Electronic Communications Committee (ECC)
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COMPATIBILITY AND SHARING STUDIES BETWEEN THE RAS OPERATING IN THE BAND 10.6-10.7 GHz AND OTHER SERVICES

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EXECUTIVE SUMMARY

This report considered the compatibility and sharing between the RAS operations in the frequency band 10.6-10.7 GHz and various other services in the same or adjacent bands.

The report describes the essence and importance of RAS operations. It also discusses, in section 3, one real case of interference from a particular GSO FSS system into a RAS radio telescope installation at Effelsberg. Possible causes of such interference are evaluated, as well as some of the workable mitigation factors.

Operation of various radiocommunication services and systems in the same or adjacent bands, i.e. FSS, EESS, FS, SRD and video SAP/SAB links (ENG/OB) is considered in Section 4 of the report.

Based on the interference example in section 3, a detailed evaluation of the level of unwanted emissions from the Fixed Satellite Service systems operating above 10.7 GHz that may fall in the RAS band 10.6-10.7 GHz is provided in Section 5 of the report, together with discussion on possible mitigation techniques to reduce them.

As a conclusion, this report has established the necessary frequency separations between the FSS and the RAS allocations, so that the level of unwanted emissions from FSS systems into the RAS band meet the RAS protection criteria.

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COMPATIBILITY AND SHARING STUDIES BETWEEN THE RAS OPERATING IN THE BAND 10.6-10.7 GHz AND OTHER SERVICES

1 INTRODUCTION

The band 10.6 – 10.7 GHz is allocated to the Radio Astronomy Service (RAS) on a primary basis, see Annex 1, the sub-band 10.68 – 10.7 GHz is exclusively passive (ITU RR No. 5.340 applies). The band has been used by RAS successfully for observations of the radio continuum of galactic and extra-galactic radio sources, including their polarisation properties and for the search for and investigation of radio pulsars.

This band is identified in the Recommendation ITU-R SM.1542 on "The Protection of Passive Service from Unwanted Emissions" as one the bands where the potential interference situations due to unwanted emissions from active services into passive service bands may be very high. In particular this band is adjacent to the band 10.7-11.7 GHz, which is allocated to the Fixed Satellite Service (Space-to-Earth) on a primary basis. Therefore this band and the mitigation techniques to be used to allow operation of both services have been discussed in ITU-R within TG 1-7 and are also subject to further consideration within CEPT.

2 USE OF THE BAND 10.6-10.7GHZ BY THE RADIO ASTRONOMY SERVICE

2.1 Single-dish observations

The frequency band 10 to 15 GHz provides some of the best angular resolutions (~2 arc minutes) for many large single-dish radio telescopes. Many non-thermal synchrotron sources are just detectable at higher frequencies, and this particular frequency range enables radio astronomers to observe them at the highest frequency where they can be detected reliably.

This high-frequency range is also important for monitoring of the intensity variability of the enigmatic quasars and other distant radio-loud galaxies. These objects, which are among farthest celestial objects that scientists can detect and which produce surprisingly large amounts of energy, have been found to vary in intensity with periods ranging from hours to years . Such observations lead to estimates of the sizes of these sources, which turn out to be very small for the amount of energy they produce.

The variability of most radio galaxies is more pronounced at high frequencies and observations at such frequencies facilitate the discovery and monitoring of such events. The energy emitted during a single burst from a quasar is equivalent to that released by the complete annihilation of a few hundred million stars in a period of a few weeks or months. The fundamental physics that can produce such events are not yet fully understood and observations of the size and variability of these sources are crucial in solving these enigmas. Such observations are best performed in the frequency range 10 to 15 GHz.

2.2 VLBI observations

The extremely small sizes of quasars (as small as milliarcseconds) are revealed from the Very Large Baseline Interferometry (VLBI) observations. Such observations are also being made in the frequency band 10.6-10.7 GHz, though at present the 8.4 GHz is a more frequently used band for VLBI observations. The 8-10 GHz range provides a better angular resolution than observations made at lower frequencies and enable scientists to determine more accurately the sizes and small-scale structure of radio galaxies.

3 CURRENT COMPATIBILITY PROBLEM

The band 10.7-11.7 GHz is allocated to the Fixed Satellite Service (FSS) on a primary basis. The use of the bands 10.7-10.95 GHz (space-to-Earth) and 11.2-11.45 GHz (space-to-Earth) by the geostationary (GSO) FSS systems is in accordance with the provisions of ITU RR Appendix 30B.

In order to make efficient use of the spectrum, the FSS aims at employing all channels within the allocation, including the outermost channels at the band edges, which may lead to interference to passive RAS services in adjacent band.

