
Jean PLA
Centre National d'Etudes Spatiales
Toulouse, FRANCE

EXECUTIVE SUMMARY

Microwave sensors in operation under the Earth Exploration-Satellite Service (EESS (passive)) are flown on satellites in low-Earth orbit to measure radio noise emissions that occur naturally, in certain frequency bands, from specific components of land, bodies of water, and the atmosphere. Allocations for EESS (passive) were first established by WARC-79 at specific frequencies where passive sensing of important parameters is uniquely possible. It can be noted that these allocations were necessarily adjacent to allocations for active services. These microwave passive frequency bands are divided into two categories according to the international regulation (Radio Regulation or RR) and fall within the category of Earth Exploration Satellite Service or EESS(passive). Purely exclusive frequency bands are dedicated to passive services only: in those bands, sharing is not possible since “all emissions are prohibited” according to RR article No 5.340. Shared frequency bands are such that both passive and active services share a given common frequency resource.

The next World Radio Conference which will be held in October-November 2007 (WRC-07) contain two agenda items (1.2 and 1.20) dealing with passive services. Agenda item 1.2 deals with in band sharing for the shared frequency bands 10.6-10.68 and 36-37 GHz with Fixed and Mobile Service. Agenda item 1.20 deals with out of band emissions since the frequency bands under consideration are exclusive (1400-1427 MHz, 23.6-24 GHz, 31.3-31.5 GHz, 50.2-50.4 GHz and 52.6-52.8 GHz).

The paper will provide an overview of the two agenda items, as well as a description of regulatory solutions currently envisaged. In particular, one solution which has the preference of the space and meteorological agencies is the inclusion of limits in terms of power or radiated power of active services within the frequency bands of passive services within RR. However, one issue that needs to be clarified is: if the proposed limits, which are based on international agreed recommendations for the protection of microwave passive sensors (such as IU-R SA.1029-2 for the current revision), are exceeded, what are the actual consequences in terms of reliability of the weather forecasting, climatology and monitoring of the environment? What are the consequences on the weather forecast if, for example, some EESS satellite pixels are corrupted with wrong data due to non-natural emissions at 24 or 50 GHz? This issue probably needs some further consideration in order to get further rationale for the purpose of the protection of the passive frequency bands.
Frequency Bands Under Study For The Next WRC-2007

AGENDA ITEM 1.2

The band 10.6-10.68 GHz is allocated to the Earth exploration-satellite service (EESS) (passive), and the radio astronomy and space research (passive) services, on a primary basis. The 10.6-10.68 GHz band is also allocated to the fixed service (FS) and the mobile service (MS) on a primary basis. No. 5.482 limits the e.i.r.p. of FS and MS stations in this band to 40 dBW and the transmitter power to –3 dBW, except in the 30 countries listed in this footnote.

The compatibility studies conducted under this agenda item have clearly shown that the provisions given in No. 5.482 are not sufficient to ensure the protection of the EESS (passive) in the band 10.6-10.68 GHz, therefore sharing criteria between the EESS (passive) and the space research (passive) service on one hand and the other primary services on the other hand need to be defined. Annex 2 shows some evidence of RFI through the usage of AMSR-E at 6 and 10.6 GHz.

The band 36-37 GHz is allocated to the Earth exploration-satellite service (EESS) (passive) and space research service (SRS) (passive), and to the fixed service (FS) and mobile service (MS), all on a primary basis. EESS (passive) and SRS (passive) operating in this band could receive interference from the emissions of systems of active services. Therefore, sharing criteria between the passive services and the active services need to be defined for the band 36-37 GHz.

The World Administrative Radio Conference in 1979 allocated both bands 10.68-10.7 and 36-37 GHz to the EESS (passive) on a co-equal basis with the FS and MS services.

The objective of agenda item 1.2 is to review the sharing situation between passive and active services at 10.6 and 36 GHz and to propose if necessary adequate limits for MS and FS.

