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Considerations on access to the frequency spectrum for Scientific Services

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Study Group 7 of ITU-R is responsible for establishing the rules of operation of Scientific Services which necessarily are the result of compromises with other Services requesting more and more portions of the spectrum for their own development. The terms of reference of Study Group-7 (SG7) are

« 1°) Systems for space operation, space research, earth exploration and meteorology, including the related use of links in the inter-satellite service.

2°) Radio astronomy and radar astronomy.

3°) Dissemination, reception and coordination of standard-frequency and time-signal services, including the application of satellite techniques, on a worldwide basis. »

In addition to the items on the WRC'07 agenda assigned to the SG7 the latter has to deal with two other tasks:

1)find solutions for 42 fundamental subjects (" Questions" in ITU-R terminology) which have been submitted to it.

2)keep up to date 105 Recommendations

Evidently all this constitutes a considerable but necessary task.

The advantage for Scientific Services being recognised by ITU-R as a Study Group equal to other activities is to be fully informed on what is going on in all domains of radio communications.

For example 30 per cent of "Questions" assigned to SG7 directly deal with band sharing.

In return SG7 has to face a large flow of exchanges some of which are urgent. In fine, the risk for Scientific Services is to loose its soul by forgetting the specific aspects of scientific research.

1- CONSIDERATIONS ON EQUIPMENT USED FOR SCIENTIFIC RESEARCH

The "Scientific Services" have certain properties which it is useful to recall:

1)physics determine the required frequencies to observe natural phenomena;

2)there is a small number of large installations which are costly, have a long life span and, from a financial point of view, they have no return on investment;

3)the sensitivity of instruments which are used is generally is much greater than that of the other Services,

4)Scientific Services on the one hand compete with other Services as far as spectrum access is concerned and on the other provides physical data to these same Services.

The above shows that Scientific Services are different in nature from the other Services, namely as far as the possibilities of band sharing are concerned.

In order to construct a representation of the World, the work of Scientific Service systems is outward oriented – there is a fundamental need for a theory to underscore the research and interrogate the real World: "to explain" is the ultimate aim of research.

Other Service systems proceed in the opposite way underlining their own coherence, including the necessity to take into account the interference of other systems. The elaboration of an appropriate model for each system is essential to guarantee the coherence: "to predict" is the main objective.

ITU document 1B/TEMP/12Rev.1-E (October 13, 2004) in response to Resolution 951 (WRC'03) states that " Decisions to modify the Radio Regulations are taken by WRCs on the basis of a consensus, and binding on all countries, the Radio Regulations reflect, at a given time, an allocation level which maximises the flexibility for all countries : this is a Pareto optimum, i.e. any significant change would have led to opposition of at least one country."

For Scientific Services operating along the lines of an outward turned model the Pareto optimum hypothesis is not valid. Pareto and his followers had already envisaged such cases in formulating the strong hypothesis of externality.

1.1 Physics and Frequency

Clearly all applications use the most appropriate frequency bands in order to obtain optimal results; however, most of them tolerate frequency differences without impending their operations. There are even cases where the status of available technology leads commercial systems to slightly change the frequency thus deviating from the technical optimum so as to preserve the profitability of the product.

The spectral lines of a large number of chemical components which exist in the interstellar space can only be detected through radio waves. While the frequency of most of these spectral lines are well known today, the shifting of frequency is unknown, because of the expansion of the universe.

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UIT-R has recognised the importance of this kind of phenomena and has taken it into account in two footnotes of the Radio Regulations (5.149 and 5.340) which, in theory, aim at keeping some bands free from any man-made emission.

1.2 Instruments of Scientific Research

The current tendency is towards installing of large instruments. Let's take two examples:

1- after radiotelescope - Arecibo (Porto Rico, USA), Nançay (France), Effelsberg (Germany), Green Bank Telecope (Vifginie, USA) , the interferometric networks take the same path – VLA (New Mexico, USA), Grand Meterwave Radio Telescope (Poona, India) and soon ALMA (Atakama Large MM Array). Two main evolutions can be noted:

i)an extension of frequency coverage, and

ii)an extension towards mm-wave necessary for the study of galaxies by observing spectral lines emanating from interstellar particles.

2- The third summit on Earth Exploration (February 2005) adopted a ten-year plan to set up the GEOSS (Global Earth Observation System of Systems). The main objective of this network is to allow a harmonised use of the various satellite sensors [the European initiative of GMES (Global Monitoring for Environment and Security) is the European contribution to this project].

These evolutions have certain advantages, because at this level international co-operation is necessary, particularly for the introduction of this kind of projects to ITU-R with a view to obtain access to the frequency spectrum.

1.3 Sensitivity of Instruments

As mentioned above the scientific approach being outward oriented, the sensitivity of instruments has increased considerably. The sensitivity of radio telescopes is such that a flux density of a millijansky (cosmic rays), that is to say in engineering terms equivalent to a spectral power flux density of -290dBW/m²/Hz, is easily observable. The sensitivity of receiving chains is sought for, also in remote sensing; for example the noise of interferograms acts directly on the performance of elevation map extraction from high resolution SAR (Synthetic Aperture Radar).

