REPORT ITU-R M.2080

Consideration of sharing conditions and usage in the 4-10 MHz band

(2006)

Scope

In preparing the text for the draft CPM-07 Report, there were a number of input documents providing information on sharing conditions in the 4-10 MHz band. Although these documents have been taken into account in the revision of the draft CPM text for WRC-07 Agenda item 1.13, they contain valuable information for ITU-R studies in HF bands and have been used to create a new Report.

Introduction

This Report gathers together texts submitted during the study period 2003-2007. Documents referenced are from this study period unless otherwise indicated. These texts address sharing issues between various allocated services and other information on the use in the HF bands. During the discussions on the various input documents, diverging views on the conclusions of the input documents were expressed by some administrations.

Structure of the Report

On the following pages an executive summary is given for each annex. Following this summary two views are expressed:

View I represents comments supporting the conclusions of the study contained in the annex.

View II represents the comments contrary to the conclusions of the study contained in the annex.

In order to have a complete understanding on the issues both views and the relevant annexes must be read.

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EXECUTIVE SUMMARY

Annex 1

Information on feasibility of frequency sharing between different radiocommunication services in the frequency range 4-10 MHz

Analysis shows that proposed sharing between adaptive systems in the fixed and maritime mobile services would result in unacceptable and harmful interference between these services. Although constraints could be applied to the fixed service to reduce this interference it would prevent optimal operation of that service. The analysis also shows that the use of narrow-beam antennas in the frequency range 4 to 10 MHz is impractical as a means of establishing compatibility between these services.

View I

The Annex considers an analysis of long-range communications using multi-hopping techniques. The results of evaluation clearly show that the increasing of antenna gain or its directivity is not the key factor which permits to improve the sharing between the services due to multiple reflection from ionosphere.

The Annex clearly shows that the implementation of the frequency-adaptive systems resulting in the usage of the same frequency at the same time and at the same area by the different systems will result in harmful interference between services.

Therefore sharing between services could cause unacceptable and harmful interference.

That is why the satisfaction of the increasing requirements of any service should be realized by the improvement of the existing systems in the interested service and without prejudice to other services.

View II

Sharing between services is already included in the procedures of the Radio Regulations, established techniques developed in ITU-R through various WRC Resolutions and ITU-R Recommendations. Taking into account the dimensions of frequency, time, and space in use of HF services, compatible and more efficient operation in the HF bands is feasible when bands are allocated for shared use.

This Annex does no more than state the obvious fact that trying to make use of the same frequency to provide communications at the same time to the same general location will fail. This observation is extended to construct an argument that consolidates frequency use over a 24-hour period and concludes that no inter or intra service sharing is possible.

The type of links analysed have powers and coverage areas that would not be out of place in broadcast planning and are not typical of the short duration point to point links that characterize many of today’s data exchange functions. Neither do the analyses recognize that even a single HF frequency can be reused at the same time if care is taken to ensure that sufficient isolation is obtained through a combination of distance separation and antenna directivity.

Thus, while the examples correctly demonstrate that attempts to reuse a frequency to the same place at the same time will fail, this conclusion ignores the key factor of being able to manage HF spectrum effectively to allow both the multiple use of frequencies within a band or the reuse of single frequencies to different locations or at different times.

The frequency spectrum is limited and the only way to accommodate additional requirements is to increase sharing arrangements between services.

Annex 2

Spectrograms from monitoring campaigns

To support the work in developing proposals for the WRC-07 on AI 1.13, monitoring stations in a part of Region 1 conducted monitoring campaigns (2 per year, since 2004) to collect information on the actual use of the spectrum between 4-10 MHz. The results of the monitoring campaigns were analysed together by experts from participating monitoring stations and representatives from all services involved in the agenda item. The Annex presents per MHz a summary of this analysis.

View I

In conducting the monitoring campaigns, all issues were carefully considered to ensure that the maximum number of emissions could be detected taking into account equipment availability, timescale and area covered.

Before the monitoring campaigns were started, a common set of parameters had to be defined to be applied to automatic measurements. Considering modern measuring equipment as well as equipment available at monitoring stations, experts found a sweep time of 10 s for a frequency range of 200 kHz was a good compromise. Although emissions with a shorter duration than 10 s may be partly missed, the probability of this was reduced by multiple stations monitoring the same range simultaneously. By monitoring identical frequency ranges at up to 4 locations, the impact of equipment failures was minimized and a much greater part of the CEPT area could be covered.

Although the monitoring campaigns were conducted in Region 1, propagation conditions allow emissions emanating from other Regions to be taken into account if they were received with a sufficient level at the participating monitoring stations. The database of manual observations confirms reception of emissions emanating from outside Region 1. The results of these monitoring campaigns should be combined with the results of equivalent campaigns conducted in Region 1 outside the European Conference of Postal and Telecommunications Administrations (CEPT) area, Region 2 and Region 3 if there are any, to provide knowledge of up-to-date frequency usage which can be used in any discussions on changes to Article 5 of the Radio Regulations.

It does not seem feasible to monitor all emissions; notably adaptive short-time-emissions which are to be received at the noise floor, within a 6 MHz broad range (4-10 MHz). The number of missed emissions will be reduced by monitoring very small bands at a large number of monitoring stations using fast equipment.

Comparison of the spectrograms with the data collected by manual monitoring confirms that short duration emissions and signals just above the noise floor are shown.

Administrations concerned about the possibility of missed emissions are invited to take part in monitoring campaigns and to contribute the results to provide an overview of frequency usage worldwide.

View II

The monitoring campaign overlooked many issues that cause it to underestimate the number of fixed and mobile transmissions. It is specific to only one region and does not consider the impact to other regions for the sharing situations that are identified. By utilizing a 200 kHz bandwidth and 10 s cut-off for transmissions, as well as the schedule to divide the bands monitored between groups of 3 to 4 monitoring stations, it is very likely that a majority of fixed and mobile transmissions were missed. Most adaptive systems in use today pass data instead of voice and most transmissions are very short to a specific location. There are usually multiple transmissions per hour but each of these individual transmissions would be lost in the large bandwidth and transmission time cut-off. In addition the received adaptive system signal is at the noise floor at the receive site given the need to maintain large net communications. These transmissions, including voice, would have been missed by this monitoring campaign.

Annex 3

Sharing analysis of specific sharing conditions in the 4-10 MHz band

Sharing situations between services is determined by receiver location and very rarely by transmitter location. HF transmission footprints can be thousands of kilometres in width and length. Co-frequency sharing situations are likely when frequency bands are allocated to different services. For adaptive systems, increasing the number of frequencies in the user group pool allows for an increase in the user group size but leaves less spectrum that is not in contention between user groups thus increasing congestion.

View I

Additional sharing between services is problematic. Adaptive systems can also experience difficulties sharing. As a result of propagation, harmful co-frequency and co-coverage interference would be a consequence if the Radio Regulations provided additional sharing.

View II

The allocation of bands for shared use by the fixed, mobile and broadcasting services is considered to offer all the services access to spectrum in a compatible manner, noting that:

– the band 3 950-4 000 kHz (R1 and R3) is allocated to the fixed and broadcasting service without there being any specific sharing criteria;

– there are already examples of geographical managed coexistence between the fixed and broadcasting service, e.g. coexistence between the fixed and mobile services and the broadcasting service, operating in accordance with RR No. 4.113, in the bands 4 850-4 995 kHz, 4 995-5 005 kHz and 5 060-5 250 kHz is long established and generally succeeds because of the predominance of near vertical incidence skywave (NVIS) techniques for the broadcasting service which, for transmissions to or from the same general location/area, naturally operate at lower frequencies than for longer distance oblique incidence skywave paths in the fixed and mobile services;

– there are already examples of time managed sharing between the maritime mobile service and the broadcasting service which, as both services operate on a time scheduled basis with a good degree of regularity, could be further developed;

– frequency agile fixed and mobile links can be designed to avoid collisions with scheduled broadcasting transmissions;

– there are already examples of geographical managed coexistence between the fixed and broadcasting service.

Annex 4

HF compatibility considerations

Review of the Joint Interim Working Party (JIWP) Report for WARC-92, supported by later developments and studies on HF systems, particularly as regards techniques for improving spectrum efficiency, demonstrates that several types of sharing scenarios including possibilities for broadcasting sharing directly with other services are feasible. The convergence in modulation and control techniques lead to similar operating characteristics. Once the circuit planning considerations, operational functions and characteristics have become so close as to be indistinguishable, the applications involved could coexist since their compatibility criteria will naturally be much the same.

View I

The allocation of bands for generic shared use by the fixed and mobile services is considered to offer a compatible and more efficient use of the HF bands, noting that:

– several frequency bands between 4 and 30 MHz are already allocated on a shared basis to various radio services including the fixed and mobile services and, after 29 March 2009, the majority of bands between 4 and 10 MHz will have multiple uses, and that adaptive systems require access to as wide a range of spectrum as possible for optimum operation (see *considering a)* of Resolution 729 (WRC-97));

– distinctions between the fixed and mobile services have become less obvious as new applications and technologies are developed and deployed.

Sharing or coexistence for fixed and mobile applications can be accomplished in real time by using:

– a combination of automated channel conflict avoidance techniques, as required by *resolves* 2 and 3 of Resolution 729 (WRC-97);

– a compatible digital modulation scheme with adaptable channel bandwidth and data traffic capabilities; and

– natural time sharing possibilities of the differing patterns of use of the various services and the relatively short transmission times of the packet based protocols of the new digital data exchange systems.

The increasing convergence between the operational characteristics of modern data exchange systems developed for fixed and mobile use in the HF bands is further demonstrated by the fact that most of these new systems now employ orthogonal frequency division multiplexing (OFDM) as a common transmission standard. There is even convergence with HF broadcasting, since the Digital Radio Mondiale (DRM) system, developed to replace analogue modulation for MF/HF sound broadcasting, operates within an OFDM envelope. A characteristic of OFDM based systems is that it is possible to tailor the transmission coding characteristics to give the best match to the service requirements and radio propagation factors at the time of transmission.

The convergence in modulation and control techniques for modern fixed and mobile applications means that their operations will increasingly take place within a similar envelope of characteristics, including the spectrum mask. Once the circuit planning considerations, operational functions and characteristics have become so close as to be indistinguishable, the applications involved could coexist since their compatibility criteria will naturally be much the same.

View II

The basis of this Annex is information contained in CCIR JIWP 10-6-8-9/1 formed prior to WARC-92. The information in that document only addresses regulatory issues and does not address the actual technical feasibility of additional sharing in the 4-10 MHz band.

At the time that document was written HF usage for the fixed and mobile services was at an all time low as alternate service methods such as satellite were investigated. These alternate service methods were not satisfactory and starting around the year 2000, HF usage once again began to increase in the fixed and mobile services. Based on WRC-92, 200 kHz was assigned to the broadcasting service worldwide on a primary basis.

As is shown in Annexes 1 and 3, harmful co-frequency, co-coverage sharing situations would be normal which makes additional sharing not feasible. Typical sharing situations in the RR involve making broadcasting primary and other users secondary (i.e. RR No. 5.147), irrespective of the actual technical feasibility of additional sharing in the 4-10 MHz band. For example, complicated and unworkable fixed and mobile sharing scenarios for co-frequency, co-coverage sharing are presented. This Annex also cites sharing within the broadcast service. Such sharing is planned and coordinated using RR Article 12 procedures.

Such coordination procedures would not be satisfactory nor practicable for fixed and mobile services due to the large number of stations and administrations involved. For several reasons including time constraints, associated costs of registering frequencies as well as the growth of HF fixed systems, the MIFR has not been steadily updated since 1995 and the entries do not represent actual usage. It is well known that many fixed assignments have not been included in the Master International Frequency Register (MIFR) and individual Administrations keep track of their own assignments and coordinate with other Administrations as necessary.

This Annex also provides an example of intra-service sharing to remove usage limitations within Appendices 17 and 25 of the Radio Regulations. Some administrations are of the view that consideration of Appendices 17 and 25 are outside the scope of WRC-07 Agenda item 1.13.

The Annex incorrectly concludes that converging of system parameters of different services automatically leads to an increase in the ability to share between services.

OFDM is not currently a standard for fixed service modulation.

This Annex does not contain technical analysis supporting feasibility of additional sharing in 4-10 MHz.

This Annex also suggests that near vertical incidence skywave (NVIS) utilization by fixed/land mobile services users would permit sharing with maritime mobile service users, however it does not take into account that many administration cannot utilize NVIS for fixed and mobile services communications because of the large service areas and long path lengths required to be covered by those administrations. Also, the non-existence or lack of NVIS use in the maritime mobile service is not taken into consideration.

NVIS refers to a radio propagation mode which involves the use of antennas with a very high radiation angle, approaching or reaching 90° for establishing radio links beyond line of sight to distances few hundred kilometres away. The useful frequency range varies in accordance with the path length. The shorter the path, the lower the MUF and the smaller the frequency range. In practice, this limits the NVIS mode of operation to the 2 to 4 MHz range at night and to the 4 to 8 MHz range during the day. These nominal limits will vary with the 11-year sunspot cycle and will be smaller during sunspot minimums. This restriction of the frequency range is due to the physics of propagation and cannot be overcome. Some problems can be expected when operating on the NVIS mode in this portion of the HF spectrum. In order to produce radiation which is nearly vertical, antennas must be selected and located carefully in order to minimize the ground-wave radiation and maximize the energy radiated towards the zenith. For mobile platforms achieving very high elevation angle of radiation can create practical problems. This Annex does not address these problems.

Annex 5

Spectrum sharing considerations in relation to Agenda item 1.13 WRC-07

This Annex supports an analysis showing that sharing is an appropriate means of solving the agenda item. The reliability of any HF communication network improves as a wider range of frequencies becomes available, thereby giving a better chance of being able to select the optimum frequency to respond to constantly changing propagation conditions, resulting from the natural diurnal and seasonal changes in the properties of the ionosphere.

View I

Based on the procedures of the Radio Regulations, established techniques developed in ITU-R through various WRC Resolutions and ITU-R Recommendations and taking into account the dimensions of frequency, time, and space in use of HF services, compatible and more efficient operation in the HF bands is feasible when bands are allocated for shared use.

View II

This Annex erroneously concludes that if there is sharing within a service, there should be the ability to share across services. This Annex suggests that by sharing, additional spectrum is available to both services, but when co-frequency, co-coverage sharing is not feasible it actually limits the available spectrum for the incumbent service. This will lead to increased congestion in the available spectrum for the incumbent service, reducing the usability of available spectrum.

Utilizing protection criteria indicated in Annexes 1 and 3, it is clearly shown that co-frequency, co-coverage sharing is not feasible. Annexes 1 and 3 state that this would be a common occurrence if additional sharing were provided for in the RR.

Annex 6

Considerations regarding a primary fixed service or mobile service allocation and secondary amateur service allocation within the same band

This Annex outlines issues concerning incumbent services with the introduction of a secondary allocation to the amateur service in the same band.

View I

There are no examples of secondary amateur allocation and primary fixed allocations in the same bands where HF adaptive systems are extensively used.

A secondary allocation to the amateur service in the same band as a primary allocation to the fixed service or mobile service would increase congestion and may cause interference to the respective primary service. In addition, frequency adaptive systems cannot differentiate between primary or secondary assignments and some assignments in the fixed system's frequency pool could become unusable. Isolating the source of interference may also be difficult as the amateur stations are not required to operate on coordinated licensed frequencies.

View II

Many of the statements in the considerations section of the Annex, concerning the potential for interference to a primary fixed service by an amateur secondary service are incorrect or misleading.

In the band 10 100-10 150 kHz (fixed primary, amateur secondary), no reports of harmful interference to the fixed service are known to have been filed in the 25 years during which the allocation has been available to the amateur service.

Amateur operators are among the first to use modern digital signal processing capabilities to cope with potential interference, and it can be anticipated that methods will be developed in time to allow coexistence with adaptive fixed systems.

Annex 1

Information on feasibility of frequency sharing between different radiocommunication services in the frequency range 4-10 MHz

Introduction

WRC-07 Agenda item 1.13 deals with feasibility of allocating additional spectrum from 250 kHz to 800 kHz to the broadcasting service (BS). Resolution 544 (WRC-03) identifies frequency bands preferable for providing the allocation of additional spectrum resource for the broadcasting service. Some administrations are of the opinion that losses of frequency resources allocated to fixed (FS) and mobile (MS) services expected as a result from spectrum relocation for the broadcasting service could be compensated by frequency sharing between fixed/land mobile and maritime mobile services (MMS) and by implementing the frequency adaptive systems.

However estimates of potential spectrum savings resulted from implementation of frequency adaptive systems and those of sharing between fixed and maritime mobile services in the frequency range 4-10 MHz are currently unavailable.

To facilitate the studies in feasibility of clearing out the frequencies for broadcasting through integration of fixed and mobile services in the frequency range 4-10 MHz a new ITU-R Report addresses the following aspects:

– analysis of existing and potential sharing scenarios between fixed and mobile services;
– scenarios of interference between fixed and maritime mobile services;
– estimates of interference between fixed and maritime mobile services;
– estimates of feasibility of sharing between broadcasting and other services based on geographical separation.

1 Analysis of existing and potential scenarios of sharing between FS and MS in the range 4-10 MHz

A number of ITU-R Working Party (WP) meetings discussed the issue of feasibility to make additional spectrum available for broadcasting service as a result of combining frequency allocations to fixed and mobile services.

Analysis of the RR Table of Frequency Allocations shows the following types of frequency allocations for the fixed and mobile services in 4-10 MHz frequency range:

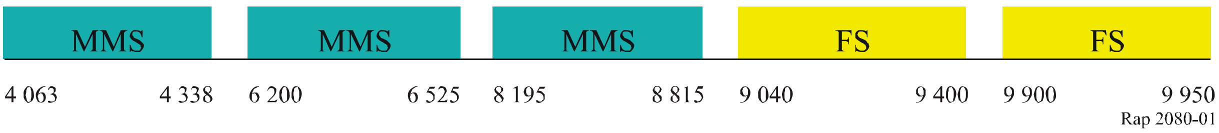
– frequency bands 9 040-9 400 kHz and 9 900-9 950 kHz exclusively allocated on a primary basis to the fixed service;
– frequency bands 4 063-4 438 kHz, 6 200-6 525 kHz, 8 195-8 815 kHz exclusively allocated to the maritime mobile service on a primary basis;
– other bands in the range 4-10 MHz co-allocated on a primary basis to the fixed and other services (land mobile service (LMS), maritime mobile service, mobile service, broadcasting service, etc.).

Results of the above analysis show that additional spectrum could be made available only as a result of combining the allocations for the fixed and mobile services in the frequency bands currently used by these services on an exclusive basis. Such a combined allocation could be provided by transferring the fixed service allocation to the frequency bands allocated on the exclusive primary basis to maritime mobile service or by transferring the MMS allocations to frequency bands allocated on the exclusive primary basis to the FS. The other bands may be excluded from consideration since allocations to fixed and mobile services have already been combined there.

In this regard some administrations conduct studies in feasibility of providing a combined allocation in the frequency bands currently allocated to the MMS on an exclusive primary basis (see Fig. 1).

FIGURE 1

Current exclusive allocations to the fixed and maritime mobile services in the frequency band 4-10 MHz



Technical, procedural and economic difficulties that may result from the change in frequency allocations in 4-10 MHz range have already been considered. Besides, such modification would require revising Appendix 25 containing the Plan of frequency allotments for the coastal telephone stations operating in frequency bands between 4 000 kHz and 27 500 kHz allocated exclusively to maritime mobile service. It is also worth noting that Article 31 prohibits any emissions that may cause harmful interference to safety and distress communications at any frequency listed in Appendices 13 and 15 including frequencies in 4-10 MHz range.

In addition to the above issues establishment of a combined allocation could run into additional problems of electromagnetic compatibility. They could be resolved by imposing stronger restrictions on the fixed service or through coordination.

The RR reflects accumulated experience in sharing between fixed and maritime mobile services in the frequency bands allocated exclusively to maritime mobile service. Operation of fixed stations in frequency bands 4 063-4 123 kHz and 4 130-4 438 kHz subject to RR No. 5.129 is an example of such sharing. Under that footnote stations in the fixed service may establish, in exceptional cases, communication at a mean power not exceeding 50 W within the boundaries of the country in which they are located providing that no harmful interference is caused to the maritime mobile service.

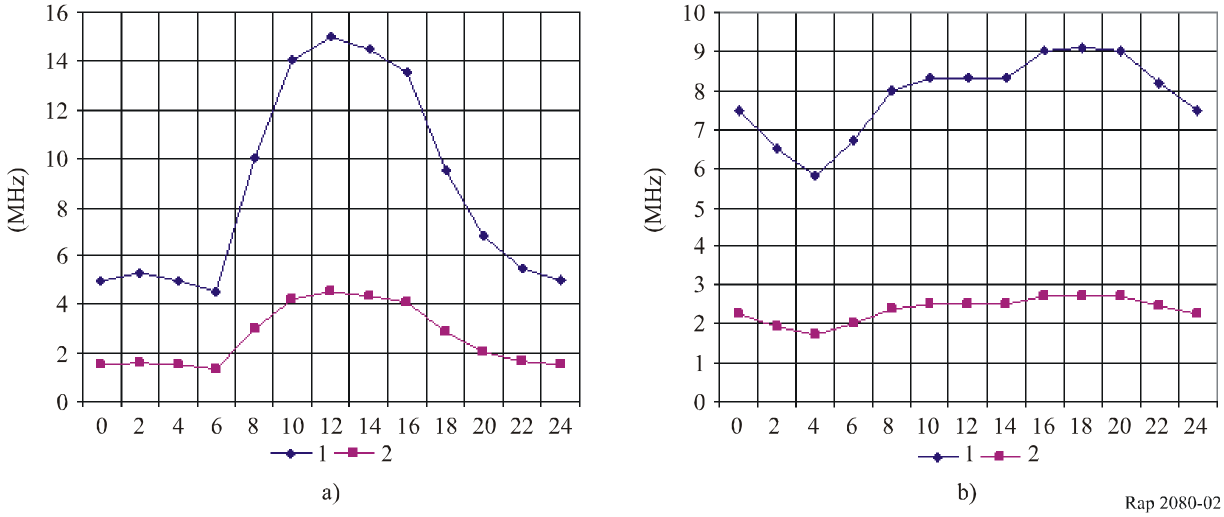
The use of frequency bands 4 063-4 123 kHz, 4 130-4 133 kHz and 4 408-4 438 kHz subject to No. 5.128 in a number of countries in Regions 1 and 3 is another example of sharing between fixed and maritime mobile services. Maritime mobile service operates in those bands and they can also be used by limited power fixed service stations which are located at least 600 km from the coast on condition that harmful interference is not caused to the maritime mobile service (WRC-97).