Table 1

<table>
<thead>
<tr>
<th>Shared EESS(passive) frequency bands</th>
<th>Scientific interest</th>
<th>Corresponding in-band allocation producing RFI</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.6-10.68 GHz</td>
<td>Rain rate, snow water content, ice morphology, sea state, ocean wind speed</td>
<td>FS, MS</td>
</tr>
<tr>
<td>36-37 GHz</td>
<td>Rain rates, snow, sea ice, clouds</td>
<td>FS, MS</td>
</tr>
</tbody>
</table>
AGENDA ITEM 1.20

Allocations for EESS (passive) were established by WARC-79 at specific frequencies where passive sensing of important parameters are uniquely possible. These allocations were necessarily adjacent to allocations for active services, many of which have been implemented for active transmission systems that, like EESS (passive) measurements, are also vital to national economies, and safety-of-life applications in some cases.

Active systems in adjacent or nearby bands emit unwanted emissions that fall within the EESS (passive) allocations (Radio Regulation (RR) Nos 1.144-1.146 and Appendix 3), thus presenting a risk that unwanted emissions could cause unacceptable interference to EESS (passive) measurements. Annex 3 shows the various definitions and mechanisms in connection to the unwanted emission issue.

Prior WRC-03, ITU-R conducted studies between the EESS (passive) and active services in certain adjacent or nearby bands. WRC-03 did not reach any agreement and decided to further the studies for specified pairs (see table 2) of frequency allocations EESS (passive) and active services. Preliminary calculations have shown that low levels of interference received at the input of the passive sensors may degrade passive sensor operations according to the thresholds contained in Recommendation ITU-R S.1029-2.

The following table shows the list of band pairs under investigation concerning agenda item 1.20. It is to be noted that only 5.340 bands are considered for this agenda item, since these bands are in principle protected from in-band emissions (except for the automative short range radars which have been unfortunately authorised in some countries). It is assumed that due to their status provided by 5.340 (« All emissions are prohibited »), those bands are able to receive RFI from services in operation in adjacent bands only: those kinds RFI are also known under the name of unwanted emissions (composed of spurious emissions and of out of band emissions).
Table 2
Agenda item 1.20: List of band pairs EESS(passive) frequency bands, their scientific interest and the source of unwanted emission in adjacent bands

<table>
<thead>
<tr>
<th>5.340 EESS(passive) frequency bands</th>
<th>Scientific interest</th>
<th>Adjacent frequency bands with their corresponding allocation producing unwanted emission within the passive bands</th>
</tr>
</thead>
</table>
| 1.4-1.427 GHz                       | Soil moisture, ocean salinity, sea surface temperature, vegetation index | Radiolocation (RL): 1 350-1 400 MHz  
FS: 1 350-1 400 MHz and 1 427-1 452 MHz  
Space Operation (SO): 1 427-1 429 MHz  
MS: 1 350-1 400 MHz and 1 427-1 452 MHz |
| 23.6-24.0 GHz                       | Water vapour, liquid water | Inter Sarellite (ISS): 22.55-23.55 GHz |
| 31.3-31.5 GHz                       | Sea ice, water vapour, oil spills, clouds, liquid water, surface temperature, reference window for 50-60 GHz range | FSS (Earth to Space): 30-31 GHz |
| 50.2-50.4 GHz                       | Reference window for atmospheric temperature profiling (surface temperature) | Fixed Satellite (Earth to Space) (FSS): 47.2-50.2 GHz  
FSS (Earth to Space): 50.4-51.4 GHz |
| 52.6-52.8 GHz                       | Atmospheric temperature profiling | FS: 51.4-52.6 GHz |

ADEQUATE METHOD TO SOLVE AGENDA ITEMS 1.2 AND 1.20

AGENDA ITEM 1.2
The most appropriate method in order to better protect the shared passive band at 10.6 and 36 GHz is to introduce within the RR a single entry emission limits taking into account the results of the compatibility analysis. Those limits would be non-retroactive for the terrestrial active systems notified or brought into use before WRC-07 (the exact date corresponding to this concept will have to be decided by WRC-07).
Advantages

The EESS (passive) would be protected from in-band emissions through regulatory provisions that would be applied consistently worldwide.

