CGMS-XXX EUM-WP-12
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# INTRODUCTION OF CAR RADAR DEVICES IN THE FREQUENCY BAND 21 – 27 GHZ


The document provides information on the plans of the car industry to implement car radar systems using Ultra-Wideband technology and operating within the frequency band 21 – 27 GHz including the EESS (passive) band 23.6 – 24 GHz.

A copy of the study produced by CNES, ESA, and EUMETSAT is attached. This study has been submitted to European frequency administrations. The status of discussions in Europe is reported. Latest updates will be provided at CGMS XXX.

# INTRODUCTION OF CAR RADAR DEVICES OPERATING IN THE FREQUENCY BAND 21 – 27 GHZ

A group of car manufacturers have organised themselves under the name SARA (Short Range Automotive Radar) and have recently published plans to introduce Short Range Radar (SRR) equipment on cars using Ultra Wide Band (UWB) technology.

The target frequency range for this application is 22.625 – 25.625 GHz, which includes the band used for very important measurements from passive sensors at 23.6 – 24 GHz. This band is a unique natural resource allowing to correct "windows" between 1 –40 GHz from the water vapour attenuation bands and giving the necessary correction for using the 50 – 60 GHz band for vertical temperature profiling. Due to the importance of this band for passive sensor measurements, the band is protected in the ITU Radio Regulations by FN 5.340 stating "No emissions allowed in this band".

The SARA group has started activities to achieve licenses for their equipment. Several workshops have been conducted under the responsibility of the European Radiocommunication Office (ERO) and European frequency regulatory administrations involving SARA and representatives of so-called "victim services" including the Earth Exploration Satellite Service (EESS).

The discussion process in Europe has resulted in a situation where a draft standard for SRR devices proposed by the European Telecommunications Standards Institute (ETSI) has been put on hold until compatibility between the new service and the existing protected services in the band has been proofed. CNES, ESA, and EUMETSAT have submitted compatibility studies. These studies were based on actual ITU Recommendations and input parameters received from SARA as well as parameters quoted in the draft ETSI standard. Present and future instruments were included into the study (conical scanned, cross-track nadir, and push-broom sensors). The studies clearly indicate that operation of the new service is not compatible to EESS applications. Several mitigation techniques have been proposed but so far, these have not resulted in acceptable sharing conditions. A copy of the most recent version of the study is attached in Annex 1 to this document.

The study was discussed at the CEPT special working group SE-24 in Bern (Switzerland). The conclusion of this group was that sharing between the car radars and EESS (passive) is not feasible. Activities are concentrated to find an alternative frequency band. Nevertheless SARA claims that they would need to start implementation of the service in the band 21 – 27 GHz. This is due to the availability of sensors, which were designed for this band. SARA representatives have proposed to develop a new type of sensor which will operate in a different band and that they intend to depart from the band covering the EESS (passive) allocation. It will now be necessary to find and agree on an alternative band and to develop a committing schedule for introduction and termination of the service. It is foreseen to fix a date after which no new equipment will be installed. Such a committing schedule could be made part of the licensing agreement issued by the frequency regulators. The EESS community could agree on this regulation recognising that

- in the first years of service implementation there would be only small numbers of cars equipped with these radars
- EESS sensors of a new, more sensitive type (as included in the compatibility study) would only be implemented in a few years.

The FCC in the USA have issued a “First Report and Order” (ET Docket 98-153) on 22 April 2002 regarding the use of Ultra-Wideband transmissions including the use of this technology for “Vehicular Radar systems”. Although this document concludes that no harmful interference will be caused to meteorological satellite measurements, it is expected that the associated spectrum masks and operation values used in this document are not giving the required protection to EESS usage in the band. It has therefore to be expected that the introduction of the new service will invalidate measurements of instruments operated on meteorological satellites. Wrong measurement values will be achieved and will invalidate not only the measurements in the 24 GHz band but also all other measurements of these instruments. This could result in a major degradation in meteorological processing based on these measurements.

A phased approach for the introduction of the Vehicle Radar System has been proposed by reducing the output power of SRR equipment after certain dates to compensate for the growing number of operating devices and the related cumulative interference from serious high numbers of equipment. Although this could improve the sharing situation, there are still doubts whether this will give the required protection. It is also noted that the equipment will be operated under part 15 of FCC rules, i.e. as unlicensed equipment.

ITU has discussed the issue of UWB and has decided that a Task Group (TG 1/8) be established in Study Group 1 in order to urgently address the compatibility between UWB devices and radiocommunication services (Q.227/1), the spectrum management framework related to the introduction of UWB devices (Q.226/1), and appropriate measurement techniques for UWB devices.

Considering the criticality of this issue to the space-component of the Global Observing System and to its all weather sounding capability CGMS is invited to discuss this issue and to elaborate on possible solutions to the problem.

The attached study provides the necessary background for these discussions. An update of developments in Europe will be given verbally at CGMS XXX.

## Annex1: Compatibility analysis between the EESS passive band 23.6-24 GHz and the automotive radar at 24 GHz.

## (Common study by CNES, ESA, and EUMETSAT)

## 1 EXECUTIVE SUMMARY

This report is a compatibility analysis between the short range automotive radars which are planned to operate in the 21-27 GHz band and the EESS(passive) meteorological sensors operating in the purely passive band 23.6-24 GHz band. The parameters for these studies are derived from:

- the draft ETSI System Reference Document for short range radars in the 24 GHz band (ETSI TR 101 982R1 v1.1.3a (2002-05)),
- the characteristics of the EESS passive sensors operating in the band 23.6-24 GHz, provided by the EESS representatives,
- the protection criteria for EESS passive sensors contained in the ITU-R recommendation SA.1029-1 and those updated by ITU-R WP 7C in February 2002,
- the protection criteria for EESS passive sensors which are envisaged by the Space and the meteorological Agencies in the far future around the year 2020,
- additional technical information provided by the SARA group as mitigation factors,
- figures from the SARA group about foreseen vehicle density scenarios.

The results show that sharing with all types of EESS sensors would result in a sizable negative margin **(up to -20 dB for current requirements and up to -27 dB in the very long term for future instruments),** corresponding to the loss of the required meteorological information. This report also contains **a ground scattering model that leads to margins up to – 25 dB (instead of – 20 dB that took into account the direct path only) for current requirements of passive sensors**.

It is to be noted that **ITU-R footnote 5.340** does not allow any emission in the band 23.6-24 GHz and that, according to the Rules of Procedures of the ITU-R Radio Regulation Board, it **is impossible to notify any system in the bands listed in footnote 5.340. Therefore, the use of the bands covered by footnote 5.340 must be avoided by any type of UWB device.**

All the above reasons come to the conclusion that **the short range radars cannot share the band with the EESS (passive) in the band 23.6-24 GHz.**

Given the importance of the use of these meteorological parameters for weather forecast, SE-24 suggests exploring the possibility to shift the UWB band to avoid entering the 23.6-24 GHz band.

The report also contains elements concerning the use of the adopted FCC regulation and also for a proposal from ETSI to introduce lower eirp and improved antenna pattern. Those two regulations are quite similar and lead to the same conclusion: the Short Range Radars using these new lower figures cannot share the band with the EESS (passive) in the band 23.6-24 GHz.