Radio wave propagation analysis shows that the above frequency bands feature extensive attenuation in the links of the first hop to provide feasibility of sharing between the services.

It is worth mentioning that when estimating feasibility of sharing between FS and MMS some administrations support such an approach. Specifically, sharing between long-haul links in MMS and short length (of up to 200-300 km) links in the FS would be feasible subject to limitation of FS transmitters power and to operation of maritime mobile service in the frequency band which is 10% above the ionosphere critical frequency as well as to operation of FS in the frequency band which is 20% below the ionosphere critical frequency. Therefore Fig. 2 shows averaged relations for diurnal changes of F2 ionosphere layer critical frequency for winter (see Fig. 2 a)) and summer (see Fig. 2 b)) seasons (Curve 1).

FIGURE 2

Diurnal changes of the critical frequency for ionosphere layer F2



It is obvious that the critical frequency of F2-layer changes from 4 MHz to 15 MHz within a year. It means that, considering the above recommendations on selecting the operational frequency bands, difference between frequency bands to be used in fixed and maritime mobile service varies from 1.2 MHz to 4.5 MHz (Curve 2 in Fig. 2). Moreover the frequency band choice would also depend on some other factors including local latitude, solar cycle, etc. Analysis of the obtained results shows that sharing between the services is provided by frequency separation but not by limiting the transmission power and combined usage of near vertical and oblique incidence of electromagnetic waves on the ionosphere.

Feasibility analysis for establishing a combined allocation of the frequency bands exclusively allocated to the MMS should consider that some administrations propose clearing out a portion of the spectrum by implementation of frequency adaptive systems in fixed and maritime mobile services. Such systems are expected to operate in overlapping frequency bands and selection of an operational frequency will be based on analysis of propagation environment and occupancy of available communication channels.

However, the available information analysis shows that in spite of long-term successful usage of frequency adaptive systems there is no information about spectral resource savings achieved as a result of their application. Moreover, a number of peculiarities in operation of maritime mobile systems could assume a situation when fixed and maritime mobile stations would concurrently use the same frequencies that may result in unacceptable interference.

Thus, the analysis shows that:

– In the range 4-10 MHz additional spectral resource can be made available only as a result of full or partial transfer of FS allocations from the bands 9 040-9 400 kHz and 9 900-9 950 kHz to the bands 4 063-4 438 kHz, 6 200-6 525 kHz, 8 195-8 815 kHz currently allocated to MMS, or vice versa, i.e. transferring a part of MMS allocations from the bands 4 063-4 438 kHz, 6 200-6 525 kHz and 8 195-8 815 kHz to the bands 9 040-9 400 kHz and 9 900-9 950 kHz allocated to FS. Other bands may be excluded from consideration since fixed and mobile services have already been combined there.

– The experience gained in sharing between maritime mobile and fixed services evidences to the requirements of imposing serious restrictions for their co-frequency operation that is inappropriate in terms of practice for the existing applications of these radio services.

– The argument that problems of sharing between fixed and maritime mobile services could be resolved through application of frequency adaptive systems is ambiguous and requires comprehensive study and confirmation.

– Sharing between short communication lines in the FS using the NVIS technology and long-haul lines in the MMS would be feasible mainly based on separation of frequencies used by FS and MMS stations but not by limiting power of emission from FS stations.

Besides, it should be noted that reallocation of these bands would require revision of RR Appendix 17 which is currently being studied under Resolution 351 (WRC-03). However, Resolution 351 (WRC-03) specifies that any changes in Appendix 17 should be aimed at improving the operation of maritime mobile service:

> "that, as soon as the ITU-R studies are completed, a future competent conference should consider necessary changes to Appendix 17 to enable the use of new technology by the MMS".

It implies that revision of Appendix 17 is not to degrade MMS performance and to impose extra limitations because of problems of sharing with a new (fixed) service.

To assess the consequences of proposed integration of maritime mobile and fixed services in 4-10 MHz range the studies of interference between these services were carried out. The results of those studies are presented below.

2 Scenarios of interference between FS and MMS

Maritime mobile systems provide communication between ship and coast stations via radio lines of up to 8 000-10 000 km. As a rule ship transmitter power is limited and the level of signal power at the input of land MMS receiver is low. In order to reduce potential interference from transmitting antennas, MMS receiving and transmitting sites are geographically separated.

Transmitting sites, depending on their purpose, may be located both in the vicinity of relevant service areas (for instance, Kaliningrad, Mourmansk), and in the vicinity of administrative centers situated at great distances from a coast area (for instance, Yakoutsk, Moscow). Depending on location of a transmitting site and its service area both directional and undirectional antennas may be used.

Receiving sites are designed for reception of signals from ships which position in the service area is not known beforehand. That is why they use undirectional antennas or combination of directional antennas with overlapping patterns. This approach allows establishing the pseudo undirectional high-gain antennas at a specified angular sector. Those operational features of maritime mobile stations result in one of the following interference scenarios.

Scenario 1 – Interference to the ship MMS stations

The scenario assumes a transmitting fixed station located at some point (point Afs, Fig. 3) in a service area. It uses ionospheric wave in its radio path. This station operates at a specified main lobe azimuth direction. Since ionospheric wave is used in the radio path, an area is formed on the Earth surface along the azimuth of the antenna pattern to provide for reception of transmitted signals. Figure 3 shows this area with a dotted line. The shape of the area is determined by antenna pattern and state of ionosphere. The scenario also assumes a receiving ship-borne MMS station (point Dmms, Fig. 3) and a fixed station (point Bfs, Fig. 3). They use frequency adaptive systems in overlapping frequency bands. The stations are located at two points inside the area of potential signal reception. Directions from the reception sites Cmms and Bfs to the transmitting stations in fixed (Afs) and maritime mobile (Cmms) services do not coincide. At a certain moment of time the MMS ship station receives an interrogating signal from the transmitting site (point Cmms, Fig. 3) at frequency f_1 which is near optimal. If the received signal quality is satisfactory the ship station sends a confirming signal and then a communication session between ship and coast radio stations begins. At the same time the fixed station at point Bfs receives a request for beginning a communication session with the fixed station.

Since directional antennas are commonly used in the fixed service for long-range communication and since direction to a transmitting MMS site usually does not coincide with direction to a fixed station a frequency adaptive system operating in the fixed service, in majority of cases, would not be able to determine that frequency f_1 is occupied.

Since points Dmms and Bfs are close to each other then radio wave propagation conditions would be similar for these stations. That is why it is highly probable that the frequency adaptive system in the fixed service would select frequency f_1 as an operational frequency thus having caused unacceptable interference to MMS stations which would have to start searching for another operational frequency.

If other candidate frequencies are not available owing to propagation conditions then a temporal inoperability of MMS communication systems could occur.

FIGURE 3

Scenario 1 − Interference from FS stations to MMS ship stations

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Scenario 2 – Interference to FS stations from MMS ship stations

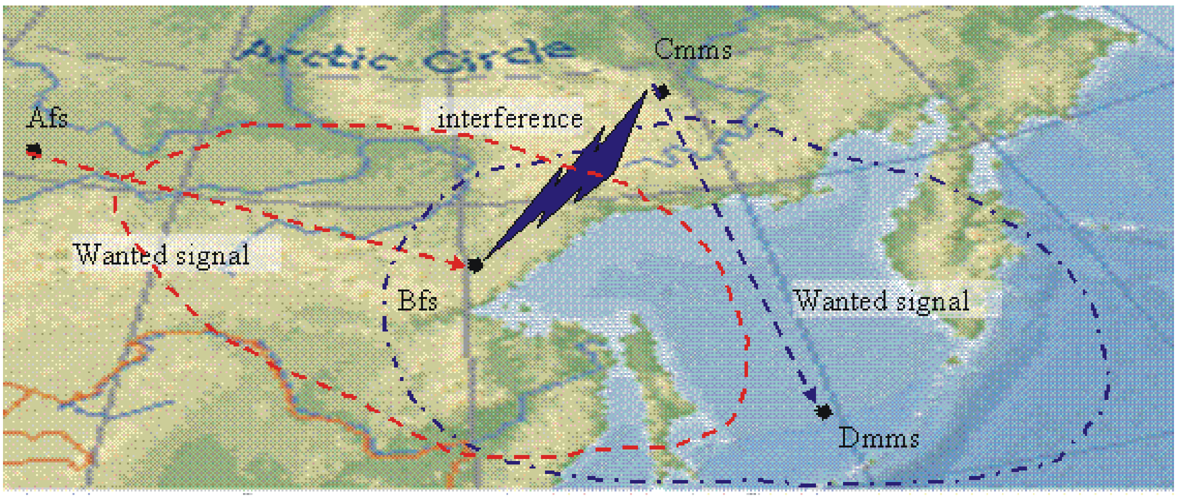
The scenario assumes a fixed station located at point Afs in a service area shown with a red dotted line in Fig. 4. The station operates at frequency f_1 due to propagation conditions in the service area. Another fixed station is deployed at point Bfs in the same service area. The later station antenna is directed to point Afs.

The scenario also assumes a transmitting MMS station deployed in point Cmms. The station service area shown with a blue dash-dotted line in Fig. 4 partially overlaps the FS station service area. It is assumed to maintain communication with a ship at the point Dmms. If Bfs station is located in an intersection of the two overlapping service areas then Cmms station could become a source of harmful interference to the fixed station (Bfs). With reducing angle φ between directions to FS and MMS transmitting stations the level of potential interference would be higher.

Since a MMS communication channel quality is a function of the signal level received by the ship station, and receiving and transmitting sites are geographically separated at a large distance the MMS frequency adaptive system would not be able to identify the channel operating at frequency f_1 as occupied and could select it for operation. Thus, the transmitting MMS station could cause unacceptable interference to the communication system in the fixed service causing its frequency adaptive system change its operational frequency or temporarily suspend a transmitting session.

FIGURE 4

Scenario 2 − Interference from MMS ship stations to FS stations



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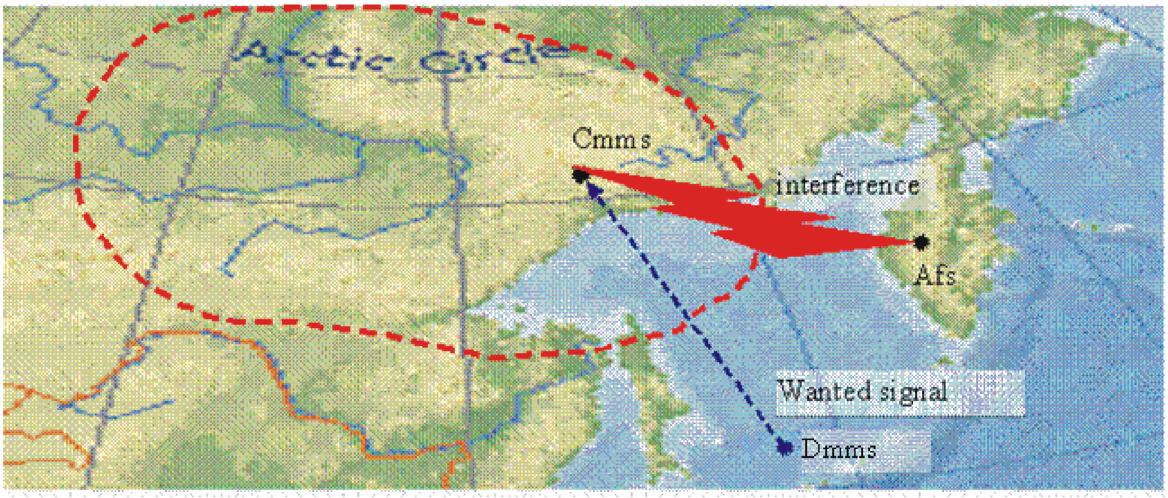
Scenario 3 – Interference to coast MMS stations

The scenario assumes a fixed station located at point Afs in a service area shown with a red dotted line in Fig. 5. The service area includes a coastal area in which a receiving MMS coast station is deployed at point Cmms. Station Cmms is designed to receive signals from ship-borne stations.

Position of a transmitting ship station is not known in advance therefore the MMS receiving site may use both undirectional and pseudo undirectional antennas. Since power of ship station signals at the point of reception is low, the frequency adaptive system in the fixed service does not identify the channel used by MMS as occupied and could start using it as an operational channel thus causing interference to the MMS coast station. Interference effect level would be a function of antenna type used at the MMS receiving site.

FIGURE 5

Scenario 3 − Interference from FS stations to MMS coast stations



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Scenario 4 − Interference to FS stations from MMS ship stations

The scenario assumes a fixed station located at point Bfs in a service area of a MMS ship station. The MMS ship station signal could fall into the fixed station antenna main lobe to result in causing interference to the FS station. However, the probability of such an interference scenario occurrence is very low due to low power of ship transmitters. Therefore the scenario is not analysed in this paper.

3 Protection criteria

3.1 FS Station protection criteria

Analysis of fixed service systems operating in the frequency band 4-10 MHz shows that they are designed to transfer digital or analogue data and to transmit signals of various emission classes. Therewith protection requirements related to digital modulation systems are significantly less stringent as compared with analogue systems. Analysis of Recommendations ITU-R associated with fixed service shows that no specific Recommendation defines protection criteria for FS systems operating in the HF range. At the same time Recommendation ITU-R F.1610 specifies that signal-to-noise (S/N) ratio should be used as a protection criterion for systems operating in the fixed service. It defines that S/N threshold values for various emission classes are specified in Recommendation ITU-R F.339-6. Analysis of Recommendation ITU-R F.339-6 shows that the required C/N value may vary from −4 dB to 33 dB depending on the emission class.

3.2 Protection criteria for MMS stations

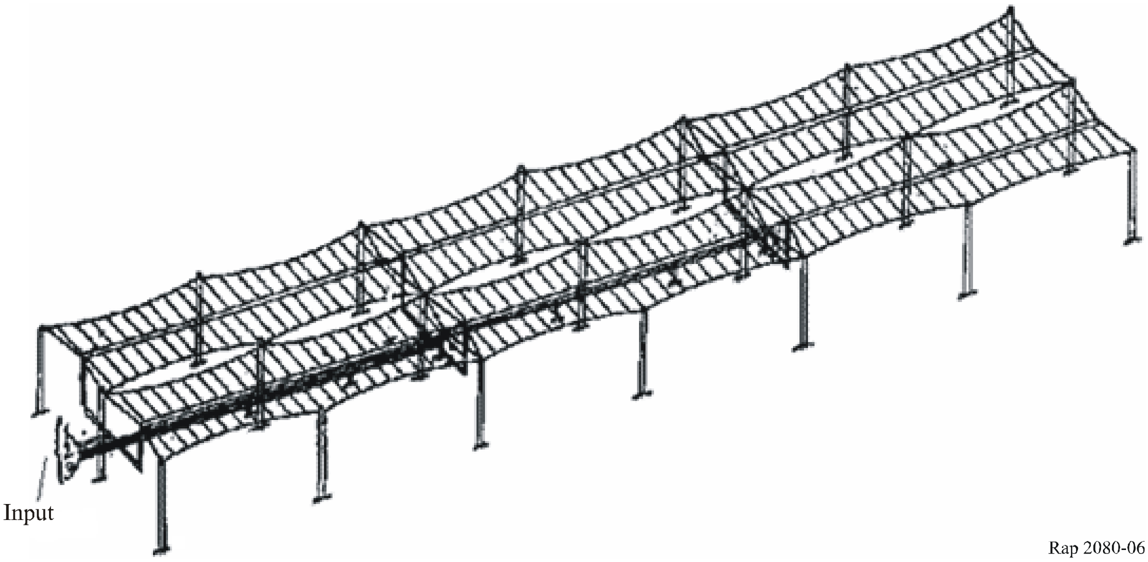
The International Maritime Organization (IMO) suggested that, according to Resolution A.801(19) IMO Provision of GMDSS radio services, signal-to-interference ratio of 9 dB for Region A2 (sea area A2) be used as one of the criteria for ensuring reliable communication with MMS coast stations operating in the GMDSS. More stringent protection criteria may be used in the frequency band 4-10 MHz for some operational modes.

4 Analysis of transmitting antenna designs used in FS, MMS and BS

The FS and MMS systems establish long-haul communication links at distances of up to 10 000 km and should operate in modes of frequency rearrangement within a specified spectrum. Operation of such systems requires high-gain wideband antennas. Such antennas could be constructed on the basis of antenna arrays of slightly directional modules. Travelling wave antennas and wideband dipole shunt-fed antennas could be used as elements of such arrays. Figure 6 depicts a double element linear array composed on the basis of three-element travelling wave antennas.

FIGURE 6

Horizontal double element antenna array based on three-element travelling wave antennas



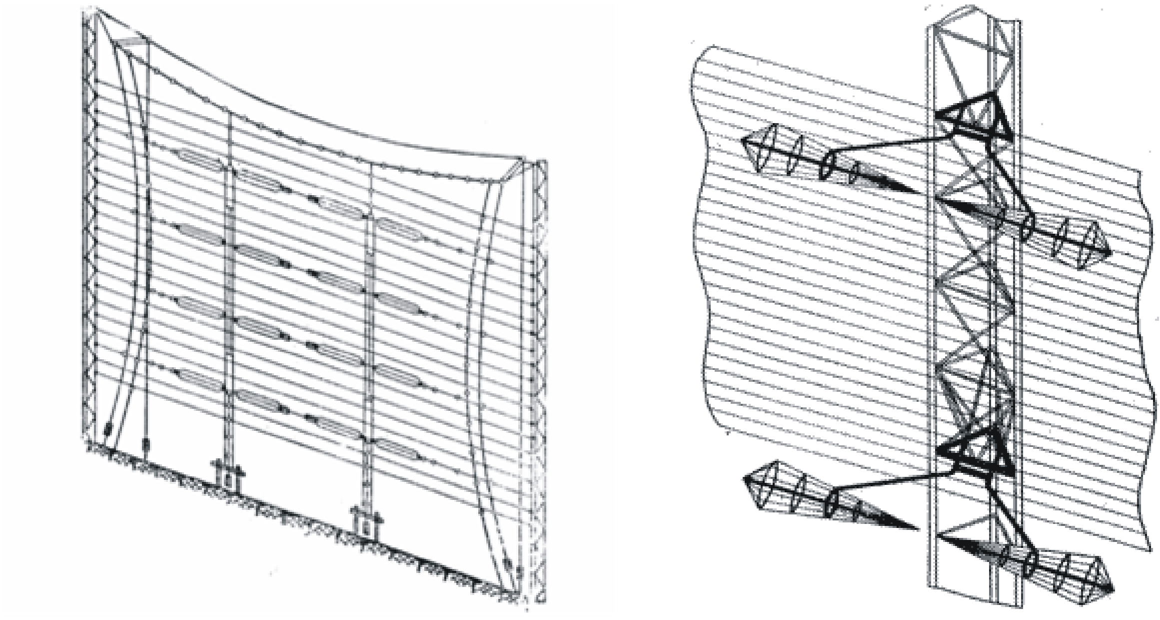
The main issue associated with operation of such antennas refers to their geometrical dimensions and impracticability of changing their spatial orientation. Antenna dimensions are a function of a wavelength and a required gain defining a number of employed elements. HF antennas could be of tens and hundreds metres in length. Impracticality of antenna orientation mechanical changing results in requirement to use a specific method for constructing the MMS antenna designed for communication with ships. The method consists in employing several antennas located to provide for overlapping their pattern main lobes at a specified level. The antenna gains could be increased either by addition of elements in a travelling wave antenna or by increasing a number of travelling wave antennas integrated in a given array. In any case that would result in enlarging antenna geometrical dimensions and in increasing complexity of its adjustment and operation costs.

Using spatial arrays with a general layout shown in Fig. 7a) could reduce antenna length. Using a screen reduces the back lobe of its pattern. Operational bandwidth of such antennas could be increased by employing an array of biconical shunt-fed dipoles as the array elements. An external view of such dipoles and a method of their fixing is shown in Fig. 7b).

Figure 7a) shows an antenna which is an array of slightly directional elements. Therefore a number of the array elements should be increased to augment its gain. That would result in increasing the antenna dimensions, its mass and wind load on the structure and also in narrowing an operational bandwidth. Arrangements for its spatial attitude control would also be required. Therefore antennas with a relatively low gain are practically employed. They are the BHD[1] antennas which is made up of 8 elements stacked in two layers of 4 horizontal dipoles in each and the BHD-4/4 antenna which is made up of 4 elements stacked in four layers of 4 horizontal dipoles in each. Figure 8 shows the BHD-4/4 antenna.

FIGURE 7

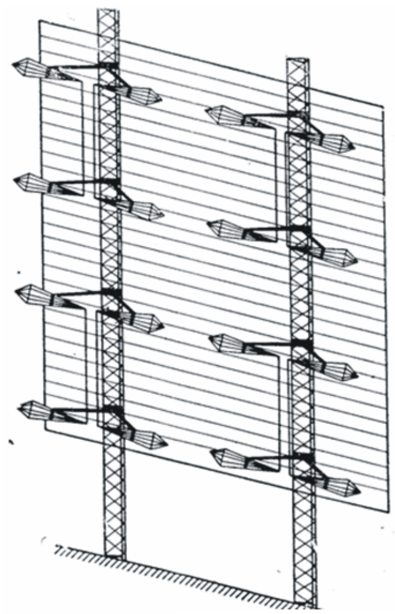
A co-phase horizontal antenna array



a) b) Rap 2080-07

FIGURE 8

The BHD-4/4 antenna



Rap 2080-08

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1 BHD antenna − Broadside horizontal dipole antenna.