For example, one real case of interference to RAS operations is described below, with a particular GEO FSS satellite system operating at lower nominal centre frequency of 10.714 MHz with a transponder bandwidth of 26 MHz.

The Figure 1 shows the results of RAS measurement at 10.6 GHz by the Effelsberg 100 m radio telescope, looking towards 3C84, one of the strongest point-like cosmic radio sources. This measurement was made before 1995. The field size is 30' x 12', the flux from the source is 20.5 Jy (~ -247 dB(W m^{-2} Hz^{-1}).

Figure 1: Unpolluted measurement of the galactic object "3C84" in the 10.6-10.7 GHz band with the Effelsberg 100m radio telescope

Then in the year 1995 a GSO FSS satellite was put into operation at certain orbital position, where other satellites had been already operating for some time. The satellite has lower transmitting centre frequency of 10.714 GHz and transponder bandwidth of 26 MHz. The resulting noise fluctuation generated by unwanted FSS emissions from that orbital position into adjacent RAS band 10.6-10.7 GHz was so strong, that it completely masked any astronomical signals.

So Fig. 2 shows consequent measurement in the same 30' x 12' field of the sky as shown in Fig. 1, , but after the satellite was put into operation in the year 1995, its orbital position being spaced 10 degrees from the measured field of the sky. For comparison, the 3C84 picture from Figure 1 has been added onto the map in Figure 2. The very strong point source is now barely visible.

**Figure 2: Measurements of the same sky field as in Figure 1,
but with harmful unwanted emissions received at Effelsberg radio telescope**

To investigate this case of interference, the satellite monitoring station at Leeheim of the German Regulatory Authority measured a spectrum of the FSS transmissions from the given satellite orbital location satellite (see Figure 3), in order to determine the level of unwanted emissions into the RAS band. However it should be noted, that the sensitivity and the dynamic range of the monitoring station are not sufficient to verify interference at the levels given as protection criteria for the radio astronomy service in Recommendation ITU-R RA.769.

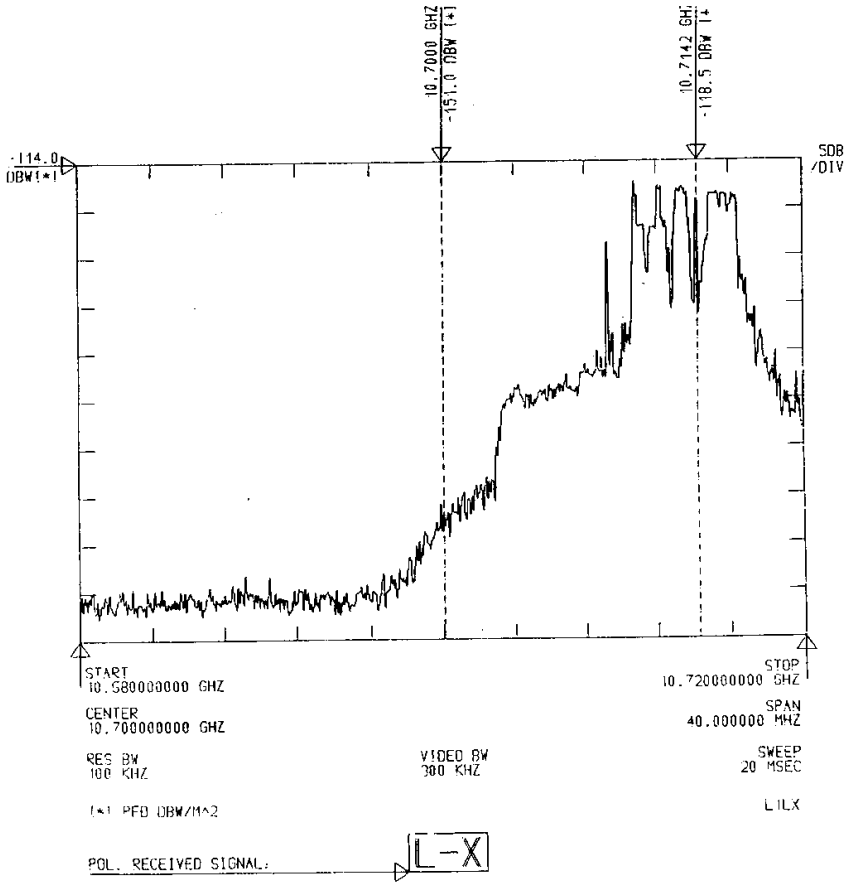

Figure 3: Measurement of interference source conducted at Leeheim monitoring station (1995)

It may be seen from Fig. 3 that at the 10.7 GHz edge of the RAS allocation, in the passive exclusive band, the unwanted emission level is measured to be –151 dB(W/m^2) in a reference bandwidth of 100 kHz. This corresponds to –201 dB(W/m^2/Hz), whereas Recommendation ITU-R RA.769 gives a 39 dB lower number, –240 dB(W/m^2/Hz), as interference threshold, and additionally considers desirable 15 dB more stringent limits to be applied in case of GSO satellites. This huge discrepancy occurs at the high edge of the 10.6 – 10.7 GHz band, and is lower in the rest of the band.

