SPECTRUM DATABASE FOR COEXISTENCE OF TERRESTRIAL FS AND FSS SATELLITE SYSTEMS IN THE 17.7-19.7 GHZ BAND

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Abstract

In this article we develop a database-based spectrum access for the K_a band, allowing fixed satellite services (FSS) receivers to coexist with the terrestrial fixed services (FS) system, thus increasing the downlink capacity of the satellite system. The main focus of this paper is to study FS interference to FSS user terminal receivers in the 17.7-19.7 GHz band as the interference from FSS to FS stations has been found to be minimal. We analyse the FS spectrum use in Finland using the information from the national FS registry, which adds novelty to our approach but, more importantly, makes our analysis realistic and in line with practical systems. The main results regarding spatial distribution, used link distances, transmission powers, antenna heights, and bandwidths are given. This provides a clear view on spectrum sharing possibilities in the band. Obtained information is used in designing secondary use, assuming the FSS system has access to the band at the locations, frequencies, and times where interference-free operation is possible. Coexistence simulations using the ITU-R path loss model P.452-15 and the database design taking into account practical parameters and findings from the FS registry analysis show that the FSS system could clearly increase its capacity.

1. Introduction

Spectrum sharing has been studied in terrestrial domain actively during the past decade. Recently there has been a growing interest in application of frequency sharing techniques in satellite bands. In general, spectrum databases have been favoured in many coexistence scenarios as a more potential spectrum awareness technique than spectrum sensing [1]. The latter technique alone cannot sufficiently guarantee interference-free operation for wireless systems coexisting in the same frequency band. Databases allow controlled sharing where the systems can experience a predictable quality of service (QoS). This helps in avoiding unstable situations such as unnecessary frequent channel switching and makes implementation of practical systems easier.

The idea of having a secondary satellite system operating in the band where the primary user is a terrestrial system might sound very challenging due to the large footprint of the satellite covering easily numerous possible primary nodes. However, in some bands this operation is worth investigating because the terrestrial system can have favourable characteristics for the spectrum sharing scenario. Especially the K_a band where the terrestrial systems are highly directed microwave links provides an interesting scenario for further studies. Interference between the systems can be kept low enough when both the terrestrial primary and satellite secondary systems are using directional antennas. The operating conditions applying to the downlinks of the shared civil K_a band are set up by the Decision ERC/DEC(00)/07 [2]. This decision sets the conditions for which the 17.7-19.7 GHz band is shared between uncoordinated/unprotected earth stations (i.e. user terminals), coordinated earth stations (i.e. gateways), and terrestrial stations.

Spectrum sharing in the K_a band has recently been studied actively and several papers considering techniques such as exclusion zones [3], [4], spectrum sensing [5], databases [3], [6] and beamforming [7] have been published. In [3] and [6] no detailed designs on the databases, including the required analysis and query information between entities in the system are given. We develop in this paper a novel stand-alone database model that can be used to verify whether a new FSS station can be operated at a specific location as well as determining if a new FS station caused interference to existing FSS earth stations. The aim is to achieve more generalized results than in [4]. Required procedures, parameters, and connection to the national FS registry are defined, and the frequency of updates of this information is redefined from previous knowledge to cover better the actual dynamicity of FS operation and consequently to enable interference free service for FSS users. In addition to the

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update of simulation parameters, an important part of the work is to study in detail an example of FS deployment and use inside Finland and develop guidelines for database based sharing in the band. The rest of the paper is organized as follows. Section 2 describes the scenario. FS registry analysis is given in Section 3 and coexistence simulations in Section 4. Section 5 defines the database concept and Section 6 concludes the paper.

2. Scenario and system parameters

The FSS satellite system is the secondary system using the frequencies of the primary FS system. One satellite spot can cover several FS links that are operating in the same frequency band. Frequency sharing between FS and FSS systems is depicted in Figure 1 by defining four sub-use cases that can be studied. Only sub-use case 4, i.e., FS interference to FSS user terminal receiver at 17.7-19.7 GHz band is under consideration in this study as we have found the interference from FSS into FS stations to be minimal in the studied frequency band. Thus, the FS system is seen as an interfering service in the following. FSS earth stations can be fixed, uncoordinated or Earth stations on mobile platforms (ESOMPs). We will study the coexistence by defining parameters e.g., regarding the antenna height of the FS system as well as taking into account variations in effective isotropic radiated power (EIRP) density and antenna gain. Assumptions are given in Table 1.