## 2 PASSIVE SERVICE

The EESS (passive) currently operates two types of passive sensors:

- Conically scanned sensors around the nadir direction, which are designed to measure two-dimensional surface (land and ocean) parameters;
- Cross-track nadir sensors which are designed to measure three-dimensional atmospheric parameters.

### 2.1 EESS (passive) frequency allocation status

**General**

In recognition of:

- the extreme vulnerability to interference of microwave passive sensors which are designed to measure very faint natural emissions,
- and the catastrophic consequences that interference may have on operational and scientific applications which rely on microwave passive measurements,

Exclusive Status has been granted to most passive allocations, in particular to those which are used for 3D atmospheric measurements, to the exception of frequency bands where the natural atmospheric attenuation provides sufficient shielding to prevent interference (for instance, in the $O_2$ absorption spectrum around 60 GHz).

**The 23.6-24 GHz frequency band**

- The **23.6-24 GHz** frequency band is allocated to the EESS (passive) with an exclusive status where the footnote 5.340 is applicable.
- **The footnote 5.340** stipulates that all emissions are prohibited in these frequency bands.
- According the **Rules of Procedures of the Radio Regulation Board**, it is impossible to notify any system in the bands listed in footnote **5.340.**

The table 1 summarises the frequency allocation around 24 GHz.

TABLE 1

**Adjacent band allocations**

| Services in lower allocated bands | | Passive band | Service in upper allocated band |
|---|---|---|---|
| **22.55-23.55 GHz** | **23-23.6 GHz** | **23.6-24 GHz** | **24-24.05 GHz** |
| FIXED<br>INTER-SATELLITE<br>MOBILE | FIXED<br>MOBILE | EARTH EXPLORATION-SATELLITE (Passive)<br>RADIO ASTRONOMY<br>SPACE RESEARCH (Passive)<br>S5.340 | AMATEUR<br>AMATEUR-SATELLITE<br>S5.150 |

NOTE – The Inter-satellite allocation could be used for GSO and non-GSO systems.

It should be emphasized that, despite the fact that interference may be suffered by the passive sensor, near the lower and upper edges of the allocated passive band, due to out-of-band emissions from active services allocated in adjacent bands, the exclusive status of the allocation essentially guarantees the cleanliness of the passive band, thus preserving the potential improvement of this sensing technique.

**Service**

**General interest of the band 23.6-24 GHz**

The band 23.6-24 GHz is of primary interest by itself to measure water vapour and liquid water. It is used by both conically scanned and cross-track nadir sensors. The total water vapour content from the ground to the satellite is best measured in this frequency band and, it is not possible to find any equivalent frequency band having this same characteristic in the whole electromagnetic spectrum.

**Auxilliary parameter for 3D vertical atmospheric temperature sensing**

Three dimensional atmospheric temperature measurements of utmost importance for operational meteorology (numerical weather forecasting models) and climate studies and monitoring are performed in the oxygen absorption spectrum around 60 GHz. Temperature is also essential to retrieve passive measurements of other atmospheric gases which play a major role in energy transport (water vapour) and photo-chemistry processes ($O_3$, $CH_4$, $NO_2$…).

Besides these primary measurements, **auxiliary parameters are simultaneously measured because they are mandatory to decontaminate the primary measurements from unwanted effects due to atmospheric moisture** (water vapour and liquid water).

Auxiliary parameters are obtained in three radiometric channels :

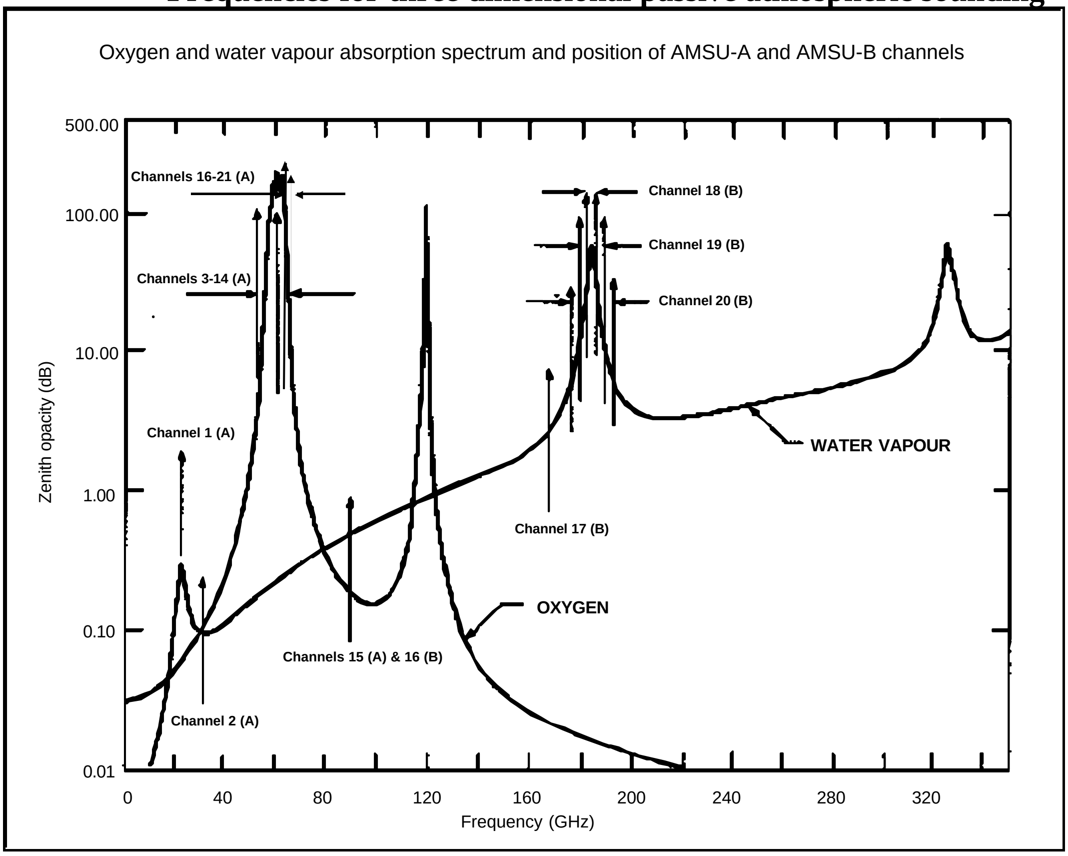
- Around 23.8 GHz for the total water vapour content ;
- Around 90 GHz for the liquid water (precipitation) ;

- Around 31.5 GHz, which is the optimum «window » in the «valley » resulting from the combination of the oxygen and water-vapour absorption curves (see the channel 2 (A) on the figure 1 below), and which serves as a reference for all other measurements

These auxiliary measurements must have radiometric and geometric performances consistent with those of the primary measurements, and must receive similar protection against interference. It is noted that the non-availability of only one auxiliary channel totally invalidates the complete data set.
These frequencies are indicated on the atmospheric $O_2$ and $H_2O$ absorption curves presented on figure 1, where « channels 1(A) and (B), 2(A) and (B), 3(A) and (B)… » refer to the AMSU-A and B vertical sounders which are currently deployed on operational meteorological satellites.

FIGURE 1

**Frequencies for three dimensional passive atmospheric sounding**




It must be emphasized that besides the numerical weather prediction, many applications relying on these measurements are strongly life and property-safety related. It was demonstrated that they can be severely hampered by any interference exceeding the internationally agreed threshold. These applications are in particular :

- Detection and signalisation of potentially hazardous meteorological events. The augmentation of these hazardous events, even at mid latitudes, raise serious concerns in the scientific community ;
- Air and sea traffic routing and safety in the vicinity of airports ;
- Off-shore activities and in general out-door industrial activities.

