_m (dBm)
 - Squelch sensitivity: P_{msd} (dBm).

5 Computation of the interference coordination distance when the existing MS system is in the communications mode

5.1 Interference from MES to base station (path (1) in Fig. 3)

It is assumed that d_1 is the maximum distance between the base station and LMS that the transmitted signal from LMS can be received with the necessary S/N at the base station. This d_1 is equivalent to the radius of the service area of the existing MS system, namely, the circle with a radius of d_1 surrounding the base station represents the service area for the MS system. Under the assumptions above, and the sensitivity of the base station receiver being assumed as C_b , equation (1) is obtained:

$$C_b = P_{mwt} + G_{mwt} - L(d_1) + G_{bwr} - L_{bwr} \quad (1)$$

where:

- P_{mwt} : LMS transmission power
- G_{mwt} : LMS transmission antenna gain
- $L(d_1)$: propagation loss along the distance of d_1 between the base station and LMS
- G_{bwr} : base station receiving antenna gain
- L_{bwr} : base station receiving feeder loss.

From equation (1), propagation loss between the base station and LMS is expressed by equation (2) and the propagation distance, d_1 , can be obtained by using Fig. 2:

$$L(d_1) = P_{mwt} + G_{mwt} + G_{bwr} - L_{bwr} - C_b \quad (2)$$

The required $(C/I)_{br}$ at the base station can be given by equation (3):

$$(C/I)_{br} = C_b - I_b \quad (3)$$

where:

- $(C/I)_{br}$: ratio of the required desired signal power to the interference signal power at base station
- C_b : sensitivity of the base station receiver
- I_b : permissible interference power from MES.

From equation (3), the permissible interference power level is expressed by equation (4):

$$I_b = C_b - (C/I)_{br} \quad (4)$$

Assuming that more than one non-GSO MSS system is operated in the same band, the permissible interference power level given in equation (4) will be shared by these non-GSO MSS systems. In the case of multiple non-GSO MSS systems operating in the same frequency band, equation (5) should substitute for equation (4):

$$I_b = C_b - (C/I)_{br} - \alpha \quad (5)$$

where α is the correction factor for the case of multiple operations of non-GSO MSS systems with use of the same frequency band. If each non-GSO MSS system could use the dedicated frequency band by using the band segmentation method, the permissible interference power level for each system can be given by equation (4).

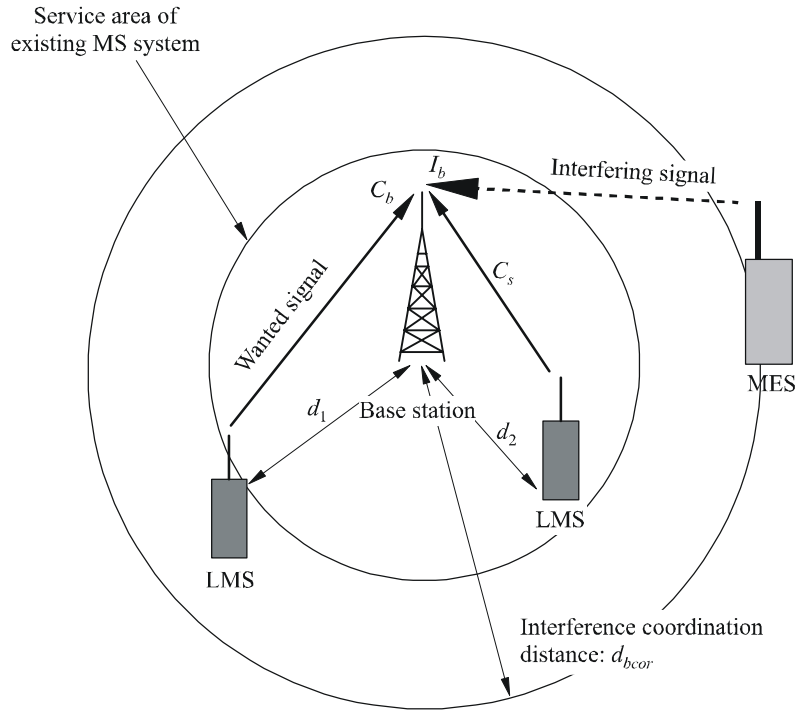
When the base station and MES are apart by the interference coordination distance, d_{bcor} , the interference signal power from MES would be received by the base station as the permissible interference power level, I_b . Therefore, equation (6) can be obtained. This relationship is shown in Fig. 4.

$$I_b = P_{it} + G_{it} - L(d_{bcor}) + G_{bwr} - L_{bwr} - I_{so} \quad (6)$$

where I_{so} represent the isolation in the case that the non-GSO MSS system adopts those channels interstitial between the existing system channels. Annex 2 shows the computer simulation results on the improvement of the adjacent channel isolation level in the interstitial channelling.