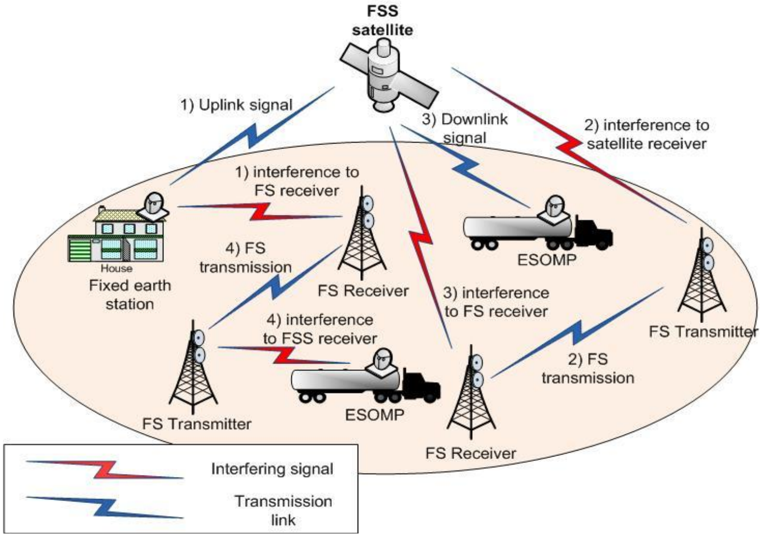

Figure 1. Secondary use of terrestrial FS spectrum by the FSS satellite in K_a band.

Table 1. System parameters and related references.

Interfering service: Terrestrial system, FS	System parameters	
	EIRP density (dBm/MHz)	16.9-57.3 [8]
	Antenna pattern	According to [9]
	Antenna height (m)	20 in [10], 40 (typical in Finland)
	Antenna gain (dB)	21.7-48.3 [8]
	Permissible interference	According to [8]
	Out-of-band emissions	According to [12]

3. Analysis of FS links in 17.7-19.7 GHz band in Finland

The band 17.7-19.7 GHz in the K_a band is used by FS transmitters in most European countries. National regulatory authorities have the knowledge about the allowed transmitters in their countries including their positions, formed links between pair of transceivers, used transmission powers, etc. Unfortunately, regulators do not always share this information openly. To be able to understand better the situation in Finland we requested information from the Finnish Communications Regulatory Authority (FICORA). Since the regulator informed that the information is not exactly static and sometimes changes can happen on a daily basis, we have taken here two sets of data to be looked at. The former is from May 2014 and the latter from October 2014. Parameters obtained from the sets from national FS registry are shown in Table 2. There are some differences that can be seen between the sets e.g., in the number of links as well as in the average antenna gains and average powers used by the FS transmitters. However, the general impression is that the sets are rather similar. What can be obtained from the results is the ability to identify exact values for the specific links as well as knowing the typical values for transmission powers and antenna gains.

Table 2. Fixed service (FS) transmitters in Finland.

	16th May 2014	17th October 2014
Frequency band	17.7-19.7 GHz	17.7-19.7 GHz
Number of 2-way FS links	2609	2644
Antenna gain	30.0 – 48.3 dB	30.0 – 48.3 dB
Average antenna gain	36.9 dB	37.0 dB
Transmission power	-10 – 30 dBm (2470 links where power > 10 dBm)	-10 – 30 dBm
Average transmission power	17.2 dBm	17.4 dBm
Average antenna height	38.6 m	38.6 m

Placement of FS links in the lower K_a band in 17.7-19.7 GHz on both the dates are shown in Figure 2 to see whether there are major differences seen in the results. The first impression from the figures is that the situation is rather static. The distribution of the links seems to follow rather well Finnish population distribution; heaviest use of links is in the areas of largest cities. There are also areas without FS links especially in Lapland where population is sparse. Since the overall figure of the Finland is not detailed enough to do comparison between the dates we focused on couple of cities and show an example in the following. Oulu is the most populous city and includes most links in Northern Finland. All the links are point-to-point services, used for carrying FS services in that area. The situation is depicted in Figure 2. There are lot of free areas where an FSS earth station could be placed. Thus, both spatial and frequency domain sharing is possible here. What is clearly seen in this detailed figure is that there are many new links in October and also some links have been shut down. This means that one needs to have up-to-date information available when she is going to share the same spectrum with the FS system in order to not to be interfered with it.