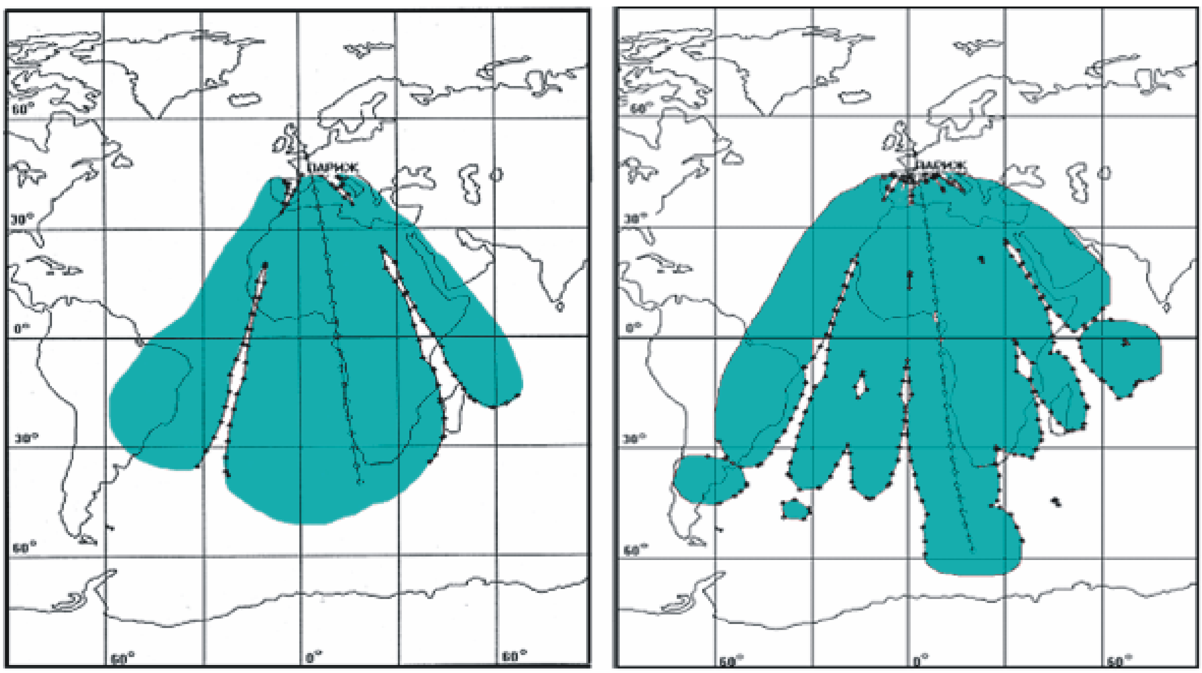
Analysis of the BHD-4/4 antenna design shows that scanning the antenna main beam by varying the antenna spatial orientation is impractical. Therefore establishing the undirectional high-gain antennas employed in maritime mobile service uses several BHD antennas with the main beams overlapping at a specific level similarly to the above case. Combining several antennas into a single array significantly increases the cost of its creating, adjustment and operation to result in its economical unfeasibility. Since HF communication links provide signal delivery to its destination by ionosphere wave propagation it would be inappropriate to assert unambiguously that increasing the gain would result in decreasing an area in which emissions from a given station would cause harmful interference. Therefore fixed and maritime mobile services employ high-gain antennas only after confirming their technical and economical validity.

5 Calculation of mutual interference caused by fixed and maritime mobile stations using high-directive transmitting antennas

Calculating the potential interference could include identification of the area where fixed and maritime mobile services produce unacceptable interference. An example corresponding to mutual interference scenario 1 is discussed on the first hand. The example assumes a fixed transmitting station deployed in a site at 48°50' N and 2°20' E (Paris). The station antenna main beam azimuth is 170°. The station may operate the BHD-2/4 and the BHD-4/8 (a 4-layer stack with 8 horizontal dipoles in each). The station transmission power is 15 kW at 9 100 MHz operation frequency. The estimations were performed for 2 a.m. Moscow time in June at a minimum of the solar cycle. Twenty sunspots are assumed. The estimations were performed for an angular sector of ±40° relative to the antenna main lobe axis orientation. Figure 9 depicts the estimation results for a potential service area with a field strength of at least 20 dB(µV/m). Figure 9a) shows the results for the station operating the BHD-2/4 transmitting antenna whereas Fig. 9b) shows the results for the BHD-4/8 antenna. Potential service areas for the fixed station are shown in blue.

FIGURE 9

A potential service area for the fixed transmitting station



a) b)

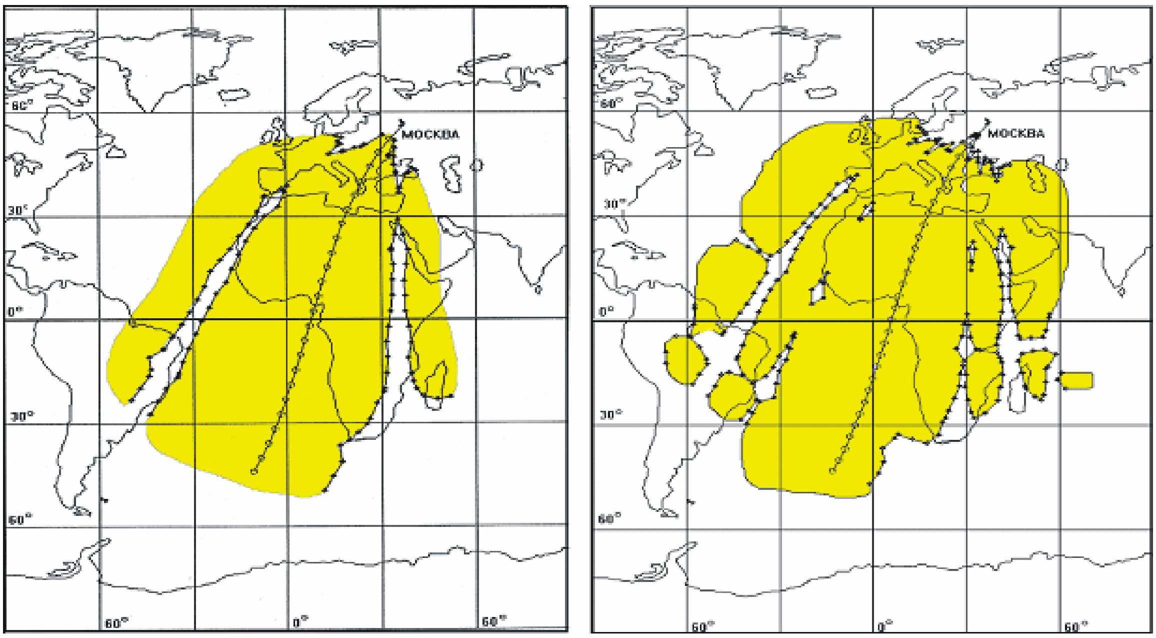
Rap 2080-09

Analysis of results derived for the BHD 2/4 antenna shows that a fixed station with such an antenna could provide not only communication with the stations deployed practically over the whole African continent but would also produce electromagnetic fields of at least 20 dB(μV/m) in strength over significant areas of the Indian and Atlantic Oceans. Endeavour to reduce areas of potential mutual interference by using the BHD-4/8 antenna featuring a higher gain failed to produce positive results. Transition from the BHD-2/4 transmitting antenna to the BHD-4/8 antenna resulted in changing a shape and dimensions of potential service area for the fixed transmitting station but it provided no significant reduction of the antenna size.

The estimations assumed a transmitting MMS site located at the point of 55°45' N and 37°37' E (Moscow). It provides for communication with ships in the South Atlantic using the BHD-2/4 and the BHD-4/8 antennas operating at 9 100 kHz. The azimuth of the antenna main lobes is 216°. The transmitter emission power is 15 kW. The estimations assumed a minimum solar cycle with conditions similar to those for the fixed station. The estimation results are shown in Fig. 10. Figure 10a) shows the results for the station operating the BHD-2/4 transmitting antenna whereas Fig. 10b) shows the results for the BHD-4/8 antenna. An area where the signal electric field strength would be at least 20 dB(μV/m) is shown in yellow.

FIGURE 10

A potential service area for the transmitting MMS station



a) b)

Rap 2080-10

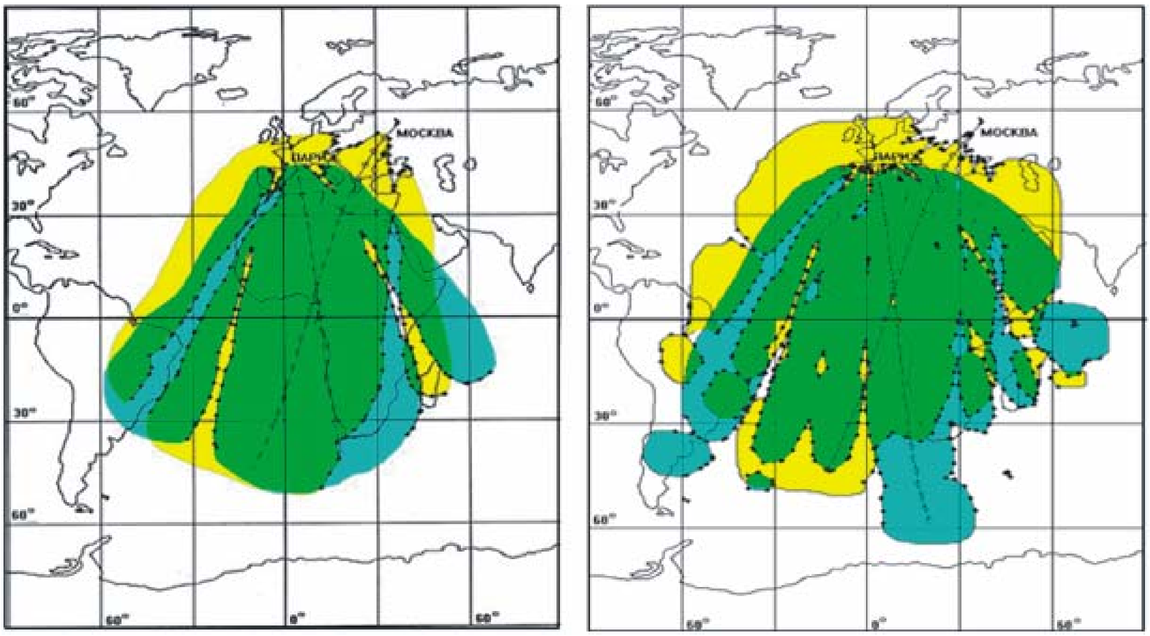
Analysis of the obtained results shows that such a transmitting station would provide for not only maintaining communication with the ship stations located in majority of the Atlantic sectors but would also produce electromagnetic fields of at least 20 dB(μV/m) in strength over significant areas of Africa, a major part of Madagascar, the Arabian peninsular and a part of the South America with any of the antennas assumed.

Figure 11 shows the results of estimation for both services considered. Figure 11a shows the results for a case when both stations operate the BHD-2/4 transmitting antenna whereas Fig. 10b) depicts the results for the BHD-4/8 at both stations. An area where the carrier-to-noise ratio would be close to 0 dB is shown in green.

Analysis of the obtained results shows that the fixed transmitting station could cause harmful interference to the maritime mobile service operation in a significant part of the Atlantic. Moreover the carrier-to-noise ratio would be close to 0 dB for the fixed stations in a greater part of Africa. It provides for conclusions that, subject to Recommendation ITU-R F.339-6, harmful interference would be caused to the stations in the fixed service. Operation of higher gain antennas at the station of both services would not result both in reducing service areas of both stations and in the significant diminishing of a zone associated with potential harmful interference. Therefore a conclusion could be drawn that operation of frequency adaptive stations in the mentioned services would be unfeasible due to their cost, large dimensions and impracticality of solving the problem of reducing the areas of mutual harmful interference.

FIGURE 11

Area of potential harmful interference to the MMS ship stations



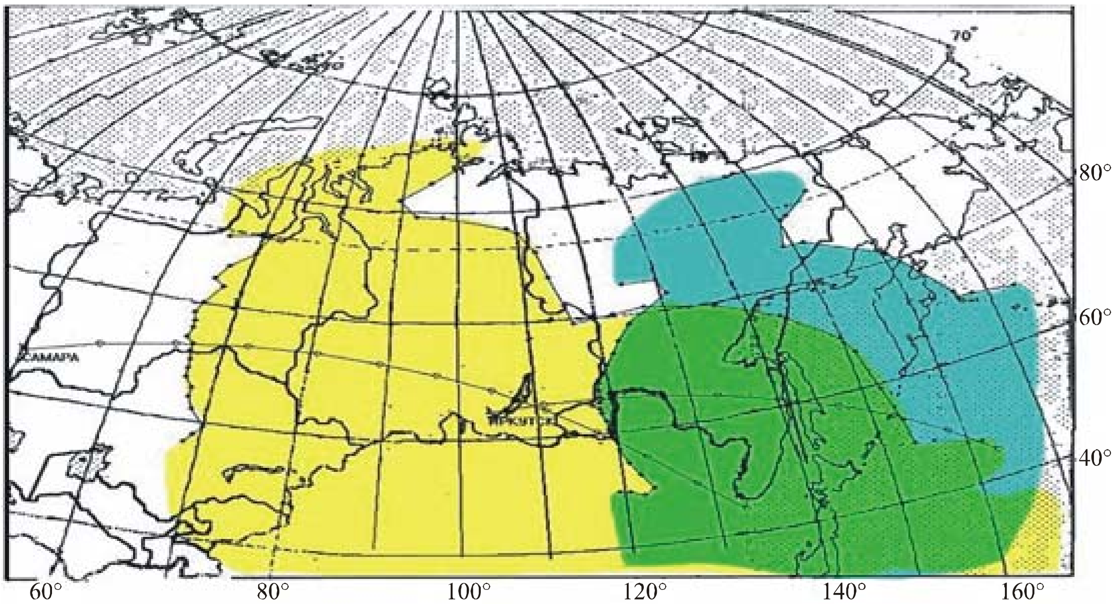
A further assessment of a situation associated with the second mutual interference scenario assumes a transmitting fixed station located in the point of 53°13' N and 50°10' E (Samara). The station could be equipped with the BHD-2/4 and the BHD-4/8 antennas with their main lobe azimuth at 66°. The estimation also assumes 8 p.m. Moscow time in February at a minimum solar cycle. 20 sunspots are assumed. Figure 12a) shows the estimation results for the BHD-2/4 antennas used in a transmitting mode at both stations whereas Fig. 12b) depicts the results for the BHD-4/8 antennas. A potential service area for the transmitting fixed station is shown in yellow.

The estimation also assumes a transmitting MMS station located at the point of 52°19' N and 104°14' E (Irkoutsk). The station establishes communication with ships located in the South-East Pacific Ocean. The MMS station is also equipped with the BHD–2/4 and the BHD-4/8 antennas with their main lobe azimuth at 80°. A potential service area for the MMS station is shown in blue in Fig. 12.

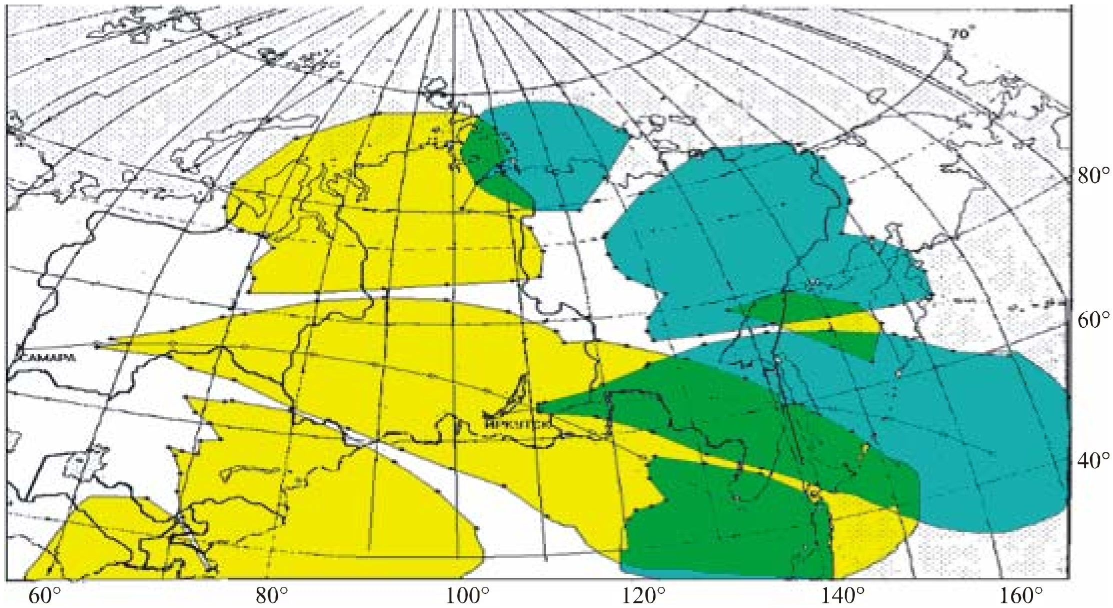
Green colour indicates areas with carrier-to-noise ratio equal to about 0 dB for both relevant stations. Analysis of the obtained results shows that, based on provisions of Recommendation ITU-R F.339-6, harmful interference could be caused to fixed stations in that area. Harmful interference could also be caused to MMS ship stations in the green area covering a part of the Pacific Ocean. Employment of higher gain antennas would result in changing a shape of probable mutual harmful interference area and its reduction as compared with the case of using the BHD-2/4 antennas at the FS and MMS stations. However changing the FS station antenna main lobe orientation or changing the distance between the FS and MMS transmitting stations could result in significant increasing in the area of potential mutual harmful interference.

FIGURE 12

Areas of mutual harmful interference



a)



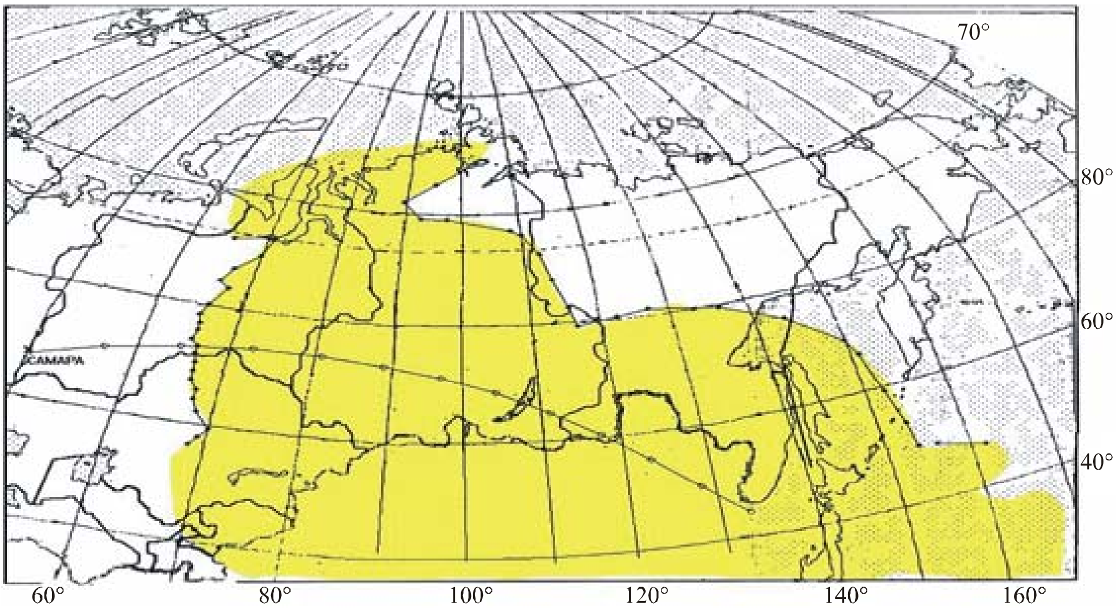
b)

Rap 2080-12

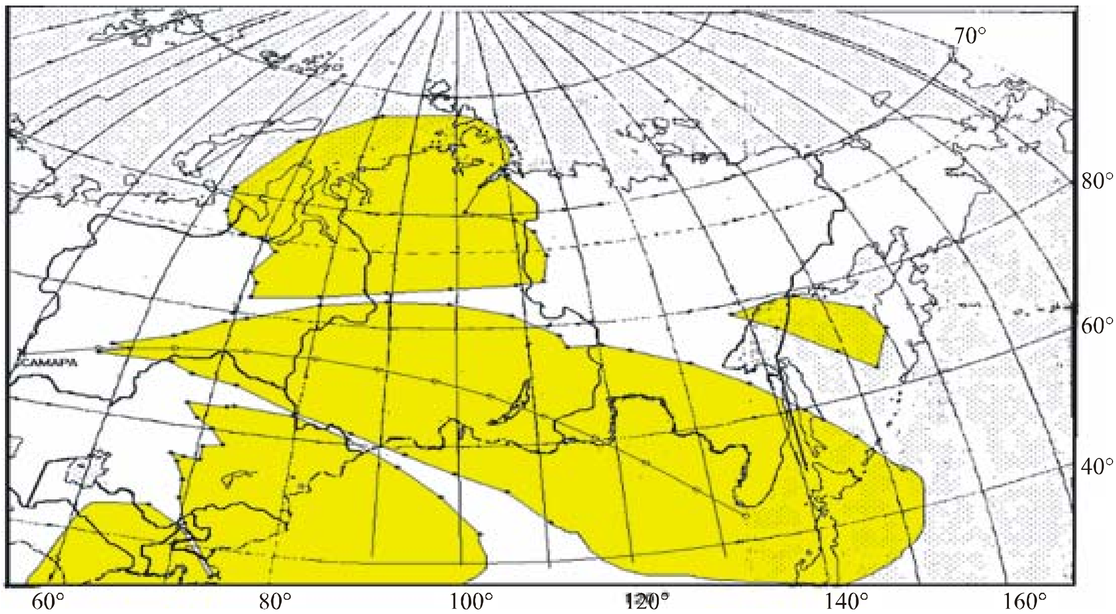
A still further analysis of the situation associated with the second scenario assumes a transmitting fixed station located in the point of 53°13' N and 50°10' E (Samara). The station is equipped with the BHD-2/4 and BHD-4/8 transmitting antennas with the main lobe azimuth at 66°. The estimation also assumes 8 p.m. Moscow time in February at a minimum solar cycle. Twenty sunspots are assumed. Figure 13 shows a yellow area where the transmitting fixed station would generate an electrical field of at least 20 dB(μV/m) in strength. Figure 13a) shows the BHD-2/4 antenna and Fig. 13b) shows the BHD-4/8 antenna.