Concerning the band 23.6-24 GHz, it is important to note that this is the unique band in the whole electromagnetic spectrum where it is possible to retrieve with a good quality the total vertical water vapour content. Therefore, it is essential to preserve such a frequency band.

**Required protection criteria**

The following three documents establish the interference criteria for passive sensors.

1) Recommendation ITU-R SA.513-3, Frequency bands and bandwidths used for satellite passive services
2) Recommendation ITU-R SA.1028-1, Performance criteria for satellite passive remote sensing.
3) Recommendation ITU-R SA.1029-1, Interference criteria for satellite remote sensing.

The interference criteria are the following.

- The interference threshold of the passive sensor is −163 dBW in a reference bandwidth of 100 MHz. This is a maximum interference level from all sources. Such a threshold corresponds to a measurement sensitivity of 0.2 K.
- For conical scan instruments, the number of measurement cells lost due to the threshold being exceeded must not exceed 5% in cases where the interference events are random, and 1% when the interference events are systematic. For three dimensional measurements of atmospheric temperature or gas concentration, the number of measurement cells lost due to the threshold must not exceed 0.01%.

It should be emphasized that operational applications which are routinely operating microwave passive sensors rely heavily on background scientific activities aiming at a better understanding and knowledge of the complex land/ocean-atmosphere machinery.

For that reason, the required performance parameters and interference criteria which are contained in the recommendations ITU-R SA.1028 and 1029 must be regularly updated to reflect such improvements, and to take advantage of the technological advances. These recommendations were recently revised (WP7C, February 2002).

The revised interference criteria are the following.

- The interference threshold of the passive sensor is −166 dBW in a reference bandwidth of 200 MHz. This is a maximum interference level from all sources. Such a threshold corresponds to a measurement sensitivity of 0.05 K.
- The number of measurement cells where the interference threshold can be exceeded must not be more than 0.01% of pixels in all service areas for any kind of instrument.

**Operational characteristics**

Operational characteristics of conically scanned instruments

The following table provides characteristics of conically scanned sensors.

TABLE 2

**Preliminary specifications for microwave radiometric applications using conically scanned sensors**

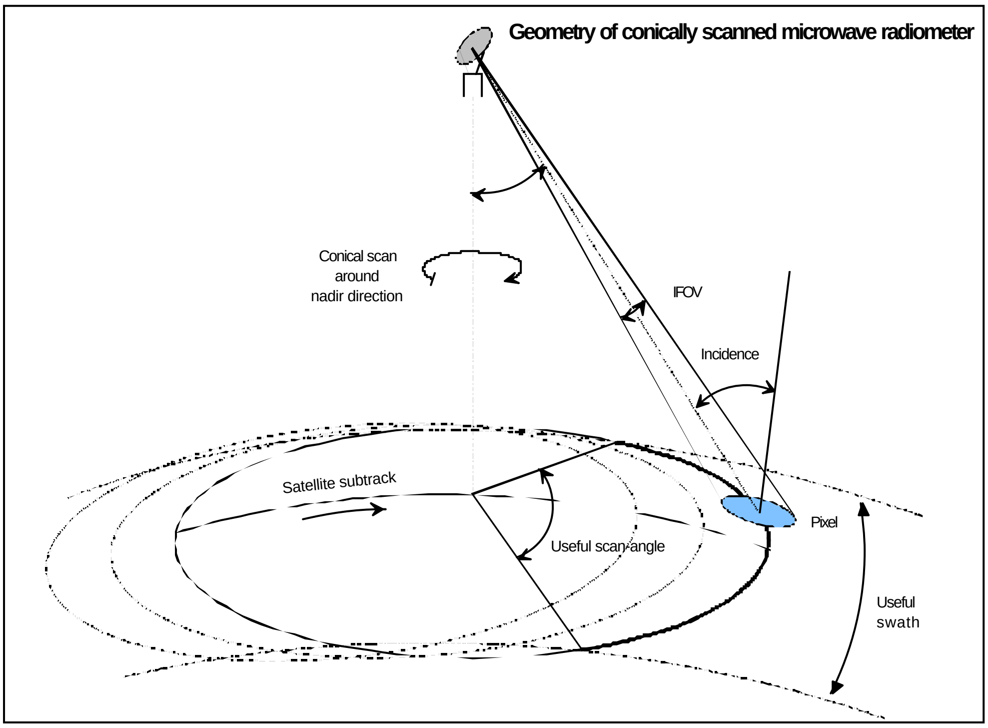
| **Channel 23.6 – 24 GHz** | **MEGHA-TROPIC** | **EOS-AMSR-E** |
|---|---|---|
| Channel bandwidth | 400 MHz | 400 MHz |
| Pixel size across track | 35.4 km | 17.6 km |

| | | |
|---|---|---|
| Beam efficiency | 96 % | 97% |
| Incidence angle i at footprint centre | 52.3° | 55° |
| Half cone offset angle | 44.5° | 47.5° |
| Useful scan angle | 130° | 122° |
| Altitude of the satellite | 817 km | 705 km |
| Maximum antenna gain | 40 dBi | 46 dBi |
| Reflector diameter | 650 mm | 1.6 m |
| Half power antenna beamwidth $?_{3dB}$ | 1.65° | 0.9° |

The pixel size across track is computed from the –3 dB contour of the antenna pattern taking into account the satellite altitude and the incidence angle of the beam boresight.
It is important to note that this kind of EESS sensor is not a nadir satellite, but a EESS sensor having a conical scan configuration centered around the nadir direction. It is important for the interpretation of surface measurements to maintain a constant ground incidence angle along the entire scan lines. The in orbit configuration of conically scanned instruments is described in the figure 2. The rotation speed of the instrument (and not the satellite) is w = 20 revolutions per minute (rpm) for MEGHA-TROPIC and 40 rpm for EOS AMSR-E. At its altitude, the conical scan radiometer measures the upwelling scene brightness temperatures over an angular sector (useful scan angle in Figure 2).

FIGURE 2

**Configuration of conically-scanned passive microwave radiometers**



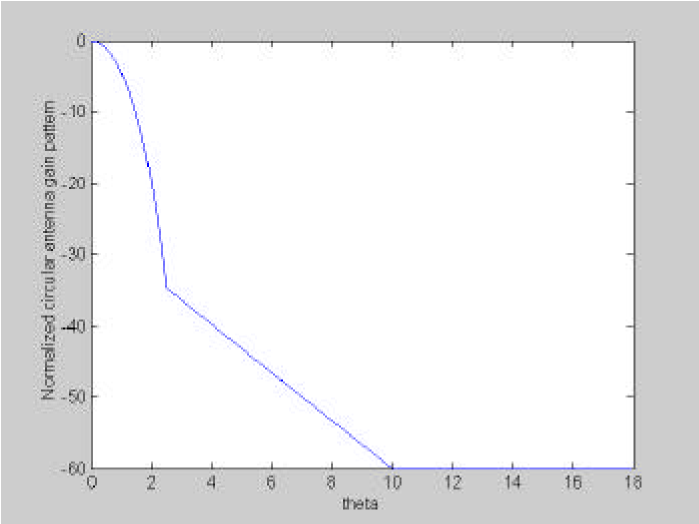

The typical geometrical parameters of this kind of instruments are the following (for an altitude of about 850 km).