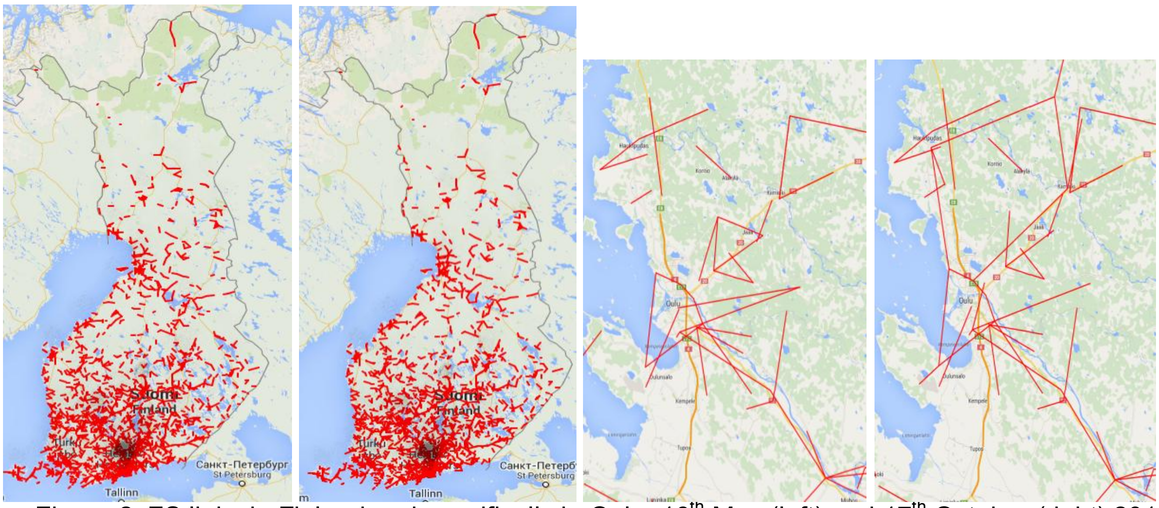

Figure 2. FS links in Finland and specifically in Oulu, 16th May (left) and 17th October (right) 2014, respectively.

Based on Figure 2 only, one might think that there are areas where sharing the spectrum is not possible due to heavy appearance of the FS links. However, the figure shows only spatial information. To better understand the current use and sharing possibilities, also frequency use information will be under study. Figure 3 shows the bandwidth of the FS links used in Finland. Almost half of the links reserves 55 MHz for transmission, other half use less bandwidth. This means that in most locations in Finland, only a small fraction of the total 2 GHz is used by the FS system. There are some points in Helsinki area where there can be more than 10 link ends at the same location. The links are 2-way links, reserving same bandwidth in both directions. Thus, a single link can reserve 2 × 55 MHz = 110 MHz from the band. This means that in some urban areas, the 17.7-19.7 GHz range may be almost fully used by FS, or the prospect of reaching saturation is possible. While in more sparsely populated areas it is likely that the saturation will never be reached, even in the long run. In more than 99 % of the Finland area the number of links is 0 or 1 at a specific location.

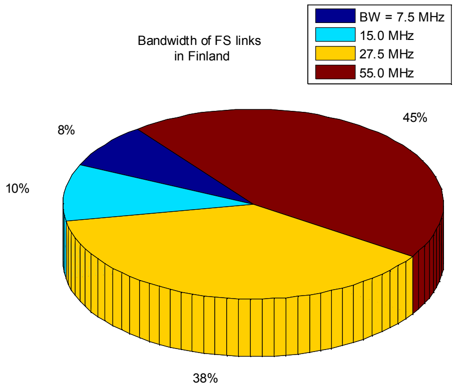

Figure 3. Distribution of bandwidth of the FS links used in Finland.

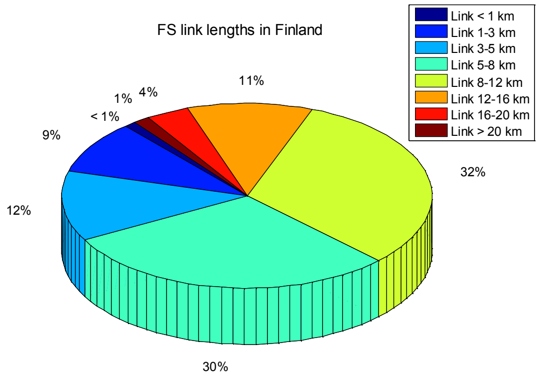

Figure 4. Distribution of FS link lengths in Finland.

Thus, for most of the country at least 2000 MHz – 2 × 55 MHz = 1890 MHz of spectrum is unused. Even assuming good guard bands around current FS transmitters, the available spectrum e.g., for FSS use is significant and can increase the capacity of satellite systems drastically. Typical antenna diameter in Finland is 0.6 meters. Frequency division duplexing (FDD) is used in all links. Figure 4 shows the distribution of FS link lengths in Finland. Majority of links are 5-12 kilometres long. There are few links that are less than 1 km or more than 20 km long. Average link length is 8.2 kilometres. This is also interesting information to be taken into account when designing spectrum sharing principles for the K_a band.

4. Coexistence simulations

The interference between FS-stations and user FSS-stations was studied by performing transmission gain simulations for FSS downlink scenario at 18 GHz. The simulation system was as follows.