FIGURE 13

Potential service areas of the fixed station equipped with different transmitting antennas



a)



b)

Rap 2080-13

Analysis of the obtained results shows that the fixed station could cause harmful interference to the MMS stations in a significant parts of the Russian and Chinese Pacific coasts, in Sakhalin and Japan and in a certain part of the Arctic Ocean irrespective of transmitting antennas at that station.

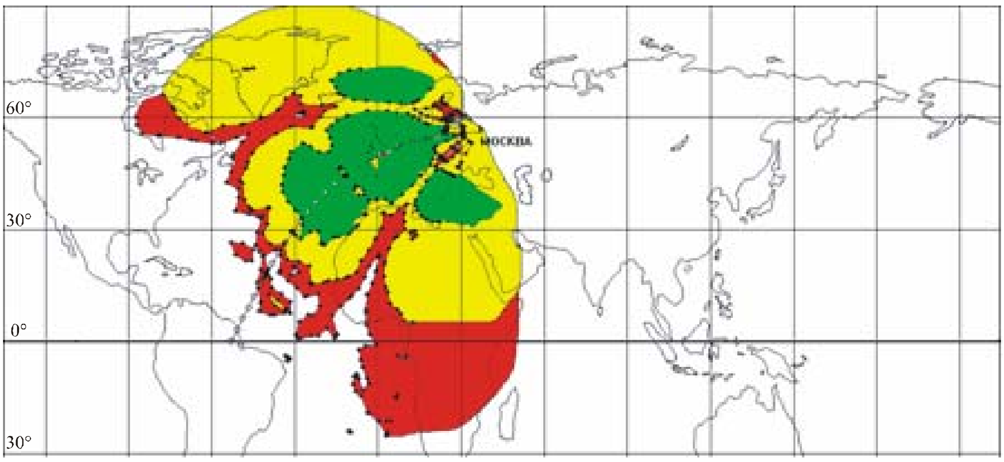
The obtained estimates also show that in case of equal radiation power the systems operating in FS and MMS would cause mutual harmful interference. If the MMS station transmission power reduced to 5 kW with the FS station transmission power of 15 kW then the FS stations would cause harmful interference to the MMS systems. Since power of transmitting fixed stations could be of up to 80 kW with power of transmitting MMS stations being limited to 15 kW (see RR Nos. 52.56, 52.104 and 52.143) the FS stations would cause harmful interference to the MMS systems even though transmitting power of the MMS stations would be at the level of 15 kW.

6 Analysis of sharing feasibility between fixed/mobile and broadcasting stations on the basis of geographical separation

Estimation of sharing feasibility between fixed or mobile and broadcasting (BS) services begins with assessing dimensions of areas where the BS could produce harmful interference to other services. The estimation assumes a typical transmitting BS station with the Viyuga-2 (Snow storm-2) transmitter of 250 kW output power and the BHD-4/4 antenna. The station is located at the site of 55°45' N and 37°37' E (Moscow). The station is designed for broadcasting to the Kaliningrad Region and for the Russian embassies in the European countries. Therefore the station main lobe is oriented at 270° azimuth. The estimation also assumes 10 p.m. Moscow time in February for the transmitting frequency of 6 MHz. 70 sunspots are assumed. The estimation results are shown in Fig. 14.

FIGURE 14

Potential broadcasting and interference areas



Rap 2080-14

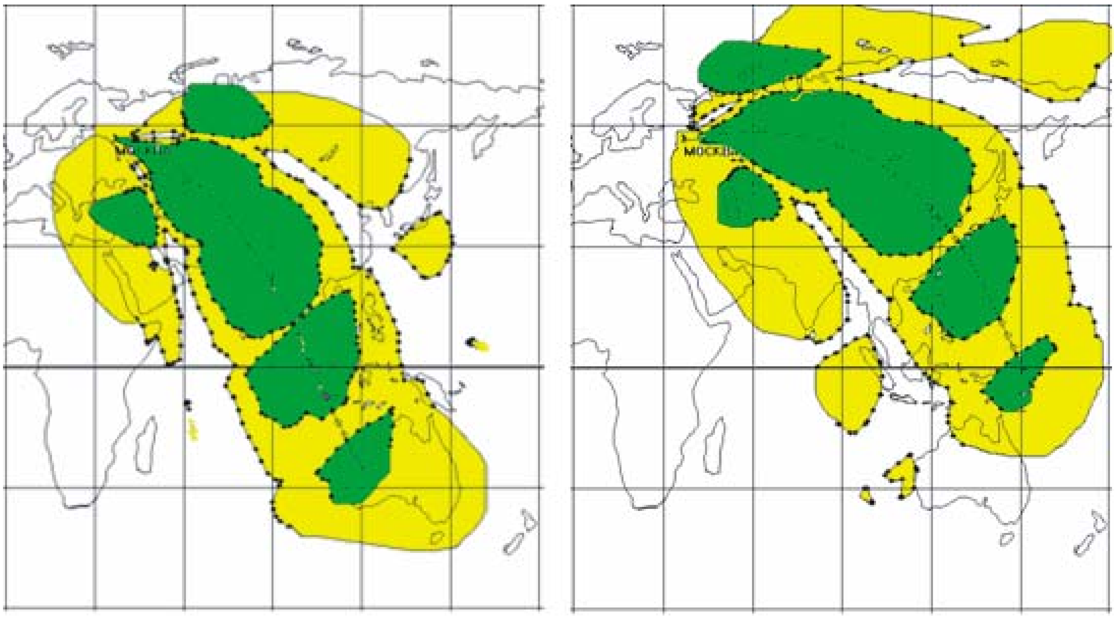
Figure 14 shows three areas of different colours. The green area refers to the broadcasting field strength of 54 dB(μV/m), the yellow area associates with broadcasting field strength of 40 dB(μV/m) and the red area refers to broadcasting field strength of no less than 30 dB(μV/m).

Analysis of the obtained results shows that the broadcasting station transmission would cause harmful interference to ship stations in areas of the Northern and North-Eastern Atlantic where the broadcasting field strength would be at least 54 dB(μV/m). Moreover, significant interference could be produced beyond that area. Taking the zone with the broadcasting field strength of at least 30 dB(μV/m) into consideration the conclusions could be drawn that such a broadcasting station could cause harmful interference to the MMS ship stations located in the Atlantic and Arctic Oceans as well to fixed and land MMS stations deployed in Africa, Greenland and Europe.

The estimation further assumes the above mentioned stations broadcasting to some regions of Siberia and the Far East at the same power and frequency. To estimate dimensions of area associated with the FS and MMS stations calculations were conducted to define an area of potential coverage for a transmitter deployed at the same geographical point and radiating signals at the same power. The estimation also assumed 10 p.m. Moscow time in February for the transmitting frequency of 6 MHz. 70 sunspots were assumed. The transmitting station used the BHD-4/4 antenna with the main lobe azimuths of 110° and 70°. The estimation results are shown in Figs. 15a) and 15b) accordingly.

FIGURE 15

Potential broadcasting area for the BHD-4/4 antenna



a) b) Rap 2080-15

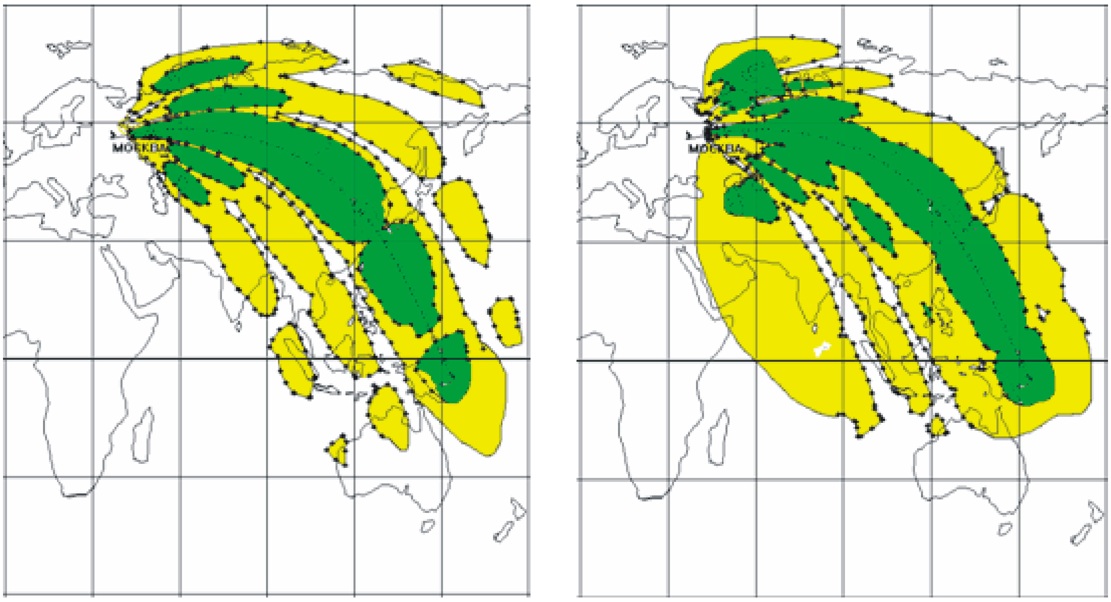
Two areas of different colours are shown in Fig. 15. The green area refers to the broadcasting field strength of 54 dB(μV/m) and the yellow area associates with broadcasting field strength of 40 dB(μV/m). Analysis of the obtained results shows that transmissions of the broadcasting station could be received not only in the specified area but also in India, China, Mongolia, Pakistan, Australia, the Arabian peninsular and in parts of Europe and East Africa for the transmitting antenna main lobe azimuth of 110°. Rotation of the transmitting antenna main lobe azimuth would result in changing the position of the potential broadcasting area and to its enlarging.

Analysis of the obtained results provide for drawing the conclusion that due to high radiation power the broadcasting stations could cause harmful interference to the fixed and mobile stations operating at significantly lower transmission power. Moreover, the interference could be caused at the territory which significantly exceeds the broadcasting station service area. Therefore a concept of geographical separation could not provide for sharing between broadcasting and fixed/maritime mobile stations.

Feasibility of reducing the potential broadcasting service area by using a high-gain antenna was also analysed. Figure 16a) shows the estimation results for the BHD-4/8 antenna at 6 MHz. Analysis of the obtained results shows that operation of the BHD-4/8 antenna would result in increasing the complexity of the shape of area where reception of the broadcasting programs is provided but not in reducing that area. Therefore attempts to provide for sharing with the stations of other services based on geographical separation could run into significant problems in areas belonging to India, China, Mongolia, Japan, Australia and in parts of Indian, Pacific and Arctic Oceans.

FIGURE 16

Potential broadcasting area for the BHD-4/8 antenna



a) b) Rap 2080-16

The effect of frequency change on the dimensions of broadcasting area was also studied. The estimation solar cycle assumptions were similar to those used for the BHD-4/8 antenna at 9 100 kHz frequency. Figure 16b) shows the estimation results. Analysis of the obtained results shows that the frequency increasing would be accompanied with enlarging the coverage area in which the broadcasting station transmissions would cause harmful interference to systems in FS and MS.

The above elaboration provides for drawing a conclusion that changing the broadcasting direction would not ensure feasibility of sharing between the broadcasting service and fixed/mobile services on the basis of geographical separation and time division. Employment of higher gain antennas would not ensure significant reduction in areas of potential interference but would result in rearrangement of radiation over an appropriate territory.

Conclusions

Analysis of the conducted estimation results shows that employment of frequency adaptive systems in the fixed and maritime mobile services could result in causing mutual harmful interference which could be overcome by imposing extra constraints on the fixed service preventing its optimal operation in the allocated frequency resource. Therefore it would be unfeasible to use the scenario of sharing between fixed and maritime mobile services as a potential method of satisfying the WRC-07 Agenda item 1.13 Issues D and E requirements.

Radio-wave propagation conditions in the frequency range 4-10 MHz render employment of narrow-beam antennas impractical for solving a problem of electromagnetic compatibility between services and could result in a negative outcome when using a concept of geographical separation.

Annex 2

Spectrograms from monitoring campaigns

Summary

A group of administrations have conducted a number of monitoring campaigns in the range 4-10 MHz using a number of monitoring stations within Europe. In addition to automated scans of 200 kHz per day (spectrograms), manual observations were also made.

Comparison of manual monitoring observations and spectrograms demonstrate that virtually all transmissions in the 4-10 MHz range can be seen on the spectrograms recorded. However, it should be noted that transmissions of extremely low power or with a very short duration (less than 10 s) may not always be visible.

Comparison of spectrograms recorded at different monitoring stations shows that the difference in transmissions observed is small. It is therefore possible to use information collected at one site as being representative for all sites.

The additional bands allocated to the broadcasting service by WARC-92 are already heavily used by the broadcasting service although not available until 1 April 2007. Additionally, the candidate bands identified in Resolution 544 (WRC-03) above 5 840 kHz are also used by the broadcasting service.

Occupancy of the bands allocated to the fixed and mobile services is generally relatively low suggesting that some form of sharing with other services may be feasible.

Utilization of the spectrum allocated to the maritime service is generally concentrated in part of the band allocated. There is scope for a possible reorganization of their usage particularly in the bands 8 200-8 350 kHz and 8 700-8 815 kHz and sharing with other services.

The aeronautical range 8 815-9 000 kHz looks to be very under utilized.

Introduction

To support a group of administrations in the preparatory work for the WRC-07 Agenda item 1.13, monitoring campaigns were organized. The intention of this document is to provide independent objective information of spectrum usage in the HF bands 4-10 MHz.

Monitoring stations

The location of the participating monitoring stations can be seen in Fig. 17.

Each monitoring station is capable of receiving HF transmissions via groundwave and skywave. The distance over which HF transmissions propagate via groundwave is given in Recommendation ITU-R P.368. This shows that the maximum distance varies inversely with frequency and with type of ground (e.g. salt water, medium-dry ground etc.) but can be in the order of tens of kilometres for frequencies in the range 4-10 MHz. Skywave reception is dependent on a number of parameters such as time of day, season, sunspot activity and frequency. In general, it is possible to receive transmissions originating at distances from a few tens to thousands of kilometres from the receiving location.

During daytime, it is therefore possible to receive transmissions in the 4-10 MHz band via either groundwave or skywave propagation originating up to at least 1 500 km from the receiving station. During night-time conditions, reception is possible for transmissions originating both within and outside the European region.

FIGURE 17

Location of participating monitoring stations

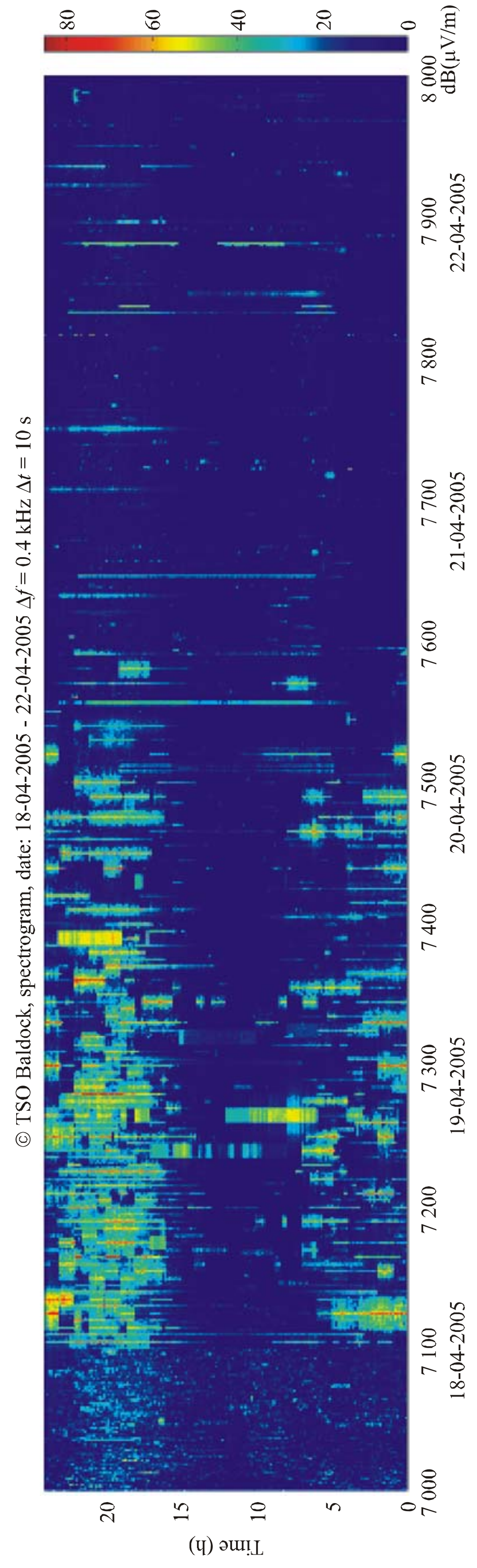
Rap 2080-17

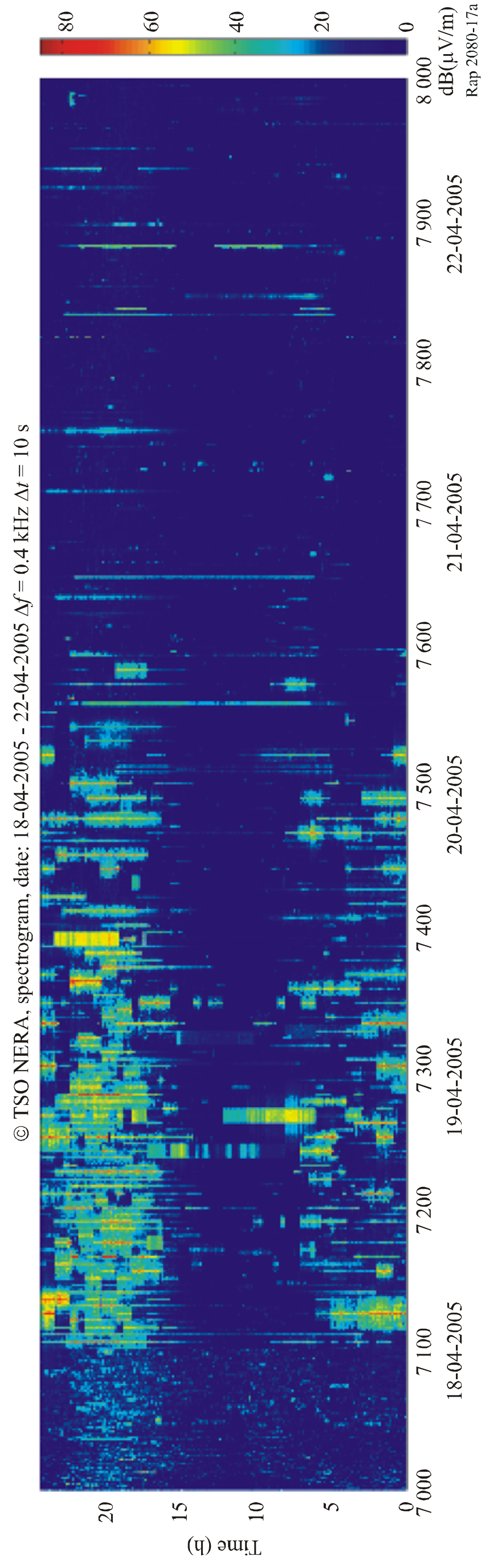
The ability to detect a weak transmission is dependent of the sensitivity of the receiving system used. Comparison of spectrograms with manual monitoring observations show that any transmission which is just above the noise floor at the receiving site can be seen on the spectrogram.