– Ground incidence angle i at footprint centre: around 50°.
– EESS offset angle to the nadir or half cone angle a to the nadir direction: about 44°.
– Useful swath of about 1600 km.
– The scanning period is chosen in order to ensure full coverage and optimum integration time (radiometric resolution).

The hereunder figure shows the relative antenna gain pattern of the MEGHA-TROPIC satellite below the maximum gain.

FIGURE 3

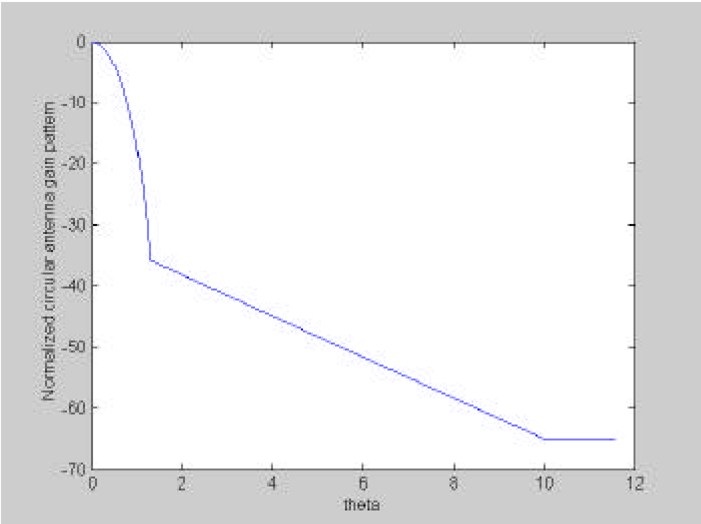
**Antenna gain pattern of the MEGHA-TROPIC satellite**




The hereunder figure shows the relative antenna gain pattern of the EOS AMSR-E satellite below the maximum gain.

FIGURE 4

**Antenna gain pattern of the EOS AMSR-E satellite**



**Operational characteristics of cross-track nadir sensors**

The cross-track nadir sensors retained for this analysis are the AMSU and the “push-broom”. They both scan in a vertical plane containing the nadir direction, normal to the velocity vector of the satellite.

The AMSU (Advanced Microwave Sounding Unit) is a mechanically scanned instrument, where the pixels are acquired sequentially. The cold-space calibration is implemented once per scan revolution by the main antenna, when looking in the cold space direction. The AMSU instrument contains 20 channels and is comprised of two major components, AMSU-A and AMSU-B. The 23.6-24 GHz band is contained within the AMSU-A instrument (module AMSU A2).

The «push-broom» is a purely static instrument with no moving parts, where all pixels in a scan-line are acquired simultaneously, enabling to significantly increase the integration time and the achievable radiometric resolution. The push-broom incorporates one fixed data acquisition antenna pointing in direction of nadir and one dedicated cold space calibration antenna.

The main characteristics of these sensors are given in Table 3.

TABLE 3

**Cross-track nadir sensors characteristics**

| **Parameter** | **AMSU** | **Push-broom** |
|---|---|---|
| Main antenna gain (dBi) | 36 | 45 |
| Antenna Back Lobe Gain (dBi) | -12 | –12 |
| IFOV (Instantaneous Field Of View) at -3 dB in ° | 3.3 | 1.1 |
| Total FOV (Field Of View) cross/along-track (°) | 96.66/3.3 | 100/1.1 |
| Pixel size (km) | 48 | 16 |
| Number of pixels per line | 30 | 90 |
| Sensor Altitude (km) | 850 | 850 |
| Cold calibration antenna gain (dBi) | 36 | 35 |
| Cold Calibration Angle (re.satellite track) | 90 | 90 |
| Cold Calibration Angle (re. nadir direction) | 83 | 83 |
| Type of Scan | Mechanical | Electronic |

The in-orbit configurations of the AMSU and the “push-broom” sensors are described on the figures 5 and 6 respectively.

FIGURE 5

**Geometry of a nadir scan passive microwave radiometer**

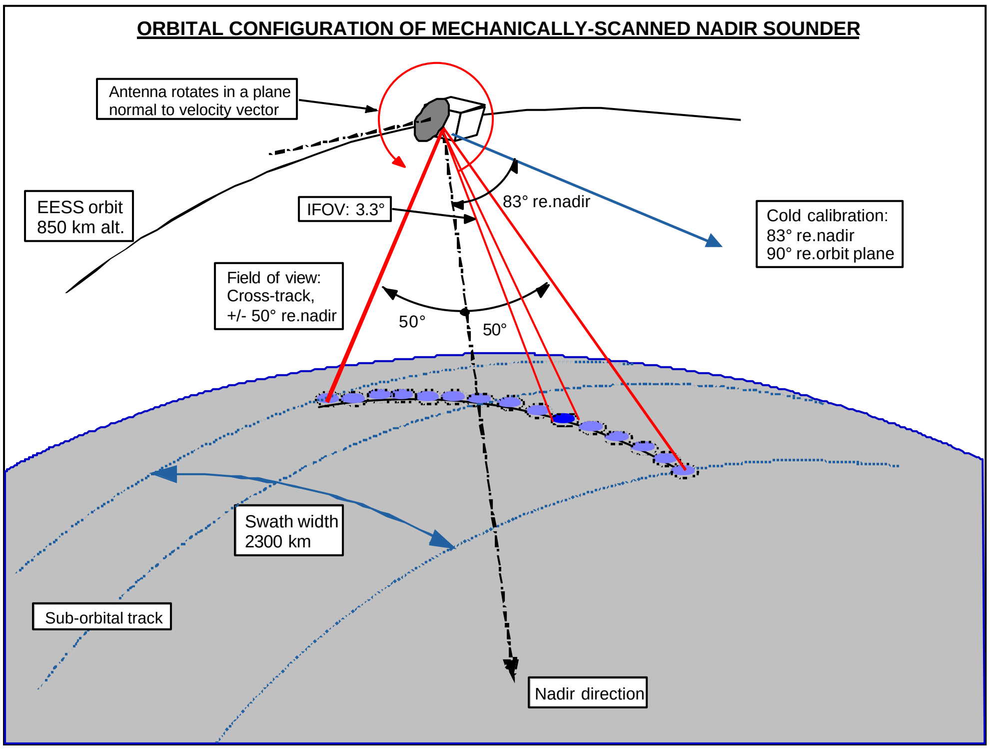
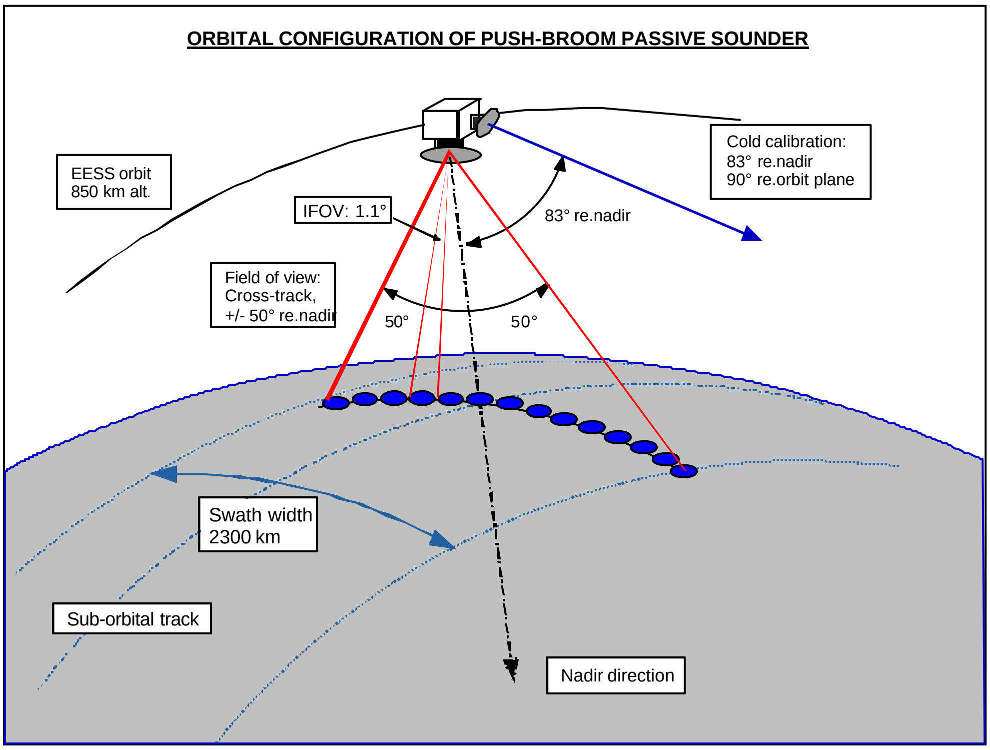