FIGURE 4

**Interference coordination distance for base station
in the communications mode**



$$C_b/I_b = (C/I)_{br}$$

$$C_s/I_b > (C/I)_{br}$$

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From equations (4) and (6), when the base station and MES are apart by the interference coordination distance, d_{bcor} , the propagation loss, $L(d_{bcor})$ is expressed by equation (7):

$$\begin{aligned} L(d_{bcor}) &= P_{it} + G_{it} + G_{bwr} - L_{bwr} - I_{so} - I_b \\ &= P_{it} + G_{it} + G_{bwr} - L_{bwr} - I_{so} - C_b + (C/I)_{br} \end{aligned} \quad (7)$$

From equation (7) and Fig. 2, d_{bcor} can be obtained which represents the interference coordination distance between the base station and MES when LMS of the existing system is communicating at the edge of the service area. In other words, it is assumed that all LMSs are operating at the edge of the service area. It is obviously understood from Fig. 4 that those LMSs nearer to the base station can secure higher S/N .

5.2 Interference from MES to LMS (path (2) in Fig. 3)

It is assumed that d_2 is the maximum distance between the base station and LMS and that the transmitted signal from the base station can be received with the necessary S/N at LMS. This d_2 is equivalent to the maximum distance for LMS to receive the signals from the base station with the necessary S/N .

Under the assumption above and the sensitivity of the LMS receiver being assumed as C_m , equation (8) can be obtained:

$$C_m = P_{bwt} + G_{bwt} - L_{bwt} - L(d_2) + G_{mwr} \quad (8)$$

where:

P_{bwt} : base station transmission power

G_{bwt} : base station transmission antenna gain

- L_{bwt} : base station transmission feeder loss
 $L(d_2)$: propagation loss in the distance d_2 between the base station and LMS
 G_{mwr} : LMS receiving antenna gain.

From equation (8), the propagation loss between the base station and LMS can be expressed by equation (9):

$$L(d_2) = P_{bwt} + G_{bwt} - L_{bwt} + G_{mwr} - C_m \quad (9)$$

where:

- $(C/I)_{mr}$: ratio of the required desired signal power to the interference signal power at LMS
 C_m : LMS receiver sensitivity
 I_m : permissible interference power.

This is expressed by equation (10):

$$(C/I)_{mr} = C_m - I_m \quad (10)$$

From equation (10), the permissible interference level, I_m , can be expressed by equation (11):

$$I_m = C_m - (C/I)_{mr} \quad (11)$$

In the case that more than one non-GSO MSS system is operated in the same band, the same correction factor defined in equation (5) is required to obtain the permissible interference power level for each non-GSO MSS system.

If LMS and MES are apart by the interference coordination distance, d_{mcor} , the interference power from MES would be received by LMS as permissible interference power, I_m , as shown in Fig. 5. This can be expressed by equation (12):

$$I_m = P_{it} + G_{it} - L(d_{mcor}) + G_{mwr} - I_{so} \quad (12)$$

From equations (11) and (12), $L(d_{mcor})$, the propagation loss of the interference coordination distance, d_{mcor} , can be expressed by equation (13):

$$\begin{aligned} L(d_{mcor}) &= P_{it} + G_{it} + G_{mwr} - I_{so} - I_m \\ &= P_{it} + G_{it} + G_{mwr} - I_{so} - C_m + (C/I)_{mr} \end{aligned} \quad (13)$$

From equation (13) and Fig. 2, d_{mcor} can be obtained which represents the interference coordination distance between LMS and MES. This coordination distance corresponds that LMS is communicating at the edge of the service area of the existing system. This assumption allows those LMS nearer to the base station to enjoy higher S/N , as illustrated in Fig. 5.

6 Computation of the interference coordination distance when the existing MS system is in the waiting mode

6.1 Interference from MES to base station (path (1) in Fig. 3)

As illustrated in Fig. 6, it is assumed that the base station would receive the interference power equal to its squelch sensitivity when MES emits at a distance, d_{bi} , from the base station. In this case, the distance, d_{bi} , represents the interference coordination distance between MES and the base station in the waiting mode. Where P_{bsd} is base station squelch sensitivity, equation (14) can be obtained:

$$P_{bsd} = P_{it} + G_{it} - L(d_{bi}) + G_{bwr} - L_{bwr} - I_{so} \quad (14)$$

