Preserving the Astronomical Sky
IAU Symposium, Vol. 196, 2001
R. J. Cohen and W. T. Sullivan, III, eds.

World Radio Conference WRC-2000

Klaus Ruf
Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany

Abstract. The World Radio Conference 2000 must be considered the most important one for radio astronomy since WARC-79. The conference agenda contains about 30 topics of substance, and more than 10 of these have direct impact on radio astronomy frequency allocations. From the perspective of radio astronomy the most important items are: "Allocation of Frequency Bands above 71 GHz to the Earth-Exploration Satellite Service (passive) and Radio Astronomy Service" and the agenda items dealing with Recommendation 66 (Unwanted Emissions). A review of the status of preparations is given.

1. Introduction

The International Telecommunication Union, ITU, has long recognised radio astronomy as a service, which needs access to uncontaminated parts of the radio spectrum. Decisions about the distribution of the radio spectrum among the many competing services are taken at international conferences organized by the ITU. Until 1992 these conferences were convened at irregular intervals on request and were called World Administrative Radio Conferences (WARCs). Then ITU changed its structure, and the conferences are now convened regularly and called World Radiocommunication Conferences (WRCs).

2. The Agenda of WRC-2000

WRC-2000 has a number of items on the agenda that are relevant for radio astronomy, at least 11 items out of a total of 33. Agendas of WRCs are written in a formalized language and are difficult to read, therefore only the interesting items are listed in the tables below. The full text has been published by ITU as Resolution 1130 of the ITU Council.

2.1. Highest Priority Issues

Agenda item 1.2 (Fig. 1) as such is a left-over from the previous conference, but the history of Recommendation 66 dates back as long as the allocations in the mm-wave bands. At WARC-79 Recommendation 66 was adopted in order to study the possibility of radio astronomical observations at the limits of sensitivity in an environment of active (transmitting) use of the radio spectrum

1.2 TO FINALIZE REMAINING ISSUES IN THE REVIEW OF APPENDIX S3 TO THE RADIO REGULATIONS WITH RESPECT TO SPURIOUS EMISSIONS FOR SPACE SERVICES, TAKING INTO ACCOUNT RECOMMENDATION 66 (REV.WRC-97) AND THE DECISIONS OF WRC-97 ON ADOPTION OF NEW VALUES, DUE TO TAKE EFFECT AT A FUTURE TIME, OF SPURIOUS EMISSIONS FOR SPACE SERVICES;

1.16 TO CONSIDER ALLOCATION OF FREQUENCY BANDS ABOVE 71 GHZ TO THE EARTH EXPLORATION-SATELLITE (PASSIVE) AND RADIO ASTRONOMY SERVICES, TAKING INTO ACCOUNT RESOLUTION 723 (WRC-97);

7.2 TO RECOMMEND TO THE COUNCIL ITEMS FOR INCLUSION IN THE AGENDA FOR THE NEXT WRC, AND TO GIVE ITS VIEWS ON THE PRELIMINARY AGENDA FOR THE SUBSEQUENT CONFERENCE AND ON POSSIBLE AGENDA ITEMS FOR FUTURE CONFERENCES,

Figure 1. Agenda items with highest priority for radio astronomy

at power levels orders of magnitude above the field strength measured from cosmic sources.

Agenda item 1.16 (Fig. 1) is of paramount importance to radio astronomy. All of the radio spectrum between 71 GHz and 275 GHz, where the table of frequency allocations in the radio regulations of the ITU still ends, is opened for reallocation. Resolution 723 of WRC-97 invites the study groups of ITU-R to take into account in their studies the present use of allocated bands. The current allocations in the mm-wave region were made at WARC-79, and the present use is such that all atmospheric windows, also above 275 GHz, are used for spectral line as well as radiocontinuum observations. Little is known about active services making use of an allocation in the part of the spectrum under consideration, and commercial use is non-existent. Nevertheless, the proposals worked out for this agenda item take the existing allocations into due consideration.

