Coexistence of Earth Station of the Fixed-Satellite Service with the Terrestrial Fixed Wireless System in 8 GHz Band

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***Abstract*—This paper presents evaluation results of coexistence between earth station of the fixed-satellite service and terrestrial fixed wireless system in 8 GHz band. The evaluation has been made based on a methodology and system characteristics assumed for analysis on frequency sharing basis. The result could be useful when new frequency allocation to the fixed-satellite service is considered in the frequency band to which the terrestrial fixed service is already allocated.**

Keywords-fixed-satellite; earth station; terrestrial fixed wiereless system; interference; coexistence

I. INTRODUCTION

Fixed-satellite service (FSS) is the official classification for communications using geostationary satellites that provide broadcast feeds to television stations, radio stations and broadcast networks. FSSs also transmit information for telephony, telecommunications and data communications [1].

In order to deploy a satellite network providing various services in a wide area as mentioned above, spectrum and orbit resources are essential. Since they are limited natural resources [2], it is very important to use them efficiently and economically.

The frequency bands 7.25-7.75 GHz and 7.9-8.4 GHz are allocated worldwide to the FSS in the direction of space-to-Earth and Earth-to-space, respectively. These bands or parts of them are also allocated worldwide to other services such as the fixed and mobile services, the meteorological-satellite service and the Earth exploration-satellite service (space-to-Earth). These bands have been generally used for military or satellite imagery. At World Radiocommunication Conference held in 2012 (WRC-12), some countries reported a shortfall of spectrum available for their current and future applications in these bands. The additional bandwidth requirements for data transmission on these next-generation satellites were estimated around a maximum of 100 MHz. To meet the requiremets, it was decided that WRC-15 should consider possible new allocations to the FSS in the frequency bands 7.15-7.25 GHz (space-to-Earth) and 8.4-8.5 GHz (Earth-to-space). When considering any additional possible frequency allocations to any space services, compatibility studies to ensure adequate protection of terrestrial services as in [3].

This paper presents the possibility of coexistence between earth station of the FSS and terrestrial fixed wireless system (FWS) in the band 8.4-8.5 GHz. The evaluation has been made based on a methodology and system characteristics assumed for analysis on frequency sharing basis as presented in Section II. Section III analyzes the coexistence of the FSS earth station with the FWS based on the results of interference calculation. Finally, we provide our conclusion form the study results.

II. METHODOLOGY AND SYSTEM CHARACTERISTICS

A. Interference Scenario and Methodology

Fig.1 shows the interference scenario considered in the study.

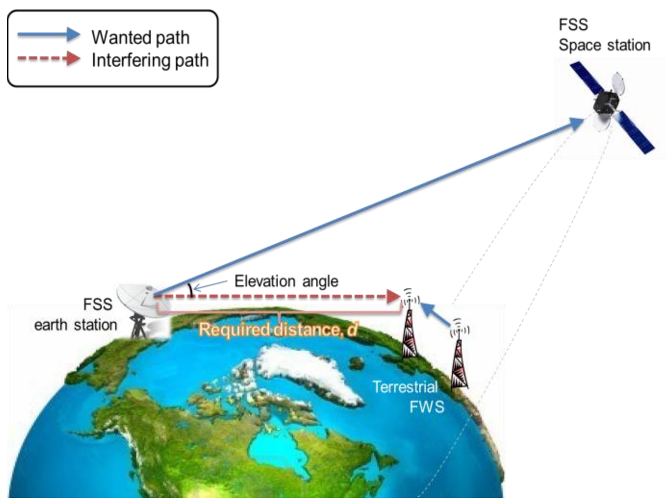

Figure 1. Interference scenario

The received interference power density at the receiver of the FWS is calculated using (1).

$$P_r = P_t + G_t(\theta_t) - L_b(p\%) + G_r(\theta_r) \quad (1)$$

where:

- P_t : Transmitter power density of FSS earth station (dBW/MHz);
- $G_t(\theta_t)$: Antenna gain of FSS earth station towards FWS system (dBi);
- θ_t : Angle between the main emission of FSS earth station and interference reception (degrees);

$G_r(\theta_r)$: Antenna gain of FWS towards FSS earth station (dBi);

θ_r : Angle between the main beam of FWS receive antenna and interference source (degrees);

$L_b(p\%)$: Path loss level not exceeded for p% time (dB).