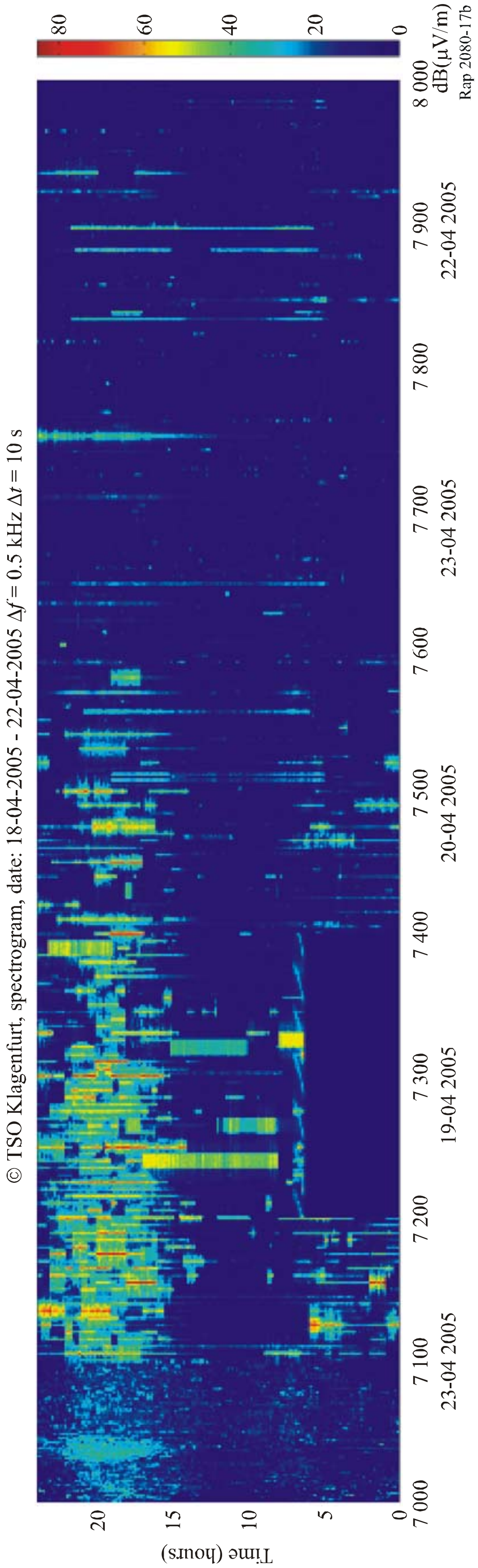
Taking all these factors into account, it is believed that virtually all transmissions in the 4-10 MHz range can be seen on the spectrograms recorded. However, it should be noted that transmissions of extremely low power or with a very short duration (less than 10 s) may not always be visible.

Since these monitoring measurements were made in Europe only, it is realized that the information does not represent the situation worldwide. At certain times of day however, with the present low sunspot activity, signals in the range from 6-10 MHz can propagate between regions, so transmissions from other parts of the world are visible in the spectrograms.

Comparison of spectrograms recorded at different Monitoring Stations shows that the difference in transmissions observed is small. It is therefore possible to use information collected at one site as being representative for all sites. This is demonstrated in the following spectrograms for the frequency range 7-8 MHz recorded at three different locations: Nera (HOL), Klagenfurt (AUT) and Baldock (G). Although there are, of course, differences in signal strength of received transmissions the overall picture is not significantly different.


© TSO Baldock, spectrogram, date: 18-04-2005 - 22-04-2005 Δf = 0.4 kHz Δt = 10 s
Time (h)
dB(μV/m)
7 000
7 100
18-04-2005
7 200
7 300
19-04-2005
7 400
7 500
20-04-2005
7 600
7 700
21-04-2005
7 800
7 900
22-04-2005
8 000


© TSO NERA, spectrogram, date: 18-04-2005 - 22-04-2005 Δf = 0.4 kHz Δt = 10 s
Time (h)
dB(μV/m)
7 000
7 100
18-04-2005
7 200
7 300
19-04-2005
7 400
7 500
20-04-2005
7 600
7 700
21-04-2005
7 800
7 900
22-04-2005
8 000
Rap 2080-17a


© TSO Klagenfurt, spectrogram, date: 18-04-2005 - 22-04-2005 Δf = 0.5 kHz Δt = 10 s
80
60
40
20
0
dB(μV/m)
Rap 2080-17b
Time (hours)
20
15
10
5
0
7 000
7 100
23-04 2005
7 200
7 300
19-04 2005
7 400
7 500
20-04 2005
7 600
7 700
23-04 2005
7 800
7 900
22-04 2005
8 000

Monitoring campaigns

A number of monitoring campaigns were organized taking into account the changes in HF propagation conditions between northern hemisphere summer and winter periods as indicated below.

– First : 14-26 April 2004
– Second : 1-13 November 2004
– Third : 17-27 May 2005
– Fourth : 7-16 November 2005
– Fifth : 15-19 May 2006

As the bands between 4-10 MHz were scanned automatically in 200 kHz segments each day, it would take 30 days for a single monitoring station to cover the whole range. Therefore, to complete the monitoring in a reasonable timescale, a schedule was prepared to divide the bands monitored between groups of 3 to 4 monitoring stations. In addition to the automatic measurements of the spectrum in the range 4-10 MHz, manual identification of transmissions observed in the same frequency range were also made.

An enormous amount of very useful occupancy data was collected and presented on a CD-ROM. It is intended that the data available will continue to be analysed further by a workgroup of specialists from both the users of the spectrum and the monitoring organizations. With help of the available manual monitoring information and measured spectrograms, some frequency ranges that could be part of a solution for Agenda item 1.13, are closely examined. In the future the full data can be accessed via the ERO website (www.ero.dk).

The purpose of this document is to provide an initial view of some of the measured spectrograms. These spectrograms are believed to give a quick and easy overview of the present occupancy of the frequency ranges as observed in Europe.

Spectrograms

Spectrograms for 1 MHz bandwidth are included for the range 4-10 MHz. Each spectrogram has a time scale of 0-24 h (vertical axis) and is measured over a 5 day period at 200 kHz per day. Further information about the measurement method and equipment setting is given in Annex 1. It is noted that the data provided by the various monitoring stations involved in the measurement campaigns may differ in term of sensitivity and dynamic range. This is unavoidable due to local site conditions and different types of antennas and equipment used.

Omitting some obviously faulty spectrograms however, still allows general conclusions to be drawn which are not affected by these differences.

Since the intention of the campaign was to establish the use of frequencies only, no precise calibrated field strength measurements were made. However, the colours of the spectrograms give an indication of the received signal strength: from dark blue ≈ 0 dB(μV/m) to dark red ≈ 85 dB(μV/m), showing a dynamic range of about 85 dB. With a correct setting of the input sensitivity of the measurement equipment, this range is believed to show both very strong and very weak signals: e.g. the carriers of some very strong broadcast transmissions as well as low power transmissions in SSB and A1A from the amateur service are both clearly visible.

This is particularly noticeable in the spectrogram for 7-8 MHz where the amateur service transmissions 7 000-7 100 kHz and the BC transmissions above 7 100 kHz can be clearly identified. As already noted, it is possible that transmissions of extremely low power or with a very short duration (less than 10 s) are not always visible.

Monitoring results

For each 1 MHz spectrogram in the range 4-10 MHz, the allocations for the different services as given in Article 5 of the Radio Regulations are shown together with general comments and conclusions about occupancy.

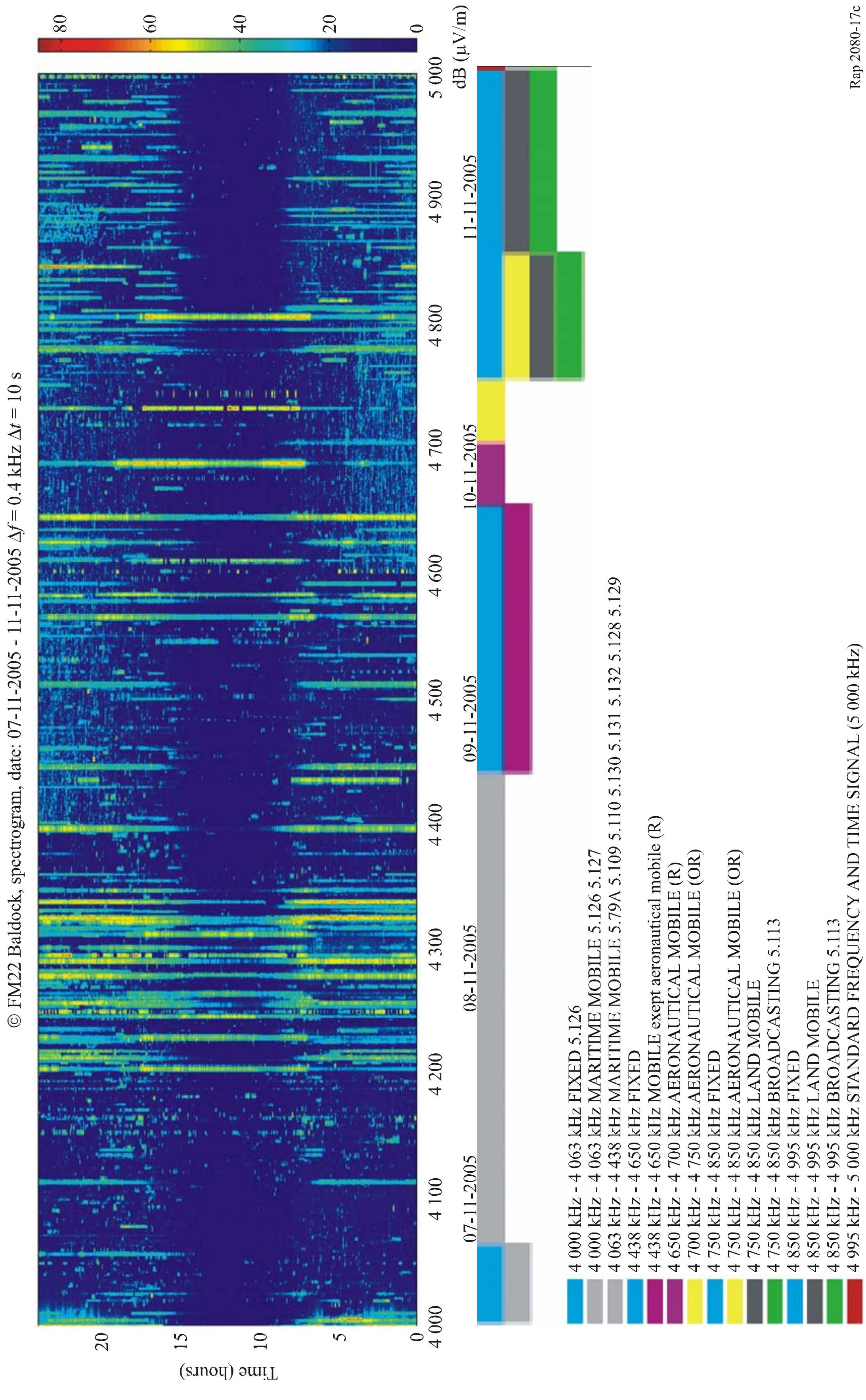
4-5 MHz range

Part of this frequency range is heavily used by the maritime mobile service in the range 4 200-4 350 kHz although the exclusive allocation to the maritime mobile service allocation is 4 063-4 438 kHz.

Regarding the candidate band (4 500-4 650 kHz) identified in Resolution 544 (WRC-03), it is noted that the occupancy by the fixed and mobile service is quite high. It may therefore be difficult to introduce broadcasting in this band. An alternative option should be explored. It is noted that the 4-5 MHz range is just located above a broadcasting band 3 950-4 000 kHz in Region 1.

Although there are some applications during daytime, e.g. a number of 24-hour and a number of short duration transmissions, the occupancy in daytime is generally rather low. This follows propagation theory as signals from longer distances on low frequencies are attenuated by the D-layer and are too weak to be received. This suggests some form of geographical reuse and/or sharing may be possible.

However, the requirements of some services during exercises and in times of crises need to be taken into account.

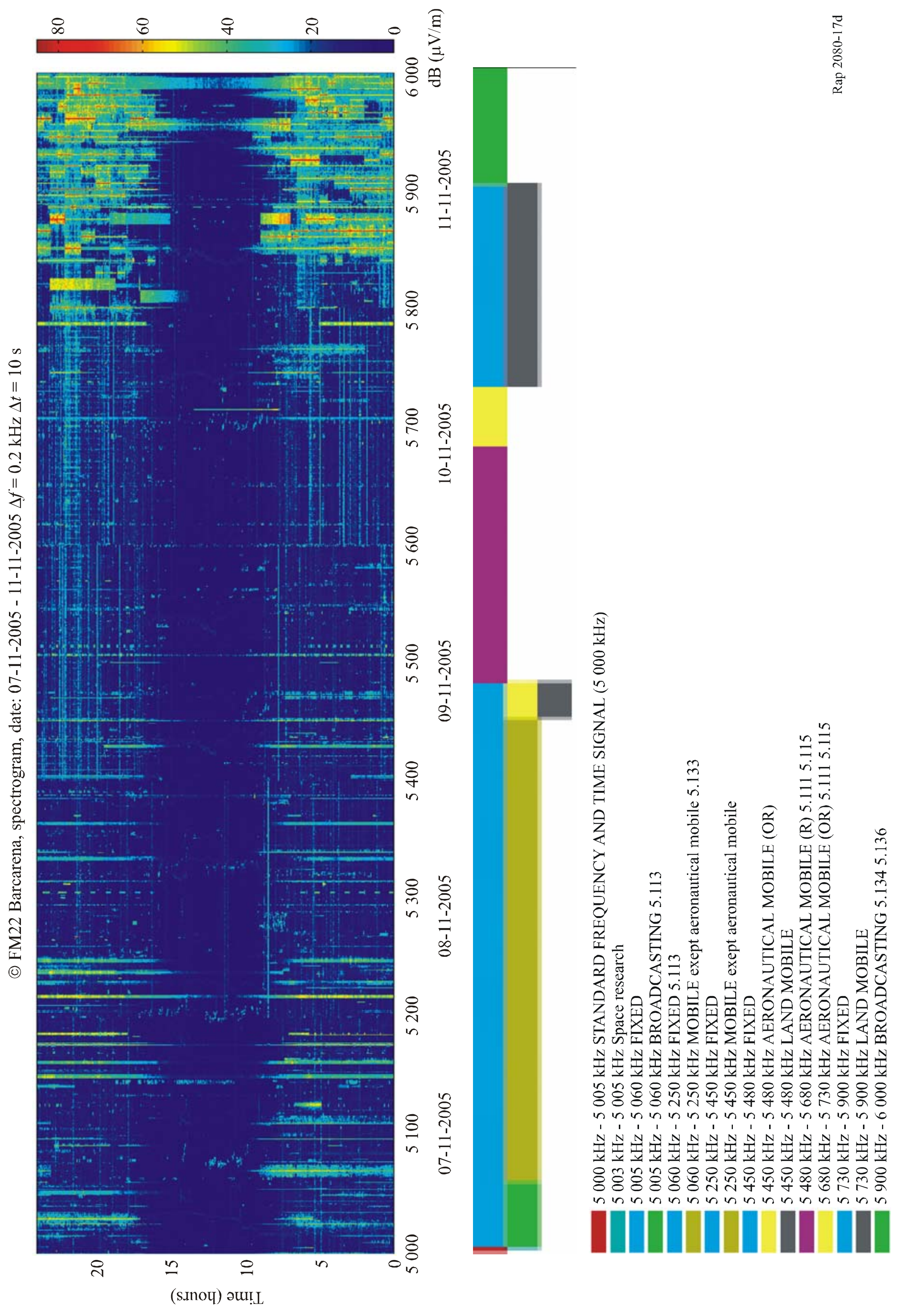

© FM22 Baldock, spectrogram, date: 07-11-2005 - 11-11-2005 Δf = 0.4 kHz Δt = 10 s
Time (hours)
0
5
10
15
20
4 000
4 100
4 200
4 300
4 400
4 500
4 600
4 700
4 800
4 900
5 000
80
60
40
20
0
dB (µV/m)
07-11-2005
08-11-2005
09-11-2005
10-11-2005
11-11-2005
4 000 kHz - 4 063 kHz FIXED 5.126
4 000 kHz - 4 063 kHz MARITIME MOBILE 5.126 5.127
4 063 kHz - 4 438 kHz MARITIME MOBILE 5.79A 5.109 5.110 5.130 5.131 5.132 5.128 5.129
4 438 kHz - 4 650 kHz FIXED
4 438 kHz - 4 650 kHz MOBILE exept aeronautical mobile (R)
4 650 kHz - 4 700 kHz AERONAUTICAL MOBILE (R)
4 700 kHz - 4 750 kHz AERONAUTICAL MOBILE (OR)
4 750 kHz - 4 850 kHz FIXED
4 750 kHz - 4 850 kHz AERONAUTICAL MOBILE (OR)
4 750 kHz - 4 850 kHz LAND MOBILE
4 750 kHz - 4 850 kHz BROADCASTING 5.113
4 850 kHz - 4 995 kHz FIXED
4 850 kHz - 4 995 kHz LAND MOBILE
4 850 kHz - 4 995 kHz BROADCASTING 5.113
4 995 kHz - 5 000 kHz STANDARD FREQUENCY AND TIME SIGNAL (5 000 kHz)
Rap 2080-17c

5-6 MHz range

As a general observation, the occupancy below 5 800 kHz is very low. During daytime, there is very little occupancy recorded in the whole band. This suggests that some geographical reuse and sharing is feasible.

The candidate band identified in Resolution 544 (WRC-03), 5 840-5 900 kHz, already shows significant occupancy by the broadcasting service although it is outside the band allocated to the broadcasting service. The other candidate band in this range, 5 060-5 250 kHz, shows some occupancy although, as noted earlier, the general level of occupancy is low.

In the spectrograms some narrow band and very narrow band 24-hour systems are visible. In addition, some other usage with shorter duration can be identified. Broadcast transmissions, with their 10 kHz bandwidth, can be easily recognized in the broadcasting band from 5 950-6 000 kHz, as well as in the WARC-92 broadcasting band from 5 900-5 950 kHz. Broadcast transmissions in DRM mode can be easily identified as they do not have a central carrier. Broadcast transmissions are mainly present during prime time in the morning and evenings and at night.


© FM22 Barcarena, spectrogram, date: 07-11-2005 - 11-11-2005 Δf = 0.2 kHz Δt = 10 s
Time (hours)
0
5
10
15
20
5 000
5 100
5 200
5 300
5 400
5 500
5 600
5 700
5 800
5 900
6 000
07-11-2005
08-11-2005
09-11-2005
10-11-2005
11-11-2005
dB (μV/m)
0
20
40
60
80
5 000 kHz - 5 005 kHz STANDARD FREQUENCY AND TIME SIGNAL (5 000 kHz)
5 003 kHz - 5 005 kHz Space research
5 005 kHz - 5 060 kHz FIXED
5 005 kHz - 5 060 kHz BROADCASTING 5.113
5 060 kHz - 5 250 kHz FIXED 5.113
5 060 kHz - 5 250 kHz MOBILE exept aeronautical mobile 5.133
5 250 kHz - 5 450 kHz FIXED
5 250 kHz - 5 450 kHz MOBILE exept aeronautical mobile
5 450 kHz - 5 480 kHz FIXED
5 450 kHz - 5 480 kHz AERONAUTICAL MOBILE (OR)
5 450 kHz - 5 480 kHz LAND MOBILE
5 480 kHz - 5 680 kHz AERONAUTICAL MOBILE (R) 5.111 5.115
5 680 kHz - 5 730 kHz AERONAUTICAL MOBILE (OR) 5.111 5.115
5 730 kHz - 5 900 kHz FIXED
5 730 kHz - 5 900 kHz LAND MOBILE
5 900 kHz - 6 000 kHz BROADCASTING 5.134 5.136
Rap 2080-17d

6-7 MHz range

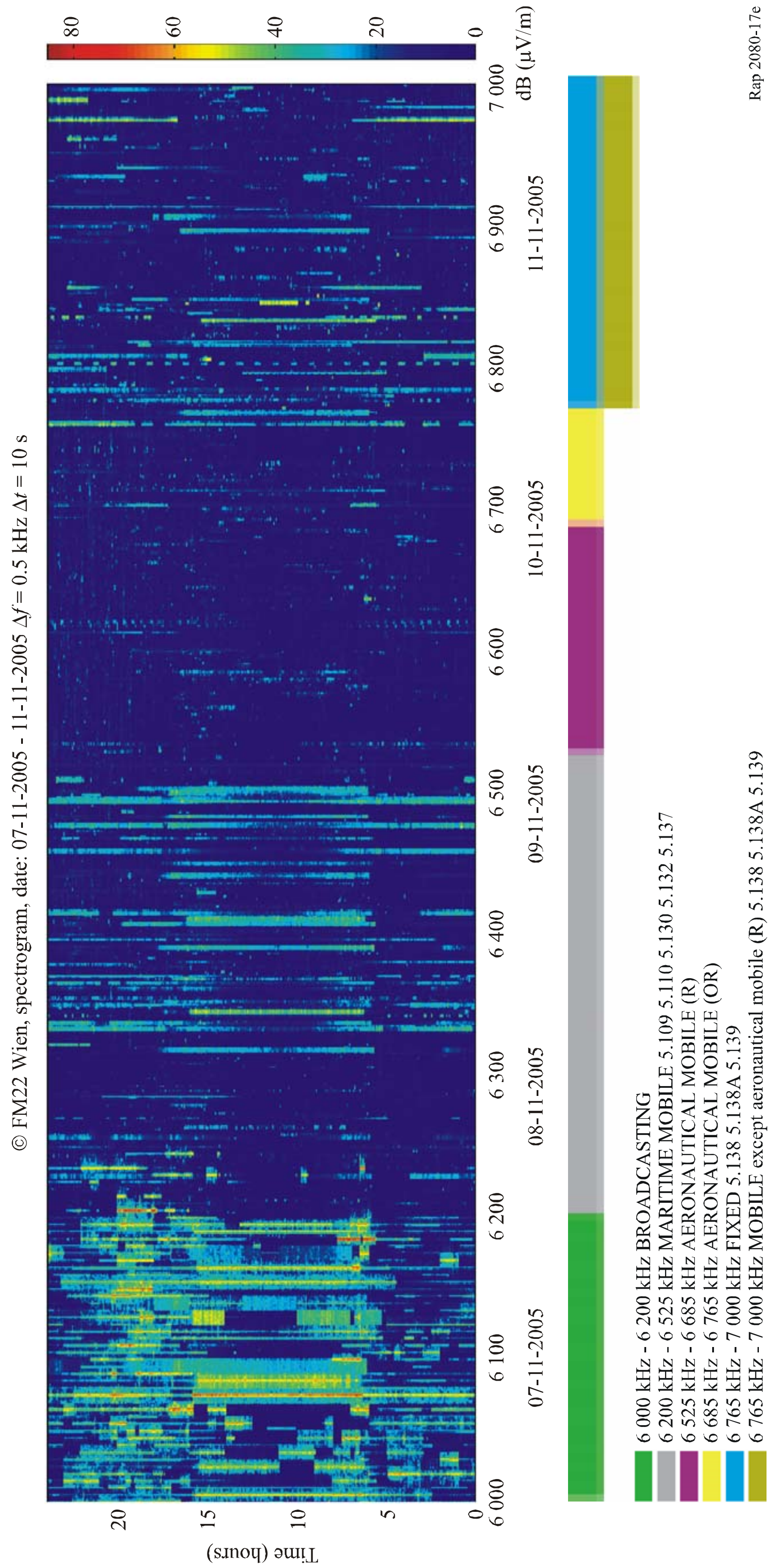
The frequency range 6-7 MHz is, in general, reasonably occupied with the exception of the allocation for the aeronautical service and the lower part of the maritime service. Therefore there are few options for reallocation in this range. However, some improvement in the use of the maritime band could be considered.