Allocations at very high frequencies and results from the studies initiated by Recommendation 66 are also part of the provisional agendas for the next conferences to follow WRC-2000. WRC-2000 will adopt the agenda for the following conference and make proposals for later ones under **agenda item 7.2** (Fig. 1). Although this is a formality repeated on each WRC agenda, circumstances make it an important point for radio astronomers this time.

2.2. Second Priority Issues

There are many other items important to radio astronomy, although of second priority. The six resolutions quoted in **agenda item 1.4** (Fig. 2) all have to do with (high density) fixed service and fixed satellite service, sharing between these two services and sharing with other services. The frequency range under consideration is roughly 30–60 GHz, and hence the radio astronomy bands at 32 and 43 GHz are possibly endangered. The preparation for this topic is controversial. Europe clearly favors allocations to *terrestrial* services for a number of the frequency bands in question, because of the greater spectrum efficiency offered by improved frequency re-use due to the much smaller cell sizes in Europe. In other parts of the world, where the relation of high traffic density regions to

1.4 TO CONSIDER ISSUES CONCERNING ALLOCATIONS AND REGULATORY ASPECTS RELATED TO RESOLUTIONS 126 (WRC-97), 128 (WRC-97), 129 (WRC-97), 133 (WRC-97), 134 (WRC-97) AND 726 (WRC-97);

1.5 TO CONSIDER REGULATORY PROVISIONS AND POSSIBLE ADDITIONAL FREQUENCY ALLOCATIONS FOR SERVICES USING HIGH ALTITUDE PLATFORM STATIONS, TAKING INTO ACCOUNT THE RESULTS OF ITU-R STUDIES CONDUCTED IN RESPONSE TO RESOLUTION 122 (WRC-97);

1.11 TO CONSIDER CONSTRAINTS ON EXISTING ALLOCATIONS AND TO CONSIDER ADDITIONAL ALLOCATIONS ON A WORLDWIDE BASIS FOR THE NON-GEOSTATIONARY (NON-GSO) MSS BELOW 1 GHZ, TAKING INTO ACCOUNT THE RESULTS OF ITU-R STUDIES CONDUCTED IN RESPONSE TO RESOLUTIONS NO. 214 (REV.WRC-97) AND 219 (WRC-97);

1.14 TO REVIEW THE RESULTS OF THE STUDIES ON THE FEASIBILITY OF IMPLEMENTING NON-GSO MSS FEEDER LINKS IN THE 15.43--15.63 GHZ IN ACCORDANCE WITH RESOLUTION 123 (WRC-97);

Figure 2. Agenda items of second priority for radio astronomy

low traffic density regions is different, the immediate availability and coverage offered by *satellite* systems have higher priority.

Agenda item 1.5 (Fig. 2) deals with a mixed case: High Altitude Platforms. Such stations, which are still in an early planning state, will be mounted on high flying balloons or airplanes and serve metropolitan areas with fixed links. In a regulatory sense they are treated as (terrestrial) fixed service stations, but they will transmit from high above and under line-of-sight conditions to a huge area, which may contain radio telescopes. The requirement of protecting radio astronomy in the 43 and 49 GHz bands from HAPs unwanted emissions is within the scope of Resolution 122.

Agenda item, 1.11 (Fig. 2), has been on the agenda of several WRCs in one form or another. It has been very difficult to find frequency bands for the mobile satellite service, MSS, in the crowded region of the spectrum below 1 GHz, and the preparation process for this agenda item shows again that the same difficulties persist. Radio Astronomy has achieved protection in a footnote, attached to all allocations to the MSS below 1 GHz, from interference due to unwanted transmissions. Some of the newer proposals, however, are for frequencies very close to our bands.