1.4 Competition and co-operation with other Services

Sciences, namely electromagnetism, have practical applications which in themselves represent sources of financing research. In turn, the efficiency governing all applications influences research not only with respect to its objectives but also to its methods : modelling and simulation. The validity of a model is relative to an experimental frame and the criterion by which agreement of input-output is gauged. Indeed, the base model is a model capable of accounting for all the input-output behaviour of the real system, it is valid in all the allowable frames; consequently the base model description can never be fully known therefore the great complexity of this model precludes its consideration as a possible simulation model. The aim is to construct a relatively simple model, called the lumped model, that will be valid in the experimental frame of current interest. Finally one might be attempting to use the lumped model to infer what the structure of the base model is like. Independently of approximations made in realising the corresponding computer programme, conditions that may be necessary to guarantee that a lumped model is valid within an experimental frame are often not so explicit; these conditions of structural inference are essential in the process to establish system compatibility: establishing the validity of a theory is at that price.

Pareto already pointed out that theories without any validity have nevertheless an impact on generally accepted ideas for two combined reasons : on the one hand they are useful and , in the other, it is generally easier to apprehend the utility of a theory rather than establish its validity.

2- CURRENT STATE OF DISCUSSION AT ITU-R

It is not my intention to make an inventory of all subjects related to scientific matters discussed in SG 7 at ITU-R, but rather to illustrate the original status of scientific Services by some examples presently under discussion.

2.1. Radio-Astronomy (RA)

As mentioned above the general tendency is to associate as many countries as possible for large projects. Moreover, equipment is wide band : SKA (0.15-20 GHz), ALMA (30-900 GHz, in ten bands), LOFAR & FASR (10-MHz-2GHz), HERSCHEL (480GHz-1.9THz), …, SWAS/ODIN (Spatial observatory already in operation in 90-560 GHz), et al.. Generally observations are focused on variations of the spectral continuum.

For the installation of such instruments on the ground Radio Quiet Zones (RQZ) are required. This is one of the main subjects at stake, since quiet geographical locations have to be selected with a radius of at least 35 km; therefore it is easily understandable that countries that are in a position to take a long term commitment are scarce. However, the risk of interference cannot be totally excluded, namely from some active sensors for scientific purposes on board satellites from Earth Exploration Satellite Services (EESS), for example, CLOUDSAT.

If for ground instruments RZQ are an essential element of their overall performance, it is even more difficult to agree on such quiet zones in space : hidden face of the moon, Lagrange 2 point, ...

2.2. Active Microwave Sensors

There is a general improvement of performances of instruments for Earth exploration on board satellites or airborne.

Synthetic Aperture Radars (SAR) around 9.6 GHz.

There are plans to enhance flying spaceborne synthetic Aperture Radars (SAR) in the band around 9.6 GHz in order to improve the spatial resolution to the order of 1metre, which would require up to 500 MHz bandwidth. Such SAR will fly in a low-Earth orbit to provide a high revisit time. It would provide global monitoring for environment with frequent revisits to fulfil several objectives such as environmental monitoring and Earth topographic mapping.

It will be necessary to expand by up to 200 MHz the existing primary allocations (9500-9800 MHz) for the EESS (active) and SRS (active) to a total bandwidth of 500 MHz in the band 9300-10000 MHz. According to WRC’07 agenda item 1.3 and Resolution 747 (WRC’03) studies will have to be conducted to confirm that sharing is feasible with the existing allocated Services to assess the potential interference with them (Radio-location and Radio-navigation Services). It is well known that the latter have a large quantity of radars of all kinds operating in the band 9300-9500 MHz with a potential increase in bandwidth of many ground and airborne (military) radars. Similarly the band 9800-10000 MHz also has an allocation for Fixed Services (FS).

Operations in the Band 1215-1300 MHz.

Very few bands are as sought for as the so-called “L-band”. The frequency band 1215-1300 MHz is shared by the EESS, the RL and the RNSS on a primary basis; in addition wind profiler radars operate in the RL Service.

The sharing of that band between space-borne SARs of EESS and all kinds of RL radars some of which very powerful and having agile waveforms constitutes a challenge.

Presently the realistic objective is to establish some mitigation techniques applicable to space borne active sensors to reduce interference from RL radars: everybody is aware of the fragility of such a procedure.

Low Frequency Radars.

There are many possible applications for radars operating in low frequency bands (HF, VHF/UHF): penetration of ice, foliage penetration, biomass evaluation, long distance detection, SAR imagery,....

More than for any higher band a deep knowledge of physical phenomena is indispensable at both conception and the processing and interpretation of data.

It goes without saying that their compatibility with the systems of other services in the bands which have already been allocated to them is extremely constraining, to the point that radar waveforms similar to those of these systems are currently under study: the price to be paid for the band sharing might well mean a reduction in radar detection performance. This adaptation of waveforms might well be a more preferable solution than mitigation techniques.