Disadvantages

These limits may unduly constrain the operations and deployment of future active systems.

AGENDA ITEM 1.20

For each band pair as indicated in Table 2, the Conference may decide a method to satisfy the Agenda Item. The main objective is to ensure equitable burden sharing for achieving compatibility between active and passive services. It is to be noted that the Conference may decide that, for a given band pair, no regulatory measures are required.

The method which is preferable is to propose for each band pair a mandatory power limit for unwanted emissions from a single transmitter of a specified service in an adjacent or nearby band.

Advantages

Provides regulatory certainty beneficial to the future planning of both active and passive services.

Passive sensors will be able to operate compatibly in the presence of future systems of the active services operating in specified adjacent or nearby bands.

Disadvantages

Precludes administrations’ flexibility in regulating unwanted emissions in the specified EESS (passive) bands.

In case the underlying assumptions, criteria and predictions used in the analyses prove not to be suitable or appropriate in practice from the standpoint of equitable burden-sharing, mandatory limits may need to be modified, requiring future Conference action.

Impact Of Wrong Or Missing Data

General Methodology Used For The Computation Of The Limits

For both agenda items 1.2 and 1.20, in order to compute the corresponding limits, it is necessary to get an accurate description (power, maximum antenna gain and pattern, deployment density, geographic distribution, …) of the existing and future active systems that could be deployed. On the other hand, the passive systems are known in terms of characteristics (maximum antenna gain and pattern, satellite orbit characteristics) and
sensitivity. The combination of both sets of characteristics allows to perform adequate
dynamic simulations.

**The sensitivity is the key element.** It is described through in force ITU-R Recommendations
RS.1028-2 and 1029-2. The main elements contained in those recommendations are noted in
the following table.

The sensitivities of radiometric passive sensors are generally expressed as a temperature
differential, $\Delta T_e$, given by:

$$
\Delta T_e = \frac{\alpha T_s}{\sqrt{B t}} \quad \text{K}
$$

where:

- $\Delta T_e$: radiometric resolution (r.m.s. uncertainty in estimation of total system
  noise, $T_s$)
- $\alpha$: receiver system constant
- $T_s$: system noise temperature (K) (antenna temperature and receiver noise
  temperature)
- $B$: spectral resolution (of spectroradiometer) or “reference bandwidth” of a
  single radiometric channel (Hz)
- $t$: sensor integration time (s);

The radiometer threshold, or minimum discernible power change, is given by:

$$
\Delta P = k \Delta T_e B \quad \text{W}
$$

where $k$ is Boltzmann’s constant $= 1.38 \times 10^{-23}$ J/K.

ITU-R recommends that the maximum interference level within the reference bandwidth
(dBW) interference level for spaceborne passive sensors in the bands in Table 3 should be set
at 20% of $\Delta P$.

It is to be noted that all the the computations conducted under agenda items 1.2 and 1.20 have
been conducted assuming that the interference level derived from active systems should be
lower than this “maximum interference level” noted in Table 3.
Table 3