Down from the edge 10.7 GHz until about 10.69 GHz, where the interfering signal reaches the noise floor of the Leeheim monitoring station (pfd ~ -160 dB(W/m^2)), its roll-off is about 10 dB per 4 MHz. If one assumes that this roll-off rate continues down to 10.6 GHz, the estimated total power emitted from that orbital location into the 10.6-10.7 GHz band would be –145.6 dB(W/m^2), which is 14.4 dB above the –160 dB(W/m^2) threshold given in Recommendation ITU-R RA.769 for the 10.6-10.7 GHz band, and therefore rendering the entire 10.6-10.7 GHz completely unusable for radio astronomy observations , as shown in Fig. 2.

The following values, shown in Table 1, were provided as maximum levels of unwanted emissions from typical FSS systems falling into the RAS band.

Sub-band	Maximum unwanted emission spfd level (dBW/m^2/Hz)	**Maximum unwanted emission pfd level (dBW/m^2)**
10.695 – 10.700 GHz	**-202**	**-135**
10.680 – 10.695 GHz	**-217**	**-145**
10.600 – 10.680 GHz	**-232**	**-153**

Table 1: Maximum levels of unwanted FSS emissions falling into the 10.6-10.7 GHz RAS band

These levels of unwanted emissions, visualised in Fig. 4, are in line with the practical Leeheim measurements provided in Fig. 3. Based on the linear decrease shown, it is possible to estimate levels of unwanted emissions from the FSS system falling into the RAS band.

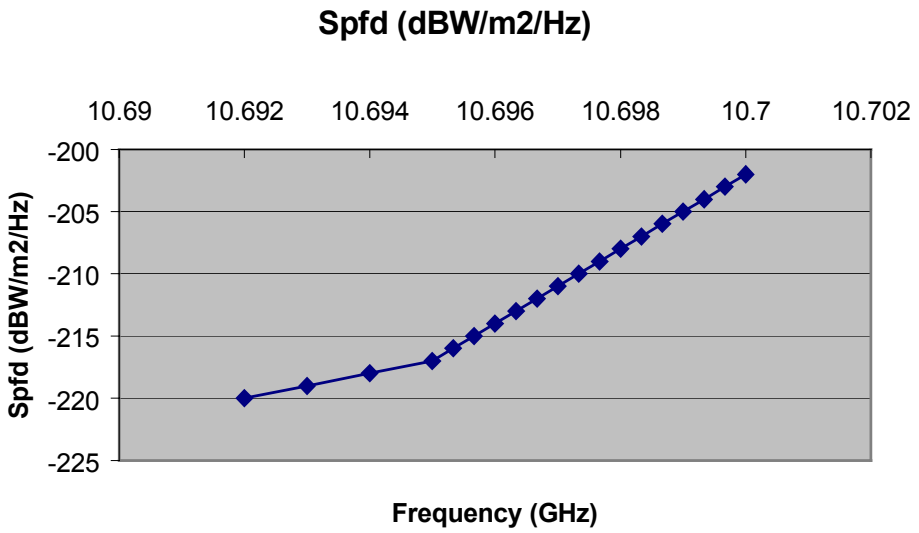

Figure 4: Linear decrease of the FSS signal in the RAS band

Using the linear decrease between the different breakpoints given in Table 1, it is possible to estimate the power falling in the sub-band 10.696 – 10.7 GHz. This gives:

$$Pfd=-140.1 \text{ dBW / m}^2$$

This level is 20 dB above the threshold interference level given in Recommendation ITU-R RA.769 for continuum observations:

$$-160 \text{ dBW / m}^2 \text{ / 100 MHz}$$

Thus it is shown that the RAS interference criterion is not met.

Extrapolating the linear decrease shown in Fig. 4 down to a frequency of 10.6 GHz, it is possible to estimate the power falling into the entire 10.6 – 10.7 GHz band. This gives:

$$Pfd=-139.6 \text{ dBW / m}^2$$

This pfd level is 20.4 dB higher than the level given in Recommendation ITU-R RA.769 for the 10.6-10.7 GHz band.