4.1 Path loss model

The ITU-R P.452-15 path loss model (dB) [11] is given as

$$PL(d) = 92.5 + 20\log d + 20\log f + L_d(p) + A_g + A_h \tag{1}$$

Where d is the link distance, f is the carrier frequency, $L_d(p)$ is the diffraction loss, p is the probability for path loss not to exceed for p % of time and A_g refers to gaseous absorption attenuation, which consists of attenuation due to dry air and water vapour. It is defined as

$$A_g = [\gamma_o + \gamma_w(\rho)]d \text{ (dB)}. \tag{2}$$

Parameter γ_o is the attenuation due to dry air and γ_w is the attenuation due to water vapour. These parameters are defined in [13]. A default water vapour density of ρ = 3 g/m^3 was used in the calculations.

A_h is the clutter loss contributed by clutters such as trees and buildings and is given as

$$A_h = 10.25F_{\mathrm{fc}} \cdot e^{-d_k}\left(1 - \tanh\left[6\left(\frac{h}{h_a} - 0.625\right)\right]\right) - 0.33 \text{ (dB)} \tag{3}$$

where $F_{\mathrm{fc}} = 0.25 + 0.375\{1 + \tanh[7.5(f - 0.5)]\}$, d_k is the distance from nominal clutter point to the antenna, h is the antenna height, and h_a is nominal clutter height above local ground level. The diffraction loss was taken into account by using a spherical earth model described in ITU-R P.526 [14]. Marginal line-of-sight (LOS) distance between two antennas can be defined as

$$d_{\mathrm{LOS}} = \sqrt{2a_e}(\sqrt{h_{\mathrm{FS}}} + \sqrt{h_{\mathrm{FSS}}}) \tag{4}$$

where a_e = 8500 km is the equivalent Earth radius, h_{FS} is the FS transmitter antenna height and h_{FSS} is the FSS station antenna height.

If the link distance d between FS and FSS antennas is equal or larger than d_{LOS} the diffraction loss in dB is calculated with the given procedure in equations (13)-(18b) in [14], i.e., starting from

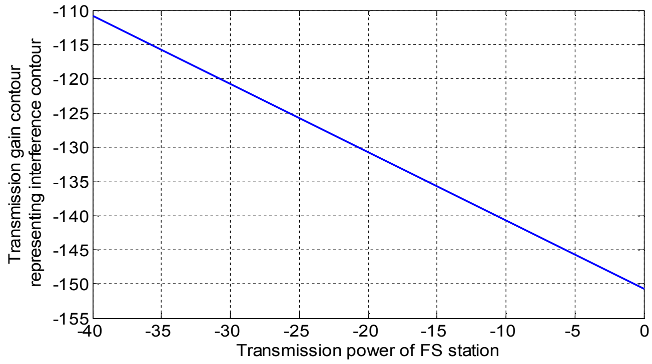

Figure 5. Relation between transmission gain contour representing interference contour and the transmission power of FS station.

$$L_d = F(X) + G(Y_1) + G(Y_2) \tag{5}$$

where $F(X)$ is the distance term, $G(Y)$ is the height gain term, X is the normalized length of the path between the antennas at normalized heights Y_1 and Y_2. Propagation is assumed to occur in line-of-sight, i.e. with negligible diffraction phenomena if there is no obstacle within the first Fresnel ellipsoid. Thus, if $d < d_{LOS}$ the concept of Fresnel zone clearance is used i.e., 0.552 of the first Fresnel-zone radius needs to be unobstructed for diffraction loss to be about 0 dB. The smallest clearance height h and the required clearance h_{req} are defined with equations (22)-(23) in [14]. If $h > h_{req}$ the diffraction loss for the path is zero. No further calculation is required. Otherwise, diffraction loss calculation is continued with the method as described with equations (24)-(25) in [14].

The local clutter provides additional shielding from interference. The height-gain model has been applied for the FSS-ground station to add shielding loss provided by the clutter. The category describing environment with sparse houses or irregularly spaced sparse trees, providing least clutter loss, was selected for the path loss calculation. This means that parameters in (3) are set as h_a = 4 m and d_k = 0.1 km. This model is actually a worst case one. By simply taking into account the terrain or building obstructions would drastically increase the sharing possibilities since the exclusion zones estimated in the following sections would be smaller. For example, deep valleys inside the main beam area of the FS transmitter (Tx) can actually be acceptable places for FSS receivers since they are not interfered by FS signals.

4.2 Transmission gain contours

The distance that is required between an interfering station and the victim receiver depends strongly on the antenna characteristics and pointing angles between the stations. The described path loss model and ITU-R antenna patterns from [9] to FS and [15] to FSS are applied in the simulation. Only the off-axis FSS-antenna pattern is defined in the ITU-R S.1855 report [15], thus the main lobe pattern of FSS-transmitter was set according to the ITU-R F.699 report [9]. Rotationally symmetric antenna patterns were assumed. The simulation results show the transmission gain as contour levels on a x-y-grid, where the FS-station is placed at (x, y) = (0, 0) and its antenna boresight is assigned to zero azimuth and zero elevation, (φ, θ) = (0, 0). The transmission gains to all possible locations of FSS-station are calculated.