FIGURE 6

**Orbital configuration of the push-broom sensor**




## Characteristics of the 24 GHz automotive radar

The applicable document is ETSI TR 101 982 V1.1.3a (2002 05).

### Transmit carrier frequency

The carrier transmitted frequency is within the range 24.05-24.25 GHz.
According to **article 5.150**, the band 24-24.25 GHz (centre frequency 24.125 GHz) is designated for industrial, scientific and medical (ISM) applications (…). ISM equipment operating in this band is subject to the provisions of No 15.13.
**Article 15.13** stipulates that Administrations shall take all practical and necessary steps to ensure that radiation from equipment used for industrial and medial applications is minimal and that, outside the bands designated for use by this equipment, radiation from such equipment is at level that does not cause harmful interference to a radiocommunication service (…).

**24 GHz automotive radar density**

The expected density of vehicles is taken from the Bosch-SARA document SE24M15_25 to be 123 vehicles/Km$^2$ for the highway scenario outside urban/suburban areas and 330 Vehicles/ Km$^2$ for urban/suburban areas.

**Limitation of vertical antenna characteristic**

The applicable ETSI document gives the limitations of vertical antenna pattern for the car radars. The following table gives the spatial antenna gain for a vertical antenna angle θ in °. Antenna gains of about 15 dBi are typical for automotive short range radars.

TABLE 4

**Limitation of vertical antenna pattern**

| **Vertical antenna angle** q **in °** | **Spatial antenna gain in dBi** |
|---|---|
| θ < -70° and θ > 40° | G_max - 26.66 |
| -70° < θ < - 30° | G_max + 0.66( θ + 30) |
| -30° < θ < 0° | G_max |
| 0° < θ < 40° | G_max - 0.66 θ |

**Power spectral density**

According to the applicable ETSI document, the mean power spectral density that falls within the EESS (passive) band and defined in the transmitter mask is –30 dBm/MHz.

**Bumper loss**

According to the applicable ETSI document, the mounting of 24 GHz SRR devices behind metallic coloured vehicle bumpers do not pose problems due to size and attenuation by the bumper material. However, this is highly critical for devices working at 77 GHz. In addition to that, concerning the application capability, it is stated that simulation and experiments tell that devices at 24 GHz can live with these application requirements while 77 GHz devices suffer from significant attenuation in excess of 20 dB. According to information provided by ETSI, the following compatibility analysis will take into account a loss of 3 dB due to bumper attenuation.

## 3 INTERFERENCE ASSESSMENT

The general methodology applicable to this document is to compute the margin given a certain expected vehicles density, as they are provided in §2.2. According to the applicable ETSI document, several automotive radars are planned for each car, but they are not all operated simultaneously. According to information provided by ETSI, the basis is 4 SRR per car that are supposed to be in operation simultaneously. However, for the specific case of the conical scan instruments due to their geometry, it is assumed a mitigation of factor of 25% due to random car directions.

### Conically scanned instruments

The hereunder table provides the results of the compatibility analysis for conical scan instruments.

TABLE 5

**Compatibility analysis between automotive radars at 24 GHz and MEGHA-TROPIC, EOS AMSR-E**

| Parameter | MEGHA-TROPIC | EOS AMSR-E |
|---|---|---|
| Maximum EIRP (power spectral density) | -30 dBm / MHz | -30 dBm / MHz |
| Bumper attenuation | -3 dB | -3 dB |
| Elevation angle in order to reach the maximum EESS antenna gain | 37.7° | 35° |
| Radar antenna gain at the above elevation angle (0° ideal elevation) | 15 – 0.66*37.7 = -9.8 dBi | 15 – 0.66*35 = -8.1 dBi |
| Radar antenna gain to be substracted | Gmax (15) – (-9.8) = 24.8 dBi | Gmax (15) – (-8.1) = 23.1 dBi |
| Direct power component | -87.8 dBW/MHz | -86.1 dBW/MHz |
| Distance radar - EESS sensor in km | 1336 | 1229 |
| Space attenuation in dB | 182.5 dB | 181.7 |
| EESS antenna gain in dBi | 40 | 46 |
| Atmospherical loss (ITU-R P.676) | -1.0 dB | -1.0 dB |
| Received power at the EESS in a 1 MHz bandwidth in dBW | -231.3 | -222.8 |
| Corresponding received power at the EESS in a bandwidth of 100 MHz in dBW for one single radar. | -211.3 | -202.8 |

| | | |
|---|---|---|
| EESS interference threshold in a reference bandwidth of 100 MHz: application of ITU-R SA 1029-1 | -163 dBW | -163 dBW |
| Number of radars in order to reach the EESS threshold | 48.3 dB (67608 radars) | 39.8 dB (9549 radars) |
| Number of active radars per car | 4 | 4 |
| Mitigation factor due to random car directions (25%) | - 6 dB | - 6 dB |
| Size of the EESS pixel: diameter in km | 35.4 | 17.6 |
| Maximum car density per km$^2$ corresponding to the above number of cars in the EESS pixel | $67608 / p\left(35.4/2\right)^2 = 68.6$<br>or 18.3 dB (cars) per km$^2$ | $9549 / p\left(17.6/2\right)^2 = 39.2$<br>or 15.9 dB (cars) per km$^2$ |
| Expected car density per km$^2$ | 123/ Km$^2$ (Highway) (20.9dB)<br>330/Km$^2$ (Urban/suburb.) (25.2dB) | 123/ Km$^2$ (Highway) (20.9 dB)<br>330/ Km$^2$(Urban/suburb.) (25.2 dB) |
| Margin in highway scenario | **-2.6 dB** | **-5 dB** |
| Margin in urban/suburban scenario | **-6.9 dB** | **-9.3 dB** |

The margin for both instruments and for both car density scenarios is negative.
A more realistic computation is to take into account the revised version of ITU-R SA. 1029-1. Therefore, the above margins become.