Agenda item 1.14 (Fig. 2) deals with an existing allocation to the fixed satellite service, FSS, (space-to-Earth), that is too close to a passive band to be useful. Sharing studies in ITU-R (the radiocommunications arm of ITU) concluded that limits in power flux density, necessary to protect radio astronomy in the band 15.35–15.4 GHz, make the allocation unattractive to FSS, and the deletion of this allocation is proposed. While this agenda item only affects one radio astronomical band, the case promises to become such a nice precedent that it is ranked among second priority agenda items.

1.6.1 REVIEW OF SPECTRUM AND REGULATORY ISSUES FOR ADVANCED MOBILE APPLICATIONS IN THE CONTEXT OF IMT-2000, NOTING THAT THERE IS AN URGENT NEED TO PROVIDE MORE SPECTRUM FOR THE TERRESTRIAL COMPONENT OF SUCH APPLICATIONS AND THAT PRIORITY SHOULD BE GIVEN TO TERRESTRIAL MOBILE SPECTRUM NEEDS, AND ADJUSTMENTS TO THE TABLE OF FREQUENCY ALLOCATIONS AS NECESSARY;

1.10 TO CONSIDER RESULTS OF ITU-R STUDIES CARRIED OUT IN ACCORDANCE WITH RESOLUTION 218 (WRC-97) AND TAKE APPROPRIATE ACTION ON THIS SUBJECT;

1.13.1 TO REVIEW AND, IF APPROPRIATE, REVISE THE POWER LIMITS APPEARING IN ARTICLES S21 AND S22 IN RELATION TO THE SHARING CONDITIONS AMONG NON-GSO FSS, GSO FSS, GSO BROADCASTING-SATELLITE SERVICE (BSS), SPACE SCIENCES AND TERRESTRIAL SERVICES, TO ENSURE THE FEASIBILITY OF THESE POWER LIMITS AND THAT THESE LIMITS DO NOT IMPOSE UNDUE CONSTRAINTS ON THE DEVELOPMENT OF THESE SYSTEMS AND SERVICES;

1.15.1 TO CONSIDER NEW ALLOCATIONS TO THE RADIONAVIGATION- SATELLITE SERVICE IN THE RANGE FROM 1 GHZ TO 6 GHZ REQUIRED TO SUPPORT DEVELOPMENTS;

1.15.3 TO CONSIDER THE STATUS OF ALLOCATIONS TO SERVICES OTHER THAN THE RADIONAVIGATION-SATELLITE SERVICE (NOS. S5.355 AND S5.359) IN THE BAND 1559--1610 MHZ;

Figure 3. Agenda items with potential impact on a single radio astronomy band

2.3. Issues Affecting a Single Radio Astronomy Band

The third generation of mobile phones, now termed IMT2000 in **agenda item 1.6.1** (Fig. 3), has already received attention at earlier conferences. The bands around 2 GHz foreseen for this application do not conflict with radio astronomy allocations, but the planned extension bands may need to be coordinated with radio astronomy stations operating at 1720 or 2700 MHz. The extention bands are thought to be necessary to increase the capacity in high traffic density areas. The satellite component of this service will probably be put into existing MSS allocations, such as 1610–1660.5 MHz, and thus increase the pressure on sharing or coordinating the two 18 cm radio astronomy bands. This pressure is potentially further increased under **agenda item 1.10** (Fig. 3), where the conference is asked to make appropriate provisions for the global distress and safety service. These services have lost their exclusive status in the band 1626.5–1660.5 MHz, but need a kind of priority access in at least part of the band, if this is used for generic mobile satellite service.

Agenda item 1.13.1 (Fig. 3) has not been formulated with radio astronomy in mind, but radio astronomy is, one of the terrestrial services concerned. Sharing in the narrow sense of sharing the same frequency band for the operation of two or more different radio services is not an issue for radio astronomy and space-based active services like the fixed satellite service (FSS) and the broadcasting satellite service (BSS). Unwanted emissions from these services in nearby

or harmonically related bands into radio astronomy bands, however, need careful consideration in planning such systems, and therefore the exercise described in agenda item 1.13.1 is of interest to radio astronomy.