The transmission gain is defined as the gain from the Tx-antenna input to receiver (Rx)-antenna output, i.e. the transmission gain is the path gain plus antenna gains at given location or angle. The FSS-antenna gain towards the FS-station depends on the location and antenna pointing angle of the FSS ground station, which depends on the satellite azimuth and elevation angles with respect to the coordinate system. The FS-antenna gain towards the FSS-station depends on the FSS-station location. Therefore, the simulations have been performed for different satellite elevation and azimuth angles.

Based on the ITU-R SF.1006 report [16] the long term threshold in dBW for FS to FSS interference is

$$I_t = 10\log(kTB) + Q - W \tag{6}$$

where k = $1.38 \cdot 10^{-23}$ J/K, T = 300 K, Q is the ratio between permissible long-term interference from any one source and thermal noise in a given station, and W is a thermal noise equivalence factor. The parameters are given in [16] as Q = 7 dB and W = 0 dB. We can now define with a reference bandwidth B = 1 MHz that our threshold is -150.8 dBW/MHz for an FSS receiver. Now the interference contour is dependent on the transmission power of the FS station. Let us take the transmission powers used in Finland into account, i.e., between -40 dBW and 0 dBW depending on the link length, as shown in Table 2. Based on that we can define the interference contour to be between -110 dB and -150 dB since the transmission gain G_{t} in dB is shortly defined as $G_{\mathrm{t}} = I_t - P_{\mathrm{FS}}$ where P_{FS} is the transmission power of the FS station. The relation is depicted in Figure 5. A typical transmission power of an FS station is around -10 dBW, leading to a contour of -140 dB.

The results shown in Figure 6 and Figure 7 are simulated assuming FS antenna height of 40 m since antenna height of an FS link in Finland is 38.6 meters on average. Satellite elevation angles of 50° and 30° and azimuth angles of 180° and 90° are used in the calculations, respectively. FS antenna has a diameter of 0.6 meters with maximum gain of 38 dB. These results show that the protection distance required between the FSS- and FS- stations is strongly dependent on the FS-antenna radiation pattern. The azimuth angle makes only a small effect on the results. The results also show that already -10 dBW transmission power of an FS station (transmission gain contour of -140 dB) leads to 26 km protection range in the main beam direction. However, the protection area is really narrow; meaning that placement of FSS stations is possible when they are side from the straight line drawn between FS transmitter and FS receiver. Already 1 km deviation from the straight line is enough to protect FSS receivers in the shown figures for typical FS transmission power and 2 km range protects all receivers with any transmission power reported in national FS registry of Finland.

Antenna height of an FS link in Finland is 38.6 meters on average and thus, the previous results represent that situation well. However, it is recommended in [10] that antenna height of 20 meters is to be used in coexistence calculations. Thus, we simulated the scenario with this lower antenna height and found out that reducing antenna height from 40 to 20 meters reduces the protection distance by 6-7 kilometers.

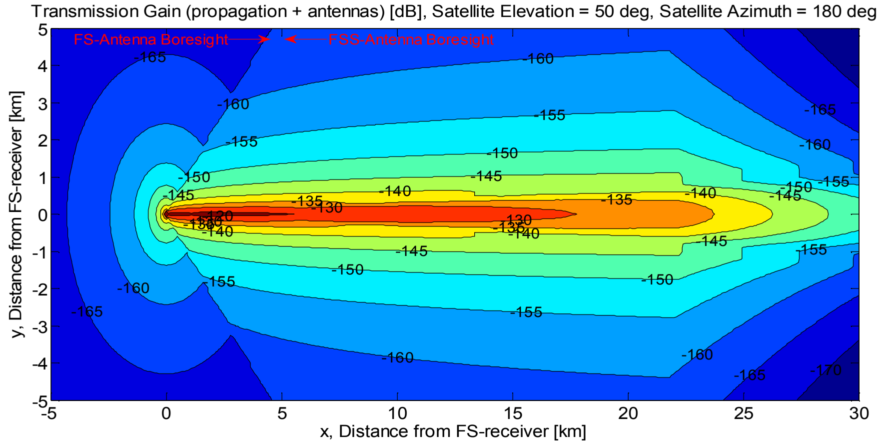

Figure 6. Transmission gain for FS to FSS link at 50 degrees elevation, satellite azimuth 180 degrees.