TABLE 6

**Resulting margins of the compatibility analysis between automotive radars at 24 GHz and MEGHA-TROPIC, EOS AMSR-E using the revised version of ITU-R recommendation SA.1029-1**

| **Parameter** | **MEGHA-TROPIC** | **EOS AMSR-E** |
|---|---|---|
| EESS interference threshold in a reference bandwidth of 200 MHz: revised ITU-R SA 1029-1 | -166 dBW | -166 dBW |
| Margin in highway scenario | **-8.6 dB** | **-11 dB** |
| Margin in urban/suburban scenario | **-12.9 dB** | **-15.3 dB** |

**Cross-track nadir sensors**

The compatibility between cross-track nadir sensors and automotive radars is evaluated in the table 7 below.

TABLE 7

**Compatibility analysis between automotive radars at 24 GHz and nadir sensors**

| Parameter | Push-Broom | AMSU-A |
|---|---|---|
| Radar EIRP density in main lobe | -30 (dBm/MHz) | -30 (dBm/MHz) |
| Bumper attenuation | -3dB | -3dB |
| Direction of interfering path | Zenith | Zenith |
| Radar antenna gain to be substracted | -26.6 | -26.6 |
| Radar EIRP density to zenith :direct power component | -89.6 dBW/MHz | -89.6 dBW/MHz |
| Distance radar - passive sensor (km): | 850 | 850 |
| Space loss at 23.8 GHz in dB | 178.6 | 178.6 |
| Atmospherical loss (ITU-R P.676) | -1.0 dB | -1.0 dB |
| EESS antenna gain in dBi | 45 | 36 |
| Power density received by the sensor from one single radar (dBW/MHz) | -224.2 | -233.2 |
| Corresponding received power at the EESS in a bandwidth of 100 MHz in dBW for one single radar. | -204.2 | -213.2 |
| EESS interference threshold in a reference bandwidth of 100 MHz: application of ITU-R SA 1029-1 | -163 dBW | -163 dBW |
| Number of radars in order to reach the EESS threshold | 41.2 dB (13182 radars) | 50.2 dB (104712 radars) |
| Number of radars active per car | 4 | 4 |
| Size of the EESS pixel: diameter in km | 16 | 48 |
| Maximum car density per km² corresponding to the above number of cars in the EESS pixel | $3295 / p\left(16/2\right)^2 = 16.3$ or 12.1 dB (cars) per km² | $26178 / p\left(48/2\right)^2 = 14.4$ or 11.6 dB (cars) per km² |
| Expected car density per km² (as from SARA forecast) | 123/ Km² (Highway) (20.9dB) 330/Km² (Urban/suburb.) (25.2dB) | 123/ Km² (Highway) (20.9 dB) 330/Km²(Urban/suburb) (25.2dB) |
| Margin in highway scenario | **- 8.8 dB** | **- 9.3 dB** |
| Margin in | **- 13.1 dB** | **- 13.6 dB** |

| | | |
|---|---|---|
| urban/suburban scenario | | |

The margin for both instruments and for both car density scenarios is heavily negative, even taking into account the ITU-R SA. 1029-1.
A more realistic computation is to take into account the revised version of ITU-R SA. 1029-1. Therefore, the above margins become.

TABLE 8

**Resulting margins of the compatibility analysis between automotive radars at 24 GHz and push-broom, AMSU-A using the revised version of ITU-R recommendation SA.1029-1**

| **Parameter** | **Push-broom** | **AMSU-A** |
|---|---|---|
| EESS interference threshold in a reference bandwidth of 200 MHz: revised ITU-R SA 1029-1 | -166 dBW | -166 dBW |
| Margin in highway scenario | **- 14.8 dB** | **- 15.3 dB** |
| Margin in urban/suburban scenario | **- 19.1 dB** | **- 19.6 dB** |

**Effect on EESS passive sensors of the calculated interference from SRR**

The following table gives the temperature error corresponding to the interference calculated for the various sensors in the two scenarios. The required protection threshold is **0.01 K,** corresponding to a **radiometric sensitivity of 0.05 K.**

TABLE 9

**Resulting radiometric temperatures of the EESS (passive) sensors due to the interference caused by the automotive radars at 24 GHz**

| **EESS Sensor** | **Equiv.DT (K) highway** | **Equiv.DT (K) Urban/suburban** |
|---|---|---|
| **3 MEGHA-TROPIC** | 0.36 | 0.98 |
| **AMSR-E** | 0.63 | 1.7 |
| **Pushbroom** | 1.51 | 4 |
| **AMSU-A** | 1.7 | 4.5 |

The sensor's performance requirements are very significantly degraded, and are brought back to the situation of the seventies. Such a step backward would negate the efforts cumulated during three decades by the public services that rely on passive measurements, and ruin their results.

## 4 FUTURE PROTECTION CRITERIA

Permissible interference based on operational weather forecast and climate monitoring

Today, the required deltaT is 0.05 K which is needed for surface remote sensing and assimilation in the numerical weather forecasts (NWP). It is to be noted that, at the time of completion of the ETSI scenario for the SARA group, the required radiometric sensitivity of the passive sensor will be well below 0.05 K. A reasonable hypothesis by the year 2020 for this value is 0.01 K, which will be needed for global climatic change monitoring and global change survey. It is therefore to be expected that a future revision of Recommendation 1029 will have a –173 dBW/200 MHz threshold value for this band around the year 2020. The sharing analysis conducted in this document uses the official figures contained in Recommendation SA.1029 and its revised version, but the sensor evolution should be kept in mind when analysing the results. These expected requirements explain why this band is designated as "purely passive" in the ITU regulations. It is of utmost importance that **the « cleanliness » of the exclusive passive sensor allocations is preserved**, in order not to unduly limit the improvement potential of the applications that rely on these passive measurements.

**Permissible interference based on the technological evolution of the passive sensors**

Taking into account the technological evolution of the on spaceborne passive sensors, it is expected that the cross track nadir sensors will be able to reach a sensitivity measurement of 0.01K.

**Review of the margins**

The following table provides the updated margins taking into account the above future threshold requirements of –173 dBW/200 MHz.

TABLE 10

**Resulting margins of the EESS (passive) sensors due to the interference caused by the automotive radars at 24 GHz using an initial measurement sensitivity requirement of 0.01 K (future evolutions of cross track nadir sensors)**

| Type of EESS sensor | Highway scenario | Urban/suburban scenario |
|---|---|---|
| Pushbroom | **Margin = - 21.8 dB** | **Margin = - 26.1 dB** |
| AMSU-A | **Margin = - 22.3 dB** | **Margin = - 26.6 dB** |

## 4 OTHER ASPECTS IN THE SHARING ANALYSIS

Although the above compatibility analysis can be used to draw conclusions on the sharing feasibility, the following factors have not been yet considered. Noting that each of the following effect is able to create additional negative margins, resulting into a compatibility situation even worse, it may not be necessary to examine in depth all the following effects.

**Scattering effects**

**Background: estimation of Coupling between Mobile Vehicular Radar and Satellite Radiometers**

The US meteorological administration (NOAA) has made a study that analyses the impact of the radar signal scattering. One of the most probable coupling scattering mechanisms between mobile vehicule radar and a satellite radiometer is a reflection of the main lobe of the radar by another directly-illuminated vehicule toward the main lobe of the radiometer. This study has shown that the reflection generated by the rear part of the car in front of the transmitting radar would create a coupling ranging from –10 to –30 dB with respect to the EESS radiometers within the range of look angles. This study considers reflections from other cars only and takes into account the reflections due to the curvature of the window (characterised by an effective radius of curvature), the glass thickness and the distance between the two cars. Assuming that the short range radars will use horizontal polarization to minimize ambiguous signals from roadway backscattering, the figures are the following for a glass thickness of 0.5 cm and for a radius of curvature of 10 m.