The last two **agenda items, 1.15.1 and 1.15.3** (Fig. 3), both deal with the radio navigation satellite service. The most well-known example of this service is the Global Positioning Satellite System (GPS). A new allocation is sought for a future system, which is planned to provide timing and location information reliably and with an accuracy that would make it suitable for instrument landing in civil aviation. Unfortunately, one system is planned for a frequency band immediately adjoining the 5 GHz radio astronomy band. Other proposals want to change the usage of the established systems, GPS and the Russian Global Navigation Satellite System (GLONASS), which could threaten the already very much troubled 1612 MHz OH-band.

While the agenda items listed in Tables 2 and 3 require the usual attention, that radio astronomers involved in the frequency protection process within ITU-R have been paying through a number of conferences, the agenda items in Table 1 are of far-reaching interest. They will therefore be described in more detail here.

3. Studies Related to Recommendation 66

Recommendation 66 has long been considered a major achievement for radio astronomy, and the revision formulated at WARC-92 clearly points out the threat of spurious emissions from satellite based transmitters. WARC-92 had been convened to find allocations for the new services like MSS and BSS (both digital audio and high definition television). All of these new satellite services were allocated frequency bands in the part of the spectrum where they had asked for it. And the revision of Rec. 66 took appropriate account of this.

So called "Recommends" 1 and 5 of RECOMMENDATION No. 66 (Rev. WARC-92) read

1. *study, as a matter of urgency, the question of spurious emissions resulting from space service transmissions, and, on the basis of those studies, develop Recommendations for maximum permitted levels of spurious emissions in terms of mean power of spurious components supplied by the transmitter to the antenna transmission line;*

5. *submit a report to the next competent conference on the result of its studies with the view to reviewing and including spurious and out-of-band emission limits in Appendix 8 of the Radio Regulations, principally for the protection of the radio astronomy and other passive services.*

These studies started smoothly in ITU-R in a Task Group, TG1-3 of Study Group 1. Radio Astronomy protection requirements turned out to be difficult to meet for a number of services, but European countries were generally advocating more stringent limits for some services than some countries in other parts of the world. At a certain stage the space services joined the studies and categorically denied that it would be possible to implement similar limits as for a number of

terrestrial services. Protection of radio astronomy to the desired level, the aim which Rec. 66 asked for, would be missed by several tens of dBs.

By the time of WRC-97 spurious emission limits for most radio services could be written into Appendix S3 of the Radio Regulations, mentioning different categories applicable in some countries, and with exemptions from the general limits for some services, but the space service community still only allowed their much relaxed limits to be qualified as "design objectives". Agenda item 1.2 of WRC-2000 will hopefully overcome this situation and the spurious emission limits for space services will become mandatory limits, although undoubtedly entering into force only after a number of years.

Having finished its work on the limitation of spurious emissions, Task Group 1-3 was dissolved and a new Task Group, TG1-5, was set up with the mandate to study possible limitations of out-of-band emissions. (*Out-of-Band Emissions* and *Spurious Emissions* together form *Unwanted Emissions.*) Recommendation 66 was accordingly revised by WRC-97. The clear words of recommends 5. in the WARC-92 revision were turned into the long phrases of recommends 7 and 8 in the WRC-97 revision:

7. *study those frequency bands and instances where, for technical or operational reasons, more stringent spurious emission limits than the general limits in Appendix S3 may be required to protect safety services and passive services such as radio astronomy, and the impact on all concerned services of implementing or not implementing such limits;*

8. *study those frequency bands and instances where, for technical or operational reasons, out-of-band limits may be required to protect safety services and passive services such as radio astronomy, and the impact on all concerned services of implementing or not implementing such limits;*