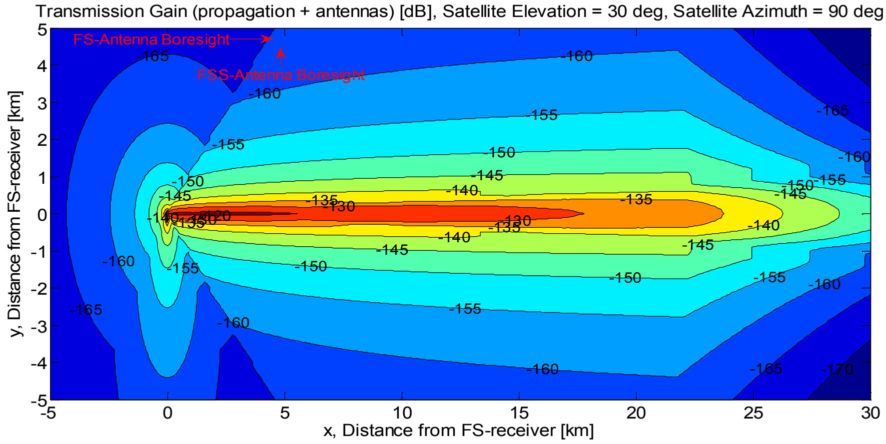

Figure 7. Transmission gain for FS to FSS link at 30 degrees elevation, satellite azimuth 90 degrees.

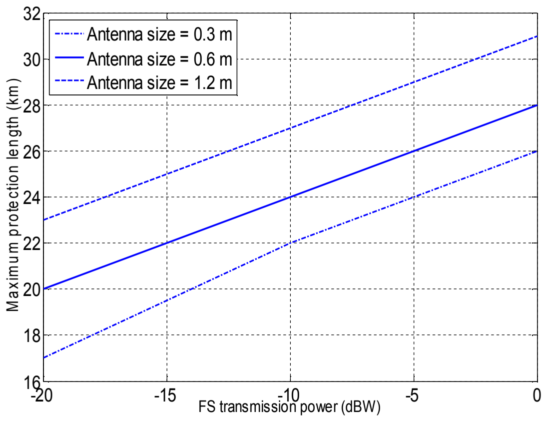

Figure 8. Maximum protection distance with different FS antenna sizes and transmission power levels, 20 degrees elevation, satellite azimuth 180 degrees, FS antenna height = 20 m.

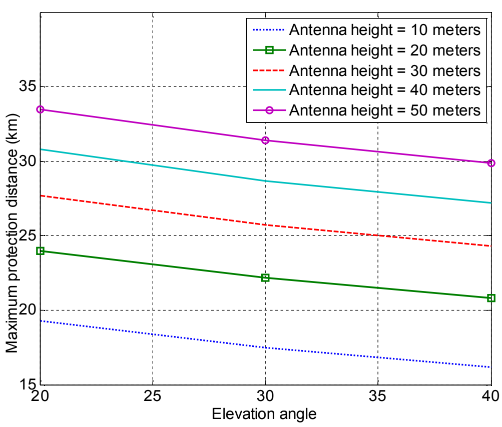

Figure 9. Maximum protection distance as a function of elevation angle with different FS antenna heights, antenna size = 0.6 m.

Since actual FS links use also 0.3 m and 1.2 meter antennas in addition to the most usual 0.6 meter diameter, we made some simulations with these as well. The simulations show that antenna height, antenna size, and elevation angle have all considerable effect on the protection distance between FS and FSS stations. Thus, the sharing decisions and database operation should be based on actual values instead of using only recommended single values provided e.g., by ECC reports. An example result of maximum protection distance vs. transmission power of FS transmitter with different antenna sizes is given in Figure 8. There is roughly 2 km difference between antenna sizes 0.3 m and 0.6 m with all transmission powers. The difference is 3 km between largest antennas.

Another view on the effect of the antenna is shown in Figure 9 with a fixed antenna size of 0.6 m by varying antenna heights and elevation angles. As can be seen in the figure, the effect of antenna height is clearly larger than the effect of the elevation angle. When the FS antenna height is 10 m, the protection distance is always below 20 km. If the antenna height is increased to 50 m which is still rather typical e.g., in Finland, the protection distance is always more than 30 km.

5. Database design

We have analyzed the frequency sharing scenario by looking at the effects of antenna size, antenna height, FSS elevation and transmission power of FS stations in previous simulations. It can be concluded that in order to share the spectrum as efficiently as possible, in non-interfering manner, one needs to take the real parameters of the FS stations into account.