⇨ Cars with a separation distance of less than 10 m: about 5% of cars and a scatter gain of – 15 dB.

⇨ Cars with a separation distance of less than 30 m and more than 10 m: about 45% of cars and a scatter gain of – 18 dB.

⇨ Cars with a separation distance of more than 30 m: about 50% of cars and a scatter gain of – 25 dB.

In addition to the above scattering gains, we take an hemispherical averaging factor of -6 dB, and a -1 dB factor due to the gain due to the scattering from asphalt.

Therefore, the averaged car scattering gain becomes:

$$car\_scattering\_gain = -6 + 10 * \log 10\left[0.05 * 10^{-1.5} + 0.45 * 10^{-1.8} + 0.5 * 10^{-2.5}\right] = -25.8\,\mathrm{dB}$$

**Compatibility analysis**

According to §3, the cross-track nadir sensors are more sensitive than conical scan sensors. Therefore, it is possible to compute the resulting averaged attenuation of the horizontal eirp of the short range radar in the EESS direction (at the nadir) taking into account the following parameters:

⇨ the above car scattering gain,

⇨ the current ETSI attenuation of the horizontal eirp of the SRR (-26.6 dB) in the EESS direction (nadir),

⇨ an additional attenuation of 1 dB due to the asphalt.

$$averaged\_eirp\_attenuation = 10 * \log 10\left[10^{-2.58} + 10^{-2.66} + 10^{\frac{-26.6-1}{10}}\right] = -21.8\,\text{dB}$$

The conclusion of the calculation shows that the scattering effect brings an additional negative margin of 4.8 dB. The resulting margins of table 8 become.

TABLE 11

**Resulting margins of the compatibility analysis between automotive radars at 24 GHz and push-broom, AMSU-A using the revised version of ITU-R recommendation SA.1029-1 and a ground scattering model**

| Parameter | Push-broom | AMSU-A |
|---|---|---|
| Margin in highway scenario | **- 19.6 dB** | **- 20.1 dB** |
| Margin in urban/suburban scenario | **- 23.9 dB** | **- 24.4 dB** |

**Residual carrier component in the sensor band**

A residual carrier component is generated by the SRR radars due to the finite phase shift precision. The current draft specification for automotive radars does not guarantee the absence of residual carrier components in the nearby sensor band. The low-cost characteristics of these radars do not guarantee a proper filtering capability. This could imply much higher power levels than the ones currently assumed in the calculations, in particular when combined with the effects of clock ageing.

**Effects of clock ageing**

The current draft specification does not give indications about the required short-term and long-term stability of the clock. Here again the low-cost concept of the radars can play a role. A drift with time of the central frequency would generate much higher interference levels than the ones considered so far in the ideal case.

**Radar misalignment**

The effect of the radar elevation with respect to the elevation angle has not been taken into consideration. These misalignments can be caused by two factors:

- The car is moving uphill.
- The radar is not mounted properly and presents max gain above $0^o$. This improper mounting is likely to happen frequently, due to the fact that the optimal configuration

for the radar does not correspond to the down-tilted mask in the ETSI document but rather to a more symmetrical configuration similar to what was presented by ETSI (BOSCH) at the first CEPT UWB workshop in 2001 in Mainz.

**Apportionment**

Since this band is exclusively allocated to the EESS (passive), interferences near the lower and upper limits of the allocated band are to be expected only due to unwanted emissions from active services allocated in the adjacent bands (see table 1 for the current allocated services). The concept of "apportioning" the interference threshold among the various interferers (which are actually the adjacent services) has not been agreed yet within ITU-R (TG1/7).

## 5 USE OF THE US FCC REGULATION

**Description of the adopted FCC rules concerning the 24 GHz automotive radars**

The US Federal Communications Commission has released a revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems. It has been adopted February 14, 2002 and released April 22, 2002.

Concerning Vehicular Radar Systems, the FCC rules state the following.

*"These devices are able to detect the location and movement of objects near a vehicule, enabling features such as near collision avoidance, improved airbag activation, and suspension systems that better respond to road conditions. Attenuation of the emissions below 24 GHz is required above the horizontal plane in order to protect space borne passive sensors operating in the 23.6-24 GHz band. (…)*

*Our primary interference concern with vehicular radar systems is cumulative interference to passive sensing systems operating in the 23.6-24 GHz band on low earth orbiting satellites, including meteorological satellites. (…)*

*NTIA based its analysis on a 22 to 23 dB antenna discrimination at elevation angles above 30 degrees above the horizon. It concluded that the emissions from vehicular radar systems in the 23.6-24 GHz must be 35 dB below the Part 15 general emission limits at elevation angles greater than 30° above the horizon. (…)*

*It agreed to permit UWB vehicular radar systems provided these systems attenuate emissions appearing within the 23.6-24 GHz band at greater than 30 dB elevation above the horizontal plane by the following amounts below the Part 15 general emission limits:*

*25 dB by January 1, 2005*

*30 dB by January 1, 2010*

*35 dB by January 1, 2014"*

The FCC Part 15 general emission limits is –41.3 dBm/MHz.

**Resulting margins using these limits**

The results contained in tables 6, 8 and 10 are reviewed taking into account the above FCC figures.

**Conical scan instruments**

TABLE 12

**Resulting margins of the compatibility analysis between automotive radars at 24 GHz and MEGHA-TROPIC, EOS AMSR-E using the revised version of ITU-R recommendation SA.1029-1 and the FCC regulation**

| Parameter | MEGHA-TROPIC | EOS AMSR-E |
|---|---|---|
| EESS interference threshold in a reference bandwidth of 200 MHz: revised ITU-R SA 1029-1 | -166 dBW | -166 dBW |
| Margin in highway scenario using a 25 dB antenna pattern attenuation by the year 2005 | **+ 7.1 dB** | **+ 4.7 dB** |
| Margin in urban/suburban scenario using a 25 dB antenna pattern attenuation by the year 2005 | **-3.2 dB** | **- 5.6 dB** |
| Margin in highway scenario using a 30 dB antenna pattern attenuation by the year 2010 | **+ 12.1 dB** | **+ 9.7 dB** |
| Margin in urban/suburban scenario using a 30 dB antenna pattern attenuation by the year 2010 | **+ 1.8 dB** | **- 0.6 dB** |
| Margin in highway scenario using a 35 dB antenna pattern attenuation by the year 2014 | **+ 17.1 dB** | **+ 14.7 dB** |
| Margin in urban/suburban scenario using a 35 dB antenna pattern attenuation by the year 2014 | **+ 6.8 dB** | **+ 4.4 dB** |

The above table shows that positive margins are expected using the FCC figures, but those figures don’t take into account the fact that, for example by the year 2014, when the antennas

having an attenuation of 35 dB instead of 30 dB or 25 dB are introduced in the automotive market, we have to keep in mind that there will be already a significant number of cars equipped with the previous antenna patterns. Therefore, all the figures contained in the above table must be decreased by several factors depending on the number of cars already in use and having several types of antenna patterns.
The situation might be highly critical for EOS AMSR-E in urban/suburban areas.