<table>
<thead>
<tr>
<th>Frequency band(s)(1) (GHz)</th>
<th>Total BW required (MHz)</th>
<th>Reference bandwidth (MHz)</th>
<th>Required $\Delta T_e$ (K)</th>
<th>Maximum interference level within the reference bandwidth (dBW)</th>
<th>Data availability(2) (%)</th>
<th>Scan mode (N, L)(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.37-1.4s, 1.4-1.427P</td>
<td>100</td>
<td>27</td>
<td>0.05</td>
<td>$-174$</td>
<td>99.9</td>
<td>N</td>
</tr>
<tr>
<td>10.6-10.68p, 10.68-10.7P</td>
<td>100</td>
<td>100</td>
<td>1.0/0.1(4)</td>
<td>$-156/-166(4)$</td>
<td>99.9</td>
<td>N</td>
</tr>
<tr>
<td>23.6-24P</td>
<td>400</td>
<td>200</td>
<td>0.05</td>
<td>$-166$</td>
<td>99.99</td>
<td>N</td>
</tr>
<tr>
<td>31.3-31.5P, 31.5-31.8P</td>
<td>500</td>
<td>200</td>
<td>0.2/0.05(4)</td>
<td>$-160/-166(4)$</td>
<td>99.99</td>
<td>N</td>
</tr>
<tr>
<td>36-37p</td>
<td>1000</td>
<td>100</td>
<td>1.0/0.1(4)</td>
<td>$-156/-166(4)$</td>
<td>99.9</td>
<td>N</td>
</tr>
<tr>
<td>50.2-50.4P</td>
<td>200</td>
<td>200</td>
<td>0.05</td>
<td>$-166$</td>
<td>99.99</td>
<td>N</td>
</tr>
<tr>
<td>52.6-54.25P, 54.25-59.3P</td>
<td>6 700(5)</td>
<td>100</td>
<td>0.3/0.05(4)</td>
<td>$-161/-169(4)$</td>
<td>99.99</td>
<td>N</td>
</tr>
</tbody>
</table>

(1) P: Primary allocation, shared only with passive services (No. 5.340 of the Radio Regulations); p: primary allocation, shared with active services; s: secondary allocation.

(2) Data availability is the percentage of area or time for which accurate data is available for a specified sensor measurement area or sensor measurement time. For a 99.99% data availability, the measurement area is a square on the Earth of 2 000 000 km$^2$, unless otherwise justified; for a 99.9% data availability, the measurement area is a square on the Earth of 10 000 000 km$^2$ unless otherwise justified; for a 99% data availability the measurement time is 24 h, unless otherwise justified.

(3) N: Nadir, Nadir scan modes concentrate on sounding or viewing the Earth's surface at angles of nearly perpendicular incidence. The scan terminates at the surface or at various levels in the atmosphere according to the weighting functions. L: Limb, Limb scan modes view the atmosphere “on edge” and terminate in space rather than at the surface, and accordingly are weighted zero at the surface and maximum at the tangent point height.

(4) First number for sharing conditions circa 2003; second number for scientific requirements that are technically achievable by sensors in the next 5-10 years.

(5) This bandwidth is occupied by multiple channels.

Performance Criteria For Passive Remote Sensing Of Environmental Data

IMPACT OF INTERFERENCE WITHIN SATELLITE PASSIVE BANDS

Two kinds of situation of situation may arise: high level of interference (§2.2.1) and undetectable levels of interference (§2.2.2). Then, §2.2.4 will address the issue of RFI within satellite passive bands from a general point of view.
IMPACT OF HIGH LEVEL OF INTERFERENCE

Annex 2 shows that from a systematic point of view, the same areas of the world are corrupted by man made RFI in the band 10.6-10.68 GHz. It means that some areas of the world will suffer from a lack of data, since it is acknowledged that those corresponding data are totally unusable, taking into account the existing high level of interference.

The question is: what is the impact of this lack of data on the overall output products if some data are systematically excluded on the same geographic areas? Are the output data still acceptable or reliable?

IMPACT OF UNDETECTABLE LEVEL OF INTERFERENCE

In case of undetectable levels of interference, which is a situation that is more than likely to occur over large areas, it would imply that corrupted data will be actually used within NWP (Numerical Weather Prediction) models or other models making usage of both data derived from satellite and terrestrial observation. In that case, the data are actually used within the model because the data were initially known to be acceptable (or assumed to be derived from natural emission only).

The corresponding question is similar as described in §2.2.1.