The main task of a database in this use case is to take locations of all devices and construct an interference map based on contour calculations. Exclusion zones around FS stations are defined based on the antenna pointing and transmission power of FSS stations. Outside these zones FSS earth stations could operate with given maximum transmission power values. The zones are frequency dependent, i.e., defined by the transmission frequency of FS stations. A suitable exclusion zone calculation method needs to be incorporated in the controller software giving access to the spectrum to requesting end users. The overall interference modelling concept is given in Figure 10. In practice path loss is the main propagation loss in the modelling, shadowing and fading can be included with some margin but very dynamic model is too resource consuming. In full modelling case, also terrain data and meteorological data are included to obtain the most reliable figure about the sharing possibilities. As mentioned earlier the modelling without terrain data is a worst case one from the FSS point of view and inclusion of the terrain data improves the sharing possibilities significantly. However, even with the simpler worst case model there is huge amount of band available in the 17.7-19.7 GHz band as shown in the FS registry analysis.

The database can be used for planning where to locate fixed Earth stations. In addition, it can provide support for dynamic case when FSS terminals are uncoordinated or ESOMPs. Since implementation of ESOMPs is only contemplated in bands where uncoordinated FSS earth stations are allowed, ESOMPs should not represent any increased interference risk to FS networks beyond that presented by uncoordinated FSS earth stations [10].

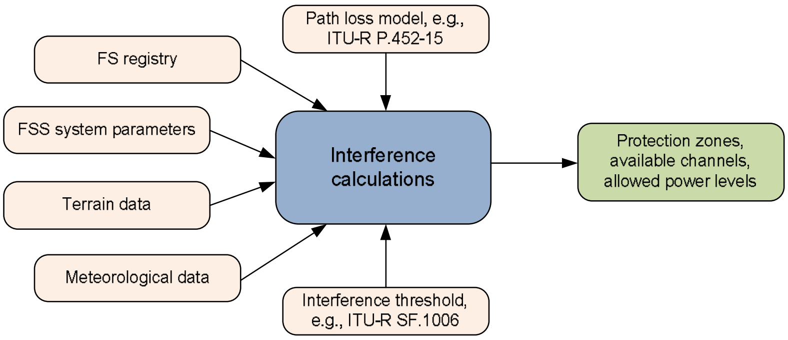

Figure 10. Interference modelling used in the database.

The operation of K_a band database with FS incumbents is close to TV white space (TVWS) operation [18], difference coming from some information that need to be delivered such as antenna pointing. In addition, the latest industry-driven spectrum sharing approach called Licensed Shared Access (LSA) [19] that is based on the geo-location database referred to as an LSA repository is a promising concept to be used for K_a band sharing purposes. Both mentioned approaches need to be modified to support the sharing with satellite communications.

There are several parameters that are defined in ITU-R documents to be included in the database and interference calculations using national registries, see [17]. Database calculations can be used both to check whether a new FSS station can be operated at a specific location as well as determining if a new FS station would cause interference to existing FSS earth stations. Thus, both FS and FSS station locations need to be included in the databases to be able to control the operation adequately. The FS database and related query information are shown in Figure 11.

The user of the FS database, that is most probably located at the national regulator premises, is the FSS operator or service provider. The user is depicted as a laptop user to emphasize the possibility to access the system through Internet anywhere. The FS database obtains information about FS stations and their usage directly from the national FS registry[1]. Then, using both this information and also FSS information from the query message as input for the controller software the FS database calculates whether requesting FSS user is allowed to access the spectrum. The user aiming to access the FS spectrum is required to include following information in the query message:

Location of the device: Database calculations are location-specific. Thus, the user needs to tell exact coordinates in the query.

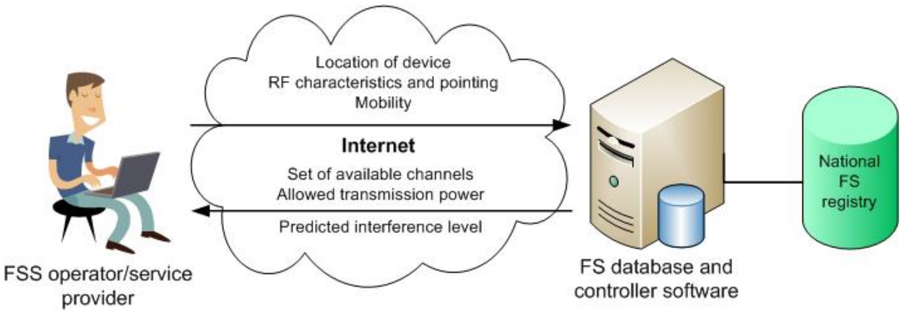

Figure 11. FS database and related query information.

RF characteristics and pointing: Natural parameters required for calculations are the carrier frequency and signal bandwidth. As described in earlier sections, antenna gain towards the FS receiver is key information in the calculations. Thus, a user is required to provide antenna gain pattern as well as pointing information. The minimum information is antenna size and antenna pointing that can be used in conjunction with ITU-R antenna pattern recommendations such as [9] or [15].