**Cross nadir instruments**

TABLE 13

**Resulting margins of the compatibility analysis between automotive radars at 24 GHz and push-broom, AMSU-A using the revised version of ITU-R recommendation SA.1029-1 and the FCC regulation**

| Parameter | Push-broom | AMSU-A |
|---|---|---|
| EESS interference threshold in a reference bandwidth of 200 MHz: revised ITU-R SA 1029-1 | -166 dBW | -166 dBW |
| Margin in highway scenario using a 25 dB antenna pattern attenuation by the year 2005 | **- 5.1 dB** | **- 5.6 dB** |
| Margin in urban/suburban scenario using a 25 dB antenna pattern attenuation by the year 2005 | **- 9.4 dB** | **- 9.9 dB** |
| Margin in highway scenario scenario using a 30 dB antenna pattern attenuation by the year 2010 | **- 0.1 dB** | **- 0.6 dB** |
| Margin in urban/suburban scenario scenario using a 30 dB antenna pattern attenuation by the year 2010 | **- 4.4 dB** | **- 4.9 dB** |
| Margin in highway scenario scenario using a 35 dB antenna pattern attenuation by the year 2014 | **+ 4.9 dB** | **+ 4.4 dB** |
| Margin in urban/suburban scenario scenario using a 35 dB antenna pattern attenuation by the year 2014 | **+ 0.6 dB** | **+ 0.1 dB** |

The same comments as those noted in §6.2.1 are valid for the above table. The situation is even much more critical for cross nadir instruments, because the positive margins are quite small by the year 2014. In addition to that, it is expected that in the meantime, the passive sensor requirements would have been modified, so that the above margins envisaged for 2014 would become negative. Therefore, the use of the FCC regulation won't solve the compatibility issue, even in the long term for cross nadir sensors.

In addition to that, if we both consider very long term protection criteria in §4 and the ground scattering effect in §5.1, all the margins contained in table 13 become largely negative.

⇨The ground scattering effect will provide an additional negative margin of:

- -4.2 dB for an attenuation of 25 dB of the antenna pattern in the direction of the nadir,
- -6.5 dB for an attenuation of 30 dB of the antenna pattern in the direction of the nadir,
- -10 dB for an attenuation of 35 dB of the antenna pattern in the direction of the nadir.

⇨ In 2020, it is expected that the cross nadir instruments will reach a radiometric sensitivity of 10 mK, so that it will result into an additional negative margin of – 7 dB.

# 6 PROPOSED MODIFICATIONS OF THE CURRENT ETSI STANDARD

## Description of the modifications proposed by ETSI

In view of the above adopted rules by the US Federal Communications Commission, ETSI has proposed some modifications concerning the current SRD for automotive collision warning Short Range Radar. These modifications have not been yet adopted by ETSI and are still under discussion.

The proposed changes are the following.

⇨ Attenuation of the short range radar horizontal eirp down to:

– 40 dBm/MHz up to 2010,

– 45 dBm/MHz between 2010 and 2014,

– 50 dBm/MHz after 2014.

⇨ The short range radar antenna gain is attenuated to -30 dB (instead of -26.6 dB) in the direction of the nadir.

## Resulting margins using these limits

The results contained in tables 6, 8 and 10 are reviewed taking into account the new above ETSI figures.

The use of the ground scattering model explained in §5.1 provides an averaged eirp attenuation of -23.5 dB (instead of -30 dB) in the nadir direction, which provides an additional negative margin of -6.5 dB.

Due to the fact that the cross nadir sensors are the most sensitive, the resulting margins will only address this specific type of passive sensor. The margins quoted in parenthesis are those obtained using the ground scattering model.

TABLE 14

**Resulting margins of the compatibility analysis between automotive radars at 24 GHz and the cross nadir sensors using the revised version of ITU-R recommendation SA.1029-1 and the new ETSI figures**

| Parameter | Push-Broom | AMSU-A |
|---|---|---|
| EESS interference threshold in a reference bandwidth of 200 MHz: revised ITU-R SA 1029-1 | -166 dBW | -166 dBW |
| Margin in highway scenario using an eirp of -40 dBm/MHz | **- 1.4 dB (-7.9)** | **- 1.9 dB (-8.4)** |
| Margin in urban/suburban scenario using an eirp of -40 dBm/MHz | **- 5.7 dB (-12.2)** | **- 6.2 dB (-12.7)** |
| Margin in highway scenario using an eirp of -45 dBm/MHz by the year 2010 | **+ 3.6 dB (-2.9)** | **+ 3.1 dB (-3.4)** |
| Margin in urban/suburban scenario using an eirp of -45 dBm/MHz by the year 2010 | **- 0.7 dB (-7.2)** | **- 1.2 dB (-7.7)** |
| Margin in highway scenario using an eirp of -50 dBm/MHz by the year 2014 | **+ 8.6 dB (+2.1)** | **+ 8.1 dB (+1.6)** |
| Margin in urban/suburban scenario using an eirp of -50 dBm/MHz by the year 2014 | **+ 4.3 dB (-2.2)** | **+ 3.8 dB (-2.7)** |

The above table shows that positive margins are expected using the FCC figures and the direct path model, but those figures don't take into account the fact that, for example by the year 2014, when the radars having an eirp of - 40 dBm instead of -35 dBm or -30 dBm are introduced in the automotive market, we have to keep in mind that there will be already a significant number of cars equipped with the previous eirp. Therefore, all the figures contained in the above table must be decreased by several factors depending on the number of cars already in use and having several types of radars.
As it is explained in §6.2.2, it is expected that in the meantime, the passive sensor requirements would have been modified, so that the above margins envisaged for 2014 would become negative for the direct path model for the urban/suburban scenario.

If we consider very long term protection criteria in §4 (additional margin of – 7 dB) and the ground scattering effect in §5.1 (see the figures in parenthesis), all the margins contained in table 14 become largely negative.

## 7 CONCLUSION

This analysis shows that the EESS interference threshold is reached as soon as a very small density of cars equipped with 24 GHz automotive radars, is located within an EESS pixel. Scenarios with **negative margins in the order of -20 dB (up to – 27 dB in the very long term)** have been identified. This result is obtained from current and foreseen EESS sensors, from ETSI documentation for the SRR part and from SARA inputs regarding mitigation factors and expected car density. If a ground scattering model is used, the above figures will be decreased by an additional negative margin of – 4.8 dB.

The conclusion is that the **24 GHz automotive radars will cause harmful interference to the EESS sensors** and, therefore, all the data derived from those measurements will be totally corrupted. The corresponding EESS observations will be systematically lost over cities (even small cities), roads or motorways.

It is to be noted that the criticality of the potential interference is of course growing with time, since it is linked to the car radars market penetration and to the appearance of high resolution EESS sensors in a few years time (for which the Recommendation SA 1029 has been recently revised).

In addition to the above considerations, the use of the FCC regulation or the proposed new ETSI figures won't be able to protect the passive sensors, especially the cross nadir instruments which are the most sensitive, even considering in the long term the improvement of the short range radar antenna pattern and the decrease of the horizontal eirp.

It is therefore proposed that the band 23.6-24 GHz be avoided by any kind of automotive short range radar and CEPT should consider to shift this application to another frequency band where the compatibility conditions are much more favourable.