EXAMPLE OF RFI IMPACT AT 1.4 GHZ

Annex 4 provides a good example of the potential impact of RFI within the band 1400-1427 MHz using a radiometer similar to SMOS. The conclusion of this simulation is quite obvious.

GENERAL ISSUES CONCERNING THE IMPACT OF INTERFERENCE

From a general point of view, the impact of RFI within satellite passive bands is not precisely known. In relation with the specific ITU-R WRC-07 agenda items 1.2 and 1.20 described above, it has to be clear that all future limits will be based on the set of sensitivities as in Table 3. Therefore, the remaining question is: if the RFI is such that the interference thresholds are exceeded, what are the consequences in terms of reliability of the weather forecasting, climatology and monitoring of the environment? What happens on the weather forecast (or other similar output products) if, for example, some EESS satellite pixels are corrupted with wrong data due to non-natural emissions at 24 or 50 GHz? This issue probably needs some further consideration in order to get further rationale for the purpose of the protection of the passive frequency bands.

The impact of potential interdependencies of interference in various passive bands is a complex issue that has not been studied thoroughly in the ITU–R including the extent of interference in one band has any impact on measurements in another band.

Eventually, another field of discussion is the impact of missing data, due to extremely level of interference. As the data are known to be wrong over the same area of the world, the corresponding are systematically deleted from the set of data to be used.
The only method which is able to adequately protect the corresponding passive bands proposes hard limits (in-band ou out-of band) which may constrain the existing or future systems in operation in those bands. Some operators already explained the quantitative consequences of a possible limitation of the power of the fixed links.

The question is again the same one: what happens if the interference power received at the radiometer exceeds the permissible interference level quoted in RS.1028 or 1029? The working party in charge of passive sensors within ITU-R already submitted a text as follows.

“Passive sensors currently in use measure RF energy levels, by integrating all natural (wanted) and man-made (unwanted emissions) sources over a period measured in terms of milliseconds (e.g. 10 to 200 milliseconds depending on the particular sensor). The integrated power level of energy from natural sources, expressed in terms of an equivalent noise temperature $T_s$ in Kelvins, is the desired information to be obtained from each passive sensor measurement. Any man-made interference power at a passive sensor receiver is additive to the power produced by the natural phenomena. Therefore, a passive sensor and the algorithms used to process the sensor data have only limited ability to discriminate between radio frequency interference and the RF power produced by the natural phenomena being measured. Consequently, interference produced by man-made sources will always bias any measurement in the direction of increasing the observed value of $T_s$.

Man-made interference levels can be divided into three ranges:

- Undetectable levels, such as the interference criteria specified in Recommendation ITU-R SA.1029-2, which are low enough to have no impact on the value of $T_s$ recorded in a measurement;
- Higher levels of interference which corrupt the value of $T_s$ for a particular measurement but by an amount that is not possible to determine because the measured value of $T_s$ falls within the range of the natural phenomena being measured; and
- Very high levels of interference which result in measured values of $T_s$ that exceed the highest possible value of $T_s$ for the natural phenomena being measured and therefore be discarded.

Measurements corrupted by interference will often go undetected, and such corrupted data will be mistaken for good data during the course of processing this data to produce the environmental, weather and climate data products provided to the public and scientific researchers. The use of such corrupted data can have some serious detrimental consequences. For example:

- it has been demonstrated that extremely small amounts of contaminated satellite data may be sufficient to generate unacceptable errors in Numerical Weather Prediction forecasts;
- the systematic deletion of data where interference is likely to occur may render impossible the recognition of new developing weather systems; and
for climate and other environmental studies, and particularly for "global change" monitoring, interference may lead to misinterpretation of climate signals.

Consequently, the interference criteria specified in Recommendation ITU-R RS.1029-2 are set at sufficiently low levels to avoid any measurable impact of man-made interference on the value of Ts recorded in a passive sensor measurement.”