2.3 Passive Microwave Sensors

The protection of passive services is complex. Indeed, the numerous bands, some of which are very narrow, present the following characteristics:

1) they are dispersed in a large part of the spectrum (from 13 MHz to 275 GHz)
2) they form two groups depending on two texts (footnotes 5.149 & 5.340) of the Radio Regulations (RR).

Moreover, since the two texts above have been elaborated at successive WRCs they may give rise to different interpretations

Given that several passive services sometimes share the same band the complexity of compatibility becomes even greater due to the fact that their sensitivity are very different. A typical example is the band 1400-1427 MHz in which the RA services share equally with EESS (passive) and SR (passive). Unwanted emissions can come from mobile-satellite service feeder links operating in the nearby bands 1390-1392 MHz (Earth to Space) and 1430-1432 MHz (Space to Earth).

It is no surprise that numerous ongoing studies are dedicated to the above subject. As, for example, an envisaged Recommendation which might propose that the level of unwanted emissions of MSS feeder links (space to Earth) operating in the band 1430-1432 MHz be kept below an epfd of –259dBW/m2 in any 20 kHz bandwidth of the band 1400-1427 MHz and should not exceed by more than 2% of observation periods of 2000 seconds for spectral line observations. A similar limitation is imposed on continuum observations.

The general protection of passive sensors from unwanted emissions (Agenda item 1.20 of WRC’07) requires that more refined unwanted emission spectral representations be developed for use in compatibility studies.

Studies on millimetre wavebands are presently divided into two sub-bands: 275-3000 GHz & above 3THz.

Emission/reception technologies in this bands are rapidly progressing. This applies also to the knowledge of refined propagation properties in the Earth atmosphere [1].
Experimental results show that future free space optical (FSO) communication systems constitute already a reliable broad band component of high data rate radio-communication networks.
Scientists are invited to rapidly make proposals before the band is taken up by too many industrial and commercial applications.

3.SUGGESTIONS FOR FUTURE RESEARCH WORK

To cope with the necessity to set up new rules and to adapt existing ones which could be accepted all the world over, on the one hand, and its willingness not to interfere with the sovereign rights of each country, on the other, ITU has to decide on regulations. Indeed there is a need for the international regulatory framework to be as flexible as possible in order to accommodate the development of new services, applications and technologies without undue delays.
The risk is that mitigation techniques and computer simulation will prevail over a scientific analytical approach; consequently there is a long term risk of introducing fragility in procedures and polluting scientific applications.
By necessarily generalising the band sharing, possible causes of interference will increase; consequently conclusions which could be reached would not be univocal. One should draw from acquired experience so as to weighten the various possible causes, in other words estimate the a priori probabilities. The well known difficulty of this problem of probability of causes requires a deep knowledge of conditions linked to the emergence of an event. The required knowledge is much larger than that necessary to solve prediction problems which can be limited to well known physical laws and neglect past experience.
Up to now it was possible to avoid this fundamental problem so as to establish regulations to the benefit of new systems: this cannot continue in the long run.
In many studies antennas are still specified on the basis of radiation patterns which are stable within the frequency band pass; this is similar to stationary filters spatially as well as in frequency.
The use of new electromagnetic materials in array antenna and reconfigurable antenna will lead sooner or later to select one or several more realistic electromagnetic descriptions better adapted to antenna with some agility in both space and frequency. For example, Electromagnetic Band Gap (EBG) antenna in which the transparency of the angular sector can be electronically controlled. Moreover a more complete electromagnetic description of antenna will be necessary to take more easily into account both the interactions antenna/structures [2] and the multiple interference entries thanks to the current performance of numerical methods.
In most regulation documents the levels of admissible interference in order to protect some frequency bands or to accept band sharing are expressed in terms of epfd (equivalent power flux density). Up to now it was understandable to base this way of proceeding on a such strong stationary hypothesis which is the only one allowing to conduct computation up to the end in order to obtain some approximation of the phenomena. The difficulty to handle non-stationary phenomena is that there are many ways of not being stationary and that generally one does not know to which one is confronted. Non-parametric methods based on less stringent hypotheses can be used, the disadvantage being that it is impossible to draw usable conclusions.

4.CONCLUSION

ITU establishes common rules allowing the various services to operate satisfactory worldwide. This valuable work is governed by the successive World Radio-communication Conferences. ITU is subjected to the formidable constraint to make decisions so as not to impede the development of new systems as well as their insertion in the frequency spectrum. By contrast, URSI should deal with fundamental scientific questions to the benefit of ITU. This is the reason why the latter invited the former as a permanent member of the Radio-communication sector (ITU-R).
The few above-mentioned suggestions show that there are plenty of subjects. The work carried out by ITU offers a vast array of research areas reaching far beyond the sole electromagnetism. I would therefore like to invite you to exert your talents in co-operating with ITU.

5. REFERENCES

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