This large discrepancy of 20.4 dB will effectively render the entire 100 MHz band unusable for radio astronomy observations, as shown in Figure 2.

4 CONSIDERATION OF SERVICES OPERATING IN THE BAND 10.6-10.7 GHZ OR ADJACENT BANDS

4.1 FSS operating in the band 10.7-11.7 GHz

The GSO FSS systems in the bands from 10.7-10.95 GHz (space-to-Earth) and 11.2-11.45 GHz (space-to-Earth) are subject to the RR **Appendix 30B** provisions, as pointed out in RR No. 5.441. This appendix defines a plan to assign and guarantee capacity to all ITU member nations. Non-GSO satellite systems are subject to other regulatory provisions.

Given the general policy of first-come, first-served in FSS bands, the creation of the **AP 30B** Plan allowed developing nations to preserve access to the GSO arc at a future time. Any imposition of constraints such as guard-bands or filtering on the FSS in the band 10.7-10.95 GHz would impact the **AP 30B** Plan. These bands are today used by several satellite systems over Europe with analogue and digital modulation.

Many international satellite operators have elected to make use of the band 10.95-11.2 GHz and 11.45-11.7 GHz for international communications. As a consequence, FSS system using this band may in some cases be the main source of international communications. Additional protection of the RAS in the band 10.6-10.7 GHz beyond current design practices could therefore impact the rates charged for these communications.

4.2 EESS operating in the band 10.6-10.7 GHz

The Earth Exploration Satellite Service (EESS) needs to make use of the passive band and will not consider a frequency shift. In particular, it has been shown in a separate study that FSS downlink operating in the band 10.7 – 11.7 GHz will not interfere with EESS systems operating in the band 10.6 –10.7 GHz.

4.3 FS operating in the band 10.5-10.68 GHz

The bands 10.15-10.3/10.5-10.65 GHz are identified by the ERC Recommendation 13-04 as preferred for the deployment of Fixed Wireless Access (FWA) systems in Europe, whereas the ERC Recommendation 12-05 establish a channel arrangements for FS in these paired bands. However the actual deployment of FWA systems vary between different European countries, as illustrated in the following examples.

United Kingdom

In the United Kingdom, the channelling plan is offset by 25 MHz below the one in the Recommendation 12-05, as shown in Table 2a. In the United Kingdom, the band is under the management of the MoD and the use by FWA systems has been negotiated through the Radiocommunications Agency. Core bands were assigned in 1996/7 for FWA services (10.125-10.225 GHz paired with 10.475-10.575 GHz). There were three national licenses awarded for FWA services, each of 2 x 30 MHz. Two of these licenses have been returned to the Agency and one has remained in existence. The Agency is currently considering the award of a further two licenses of 2 x 30 MHz for FWA services following consultation. Details regarding the consultation process are available on the Agency's web site.

User	From GHz	To GHz	Total MHz
FWA	10.125	10.155	30
Guard Band	10.155	10.160	5
FWA	10.160	10.190	30
Guard Band	10.190	10.195	5
FWA	10.195	10.225	30
FWA	10.475	10.505	30
Guard Band	10.505	10.510	5
FWA	10.510	10.540	30
Guard Band	10.540	10.545	5
FWA	10.545	10.575	30
Guard Band	10.575	10.577	2

Table 2a: Details of 10 GHz band use in the UK

It should be noted that the FWA system can have an eirp of up to +33 dBW. The equipment to be deployed in this band will be compliant with the relevant ETSI Standards.

Ireland

Following consultation in May 2002 in Ireland, frequencies have been assigned to 10 GHz FWA systems. A total of three 2 x 28 MHz spectrum blocks will be available with a 2 x 7 MHz block being retained between each 2 x 28 MHz block to facilitate co-existence between users of adjacent spectrum, as shown in Table 2b. Licences will be made available on an individual base station basis.

User	From GHz	To GHz	Total MHz
FWA	10.154	10.182	28
Guard Band	10.182	10.189	7
FWA	10.189	10.217	28
Guard Band	10.217	10.224	7
FWA	10.224	10.252	28
FWA	10.504	10.532	28
Guard Band	10.532	10.539	7
FWA	10.539	10.567	28
Guard Band	10.567	10.574	7
FWA	10.574	10.602	28

Table 2b: Details of 10 GHz band use in Ireland

Finland

Details of the frequencies currently issued within Finland are given in Table 2c, the licences utilise 5 channels of 2 x 30 MHz.