General protection of radio astronomy to the levels given and explained in a long recognised ITU-R Recommendation has been declared unpracticable, mainly by the space services. Instead, particular frequency bands and instances are to be studied, to see if more stringent limits may be required. This has been named the band-by-band study and is going on in a number of Working Parties of ITU-R Study Groups and in Task Group 1-5. The results of this study will not be ready for WRC-2000, but, as some studies asked for by other recommends of Rec. 66 are fullfilled, WRC-2000 will certainly revise Rec. 66 again and propose related agenda items for future conferences. We must certainly take great care to protect Rec. 66, because it has become apparent that strong forces want to abuse the band-by-band study to open up the ITU-R Recommendation containing the radio astronomy protection requirements. The same forces are determined to drop the whole issue of protecting radio astronomy, if they are not successful in questioning our interference threshold levels. We will need to be very vigilant that neither of these ploys happens.

4. New Allocations in the Mm- and Submm-Wave Bands

Agenda item 1.16, even though attempting to redistribute almost three quarters of the allocated radio spectrum has been much less controversial in the WRC

preparations. As mentioned above, the current usage of the mm- and submm-bands is mostly passive and for scientific purposes. Nevertheless, in order not to exclude the future use of this part of the radio spectrum by radiocommunication services, care has been taken to allocate the same amount of spectrum to active services as they now have. The guidelines in this planning exercise have been

1. to allocate frequency bands to radio astronomy around the most important spectral line frequencies and the central parts of the atmospheric windows, and

2. to avoid any shared or nearby allocations between radio astronomy and space-to-Earth transmissions of satellite services.

One way to accomodate these diverging requirements has been to encourage sharing whenever possible. Best candidates for sharing frquency bands with radio astronomy are terrestrial fixed and mobile services, which can be coordinated so that they are located outside exclusion zones around mm-wave observatories.

The result of this planning exercise, which resulted in very similar allocation proposals being discussed in different parts of the world, has been an enormous increase in bandwidth allocated to radio astronomy, in good representation of current usage, but a decrease in exclusive passive allocations. As an example the current allocation table for the frequency range 105 - 122.5 GHz is given in Fig. 4, together with proposals discussed in the US and in Europe.

105–116 EARTH EXPLORATION-SATELLITE (passive) RADIO ASTRONOMY SPACE RESEARCH (passive) S5.340 S5.341	**105–109.8** FIXED MOBILE RADIO ASTRONOMY SPACE RESEARCH (passive) ADD S5.CCC S5.341 MOD S5.149	**105–109.5** FIXED MOBILE RADIO ASTRONOMY SPACE RESEARCH (passive) S5.CCC MOD S5.149 S5.341
	109.8–111.8 EARTH EXPLORATION-SATELLITE (passive) RADIO ASTRONOMY SPACE RESEARCH (passive) MOD S5.340 S5.341	**109.5–111.8** EARTH EXPLORATION-SATELLITE (passive) RADIO ASTRONOMY SPACE RESEARCH (passive) S5.340 S5.341
	111.8–114.25 FIXED MOBILE RADIO ASTRONOMY SPACE RESEARCH (passive) ADD S5.CCC S5.341 MOD S5.149	**111.8–114.25** FIXED MOBILE RADIO ASTRONOMY SPACE RESEARCH (passive) S5.CCC S5.341 MOD S5.149
	114.25–122.25 EARTH EXPLORATION-SATELLITE (passive) INTER-SATELLITE S5.XXX RADIO ASTRONOMY SPACE RESEARCH (passive) S5.138 MOD S5.340 S5.341	**114.25–116** EARTH EXPLORATION-SATELLITE (passive) RADIO ASTRONOMY SPACE RESEARCH (passive) S5.340 S5.341

Figure 4. 105-116 GHz Band: Current Table of Frequency Allocations (1st column) and proposals discussed in the US (2nd column) and Europe (3rd column)

https://doi.org/10.1017/S0074180900164149 Published online by Cambridge University Press