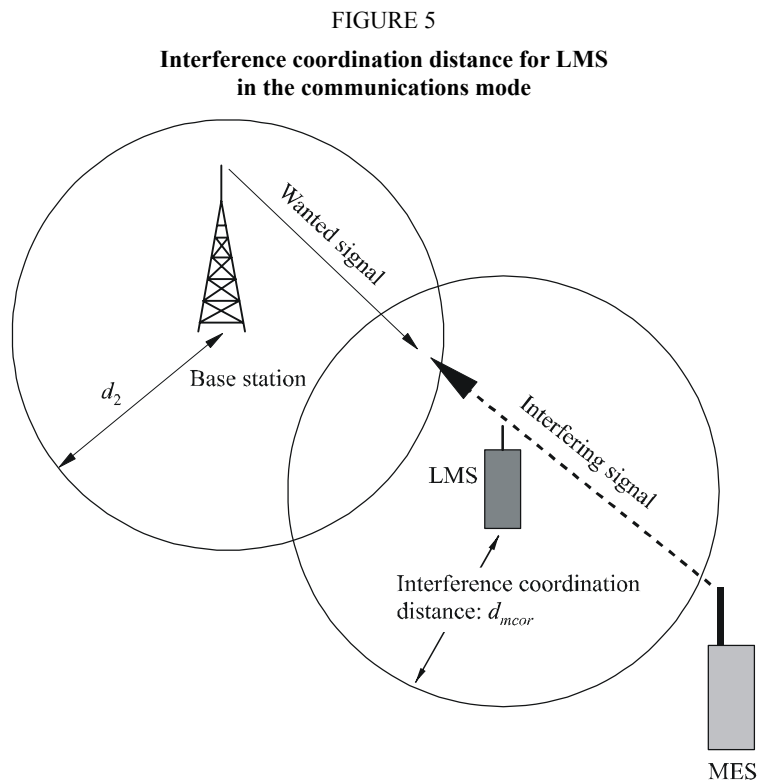
$L(d_{bi})$ is the distance between the base station and MES that makes the base station receive the interference power equal to its squelch sensitivity. From equation (14) and Fig. 2, the interference coordination distance, d_{bi} , can be obtained.

6.2 Interference from MES to LMS (path (2) in Fig. 3)

As illustrated in Fig. 7, it is assumed that LMS would receive the interference power equal to its squelch sensitivity when MES emits at a distance, d_{mi} , from LMS. In this case, the distance, d_{mi} , represents the interference coordination distance between MES and LMS in the waiting mode. Where P_{msd} is MS squelch sensitivity, equation (15) can be obtained:

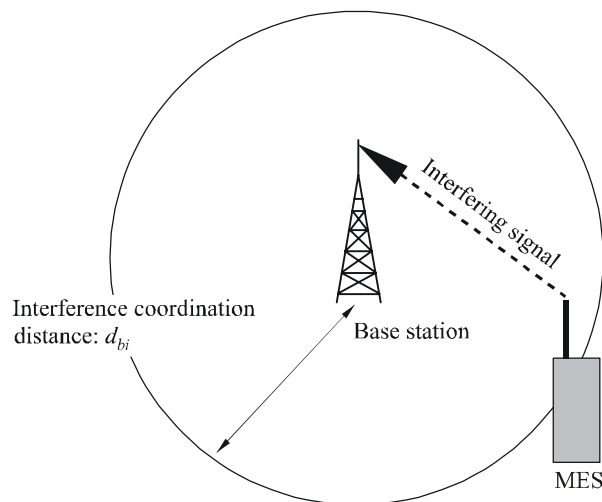
$$P_{msd} = P_{it} + G_{it} - L(d_{mi}) + G_{mwr} - L_{mwr} - I_{so} \quad (15)$$

$L(d_{mi})$ is the distance between LMS and MES that makes LMS receive the interference power equal to its squelch sensitivity. From equation (15) and Fig. 2, the interference coordination distance, d_{mi} , can be obtained.



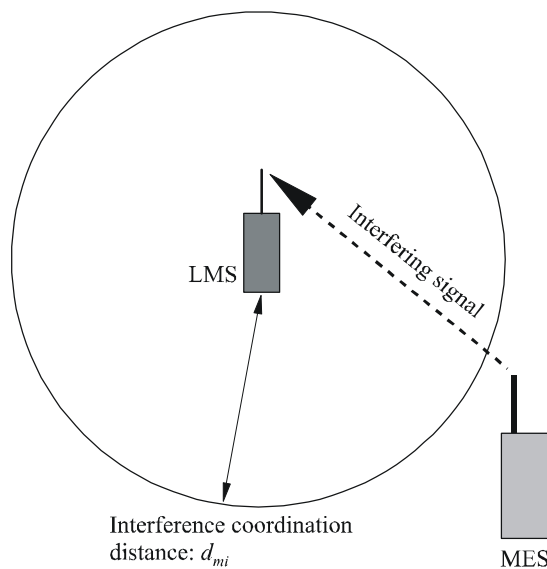
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FIGURE 6
Interference coordination distance for
base station in the waiting mode