The broadcasting part from 6 000-6 200 kHz is heavily used, especially during evening and early morning corresponding to broadcasting prime time. At these times congestion is clearly visible.

The band from 6 200-6 525 kHz is allocated to the maritime mobile service and several 24-hour systems are visible. However, occupancy is not very high suggesting there is scope for considering additional sharing arrangements.

The Aeronautical band from 6 525-6 765 kHz looks very under utilized. The band from 6 765 to 7 000 kHz is used more intensively, but still appears to be under utilized. Again, it may be possible to consider additional sharing arrangements.

However, in considering any new sharing arrangements, the requirements of some services during exercises and in times of crises need to be taken into account.


© FM22 Wien, spectrogram, date: 07-11-2005 - 11-11-2005 Δf = 0.5 kHz Δt = 10 s
Time (hours)
0
5
10
15
20
6 000
6 100
6 200
6 300
6 400
6 500
6 600
6 700
6 800
6 900
7 000
07-11-2005
08-11-2005
09-11-2005
10-11-2005
11-11-2005
dB (µV/m)
0
20
40
60
80
6 000 kHz - 6 200 kHz BROADCASTING
6 200 kHz - 6 525 kHz MARITIME MOBILE 5.109 5.110 5.130 5.132 5.137
6 525 kHz - 6 685 kHz AERONAUTICAL MOBILE (R)
6 685 kHz - 6 765 kHz AERONAUTICAL MOBILE (OR)
6 765 kHz - 7 000 kHz FIXED 5.138 5.138A 5.139
6 765 kHz - 7 000 kHz MOBILE except aeronautical mobile (R) 5.138 5.138A 5.139
Rap 2080-17e

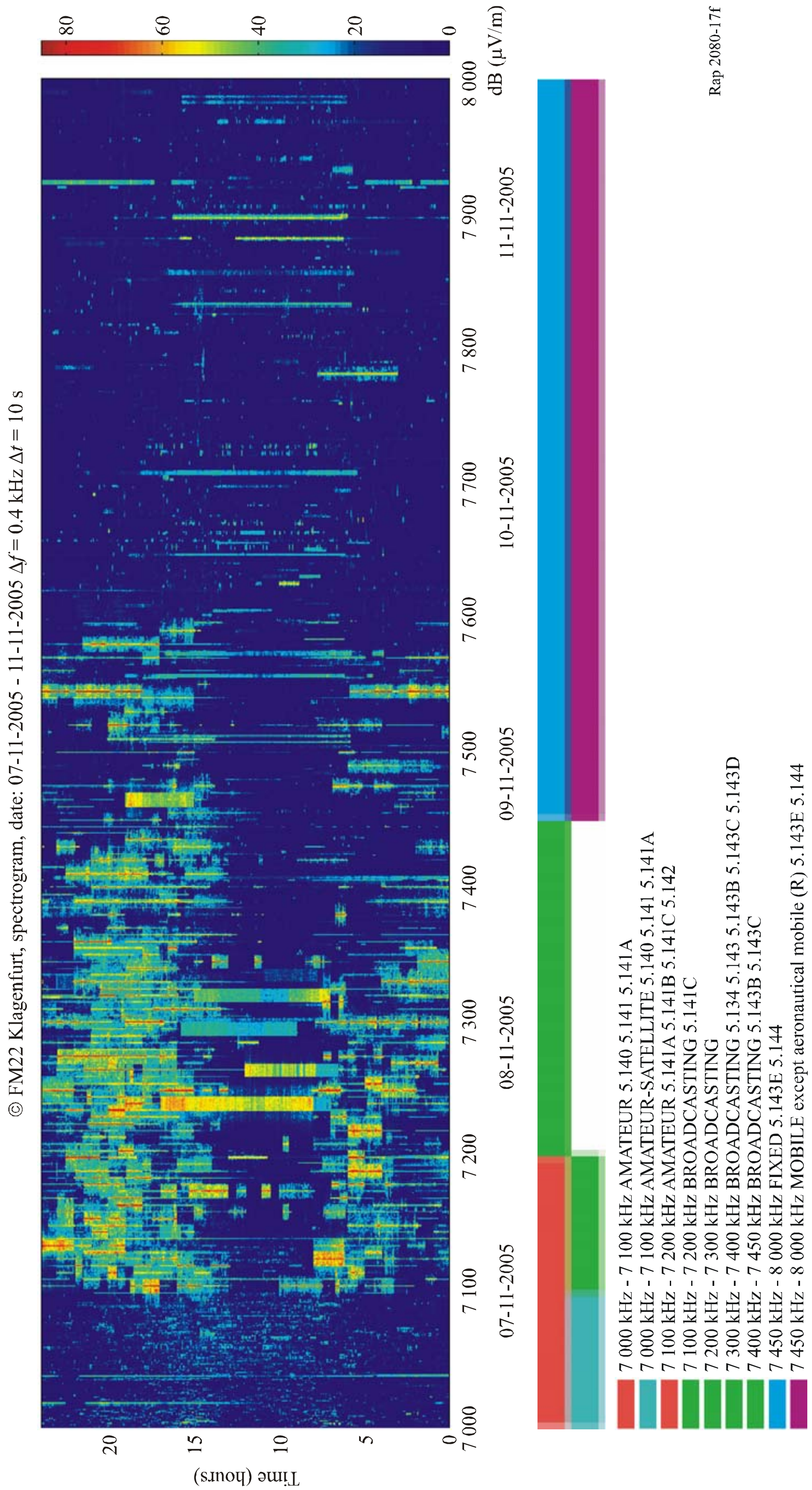
7-8 MHz range

A lot of activity is visible by the amateur service in the range from 7 000-7 100 kHz.

The broadcasting band from 7 100-7 350 kHz is very congested during the dark hours, not only is every 10 kHz occupied but during prime time morning and evening hours almost every 5 kHz channel is used by a 10 kHz bandwidth transmission. Several DRM transmissions can be identified as well (e.g. 7 240, 7 265, 7 295 kHz). It should be noted that the 7 100-7 200 kHz band will be allocated to the amateur service in 2009 so the broadcasting service will have to remove their transmissions from this band.

The band 7 350-7 600 kHz is currently assigned to the FX and land mobile service but only some usage of the FX\land mobile service can be seen. It is clear that the majority of usage is by the broadcasting service as some administrations allow this under Article 4.4 of the Radio Regulations.

In the range 7 600-8 000 kHz some usage of the FX/mobile service is visible. Most usage is visible during daylight hours although some night time use is visible as well. It looks possible for this band to accommodate FX/mobile service transmissions displaced from the band 7 350-7 450 kHz when this becomes allocated to the broadcasting service in 2009.

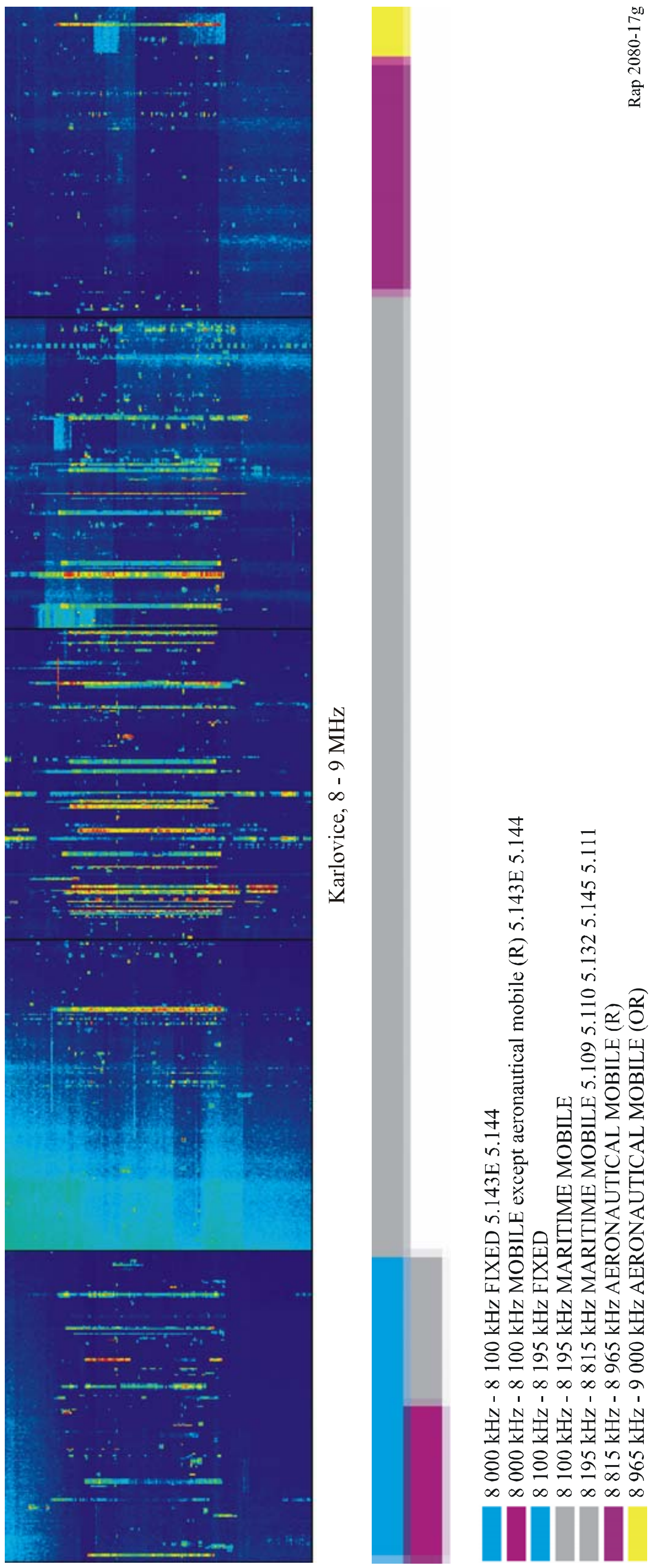

© FM22 Klagenfurt, spectrogram, date: 07-11-2005 - 11-11-2005 Δf = 0.4 kHz Δt = 10 s
Time (hours)
0
5
10
15
20
7 000
7 100
7 200
7 300
7 400
7 500
7 600
7 700
7 800
7 900
8 000
07-11-2005
08-11-2005
09-11-2005
10-11-2005
11-11-2005
dB (μV/m)
0
20
40
60
80
7 000 kHz - 7 100 kHz AMATEUR 5.140 5.141 5.141A
7 000 kHz - 7 100 kHz AMATEUR-SATELLITE 5.140 5.141 5.141A
7 100 kHz - 7 200 kHz AMATEUR 5.141A 5.141B 5.141C 5.142
7 100 kHz - 7 200 kHz BROADCASTING 5.141C
7 200 kHz - 7 300 kHz BROADCASTING
7 300 kHz - 7 400 kHz BROADCASTING 5.134 5.143 5.143B 5.143C 5.143D
7 400 kHz - 7 450 kHz BROADCASTING 5.143B 5.143C
7 450 kHz - 8 000 kHz FIXED 5.143E 5.144
7 450 kHz - 8 000 kHz MOBILE except aeronautical mobile (R) 5.143E 5.144
Rap 2080-17f

8-9 MHz range

It is noted that the utilization of the maritime spectrum is concentrated in the middle part of their exclusive allocation. Therefore, there is scope for a possible reorganization of their usage in this band, e.g. the bands 8 200-8 350 kHz and 8 700-8 815 kHz could be used for other maritime applications.

The aeronautical range 8 815-9 000 kHz looks to be very under-utilized.

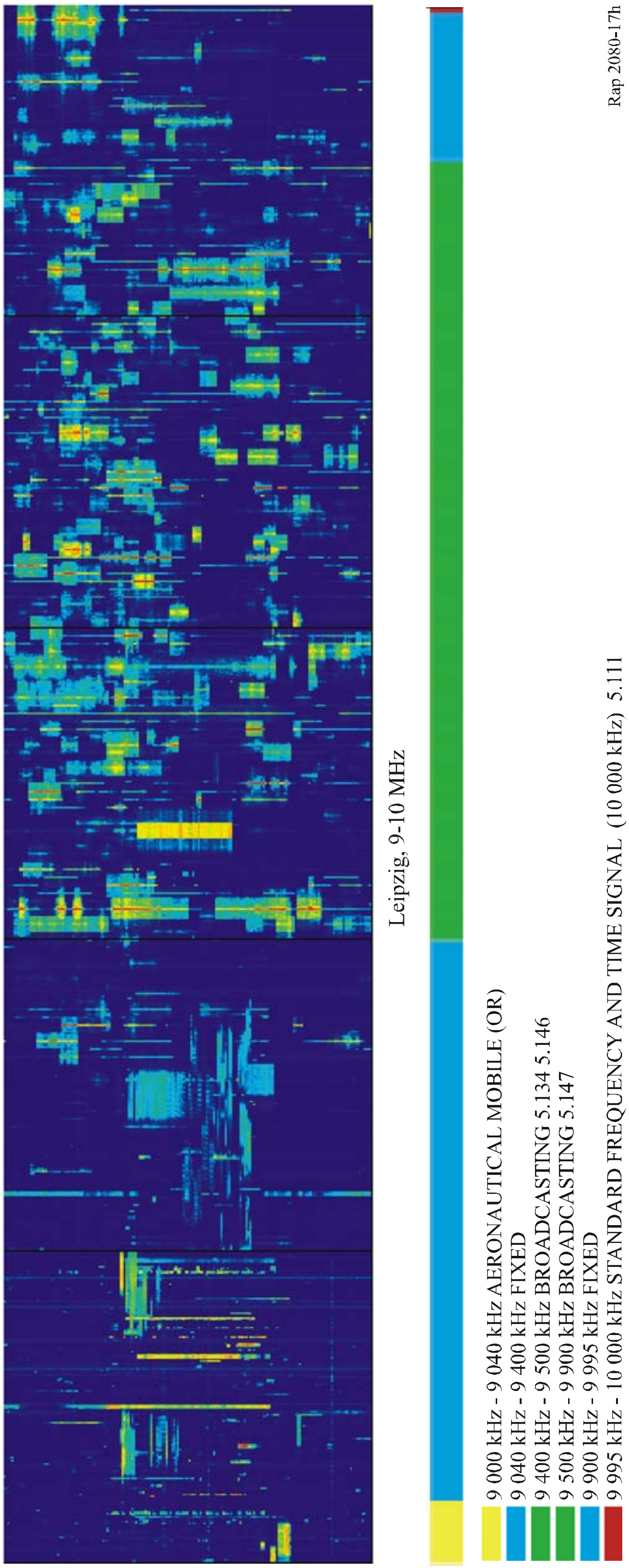
As the occupancy of this band appears to be mainly during daytime and overall occupancy is low, there may be scope for considering additional services perhaps on a time sharing basis.


Karlovice, 8 - 9 MHz
8 000 kHz - 8 100 kHz FIXED 5.143E 5.144
8 000 kHz - 8 100 kHz MOBILE except aeronautical mobile (R) 5.143E 5.144
8 100 kHz - 8 195 kHz FIXED
8 100 kHz - 8 195 kHz MARITIME MOBILE
8 195 kHz - 8 815 kHz MARITIME MOBILE 5.109 5.110 5.132 5.145 5.111
8 815 kHz - 8 965 kHz AERONAUTICAL MOBILE (R)
8 965 kHz - 9 000 kHz AERONAUTICAL MOBILE (OR)
Rap 2080-17g

9-10 MHz range

The bands allocated to the broadcasting service, 9 400-9 900 kHz overall, are heavily used throughout the day but are most intense at broadcast prime time in the evenings. Some broadcasting transmissions are also noted in the candidate band 9 900-9 940 kHz.

The candidate band 9 290-9 400 kHz identified in Resolution 544 (WRC-03) is partly occupied but it appears to be possible to move those applications to another part of the fixed spectrum. The broadband emission belongs to the radiolocation service which should be removed from that band.


Leipzig, 9-10 MHz
9 000 kHz - 9 040 kHz AERONAUTICAL MOBILE (OR)
9 040 kHz - 9 400 kHz FIXED
9 400 kHz - 9 500 kHz BROADCASTING 5.134 5.146
9 500 kHz - 9 900 kHz BROADCASTING 5.147
9 900 kHz - 9 995 kHz FIXED
9 995 kHz - 10 000 kHz STANDARD FREQUENCY AND TIME SIGNAL (10 000 kHz) 5.111
Rap 2080-17h

Measuring method

It was accepted that differing equipment and antennas would be used to gather the required data.

A discussion took place regarding the accuracy of the field strength readings and the need to use a calibrated antenna. It was decided that the main requirement of this request was to establish use of the frequency and not necessarily to perform precise field strength measurements as long as the results were of an acceptable accuracy to provide the information requested within a rather short period of time.

The settings should be as close as possible to a common standard as defined below:

Parameter	Ideal settings	Comments
Span	200 kHz	May be reduced to 100 kHz or lower if required
Number of steps	500 (or 1 000)	> 400 values
Step size or dot points	400 (or 200) Hz	200 kHz/500 steps
Filter bandwidth	500 (or 250) Hz	Just greater than step size
Sweep time	10 s	10 s minimum to limit the quantity of data collected
Antenna	Omnidirectional	
Attenuation	0 or 10 dB	Depending on local conditions
RF level	As required	Allow for strongest expected signal
Detector	Average	

Spectrum analysers or receivers could be used to perform the task and the settings will need to be adjusted accordingly.

Annex 3

Analysis of specific sharing conditions in the 4-10 MHz band

Background

There have been many documents addressing specific sharing conditions in the 4-10 MHz band. There have been many regulatory analyses that examine current sharing conditions in the radio regulations and attempt to apply them to additional sharing situations. There was also a discussion on general sharing techniques and protection criteria with an examination of service specific needs.

This analysis addresses specific technical situations based on the long term conflict between spectrum requirements of existing services in the 4-10 MHz band. It is intended to address expanding co-primary sharing between the fixed and mobile service along with sharing between existing allocations with maritime mobile and sharing between existing allocations with the broadcasting service. It will also examine sharing using near vertical incident skywave (NVIS) techniques for one service to enable sharing with another.

Frequency adaptive techniques were carefully examined in development of this analysis and the sharing cases presented in this document provide information on sharing conditions when user congestion limits the normal benefits of adaptive techniques or those cases were non-adaptive HF systems are utilized. Although adaptive HF techniques are heavily utilized throughout the developed administrations, there is still significant usage of non-adaptive systems in developed administrations as well as almost exclusive use in developing administrations.

User congestion occurs for the typical frequency adaptive network when the number of users within a net exceeds the capability of the net frequency pool to provide adequate spectrum resources that propagate at a given time of day. It also occurs when there are competing interests for frequencies between non-adaptive to adaptive users, between adaptive to adaptive networks where differing generations of equipment exist, and between adaptive to adaptive networks where differing system characteristics (as between different services) are employed. Of these four cases the first two (user net congestion and non-adaptive system to adaptive system) create the largest problem, however overall frequency congestion is exacerbated by the last two cases (differing generations of adaptive systems, and use of differing system characteristics (particularly bandwidth, large difference in required signal-to-noise ratio, and power level). The net effect of congestion is that it leads to co-frequency, co-footprint operations between user groups since individual frequencies are not available for exclusive use by a single service at any given time of day. The analysis in this document addresses these cases.

Introduction

Two types of efficiencies are gained from using adaptive HF systems:

The first is found when the ionosphere reflection path link between two stations is short to medium range (one hop) and is characterized by a similar propagation environment. In this situation adaptive HF systems provide the highest frequency under the maximum usable frequency (MUF) that is propagating (called the optimum frequency) and adapts the system to use the lowest possible power. This results in the most efficient transmission link possible and typically provides for very high quality reception.

The second efficiency is found when the ionosphere reflection path link between two stations is long to extremely long range (2 or 3 hops) and is characterized by a very dissimilar propagation environment based on the relative difference in time-of-day, atmospheric conditions, etc. In this situation Adaptive HF systems find the best overall frequency that will propagate and often results in a higher power link. Although less efficient by normal standards, it does provide the ability to establish an HF link in situations that would normally not be possible based on HF predictive models nor with any other single radio-frequency technology. It also allows for cross continent communications nets which are not feasible by other means.

It is very important to understand that sharing situations between services is determined by receiver location and very rarely by transmitter location. As long as the ground wave portion of a transmitter is not in the receiver location of another service (typically they are not), then sharing at the receiver location is the only consideration. Given the extremely large footprints of HF systems utilizing ionosphere reflection (it grows exponentially with each hop utilized) co-frequency sharing situations are common between mixed services as the coverage area of even good (directive) antennas measure in hundreds to thousands of kilometres in width (depending on the number of hops analysed). Even though, for example, the broadcasting service may only provide coverage to their customers over a single hop (for quality purposes), the signal continues to propagate over multiple hops at power levels that can cause significant interference to other services if they are operating co-frequency.

To better understand the efficiency curve for employing adaptive networks a look at a typical 2G ALE network can be used.