In order to evaluate if the received interference power density at the receiver of the FWS from the emission of FSS earth station can meet the protection criterion of the FWS, we calculated $L_b(p\ \%)$ and got the required protection distance between interfering FSS earth station and FWS receiver. The required protection distance is determined based on the propagation losses indicated in the methodology which is given in [4] which is widely used in similar studies as in [5].

If FSS in the Earth-to-space direction is to be introduced into bands already heavily used, aggregate interference impacts on the existing services in the bands should be considered as appropriate. *I/N* values for long-term interference of -6 dB or -10 dB, as appropriate, may be applicable where the risk of simultaneous interference from the stations of the other co-primary allocations is negligible and in other cases, a more stringent criterion may be required to account for aggregate interference from all interfering co-primary services [6].

It is possible to apportion allowable interference in digital FWS to the FS, other services and other emissions respectively as 89 %, 10 % and 1 % of the total interference allowance [7]. Allowing 20 % degradation due to total interference, this means that the allowance for other co-primary services is 2 % of the error performance objectives. If only FSS is considered in the band, the FSS portion would then be 2 % of the error performance objective, leading to an allowable *I/N* of −17 dB. If another or two other co-primary service(s) is/are considered as co-primary service(s) in the band, the FSS portion would be 1 % or 0.67 %, leading to an allowable *I/N* of -20 dB or -21.7 dB.

B. System Characteristics for Interference Analysis

Table I presents system characteristics of FSS earth station assumed for interference analysis in the study. We considered five types of FSS earth station for various applications in the FSS.

We assumed antenna pattern for the FSS earth station as in Fig. 2. The earth stations of Type 1 to Type 4 have the same antenna pattern except for the maximum gain as given by (2) for $D/\lambda \geq 50$, where D is antenna diameter and λ is wavelength [8]. The earth station of Type 5 has a different pattern from the others, since the antenna pattern of Type 4 was extended for $D/\lambda < 50$ as given by (3) [9].

$$G(\varphi) = G_{max} - 2.5\times10^{-3}(D/\lambda\cdot\varphi)^2 \quad \text{for } 0° \leq \varphi < \varphi_m \qquad (2)$$
$$= G_1 \quad \text{for } \varphi_m \leq \varphi < \varphi_r$$
$$= 32 - 25\log\varphi \quad \text{for } \varphi_r \leq \varphi < 20°$$
$$= 52 - 10\log(D/\lambda) - 25\log\varphi \quad \text{for } 20° \leq \varphi < \varphi_b$$
$$= 10 - 10\log(D/\lambda) \quad \text{for } \varphi_b \leq \varphi \leq 180°$$

TABLE I. SYSTEM CHARACTERISTICS OF FSS EARTH STATION

FSS earth station parameters	Units	Type 1	Type 2	Type 3	Type 4	Type 5
Frequency	GHz	8.45	8.45	8.45	8.45	8.45
Maximum transmit output power	dBW	33.0	33.0	27.8	33.0	30.0
Bandwidth	MHz	50	50	50	2	2
Transmit antenna diameter	m	18.0	11.0	5.0	2.5	1.5
Transmit antenna gain	dBi	62	58	51	45	40
Earth station side lobe attenuation	dB	58	54	47	41	29.3
Transmit antenna height	m	15	15	5	5	5
Transmit loss	dB	2	2	2	2	2
Transmit off-axis e.i.r.p.	dBW	35.0	35.0	29.8	35.0	38.7
Transmit off-axis e.i.r.p. density in 1 MHz bandwidth	dBW/MHz	18.0	18.0	12.8	32.0	35.7

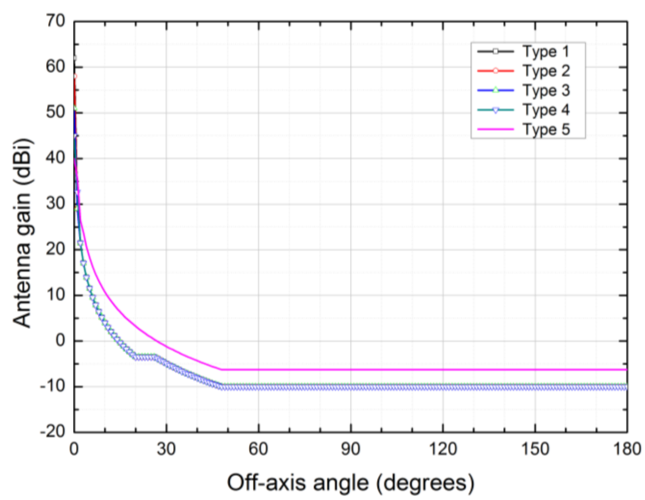

Figure 2. Antenna pattern of FSS earth stations

where:

G_{max} = Maximum antenna gain;

$D/\lambda = (10^{(G_{max}/10)} / \eta\,\pi^2)^{0.5}$;

$\varphi_m = 20\,\lambda/D\cdot(G_{max}-G_1)^{0.5}$;

$G_1 = 2 + 15\log(D/\lambda)$; for $D/\lambda \leq 150$

$= -1 + 15\log(D/\lambda)$; for $D/\lambda > 150$

$\varphi_r = 15.85\,(D/\lambda)^{-0.6}$; for $D/\lambda \geq 100$

$= 100\,(\lambda/D)$; for $D/\lambda < 100$

$\varphi_b = 48^\circ$.

$$G(\varphi) = G_{max} - 2.5\times10^{-3}(D/\lambda\cdot\varphi)^2 \quad \text{for } 0° \leq \varphi < \varphi_m \qquad (3)$$
$$= G_1 \quad \text{for } \varphi_m \leq \varphi < \varphi_r$$
$$= 52 - 10\log(D/\lambda) - 25\log\varphi \quad \text{for } \varphi_r \leq \varphi < \varphi_b$$
$$= 10 - 10\log(D/\lambda) \quad \text{for } \varphi_b \leq \varphi \leq 180°$$

Table II presents system characteristics of FWS assumed for interference analysis in the study.

TABLE II. SYSTEM CHARACTERISTICS OF FWS

FWS parameters	Units	Value
FWS receiver antenna gain	dBi	48.6
FWS side lobe attenuation	dB	16
FWS receiver antenna height	m	50
FWS cable loss	dB	3

We assumed antenna pattern for the FWS as given by Fig. 3 using (4) [10].

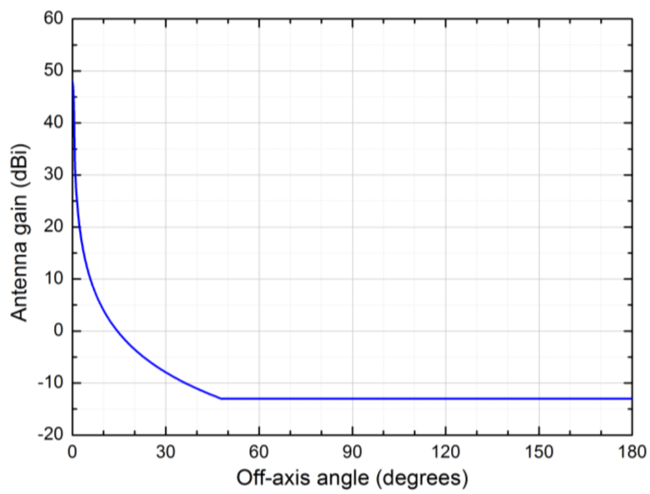

Figure 3. Antenna pattern of FWS

$$G(\varphi) = G_{max} - 2.5\times10^{-3}(D/\lambda\cdot\varphi)^2 \quad for\ 0^\circ < \varphi < \varphi_m \tag{4}$$

$$= G_1 \quad for\ \varphi_m \le \varphi < \max(\varphi_m, \varphi_r)$$

$$= 29 - 25 \log \varphi \quad for\ \max(\varphi_m, \varphi_r) \le \varphi < 48^\circ$$

$$= -13 \quad for\ 48^\circ \le \varphi \le 180^\circ$$

where:

G_{max}: Maximum antenna gain (dBi);

$G(\varphi)$: Gain relative to an isotropic antenna (dBi);

φ: Off-axis angle (degrees);

D: Antenna diameter (m);

λ: Wavelength (m);

G_1: Gain of the first side lobe;

$= 2 + 15 \log (D/\lambda)$;

$$\varphi_m = \frac{20\lambda}{D}\sqrt{G_{max} - G_1} \quad \text{(degrees);}$$

$$\varphi_r = 12.02\,(D/\lambda)^{-0.6} \quad \text{(degrees).}$$

III. CALCULATION RESULTS AND ANALYSIS OF COEXISTENCE OF FSS EARTH STATOIN WITH FWS

We calculated required L_b (*p* %) to meet the protection criteria of FWS taking into account for propagation model with flat terrain and time percentage, *p* of 20 % for long-term analysis and finally found the required protection distance creating the required L_b (*20* %). Fig. 4 shows the calculated L_b (*20* %) based on the system characteristics provided in the previous section. We assumed the average radio-refractive index lapse-rate through the lowest of the atmosphere ΔN = 45 and the sea-level surface refractivity N_0 = 310. The propagation mechanisms include tropospheric scatter, ducting, fade and gaseous absorption over the path between the location of emission and reception.