This text appears to be a qualitative explanation of the consequences of various levels of aggregate interference received by a passive sensor. It is now becoming a very urgent matter to get a quantitative explanation of those various levels of degradation. It is still possible to keep arguing that it is not so obvious to derive this kind of information since complex algorithms are needed to model the atmosphere which is known to be very unstable by nature. It is true that it is hard to distinguish between weak radio frequency interference and naturally geophysical variability. However, Space and meteorological agencies have to bring evidence that interference exceeding the interference quoted in RS.1029-2 will disrupt the existing or planned algorithms.

References


Annex 1

Sensitivity of brightness temperature to geophysical parameters over land and ocean surface

FIGURE A1-1
Sensitivity of brightness temperature to geophysical parameters over ocean surface

FIGURE A1-2
Sensitivity of brightness temperature to geophysical parameters over land surfaces
Annex 2

Interference to passive sensors in the 10.6-10.68 GHz band

This annex contains a picture proposed by Chris Kidd from the University of Birmingham (UK) and is a global composite image of Radio frequency interference in different Microwave frequencies derived from one month of AMSR-E sensor data (August 2004) (yellow is the 6-7 GHz and red 10.6 GHz).

FIGURE A2-1
Radio frequency interference to AMSR passive sensor in the 6-7 GHz and 10.6 GHz bands

This picture is based on negative polarisation differences (i.e. H-pol > V-pol) using a 5K negative polarisation criteria, recognising that negative polarisation higher than 5K can only occur at these wavelengths through man-made emissions in H-pol.

Concerning the band 10.6-10.68 GHz, these plots show in particular large degradation due to interference over Japan, UK and Italy.

However, it should be noted that this figure only shows one form of interference (Horizontal polarisation emissions) and, overall, fails to show how extensive undetectable interference are. However it is reasonable to assume that in regions of extensive detectable RFI there is likely to be larger areas of undetectable interference.

Therefore, detectable interference at high levels, is a symptom of a problem but absence of detectable RFI does not imply that there is not a problem. The plot illustrates that the problem is real and growing (given that such signatures were not detectable a few years ago).
With regards to the potential interference level, acknowledging that these figures are presenting negative polarisations higher than 5K, one can assume that, roughly, interference are, at a minimum, also higher than these 5K. Considering the current interference threshold as given in Recommendation ITU-R RS.1029-2 (i.e. – 166 dBW/100 MHz corresponding to 0.02 K), it shows that these interference are at least 24 dB above the threshold. In addition, Recommendation ITU-R RS.1029-2 also provides, for the 10.6-10.7 GHz, a 0.1% percentage of area permissible interference level may be exceeded over a 10 000 000 km² measurement area. Considering roughly that over UK and Italy territories, an average of half territory (i.e. about a total 277 000 km² = (253 000 + 301 000)/2) is polluted at very high levels, the highly contaminated area already corresponds to a 2.8 %, also exceeding by far the area criteria (0.1%), stressing that other areas are contaminated without being detectable and are hence not considered in this estimation.
Annex 3

General description of the unwanted emission problem
The boundary between the out-of-band and spurious domains occurs at frequencies that are indicated in Figure A3-1: in general, the boundary, on either side of the centre frequency of the emission, occurs at a separation of 250% of the necessary bandwidth, or at 2.5 BN, with BN being the necessary bandwidth of the active transmitter.

FIGURE A3-1
Unwanted emission definitions

FIGURE 1
Out-of-band and spurious domains

FIGURE A3-2
Realistic spurious emissions vs. spurious emissions limit
Annex 4

1400-1427 MHz EESS(passive) band: RFI simulation (T-array, similar parameters to the Y-array of MIRAS on SMOS)

A simulation has been made in order to assess the interference impact on SMOS if a single device active is transmitting in an adjacent band to the passive band 1 400–1 427 MHz. Different values of average unwanted emission power are considered for a single transmitter. It is to be noted that the active device can either be a radiolocation or a fixed service transmitter, and that the power noted below is an average. Figure A4-1 shows the source brightness temperature map used as input to the simulator.