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FIGURE 7
Interference coordination distance for LMS
in the waiting mode



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7 Evaluation of interference probability

In the previous sections, the methods are presented to evaluate the interference coordination distances for two potential interference paths between MES and the base station, and between MES and LMS, when the existing systems are in the communications mode and in the waiting mode, respectively. This section proposes the method for obtaining the probability of interference.

7.1 Probability of co-channel transmission of MS system and MES

Let P_I be the probability that a channel used by MS system has co-channel interference from an MES. P_I is evaluated by:

$$P_I = \sum_{i=0}^m (P(\text{Interference into MS} | i \text{ channels active}) \times P(i \text{ channels active})) \quad (16)$$

where $P(i \text{ channels active})$ indicates the probability that i channels are occupied by active MESs of the satellite system, and m is the maximum number of simultaneous operable channels for one non-GSO satellite. The worst-case evaluation of P_I can be made for the following conditions:

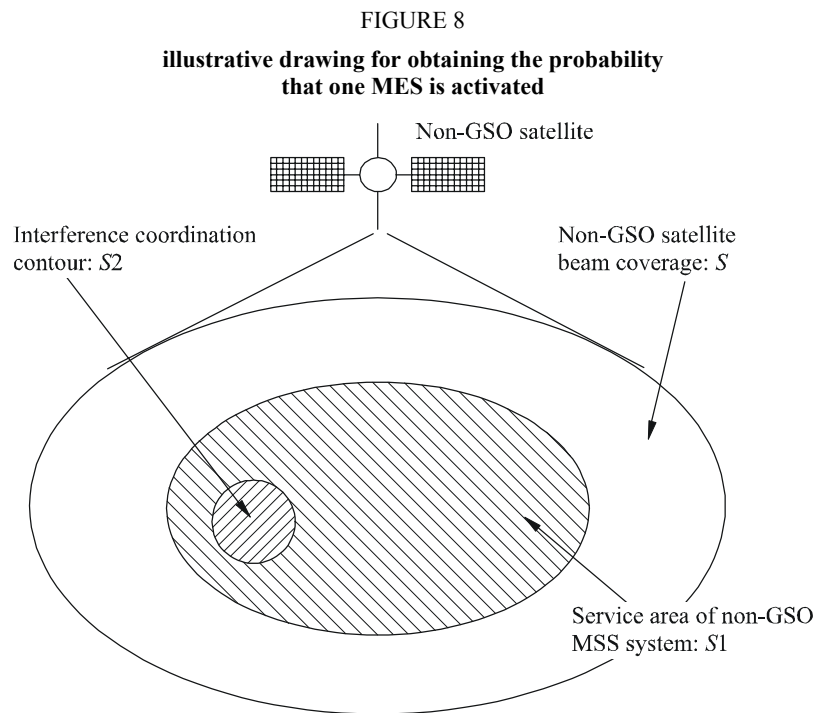
$$P(m \text{ channels active}) = 1$$

$$P(i \text{ channels active}) = 0 \quad (i \neq m)$$

Under the assumption that MESs are uniformly distributed in the area of MSS coverage, the maximum number of simultaneous operable channels for one non-GSO satellite is given by equation (17):

$$m(S2) = m \times \frac{S2}{S1} \quad (17)$$

where $S1$ shows the service coverage of MSS systems, and $S2$ shows the interference coordination contour with a radius equal to the interference coordination distance. Figure 8 shows the relationship between the area of $S1$ and $S2$.



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This is because $P(\text{Interference into MS} | i \text{ channels active})$ is largest when $i = m(S2)$. Therefore P_I at the worst case becomes:

$$P_I = P(\text{Interference into MS} | m(S2) \text{ channels active}) \quad (18)$$

If this assumption is too pessimistic, a factor η_L can be multiplied to take account of the percentage of time that the non-GSO MSS system is in use, i.e.:

$$P_I = P(\text{Interference into MS} | m(S2) \text{ channels active}) \times \eta_L \quad (19)$$

When assuming that the maximum number of available channels for non-GSO MSS system is M , the probability that one channel selected by MES out of $m(S2)$ channels would cause interference to the MS system using the same channel, η_c is given by equation (20):

$$\eta_c = \frac{m(S2)}{M} \times \gamma \quad (20)$$

where γ is the correction factor for the probability of MES channel selection. Since the activity of M channels is not often uniformly assigned due to the operation of dynamic channel activity assignment system (DCAAS), the maximum number of available channels would be considered with the correction factor.