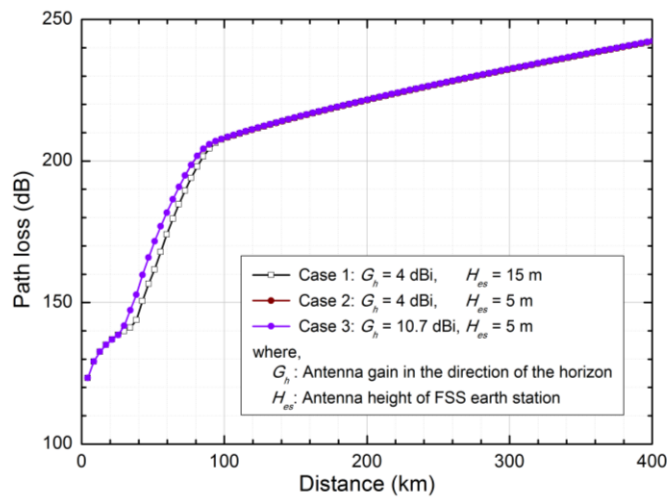

Figure 4. Calculation results of path loss vs. distance

In Fig. 4, Case 1, to which Types 1 and 2 of the FSS earth station belong, shows slightly low path loss compared to Cases 2 and 3 on the distance below 100 km, while Cases 2 and 3, to which Types 3 and 4 and Type 5 belong, respectively, show the same result. It implies that the antenna height of FSS earth station would be a dominant factor for the path loss.

Based on the results given in Fig. 4, we could get the required distance to meet long-term interference level of terrestrial FWS from the emission of FSS earth station. Table III presents the calculation results of the required separation distance.

The results of the static analysis shows that FSS earth station of all types can be compatible with FWS if it would ensure the required protection distances from 79.8 km to 261.5 km.

It should be noted that the calculations were carried out for flat terrain not taking into account the actual path profile of the interfering signal. Since, in real situation, the interference will be additionally decreased due to natural and artificial obstacles, the required distance between FSS earth station and FWS will be less than the calculated results shown in Table III.

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TABLE III. CALCULATION RESULTS OF REOUIRED DISTANCE FROM FSS EARTH STATION TO MEET LONG-TERM INTERFERENCE LEVEL OF FWS

Calculation item	Units	Case 1						Case 2						Case 3		
		Earth Station type 1			Earth Station type 2			Earth Station type 3			Earth Station type 4			Earth Station type 5		
Calculated interference power density	dBW/MHz	47.6			47.6			42.4			61.6			65.3		
Allowable I/N	dB	-17	-20	-21.7	-17	-20	-21.7	-17	-20	-21.7	-17	-20	-21.7	-17	-20	-21.7
FWS nominal long term interference criteria	dBW/MHz	-158.5	-161.5	-163.2	-158.5	-161.5	-163.2	-158.5	-161.5	-163.2	-158.5	-161.5	-163.2	-158.5	-161.5	-163.2
Required attenuation	dB	206.1	209.1	210.8	206.1	209.1	210.8	200.9	203.9	205.6	220.1	223.1	224.8	223.8	226.8	228.5
Required protection distance	Km	93.3	107.3	118.2	93.3	107.3	118.2	79.8	84.7	89.0	188.4	214.1	229.1	218.7	245.8	261.5

IV. CONCLUSION

This paper addresses the feasibility of coexistence between transmitting FSS earth station and receiving terrestrial FWS in 8 GHz band. We calculated required separation distance of FSS earth station to meet the long-term interference level of FWS from interference path loss, taking into account interference methodology and system characteristics presented in the previous section.

The results show that the required separation varies up to a few hundreds kilometers if all types of FSS earth station will be deployed. If we apply actual path profile for the calculation, the required distance could be reduced due to natural and artificial obstacles.

Based on the results, we can select a certain type of FSS earth station for coexistence with terrestrial FWS, when we consider new frequency allocation to the FSS.

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