Mobility: This parameter tells whether the requesting terminal is fixed or mobile. The database is designed to support both fixed and mobile users such as ESOMPS. The permission to use the band is given for a specific location. New request is required if the user moves *X* meters from that location. For

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[1] The formats of national registries differ for each administration [20]. Thus, a preferable way is to have a separate controller software and FS database for each country.

example, in the IEEE 802.11af standard a new request is required when the terminal has moved more than 50 meters from the last reported position [21].

The answer message from the database includes both the set of available channels at the location of request as well as transmission power limit for the FSS terminal (in the uplink band of 27.5-29.5 GHz). In the downlink band of 17.7-19.7 GHz the database estimates the level of interference FS transmitters would cause to the FSS terminal at the band of interest. To be compatible with ITU-R recommendations such as [22] regarding the protection zone estimation, the controller software calculates the allowed transmission power in dBW as

$$(P_{\mathrm{TX}})_{\mathrm{FSS}} \leq I_{\mathrm{t}} + (L_{\mathrm{F}})_{\mathrm{FSS}} - \left(G_{\mathrm{TX}}(\varphi)\right)_{\mathrm{FSS}} + PL(d) - \left(G_{\mathrm{RX}}(\vartheta)\right)_{\mathrm{FS}} + BW_{\mathrm{cor}} \tag{7}$$

where $(P_{\mathrm{TX}})_{FSS}$ is FSS transmission power (dBW), I_{t} the maximum interference power FS receiver can tolerate (dBW), $(L_{\mathrm{F}})_{\mathrm{FSS}}$ is FSS transmission loss (dB), $(G_{\mathrm{TX}}(\varphi))_{\mathrm{FSS}}$ is the FSS gain in the direction of the fixed service terminal (dBi) and φ is the angle between FSS transmit boresight and the FS receiver (degrees). $PL(d)$ is the path loss between FSS transmitter and FS receiver, based on (1), $(G_{\mathrm{RX}}(\vartheta))_{FS}$ is the FS antenna gain in the direction of the FSS transmitter (dB), ϑ is angle between FS receiver boresight and FSS transmitter (degrees), and BW_{cor} is the overlap bandwidth correction (dB), higher of 0.0 or $10\log(BW_{\mathrm{tx}})_{\mathrm{FSS}}/(BW_{\mathrm{rx}})_{\mathrm{FS}}$.

The same procedure is used when determining the interference at the FSS terminal caused by FS transmission. One needs basically to change then FS and FSS parameters head to head in the above equation, i.e.,

$$I_{\mathrm{t}} = (P_{\mathrm{TX}})_{\mathrm{FS}} - (L_{\mathrm{F}})_{\mathrm{FS}} + \left(G_{\mathrm{TX}}(\varphi)\right)_{\mathrm{FS}} - PL(d) + \left(G_{\mathrm{RX}}(\vartheta)\right)_{\mathrm{FSS}} - BW_{\mathrm{cor}}. \tag{8}$$

Using this equation the software calculates whether it is possible for FSS earth station to operate at the location of interest using the given carrier frequency in the estimation. If not possible, then the database provides set of alternative channels that could be used if any.

When a new FS station arrives, 1) it should be located not to interfere with the existing FSS stations when possible. 2) If not possible, FS is primary user and FSS is relocated in frequency. It is expected that the first option is possible almost always at least in Finland based on the conducted FS use analysis. The database will need to be updated whenever changes occur in the channel occupancy. Monthly or more frequent updates regarding FS usage are mentioned in [20] to have reasonably up to date information available. Based on the analysis it seems that the updates should be done clearly more frequently than on monthly basis in order to keep operation interference-free.

6. Conclusions

This paper has analysed current use of K_a band in Finland, made coexistence calculations between the primary terrestrial FS and the secondary satellite FSS system in the band, and developed a database model to enable coexistence. The results show that with the help of spectrum database the FSS systems could increase their capacity considerably by extending the downlink spectrum from current 500 MHz to more than 2 GHz. Analysis of FS spectrum use in the K_a band in Finland reveals that clearly more than 90 % of the Finnish area is underusing the studied 17.7–19.7 GHz band. The results from other countries seem to confirm same kind of situation in other European countries as well, see e.g., [3].

Conducted simulations and the following database design that imitates partially currently used TV whites space databases or LSA approaches, and uses relevant ITU-R recommendations, show how the sharing can be done taking into account the characteristics of FS stations such as transmission powers, antenna parameters, and heights. The database takes information from the national FS registry and also given information about the FSS terminals e.g. elevation angle, antenna size, and transmission power and calculates where and how the FSS users are allowed to operate in the band. It remains as a future work to develop the practical databases including the separate controller software and FS databases for each country. Implementations and testing is still required to obtain the best solution fulfilling the regulatory guidelines as well.

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