User	From GHz	To GHz	Total MHz
FWA	10.15	10.18	30
FWA	10.18	10.21	30
FWA	10.21	10.24	30
FWA	10.24	10.27	30
FWA	10.27	10.30	30
FWA	10.50	10.53	30
FWA	10.53	10.56	30
FWA	10.56	10.59	30
FWA	10.59	10.62	30
FWA	10.62	10.65	30

Table 2c: Details of 10 GHz band use in Finland

It should be noted that FWA can have an eirp of up to +33 dBW , SRDs in the same band with up to 0 dBW eirp. The equipment deployed in this band is compliant with the relevant ETSI Standards.

4.4 SRD

SRDs may operate in the band 10.5-10.6 GHz using a power up to 500mW (eirp). Technical characteristics of SRD systems are given in ERC/REC 70-03.

4.5 Mobile Applications: video SAP/SAB links (ENG/OB)

The frequency band 10.0-10.68 GHz is also used by Services Ancillary to Programme making and Services Ancillary to Broadcasting (SAP/SAB). ECC Report 02 on SAP/SAB provides information on the current and future use of various video SAP/SAB links (ENG/OB systems) in this band.

The report notes that the band 10.0-10.68 GHz is widely used by video SAP/SAB links in Europe. Of 18 analysed countries, only 2 indicated no SAP/SAB use in this band. Of 16 positively responding countries, 12 would allow video SAP/SAB links in the middle part of the band (around 10.3-10.5 GHz), 10 in the upper parts (10.5-10.68 GHz) and 6 in the lower parts (10-10.15 GHz).

The report concludes that it is likely that the use of this band by the video SAP/SAB links shall continue, on a shared basis with other services, e.g. utilising separation gaps between go-return duplex parts within FWA deployment scenarios, non-radar parts, etc.

The foreseen by the report video SAP/SAB applications in this band include temporary point-to-point video links, portable video links and cordless cameras.

The later study into the issue of sharing between the video SAP/SAB links and EESS (passive) sensors in the band 10.6-10.68 GHz concluded that operation of cordless cameras and portable links in this band is likely to cause interference to EESS. Therefore it is recommended that only temporary point-to-point video SAP/SAB links are allowed between 10.6-10.68 GHz, in limited numbers.

5 POSSIBLE MITIGATION TECHNIQUES TO DECREASE THE LEVEL OF UNWANTED EMISSIONS RECEIVED BY RAS RECEIVERS

5.1 Mitigation technique currently used

In order to continue RAS observations in the case of interference, described in Section 3 of this report, a filter was introduced into the receiver front-end. The specification for the filter was designed so as to suppress the main transmission from interference source by 70 dB, while leaving sufficient pass-band with minimal insertion loss.

Amplifiers based on field effect transistors could be re-tuned to the somewhat lower frequency without loss of gain or increase in noise figure. A good commercially available filter design could be found. Figure 5 shows the transfer function for the filter, as provided by the filter manufacturer.

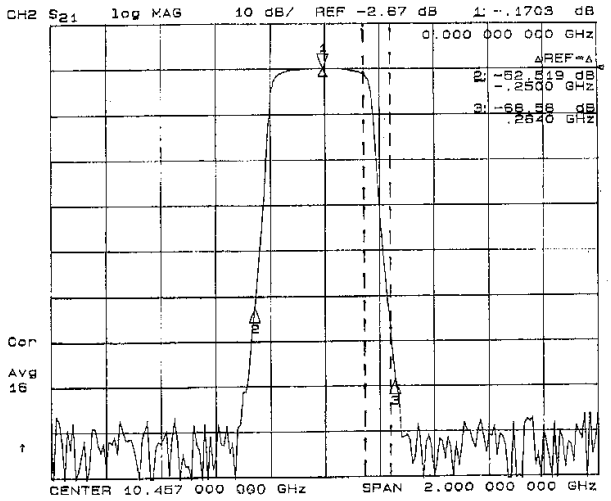

Figure 5: Filter attenuation curve of the employed band-rejection filter

Marker 3 in Fig. 5 is set to the nominal centre frequency of interfering satellite transmission, that is 10.714 GHz. Note that the RAS band allocation, 10.6 – 10.7 GHz is marked by the dashed lines.

In order to make efficient use of the spectrum, both the FSS and the RAS systems aim to employ all channels within their respective allocations, including the outermost channels. The measurements of the FSS unwanted emission spectrum do not provide clear evidence of the required frequency separation, at which the interference threshold limit to protect the RAS is met.

It could be noted that the above described filter, which has been designed to protect the RAS receiver, provides minimal insertion loss at a frequency separation of roughly 200 MHz from the centre frequency of a rejected signal. As filter technology progresses, better figures may be achievable, but the currently available instrumentation requires a frequency shift of at least 100 MHz to be made.