2G ALE network

This example provides the characteristics for a typical 2G ALE network (user group) and then examines the user occupancy to determine the maximum usable number of users before efficiency is lost.

Frequency pool

A pool of ten frequencies spread through the HF spectrum will be shared by varying numbers of 2G ALE stations. For simplicity, the ten frequencies chosen are in the aeronautical mobile bands, and represent a plausible set of frequencies for a mix of long and short paths during low sunspot activity: 3.1, 4.7, 5.7, 6.7, 7.3, 9.0, 11.2, 13.2, 15.0, and 18.0 MHz.

Transmissions

Traffic and ALE overhead transmission statistics are as follows:

1 Each ALE radio sounds for 10 s on each channel, once per hour.

2 On average each station places one call per hour:

a) Each ALE calling attempt lasts 10 s.

b) Channels are tried in order of measured link quality.

c) Calls are not placed on channels found to be busy; such channels are marked for retry later if the call is not completed on any other channel; if the channel is still busy when retried, the call fails.

d) Voice traffic lasts 73 s, on average, after linking (typical for voice traffic measured on a large ALE voice network).

Propagation analysis

Propagation on these paths was analysed using ICEPAC for the month of July with a smoothed sunspot number of 10. The analysis is restricted to the hours 2000 through 2200 UTC.

Frequencies were declared to be useful for voice traffic if the median signal-to-noise ratio (SNR) was at least 10 dB in 3 kHz. In Fig. 18, each example link is tagged with the frequencies usable on links of that length and orientation.

Channel occupancy analysis

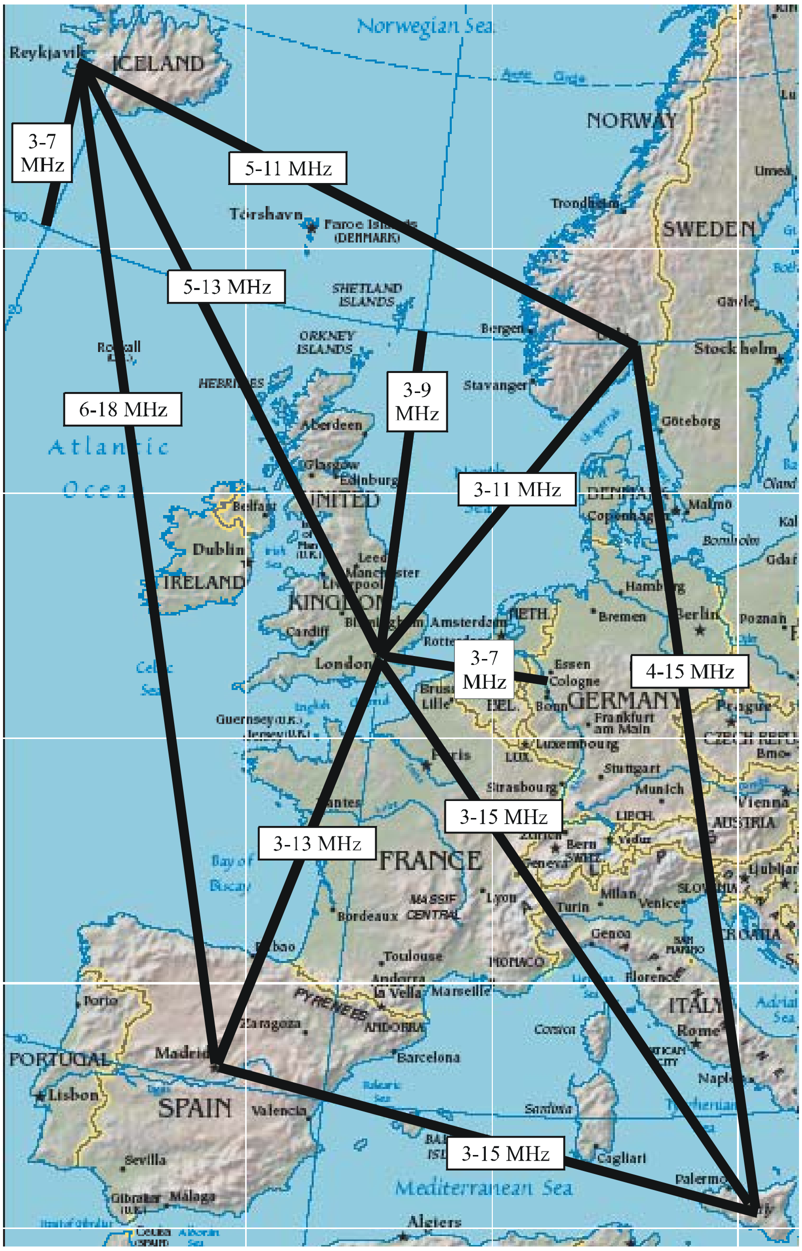
Each ALE station sounding will present a load of 10 s/h (0.28%) on each channel.

Traffic loading presented by each station comprises two components: link establishment and voice traffic. If listen-before-transmit is completely effective in preventing calls on busy channels (and ignoring the potential for hidden stations), then each voice call will result in a single, successful ALE call (possibly after several seconds of listening to busy channels), followed by voice conversation. This will present a traffic load of 83 channel-seconds per hour (2.31% of one channel) per active station.

With 11 possible path types (length and orientation) for each call, if each type is equally likely, the probability of each is 9.1%. Of these path types, the most constrained category is the shortest paths, for which only five of our frequencies are usable. Thus, the five lowest frequencies will become the most congested, and they will limit the useful size of the network.

FIGURE 18

Example links and usable frequencies
(July, SSN 10, 2000-2200 h)



Rap 2080-18

If we consider first only one station placing calls, the simplest model of channel occupancy assumes equal probability for each link type, and equal probability of choosing any one of the frequencies that works for that path. The resulting channel selection probabilities and total channel utilizations are as follows:

TABLE 1

Frequency selection probability and channel utilization

Frequency (MHz)	3.14	4.72	5.71	6.72	7.33	9.02	11.23	13.22	15.04	18.00
Selection prob.	9.6%	10.7%	15.2%	15.2%	15.2%	11.6%	10.1%	6.9%	4.3%	1.1%
Channel utilization	0.50%	0.53%	0.63%	0.63%	0.63%	0.54%	0.51%	0.44%	0.38%	0.30%

As the number of active stations is increased, the channel utilizations will increase linearly at first, until calling stations begin to encounter busy channels a noticeable fraction of the time. As this occurs, stations that initially chose a popular frequency for their first calling attempt will select a less popular frequency to place the call, resulting in traffic diffusion over all working frequencies. An upper bound on channel utilization would be found by assuming that such traffic diffusion did not occur. Under this conservative assumption, in a single network of users, we find that congestion in the 5 through 7 MHz frequencies is:

– negligible for 10 stations (channel utilization is 6%);
– noticeable for 20 stations (channel utilization reaches 13%);
– significant for 50 stations (channel utilization reaches 31%).

As can be seen by this analysis a user group of 50 stations or larger creates significant congestion. A typical user group therefore needs to be limited to 20 stations or less. However this can lead to overall congestion as more user groups are created and competing for the same spectrum resources whenever additional services are considered for sharing in specific portions of the spectrum. If the new services (as in the case of broadcasting) do not employ the same generation of adaptive techniques it usually creates false congestion for the more advanced systems since they utilize predictive modeling instead of active sounding based on traffic. This means that more advanced systems do not compete for channels tagged as active (channel utilization over 20%). Increasing the number of frequencies in the user group pool allows for an increase in the user group size but leaves less spectrum that is not in contention between multiple user groups also increasing congestion.

Proposed sharing conditions

It has been proposed that increased fixed/mobile services sharing is feasible, as well as introduction of sharing with broadcasting service to the fixed service and/or mobile service. Currently there are sharing situations that exist between services but the actual usage in these frequency bands must be taken into account:

Sharing with broadcasting

The fixed service and mobile service in various places in the RR share spectrum with the broadcasting service. In fact, the footnotes applied to this service sharing places the fixed and/or mobile services secondary to the broadcasting service in the 4-10 MHz band. The majority of sharing allowed in the RR with the broadcasting service is in the equatorial bands with severe limits on the operation of the fixed and/or mobile services. Outside of the equatorial bands there are some limited sharing situations but almost all of these involve severe limits on the fixed/mobile services. There are a few regional situations where the broadcasting service and the fixed/mobile services share on a co-primary basis but these are clearly an exception to the rules applied in the RR. In Region 2 there is no co-primary sharing between the broadcasting service and fixed/mobile services.

Sharing between the fixed and mobile services

There are many cases where the fixed and mobile service is allocated co-primary status in the RR. In practice however, unless the systems are designed to support each other (very rare situation), administrations must take steps to ensure that co-frequency sharing does not occur. This results in a splitting of the spectrum between the services to individual portions occupied by fixed service stations or mobile service stations exclusively. If adaptive techniques are used this is still the case since the difference in relative power makes it near impossible for a mobile service station to share with a fixed service station to the same receiver location.

Analysis

The analysis of the various sharing situations was performed using VOACAP. This program was developed using monitoring data to develop an update to ICECAP which is the basis for the existing propagation model in Radiocommunication Study Group 3. VOACAP is the basis for the liaison work between WP 9C and WP 3L to develop a more advanced propagation model recommendation.

VOACAP signal to interference analysis performed below takes into account a smooth sunspot number (10) and provides figures for the average propagation probabilities based on all times of day for all months (365 days, all hours of each day). This ensures that a worst case scenario is not used and can under-report the possible interference situation depending on a specific month, time of day, or sunspot anomaly but this method represents a realistic look at the potential interference between services where there is co-frequency, overlapping coverage to the receive locations.

The minimum required SNR was utilized for the various analysis cases. Particularly with the fixed service there are significantly higher required SNR links that are scheduled to occur when specific atmospheric conditions allow a probability of link establishment to achieve 80% or 90% at a reliability factor of 50% or greater. In these cases the interfering signals from another service would be particularly egregious since these conditions usually can be found only once a month and are may not be available every month.

1 Fixed interference into maritime mobile at 4.3 MHz

Potential interference from a fixed link between Norfolk, VA to San Diego, CA

Wanted link from Honolulu, HI to a maritime platform 20 km off San Diego, CA

Desired transmitter:

10 kW into quarter-wave monopole over poor ground (antenna type SAMPLE.32 with dielectric constant = 4 and conductivity = 1 mS)

Interfering transmitter:

5 kW into horizontal Log-periodic antenna over good ground (antenna type SAMPLE.05 with dielectric constant = 13 and conductivity = 5 mS)

Receiver:

Quarter-wave monopole over salt water (antenna type SAMPLE.32 with dielectric constant = 80 and conductivity = 5 000 mS)

Environment:

7.5 MHz, man-made noise specified as −164 dB(W/Hz) at 3 MHz (rural quite noise level) at the receive site

Maritime mobile link

Data availability – 18 dB SNR required

Analogue availability – 15 dB SNR required

Digital availability – 9 dB SNR required

Table 2 provides the percentage chance that the wanted link at a specific required SNR can be established at a specific reliability in a given month. It is assumed that the lowest reliability in a given month is 50%, otherwise there is not sufficient connectivity guaranteed to provide a reliable link between stations. As can be seen in Table 1 when all months and all times of day are taken into account there is not a high probability of establishing a link. However at particular times of day or months the reliability is higher, there is also a corresponding increase in link availability reduction so the data presented in Table 2 gives a good indication of the possibility of maintaining a link at a given required SNR. Of course, frequency selection also plays an important part and the results in Table 2 and Table 3 are the mean probabilities associated with the given frequency band. At specific times of day the probabilities can change significantly but there is a correlated change between the wanted signal and the interfering signal.

TABLE 2

Reliability in a given month

Link reliability in a given month									
Required SNR	**90%**	**80%**	**70%**	**60%**	**50%**	**40%**	**30%**	**20%**	**10%**
18 dB	0.00%	0.00%	0.58%	6.48%	18.17%	28.82%	42.48%	47.80%	50.46%
15 dB	0.00%	0.35%	7.18%	21.30%	38.19%	46.18%	48.61%	50.46%	51.62%
9 dB	1.27%	24.19%	45.02%	48.38%	49.88%	51.04%	51.62%	52.78%	54.40%

TABLE 3

Mean link availability reduction

	Required SNR	**Reduction (%)**
Mean data link availability reduction	18 dB (*C*/*I*+*N*)	28.41
Mean analogue link availability reduction	15 dB (*C*/*I*+*N*)	36.37
Mean digital link availability reduction	9 dB (*C*/*I*+*N*)	44.08

2 Maritime mobile interference into fixed at 5.8 MHz

Potential interference from a maritime station in Honolulu, HI to a maritime platform 20 km off San Diego, CA

Wanted fixed link from Norfolk, VA to San Diego, CA

Desired transmitter:

5 kW into horizontal Log-periodic antenna over good ground (antenna type SAMPLE.05 with dielectric constant = 13 and conductivity = 5 mS)

Interfering transmitter:

10 kW into quarter-wave monopole over poor ground (antenna type SAMPLE.32 with dielectric constant = 4 and conductivity = 1 mS)

Receiver:

Horizontal log-periodic antenna over good ground (antenna type SAMPLE.05 with dielectric constant = 13 and conductivity = 8 mS)

Environment:

5.8 MHz, man-made noise specified as −144 dB(W/Hz) at 3 MHz (residential noise level) at the receive site

Fixed link

Data availability – 18 dB SNR required

Analogue availability – 15 dB SNR required

Digital availability – 9 dB SNR required

Table 4 provides the percentage chance that the wanted link at a specific required SNR can be established at a specific reliability in a given month. It is assumed that the lowest reliability in a given month is 50%, otherwise there is not sufficient connectivity guaranteed to provide a reliable link between stations. As can be seen in Table 4 when all months and all times of day are taken into account there is medium probability of establishing a link. However at particular times of day or months the reliability is higher, there is also a corresponding increase in link availability reduction so the data presented in Table 4 gives a good indication of the possibility of maintaining a link at a given required SNR. Of course, frequency selection also plays an important part and the results in Table 4 and Table 5 are the mean probabilities associated with the given frequency band. At specific times of day the probabilities can change significantly but there is a correlated change between the wanted signal and the interfering signal.

TABLE 4

Reliability in a given month

Link reliability in a given month									
Required SNR	**90%**	**80%**	**70%**	**60%**	**50%**	**40%**	**30%**	**20%**	**10%**
18 dB	0.00%	0.00%	2.20%	28.82%	45.60%	49.42%	51.50%	53.59%	56.13%
15 dB	0.00%	1.04%	25.46%	45.95%	50.93%	52.55%	54.28%	56.25%	58.45%
9 dB	2.78%	41.32%	50.58%	54.05%	56.48%	58.33%	59.26%	59.95%	60.53%

TABLE 5

Mean link availability reduction

	Required SNR	**Reduction (%)**
Mean data link availability reduction	18 dB (*C*/*I*+*N*)	1.43
Mean analogue link availability reduction	15 dB (*C*/*I*+*N*)	1.19
Mean digital link availability reduction	9 dB (*C*/*I*+*N*)	0.73

3 Land mobile interference into maritime mobile at 6.4 MHz

Potential interference from a land mobile link between Norfolk, VA to San Diego, CA

Wanted link from Honolulu, HI to a maritime platform 20 km off San Diego, CA

Desired transmitter:

10 kW into quarter-wave monopole over poor ground (antenna type SAMPLE.32 with dielectric constant = 4 and conductivity = 1 mS)

Interfering transmitter:

500 W into 3.5-m monopole (antenna type SAMPLE.32 with dielectric constant = 13 and conductivity = 5 mS)

Receiver:

Quarter-wave monopole over salt water (antenna type SAMPLE.32 with dielectric constant = 80 and conductivity = 5 000 mS)

Environment:

6.4 MHz, man-made noise specified as −164 dB(W/Hz) at 3 MHz (rural quite noise level) at the receive site

Maritime mobile link

Data availability – 18 dB SNR required

Analogue availability – 15 dB SNR required

Digital availability – 9 dB SNR required

Table 6 provides the percentage chance that the wanted link at a specific required SNR can be established at a specific reliability in a given month. It is assumed that the lowest reliability in a given month is 50%, otherwise there is not sufficient connectivity guaranteed to provide a reliable link between stations. As can be seen in Table 6 when all months and all times of day are taken into account there is a fairly high probability of establishing a link. However at particular times of day or months the reliability is higher, there is also a corresponding increase in link availability reduction so the data presented in Table 6 gives a good indication of the possibility of maintaining a link at a given required SNR. Of course, frequency selection also plays an important part and the results in Table 6 and Table 7 are the mean probabilities associated with the given frequency band. At specific times of day the probabilities can change significantly but there is a correlated change between the wanted signal and the interfering signal.

TABLE 6

Reliability in a given month

Link reliability in a given month									
Required SNR	**90%**	**80%**	**70%**	**60%**	**50%**	**40%**	**30%**	**20%**	**10%**
18 dB	0.00%	6.37%	28.24%	46.99%	52.78%	54.40%	56.60%	57.87%	59.49%
15 dB	1.16%	27.08%	46.76%	53.36%	56.02%	57.06%	58.45%	59.49%	61.57%
9 dB	34.49%	51.62%	56.48%	58.45%	59.49%	61.00%	61.92%	62.73%	64.58%

TABLE 7

Mean link availability reduction

	Required SNR	Reduction (%)
Mean data link availability reduction	18 dB (*C*/*I*+*N*)	61.02
Mean analogue link availability reduction	15 dB (*C*/*I*+*N*)	67.31
Mean digital link availability reduction	9 dB (*C*/*I*+*N*)	71.95

4 Maritime mobile interference into land mobile at 8.6 MHz

Potential interference from a maritime station in Honolulu, HI to a maritime platform 20 km off San Diego, CA

Wanted land mobile link from Norfolk, VA to San Diego, CA

Desired transmitter:

500 W into 3.5-m monopole (Antenna type SAMPLE.32 with dielectric constant = 13 and conductivity = 5 mS)

Interfering transmitter:

10 kW into quarter-wave monopole over poor ground (antenna type SAMPLE.32 with dielectric constant = 4 and conductivity = 1 mS)

Receiver:

Horizontal log-periodic antenna over good ground (antenna type SAMPLE.05 with dielectric constant = 13 and conductivity = 8 mS)

Environment:

8.6 MHz, man-made noise specified as −144 dB(W/Hz) at 3 MHz (residential noise level) at the receive site

Land mobile link

Data availability – 18 dB SNR required

Analogue availability – 15 dB SNR required

Digital availability – 9 dB SNR required

Table 8 provides the percentage chance that the wanted link at a specific required SNR can be established at a specific reliability in a given month. It is assumed that the lowest reliability in a given month is 50%, otherwise there is not sufficient connectivity guaranteed to provide a reliable link between stations. As can be seen in Table 8 when all months and all times of day are taken into account there is high probability of establishing a link. Table 7 gives a good indication of the possibility of maintaining a link at a given required SNR. Of course, frequency selection also plays an important part and the results in Table 8 and Table 9 are the mean probabilities associated with the given frequency band. At specific times of day the probabilities can change significantly but there is a correlated change between the wanted signal and the interfering signal.

TABLE 8

Reliability in a given month

Link reliability in a given month									
Required SNR	**90%**	**80%**	**70%**	**60%**	**50%**	**40%**	**30%**	**20%**	**10%**
18 dB	32.18%	45.95%	61.23%	75.35%	82.75%	86.00%	89.12%	93.06%	96.99%
15 dB	40.51%	55.56%	71.18%	80.09%	85.42%	88.31%	91.32%	95.14%	97.22%
9 dB	55.56%	72.92%	81.25%	85.76%	89.12%	91.55%	95.02%	96.99%	97.69%

TABLE 9

Mean link availability reduction

	Required SNR	**Reduction (%)**
Mean data link availability reduction	18 dB ($C/I+N$)	2.62
Mean analogue link availability reduction	15 dB ($C/I+N$)	2.25
Mean digital link availability reduction	9 dB ($C/I+N$)	1.69

5 Fixed interference into broadcasting at 4.6 MHz

Potential interference from a fixed station link interference between Kabul, Afghanistan to Cairo, Egypt

Wanted broadcasting link between Florence, Italy to Cairo, Egypt

Desired transmitter:

250 kW into 4x4 curtain array over average ground (antenna type SAMPLE.12 with dielectric constant = 15 and conductivity = 50 mS)

Interfering transmitter:

5 kW into horizontal log-periodic antenna over poor, sandy ground (antenna type SAMPLE.05 with dielectric constant = 3 and conductivity = 1 mS)

Receiver:

Short vertical shortwave receiving whip (antenna type SWWHip.VOA)

Environment:

4.6 MHz, man-made noise specified as −150 dB(W/Hz) at 3 MHz (rural noise level) at the receive site

Broadcasting link

Required availability – 17 dB SNR required

Table 10 provides the percentage chance that the wanted link at a specific required SNR can be established at a specific reliability in a given month. It is assumed that the lowest reliability in a given month is 80%, otherwise there is not sufficient connectivity guaranteed to provide a reliable link for the broadcasting service. As can be seen in Table 10 when all months and all times of day are taken into account there is high probability of establishing a link. Table 10 gives a good indication of the possibility of maintaining a link at a given required SNR. Of course, frequency selection also plays an important part and the results in Table 10 and Table 11 are the mean probabilities associated with the given frequency band. At specific times of day the probabilities can change significantly but there is a correlated change between the wanted signal and the interfering signal.