The simulations contained in this Annex have been performed by ESA.

This interference impact simulation has been made for a passive interferometer with similar characteristics to SMOS. For the purpose of the calculation, the antenna for the passive sensor is a T array instead of an Y array which is planned for the SMOS sensor. The average unwanted emission power in the passive band was varied from –40 dBW to 0 dBW. The antenna gain of the active system has not been taken (actually 0 dBi) into account as the probability for a main-to-main lobe coupling will be very small for the vast majority of active systems. It is to be noted that only the case has been simulated where the radiolocation system is located within the field of view (FOV). The situation of the case where the satellite appears on the horizon will occur but its effect has not been simulated. Also, no account has been taken of multiple interferers within the FOV. The results are shown in this Annex.

From these results it can be concluded that the impact of interference at a level of around -30 dBW/27 MHz is still noticeable. Far from representing the ideal situation, a scenario with unwanted emission limits around -30 dBW/27 MHz would represent the absolute limit beyond which the satellite measurements will become unusable.
FIGURE A4-1
Input brightness temperature map depicting a segment of the Yellow River near Xi’an, a city located in the north-west of China

The field of view used in the simulation is around 70 degrees, which is corresponding to an area larger than 1000 x 1000 km. The simulated average power levels are ranging from -40 dBW/27MHz to 0 dBW/27MHz.

FIGURE A4-2
Reconstructed brightness temperature map with RFI using an average level of -40 dBW
FIGURE A4-3
Reconstructed brightness temperature map with RFI using an average level of -30 dBW

FIGURE A4-4
Reconstructed brightness temperature map with RFI using an average level of -20 dBW
FIGURE A4-5
Reconstructed brightness temperature map with RFI using an average level of -10 dBW

FIGURE A4-6
Reconstructed brightness temperature map with RFI using an average level of 0 dBW
Annex 5

Interference to passive sensors in the 6-7 GHz band

Space borne passive sensor in 6-7 GHz is very useful in monitoring soil moisture, sea surface temperature and sea surface wind speed. The current data in this Annex is derived from observations made by JAXA. The 6.9 GHz band (350 MHz width) was used in the AMSR (Advanced Microwave Scanning Radiometer) mounted on the ADEOS-II, and is used in the AMSR-E mounted on the AQUA, the WindSat mounted on the USA Coriolis satellite and will be used in the CMIS (Conical Microwave Imager/Sounder) mounted on the NPOES (National Polar-orbiting Operational Environmental Satellite).

A5.1 Examples of interference in AMSR-E

A5.1.1 Land area

Figures A5-1 to A5-4 show the global distribution of brightness temperature (Tb) maximum values observed by AMSR-E in 2003 at 6.9GHz horizontal and vertical polarization channel. Most of the red regions in the figures are probably due to the man-made emissions except the areas around the Antarctic (they are probably caused by solar reflection). The effect seems to be notable in the United States of America, Japan, India, Middle East, and Europe.

A5.1.2 Ocean area

Non-natural patterns are detected in imagery of 6.925GHz for AMSR and AMSR-E data all over the ocean.

These patterns were detected a few in 2002 and 2003, but its level and latency seems to be increasing since 2004. The intensity and width of the RFI seem to depend on the ocean wind condition such as low- or high-wind speed, surface condition and RFI source condition. The position of the RFI appearance indicates that the source is moving, compared with the pattern of sun glitter, and the sources are existing all over the ocean.

A5.2 Conclusion

Examples of interference in 6.9GHz band imagery not only in land but also in ocean are presented. These interferences seem to increase year by year.
FIGURE A5-5 OVERVIEW OF RFI IN OCEAN AREA (AMSR-E/DAY)

AMSR-E/Aqua Ocean Wind [kt]
2005_08_11 Ascending (Day)

JAXA/EORC Ocean Wind Project, 2005.