It should be also noted that usable RAS observations can be made at Effelsberg in a frequency band around 10.5 GHz, which is allocated to the terrestrial fixed service, and in which interference is reported only occasionally.

5.2 Possible way to derive a frequency separation

Figure 6 shows the spfd levels of a digitally modulated FSS signal with a symbol rate of 22 Msps, a roll-off of 35% and a transponder bandwidth of 26 MHz. For practical reasons, the real signal power envelope was extrapolated by a linear function in order to estimate the power falling into the entire 100 MHz RAS band with or without guard band.

The Table 3 shows the reference points of so derived linear emission mask.

Frequency (GHz)	Unwanted emission spfd level (dBW/m2/Hz)
10.570	-285
10.656	-256
10.662	-237
10.680	-237
10.700	-195

Table 3: Levels of unwanted emissions falling into the 10.57 - 10.7 GHz frequency band at specific points

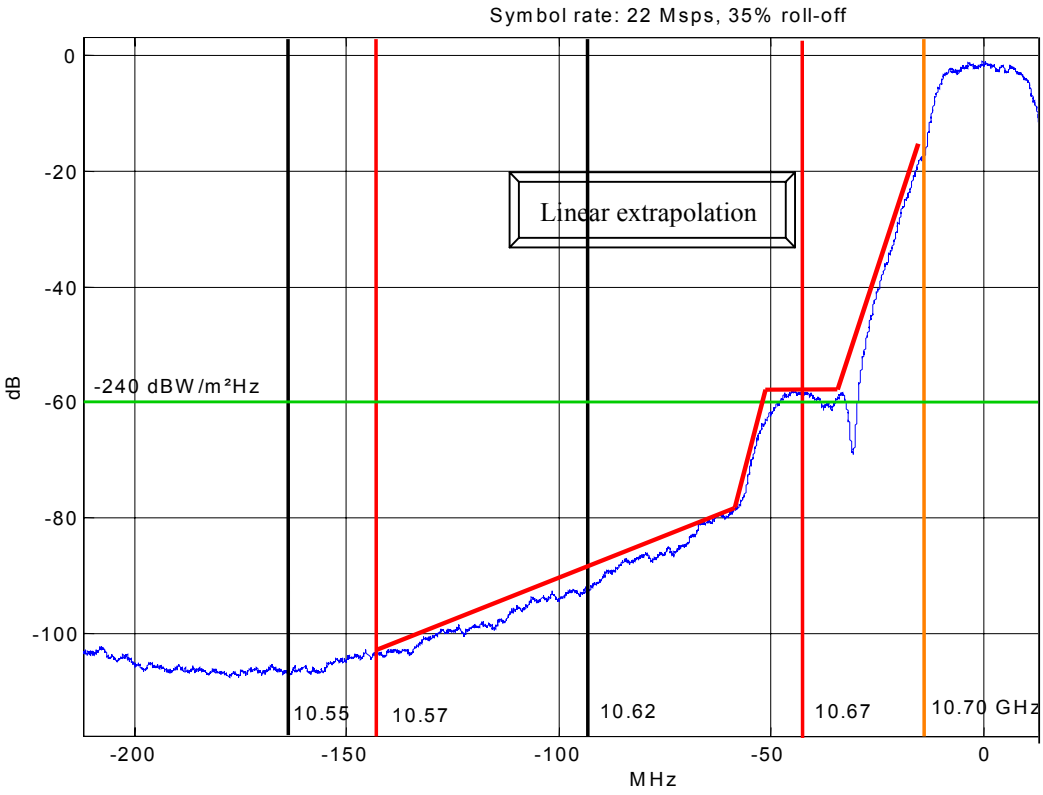

Figure 6: Out-of-band emission mask of digitally modulated FSS signal

Due to the nature of digital modulation, the necessary bandwidth of digitally modulated signal is very close to the transponder bandwidth. Therefore, the spfd levels falling into the upper part of the RAS frequency band are much greater than the spfd levels observed for an analogue modulation (see Figure 7).