By using equations (17) and (19), the probability, P_I , given in equation (18) can be obtained by equation (21):

$$\begin{aligned} P_I &= \eta_c \times \eta_L \\ &= \frac{m(S2)}{M} \times \gamma \times \eta_L = \frac{m}{M} \times \gamma \times \frac{S2}{S1} \times \eta_L \end{aligned} \quad (21)$$

In equation (21), the area of $S2$ can be obtained by using the interference coordination distance which is given by equations (7), (13), (14) and (15).

When the base station or LMS of the existing MS system is in the communications mode, the probability, P_I , can be given by equations (22) and (23), respectively:

Base station of MS system is in the communications mode

$$P_{bc} = \left(\frac{m}{M} \right) \times \gamma \times \eta_L \times \pi \times \frac{(d_{bcor})^2}{S1} \quad (22)$$

LMS of MS system is in the communications mode

$$P_{mc} = \left(\frac{m}{M} \right) \times \gamma \times \eta_L \times \pi \times \frac{(d_{mcor})^2}{S1} \quad (23)$$

When the base station or LMS of the existing MS system is in the waiting mode, the probability P_I can be given by equations (24) and (25), respectively.

Base station of MS system is in the waiting mode

$$P_{bw} = \left(\frac{m}{M} \right) \times \gamma \times \eta_L \times \pi \times \frac{(d_{bi})^2}{S1} \quad (24)$$

LMS of MS system is in the waiting mode

$$P_{mw} = \left(\frac{m}{M} \right) \times \gamma \times \eta_L \times \pi \times \frac{(d_{mi})^2}{S1} \quad (25)$$

7.2 Other parameters to be considered

For the evaluation of interference probability from MES to the existing system either in the communication mode or waiting mode, it is necessary to take the following parameters into consideration in addition to the probabilities, that a channel used by MS system has co-channel interference from a MES.

Parameter 1: Percentage of time that the existing system is in the communications mode

The percentage of time that the existing system is in the communications mode is assumed to be η_m . In practice, the existing system is usually operated in the one-way mode by using the press talk type terminal. In this case, the percentage of time for each direction of channel in communicating is 1/2 of η_m .

Parameter 2: Probability that DCAAS fails to detect the active channel used by the existing system

The DCAAS on-board satellite has a capability to detect all channels being used by the existing system; however, there might be a blockage between LMS and the satellite that disables the DCAAS to detect the signals transmitted from LMS. Taking into account this fact, the probability that DCAAS fails to detect the active channel being used by the existing system is assumed to be η_D .

Parameter 3: Satellite visibility factor in the case of multiple gateway earth stations

If more than one gateway earth station is installed in an area, the number of satellites increases so that MESs can access simultaneously, and the interference probability to the existing system also increases. η_G is assumed as the ratio of available number of channels with multiple gateway earth stations to a single gateway earth station.

Parameter 4: Number of interfering signals within the occupied bandwidth of the MS carrier

If the occupied bandwidth for the non-GSO MSS carrier is narrower than that for the MS carrier, a multiple interfering carrier would be observed in the wanted MS carrier occupied bandwidth. Under the assumption described above, the additional interference power level given by equation (26) might be considered in the calculation of C/I :

$$I = 10 \log \left(\frac{B_w}{B_i} \right) \quad (26)$$

where B_w and B_i are the occupied bandwidths for the MS carrier and MES carrier, respectively. Under the condition that non-GSO systems shall not assign more than one channel in each frequency grid allocated for the existing system, it is unnecessary to consider the additional interference power level given by equation (26).

Among the above-mentioned parameters, parameters 1 to 4 are required for the evaluation of interference probability when the existing system is in the communication mode, and parameters 3 and 4 are required for the evaluation of interference probability when the existing system is in the waiting mode.

7.3 Overall of interference probability

On the basis of what is presented in the above sections, the interference probability, P_t , for two potential interference paths from MES to the base station, and MES to LMS, both in the communications mode and in the waiting mode, are given by the following equations:

– Existing MS system is in the communications mode

$$P_t \text{ (base station)} = P_{bc} \times \eta_D \times \eta_G \quad (27)$$

$$P_t \text{ (LMS)} = P_{mc} \times \eta_D \times \eta_G \quad (28)$$

It should be noted that the percentage of time of interference can be calculated by multiplying P_t by the factor η_m .