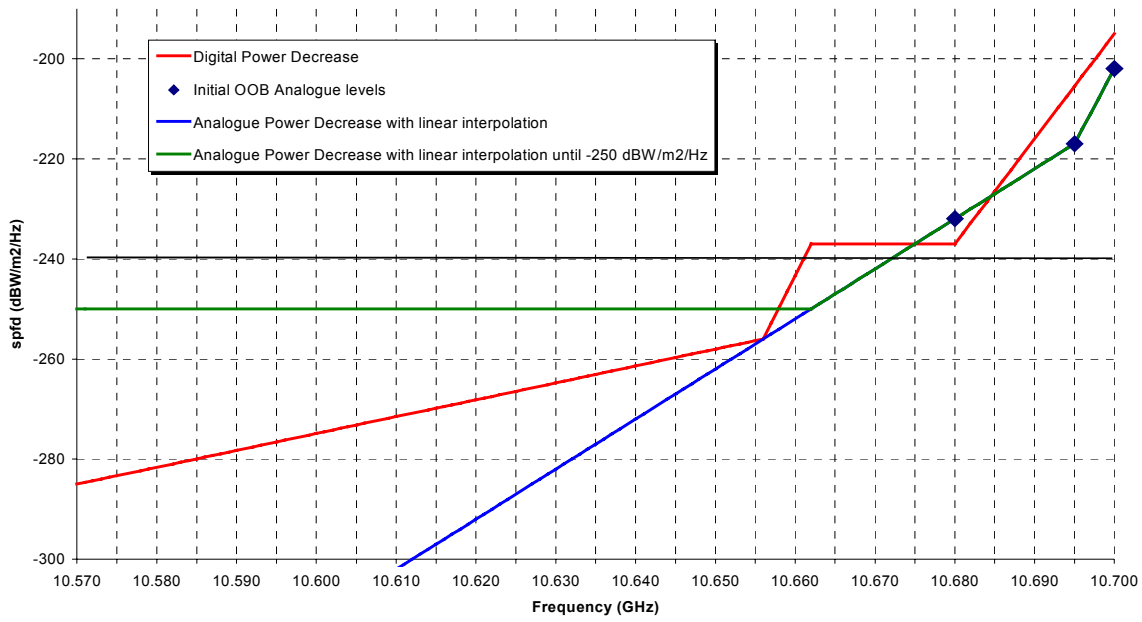

Figure 7: OOB emissions from various FSS signals into the frequency band below 10.7 GHz

Due to the lack of information regarding the spfd levels falling into the frequency band below 10.660 GHz for an analogue modulation, two cases were considered based on the above described measurement of particular interference case conducted at Leeheim monitoring station (see Fig. 3).

First, a linear decrease between 10.7 and 10.68 GHz and a linear interpolation between 10.68 and 10.57 GHz was considered. For the second case, the approximation line as in first case was extended with a plateau at -250 dBW/m2/Hz for all frequencies below 10.662 GHz.

These 2 analogue modulation cases are complemented for further analysis with the digital modulation case.

Based on these 3 masks, power falling in a 100 MHz band was evaluated with varying guard band between the RAS band and the FSS band of 0 to 30 MHz. Results are shown in Fig. 8.

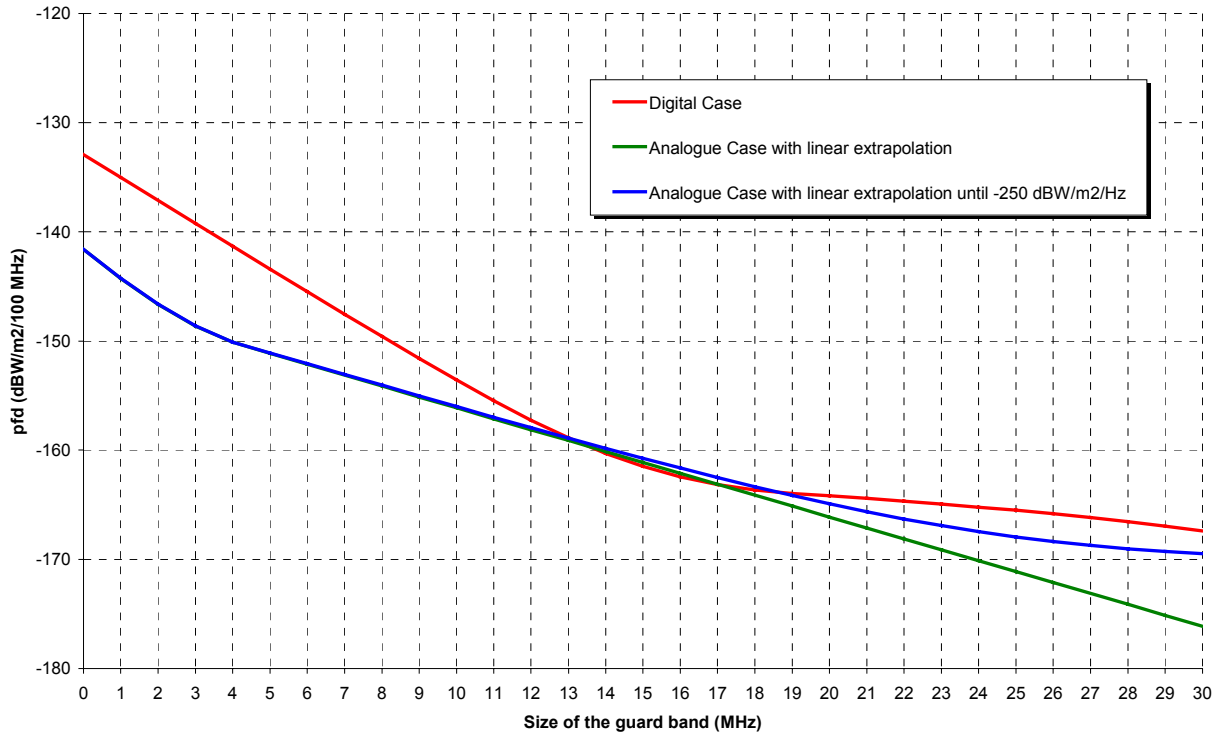

Figure 8: Evaluation of guard band necessary to protect the RAS

Figure 8 shows that for each of 3 analysed cases, the guard band necessary in order to respect the RAS protection criteria given in Recommendation ITU-R RA. 769 for continuum observations (i.e. -160 dBW / m^2 /100 MHz) is around 15 MHz.

6 CONCLUSION

Based on the considerations given in section 5.2, the required frequency separation between the RAS and the FSS is in the order of 15 MHz.

Taking into account the additional 15 dB attenuation in case of GSO satellites as suggested in the ITU-R Rec. RA.769-1 and the slope of the RAS filtering (see section 5.1), the required frequency separation may be in the order of 100 MHz.

The impact on both the FSS and RAS of the implementation of such a guard band needs to be studied taking into account all relevant aspects.

ANNEX 1: TABLE OF ALLOCATIONS AROUND 10.7 GHz

Radio Regulations			European common allocation	Major utilisation within Europe
Region 1	**Region 2**	**Region 3**		
10.5 - 10.55 GHz FIXED MOBILE Radiolocation	**10.5 – 10.55 GHz** FIXED MOBILE RADIOLOCATION		**10.5 – 10.55 GHz** FIXED MOBILE Radiolocation	Fixed includes point to multipoint. ENG/OB is envisaged. Motion sensors.
10.55 - 10.6 GHz FIXED MOBILE except aeronautical mobile Radiolocation			**10.55 - 10.6 GHz** FIXED MOBILE except Aeronautical Mobile Radiolocation	Fixed includes point to multipoint. ENG/OB is envisaged. Motion sensors.
10.6 - 10.68 GHz EARTH EXPLORATION-SATELLITE (passive) FIXED MOBILE except aeronautical mobile RADIO ASTRONOMY SPACE RESEARCH (passive) Radiolocation 5.149 5.482			**10.6 - 10.65 GHz** FIXED MOBILE except Aeronautical Mobile RADIO ASTRONOMY EARTH EXPLORATION-SATELLITE (passive) SPACE RESEARCH (passive) Radiolocation 5.149 5.482	Fixed includes point to multipoint. ENG/OB is envisaged. Passive applications.
			10.65 - 10.68 GHz EARTH EXPLORATION-SATELLITE (passive) FIXED MOBILE except Aeronautical Mobile RADIO ASTRONOMY SPACE RESEARCH (passive) 5.149 5.482	Fixed includes point to multipoint. ENG/OB is envisaged. Passive applications.
10.68 - 10.7 GHz EARTH EXPLORATION-SATELLITE (passive) RADIO ASTRONOMY SPACE RESEARCH (passive) **5.340 5.483**			**10.68 - 10.7 GHz** EARTH EXPLORATION-SATELLITE (passive) RADIO ASTRONOMY SPACE RESEARCH (passive) **5.340**	Passive applications.
10.7 - 11.7 GHz FIXED FIXED-SATELLITE . (space-to-Earth) . (Earth-to-space) . **5.441 5.484 5.484A** MOBILE except aeronautical mobile **21.6 21.12 21.16 22.5E**	**10.7 – 11.7 GHz** FIXED FIXED-SATELLITE (space-to-Earth) S5.441 S5.484A MOBILE except aeronautical mobile **21.16 22.5E**		**10.7 – 11.7 GHz** FIXED FIXED-SATELLITE (space-to-Earth) S5.441 S5.484 Land Mobile-Satellite (space-to-Earth) Mobile except Aeronautical Mobile	Fixed links. Fixed Satellite Plan 10.7 - 10.95 / 11.2 – 11.45 GHz in accordance with App. 30B.