TABLE 10

Reliability in a given month

Link reliability in a given month									
Required SNR	**90%**	**80%**	**70%**	**60%**	**50%**	**40%**	**30%**	**20%**	**10%**
17 dB	63.08%	64.00%	65.34%	66.20%	66.90%	67.30%	67.59%	68.29%	68.92%

TABLE 11

Mean link availability reduction

	Required SNR	**Reduction (%)**
Mean data link availability reduction	17 dB (*C*/*I*+*N*)	67.06

6 Broadcasting interference into fixed at 5.1 MHz

Potential interference from a broadcasting station link between Florence, Italy to Cairo, Egypt

Wanted fixed link between Kabul, Afghanistan to Cairo, Egypt

Desired transmitter:

5 kW into horizontal log-periodic antenna over poor, sandy ground (antenna type SAMPLE.05 with dielectric constant = 3 and conductivity = 1 mS)

Interfering transmitter:

250 kW into 4x4 curtain array over average ground (antenna type SAMPLE.12 with dielectric constant = 15 and conductivity = 50 mS)

Receiver:

Horizontal log-periodic antenna over poor, sandy ground (antenna type SAMPLE.05 with dielectric constant = 3 and conductivity = 1 mS)

Environment:

5.1 MHz, man-made noise specified as −150 dB(W/Hz) at 3 MHz (rural noise level) at the receive site

Fixed link

Data availability – 18 dB SNR required

Analogue availability – 15 dB SNR required

Digital availability – 9 dB SNR required

Table 12 provides the percentage chance that the wanted link at a specific required SNR can be established at a specific reliability in a given month. It is assumed that the lowest reliability in a given month is 50%, otherwise there is not sufficient connectivity guaranteed to provide a reliable link between stations. As can be seen in Table 12 when all months and all times of day are taken into account there is not a high probability of establishing a link. However at particular times of day or months the reliability is higher, there is also a corresponding increase in link availability reduction so the data presented in Table 12 gives a good indication of the possibility of maintaining a link at a given required SNR. Of course, frequency selection also plays an important part and the results in Table 12 and Table 13 are the mean probabilities associated with the given frequency band. At specific times of day the probabilities can change significantly but there is a correlated change between the wanted signal and the interfering signal.

TABLE 12

Reliability in a given month

Link reliability in a given month									
Required SNR	**90%**	**80%**	**70%**	**60%**	**50%**	**40%**	**30%**	**20%**	**10%**
18 dB	0.00%	0.00%	0.69%	15.28%	25.35%	34.95%	44.91%	49.42%	51.85%
15 dB	0.00%	0.46%	17.71%	28.24%	41.90%	48.03%	49.77%	51.16%	53.13%
9 dB	8.22%	30.44%	46.64%	49.77%	50.93%	51.50%	52.55%	53.01%	55.67%

TABLE 13

Mean link availability reduction

	Required SNR	**Reduction (%)**
Mean data link availability reduction	18 dB (*C*/*I*+*N*)	47.88
Mean analogue link availability reduction	15 dB (*C*/*I*+*N*)	58.84
Mean digital link availability reduction	9 dB (*C*/*I*+*N*)	73.03

7 Land mobile interference into broadcasting at 4.6 MHz

Potential interference from a land mobile station link interference between Al Najaf, Iraq to Cairo, Egypt

Wanted broadcasting link between Florence, Italy to Cairo, Egypt

Desired transmitter:

250 kW into 4x4 curtain array over average ground (antenna type SAMPLE.12 with dielectric constant = 15 and conductivity = 50 mS)

Interfering transmitter:

500 W into 3.5-m monopole over poor, sandy ground (antenna type SAMPLE.32 with dielectric constant = 3 and conductivity = 50 mS)

Receiver:

Short vertical shortwave receiving whip (antenna type SWWHip.VOA)

Environment:

4.6 MHz, man-made noise specified as -150 dBW/Hz at 3 MHz (Rural noise level) at the receive site

Broadcasting link

Required availability – 17 dB SNR required

Table 14 provides the percentage chance that the wanted link at a specific required SNR can be established at a specific reliability in a given month. It is assumed that the lowest reliability in a given month is 80%, otherwise there is not sufficient connectivity guaranteed to provide a reliable link for the broadcasting service. As can be seen in Table 14 when all months and all times of day are taken into account there is high probability of establishing a link. Table 14 gives a good indication of the possibility of maintaining a link at a given required SNR. Of course, frequency selection also plays an important part and the results in Table 14 and Table 15 are the mean probabilities associated with the given frequency band. At specific times of day the probabilities can change significantly but there is a correlated change between the wanted signal and the interfering signal.

TABLE 14

Reliability in a given month

Link reliability in a given month									
Required SNR	**90%**	**80%**	**70%**	**60%**	**50%**	**40%**	**30%**	**20%**	**10%**
17 dB	63.08%	64.00%	65.34%	66.20%	66.90%	67.30%	67.59%	68.29%	68.92%

TABLE 15

Mean link availability reduction

	Required SNR	**Reduction (%)**
Mean data link availability reduction	17 dB ($C/I+N$)	21.86

8 Broadcasting interference into land mobile at 5.1 MHz

Potential interference from a broadcasting station link between Florence, Italy to Cairo, Egypt

Wanted land mobile link between Al Najaf, Iraq to Cairo, Egypt

Desired transmitter:

500 W into 3.5-m monopole over poor, sandy ground (antenna type SAMPLE.32 with dielectric constant = 3 and conductivity = 50 mS)

Interfering transmitter:

250 kW into 4x4 curtain array over average ground (antenna type SAMPLE.12 with dielectric constant = 15 and conductivity = 50 mS)

Receiver:

Horizontal log-periodic antenna over poor, sandy ground (antenna type SAMPLE.05 with dielectric constant = 3 and conductivity = 1 mS)

Environment:

5.1 MHz, man-made noise specified as −150 dB(W/Hz) at 3 MHz (rural noise level) at the receive site

Land mobile link

Data availability – 18 dB SNR required

Analogue availability – 15 dB SNR required

Digital availability – 9 dB SNR required

Table 16 provides the percentage chance that the wanted link at a specific required SNR can be established at a specific reliability in a given month. It is assumed that the lowest reliability in a given month is 50%, otherwise there is not sufficient connectivity guaranteed to provide a reliable link between stations. As can be seen in Table 16 when all months and all times of day are taken into account there is not a high probability of establishing a link. However at particular times of day or months the reliability is higher, there is also a corresponding increase in link availability reduction so the data presented in Table 16 gives a good indication of the possibility of maintaining a link at a given required SNR. Of course, frequency selection also plays an important part and the results in Table 16 and Table 17 are the mean probabilities associated with the given frequency band. At specific times of day the probabilities can change significantly but there is a correlated change between the wanted signal and the interfering signal.

TABLE 16

Reliability in a given month

Link reliability in a given month									
Required SNR	**90%**	**80%**	**70%**	**60%**	**50%**	**40%**	**30%**	**20%**	**10%**
18 dB	0.00%	0.00%	6.71%	18.06%	36.86%	45.95%	53.13%	57.23%	60.19%
15 dB	0.00%	6.31%	20.60%	38.95%	50.46%	55.09%	58.16%	58.91%	62.73%
9 dB	12.79%	40.45%	53.53%	58.10%	59.14%	60.42%	61.69%	63.48%	67.59%

TABLE 17

Mean link availability reduction

	Required SNR	**Reduction (%)**
Mean data link availability reduction	18 dB ($C/I+N$)	49.67
Mean analogue link availability reduction	15 dB ($C/I+N$)	59.01
Mean digital link availability reduction	9 dB ($C/I+N$)	70.71

9 Maritime mobile interference into broadcasting at 4.6 MHz

Potential interference from a maritime mobile station link between Persian Gulf to Cairo, Egypt

Wanted broadcasting link between Florence, Italy to Cairo, Egypt

Desired transmitter:

250 kW into 4x4 curtain array over average ground (antenna type SAMPLE.12 with dielectric constant = 15 and conductivity = 50 mS)

Interfering transmitter:

1 kW into quarter-wave monopole over salt water (antenna type SAMPLE.32 with dielectric constant = 80 and conductivity = 50 mS)

Receiver:

Short vertical shortwave receiving whip (antenna type SWWHip.VOA)

Environment:

4.6 MHz, man-made noise specified as −150 dB(W/Hz) at 3 MHz (rural noise level) at the receive site

Land mobile link

Required availability – 17 dB SNR required

Table 18 provides the percentage chance that the wanted link at a specific required SNR can be established at a specific reliability in a given month. It is assumed that the lowest reliability in a given month is 80%, otherwise there is not sufficient connectivity guaranteed to provide a reliable link for the broadcasting service. As can be seen in Table 18 when all months and all times of day are taken into account there is high probability of establishing a link. Table 18 gives a good indication of the possibility of maintaining a link at a given required SNR. Of course, frequency selection also plays an important part and the results in Table 18 and Table 19 are the mean probabilities associated with the given frequency band. At specific times of day the probabilities can change significantly but there is a correlated change between the wanted signal and the interfering signal.

TABLE 18

Reliability in a given month

Link reliability in a given month									
Required SNR	**90%**	**80%**	**70%**	**60%**	**50%**	**40%**	**30%**	**20%**	**10%**
17 dB	63.08%	64.00%	65.34%	66.20%	66.90%	67.30%	67.59%	68.29%	68.92%

TABLE 19

Mean link availability reduction

	Required SNR	**Reduction (%)**
Mean data link availability reduction	17 dB ($C/I+N$)	23.28

10 Broadcasting interference into maritime mobile at 5.1 MHz

Potential interference from a broadcasting station link between Florence, Italy to Cairo, Egypt

Wanted maritime mobile link between Persian Gulf to Cairo, Egypt.

Desired transmitter:

1 kW into quarter-wave monopole over salt water (antenna type SAMPLE.32 with dielectric constant = 80 and conductivity = 50 mS)

Interfering transmitter:

250 kW into 4x4 curtain array over average ground (antenna type SAMPLE.12 with dielectric constant = 15 and conductivity = 50 mS)

Receiver:

Horizontal log-periodic antenna over poor, sandy ground (antenna type SAMPLE.05 with dielectric constant = 3 and conductivity = 1 mS)

Environment:

5.1 MHz, man-made noise specified as −150 dB(W/Hz) at 3 MHz (rural noise level) at the receive site

Land mobile link

Data availability – 18 dB SNR required

Analogue availability – 15 dB SNR required

Digital availability – 9 dB SNR required

Table 20 provides the percentage chance that the wanted link at a specific required SNR can be established at a specific reliability in a given month. It is assumed that the lowest reliability in a given month is 50%, otherwise there is not sufficient connectivity guaranteed to provide a reliable link between stations. As can be seen in Table 20 when all months and all times of day are taken into account there is a high probability of establishing a link. Table 20 gives a good indication of the possibility of maintaining a link at a given required SNR. Of course, frequency selection also plays an important part and the results in Table 20 and Table 21 are the mean probabilities associated with the given frequency band. At specific times of day the probabilities can change significantly but there is a correlated change between the wanted signal and the interfering signal.

TABLE 20

Reliability in a given month

Link reliability in a given month									
Required SNR	**90%**	**80%**	**70%**	**60%**	**50%**	**40%**	**30%**	**20%**	**10%**
18 dB	49.88%	58.16%	59.49%	61.46%	63.08%	64.41%	65.45%	66.78%	68.75%
15 dB	57.52%	59.38%	61.69%	63.72%	64.99%	66.44%	67.36%	68.92%	70.54%
9 dB	60.65%	63.77%	65.74%	67.77%	69.21%	70.20%	71.41%	72.51%	73.96%

TABLE 21

Mean link availability reduction

	Required SNR	Reduction
Mean data link availability reduction	18 dB ($C/I+N$)	76.67%
Mean analogue link availability reduction	15 dB ($C/I+N$)	76.26%
Mean digital link availability reduction	9 dB ($C/I+N$)	73.77%

Conclusions

There are several important results presented in this annex. Although we allocate spectrum based on bands instead of individual frequencies in the ITU, the utilization of individual frequencies must be taken into account when assigning these bands and the impact to all affected services. Given the size of HF transmission footprints (several hundreds to several thousands of kilometres in width and length) even with highly directive antennas over successive "hops" of ionosphere reflection, it is likely that there will be co-coverage, co-frequency sharing situations when frequency bands are allocated to different services. Additional sharing would therefore be detrimental to existing services given the current requirements of the fixed and mobile services. Results of the analyses contained in this Annex have been grouped below to show the impact to additional allocation to the broadcasting service in frequency bands currently allocated to the fixed and mobile services. These results are also valid when considering increased general allocations to the fixed and mobile services.

Congestion

There are severe implications to congestion and frequency usability by reducing the amount of spectrum currently available to the fixed and mobile services. There is a significant chance of improving congestion when the number of users within a single user net exceeds the capability of the net frequency pool to provide adequate spectrum resources. Increasing the frequency pool size does not necessarily reduce the congestion because you end up with overlapping resources between user groups, also increasing congestion. There are also issues of congestion when non-adaptive and adaptive systems utilize the same frequency resources. Utilizing frequency adaptive techniques improves the sharing situation and can reduce congestion under normal conditions but can exacerbate the problem when frequency resources become too limited, when different generations of frequency adaptive systems operate on the same frequency resources, or when different services attempt to utilize the same frequency resources.

Sharing between fixed and maritime mobile services

As the analyses in this text show, it is not feasible for increased sharing between fixed and maritime mobile services. Given the nature of the noise environment for the maritime mobile service there is significant impact from overlapping footprints when the fixed service utilizes the same frequency resources. The reverse case is not as problematic with only a slight decrease in link availability of the fixed service from a single maritime mobile transmission. However, given the volume of maritime mobile traffic it is likely that the aggregate interference will cause significant harm to the fixed service.

Sharing between land mobile and maritime mobile services

As the analyses in this annex shows, it is not feasible for increased sharing between land mobile and maritime mobile services. Given the nature of the noise environment for the maritime mobile service there is significant impact from overlapping footprints when the land mobile service utilizes the same frequency resources. The reverse case is not as problematic with only a slight decrease in link availability of the land mobile service from a single maritime mobile transmission. However, given the volume of maritime mobile traffic it is likely that the aggregate interference will cause significant harm to the land mobile service.

Sharing between fixed and broadcasting services

Given the nature of fixed and broadcasting services transmissions (high power), the analysis in this annex shows, it is not feasible for increased sharing between the fixed and broadcasting services on a co-equal basis. There is significant impact to both services whenever there would be overlapping footprints between the fixed and broadcasting services receivers.

Sharing between land mobile and broadcasting services

Given the high power nature of broadcasting services versus the much lower power transmissions of the land mobile service, the analyses in this annex shows, it is not feasible for increased sharing between the land mobile and broadcasting services on a co-equal basis. There is impact to the broadcasting service whenever there would be overlapping footprints from the land mobile service to the broadcasting service. There is severe impact to the land mobile service whenever there would be overlapping footprints from the broadcasting service to the land mobile service.

Sharing between maritime mobile and broadcasting services

Given the high power nature of broadcasting services versus the much lower power transmissions of the maritime mobile service, the analyses in this annex shows, it is not feasible for increased sharing between the maritime mobile and broadcasting services on a co-equal basis. There is impact to the broadcasting service whenever there would be overlapping footprints from the maritime mobile service to the broadcasting service. There is severe impact to the maritime mobile service whenever there would be overlapping footprints from the broadcasting service to the land mobile service.

Annex 4

HF compatibility considerations

Introduction

The HF spectrum is used by a number of radio services. The studies so far on Agenda item 1.13 have confirmed the conclusion of previous studies and conferences that most of these services have been unable to satisfy all their requirements and have experienced operational difficulties due to congestion in the HF bands. Because the amount of available HF spectrum is limited, diligent consideration must be given to using it in the most efficient manner.

WRC-07 Agenda item 1.13 aims to optimize service allocations in the HF bands between 4 to 10 MHz in order to meet changing demands and patterns of use. In many respects, this can be seen as a continuation of work started at WARC-92 under its Agenda item 2.2.2. In addition, WRC-03 continued certain aspects of those studies in relation to realignment of bands round 7 MHz and broadcasting spectrum needs between 4 and 10 MHz under its Agenda items 1.23 and 1.36, which led to the development of Resolution 544 (WRC-03) and the adoption of the present Agenda item.

Although the WARC-92 work could be seen as having a greater focus on the possible extension of the HF broadcasting bands than does that for WRC-07, where the issue of additional allocations for the broadcasting service under Resolution 544 (WRC-03) is only one aspect of Agenda item 1.13, the similarities do indeed go much wider and deeper.

In addition to the need for action in respect of the shortfall in broadcasting spectrum, identified by Recommendation 511 (HFBC-87), it was recognized that WARC-92 would have to consider the long term requirements of the existing HF services as an essential part of its work. In consequence, comprehensive sharing studies were undertaken in respect of the HF services to support the WARC-92 preparations. In particular, the CCIR JIWP 10-3-6-8/1 was established with instructions to:

1) develop more accurate sharing criteria between broadcasting, fixed, mobile and amateur services in the band 2-30 MHz, and

2) Report to JIWP WARC-92.

The similarities continue with the example method for issue, which recalls many features of the European Common Proposals to WARC-92 (Doc. CAMR-92/20) on possible ways to reallocate spectrum.

This analysis addresses several potential approaches for making more efficient use of the HF spectrum by extending multiple service access and is intended to inform the development of the CPM text on Agenda item 1.13. It takes account of the compatibility considerations likely to result from making additional spectrum resources available for fixed, mobile and broadcasting use, which is expected to occur at WRC-07.

Information on sharing between services in the HF bands

A developing theme during the preparatory studies on HF issues at WARC-92, WRC-95, WRC-97, WRC-03 and again at WRC-07 for Agenda item 1.13 is the extent to which HF spectrum can be reused both within a service and between services in shared bands, especially as regards the extent to which dynamic frequency management can facilitate sharing. As with previous conferences therefore, information on sharing and on the methods used to achieve inter- and intra-service sharing in the HF bands is essential for guiding the discussions at WRC-07.

Multi-service operation in shared HF bands should often be more properly described as coexistence where no formal coordination procedures are applied. In fact, WRC-95 decided, through Resolution 23 (WRC-95), that the examination of frequency assignments in the bands below 28 MHz was no longer necessary. The Bureau therefore does not make any examination related to the probability of harmful interference and neither does it provide any guidance as to whether a new frequency assignment should be able to operate without causing interference.

At first sight, service sharing or coexistence at HF appears difficult, as signals are intended to be transmitted over long distances by reflections from the ionosphere. A one-hop path, using a single reflection from the ionosphere, can easily provide communications over distances of a few thousand km. Longer ranges can be achieved with multiple hops when propagation conditions support several subsequent reflections between the ground and the ionosphere. However, any consideration of HF compatibility must take account of the additional dimensions of geographical and time sharing offered by the same properties of the ionosphere that makes long distance HF radiocommunications possible in the first place.

The information to be found in the Report of JIWP 10-6-8-9/1 (25 October 1990) concerning "Compatibility considerations arising from the allocation of spectrum to HF broadcasting" remains the main reference source in ITU-R. This study, which formed Section 5 of the CCIR Report to WARC-92, was also reproduced in the Report of the Director to WRC-2000 in response to Resolution 29 (WRC-97) (see Attachment 1 to Doc. CMR-2000/5) and was referenced as the main study source in § 5.6.1 of the CPM Report to WRC-03 (see Chapter 5 of Doc. CMR03/3) on the "Summary of technical and operational studies" for WRC-03 Agenda item 1.23.

With such strong parallels between the problems and potential solutions identified during the preparations for WRC-07 and WARC-92 for the reallocation of HF bands, the JIWP Report to WARC-92 therefore still serves as an essential element for examining sharing possibilities between all HF services. For ready reference, and to place the material formally within the studies for WRC-07, the JIWP Report has been reproduced at the annex here.

Since WARC-92 changes and updates in the ITU-R texts relevant to sharing between services in the HF bands have been included in the following revised texts:

a) Recommendation ITU-R P.1060 – Propagation factors affecting frequency sharing in HF terrestrial systems. This text identifies the propagation factors and conditions that may facilitate sharing in the HF bands.

b) Recommendation ITU-R BS.1514 – System for digital sound broadcasting in the broadcastings bands below 30 MHz. The text includes a description of the recommended DRM system for digital sound broadcasting below 30 MHz, together with compatibility consideration regarding intra-service sharing with analogue broadcasting.

c) Recommendation ITU-R BS.1615 – "Planning parameters" for digital sound broadcasting at frequencies below 30 MHz. The text includes comprehensive tables of protection ratios between the various modes of digital operation and between digital and analogue operation.

d) Recommendation ITU-R BS.560-4 – Radio-frequency protection ratios in LF, MF and HF broadcasting. Annex 4 to this Recommendation has been updated to include the planning parameters adopted by HFBC-87.

e) Recommendation ITU-R F.240-6 – Signal-to-interference protection ratios for various classes of emission in the fixed service below about 30 MHz. Table 1 to this Recommendation has been updated and complemented. The CCIR Report to WARC-92 indicated this text as the most suitable to provide a satisfactory set of protection criteria applicable to sharing of frequencies by fixed and mobile stations.

Additional useful information concerning conditions to support sharing may be found in these texts:

f) Recommendation ITU-R P.372-8 – Radio noise.

g) Recommendation ITU-R BS.216-2 – Protection ratio for sound broadcasting in the Tropical Zone.

h) Recommendation ITU-R BS.48-2 – Choice of frequency for sound broadcasting in the Tropical Zone.

i) Report ITU-R BS.302-1 – Interference to sound broadcasting in the shared bands in the Tropical Zone.

Intra-service spectrum sharing is a common practice and is normally accomplished through provisions in the Radio Regulations applicable to each radio service. A particularly relevant example to Agenda item 1.13 is Resolution 543 (WRC-03) on provisional RF protection ratio values for analogue and digitally modulated emissions in the HF broadcasting service, which provides relative protection ratios (based on the absolute values given in Recommendation ITU-R BS.1615) for DRM to analogue (A3E) emissions, with the co-channel protection ratios to be used in planning HFBC services.

Inter-service sharing is more difficult but has frequently been accomplished under certain circumstances, usually on a basis of technical or operating conditions designed to avoid causing harmful interference. There is *de facto* sharing in many HF bands that are allocated to several radiocommunication services. The techniques for the types of sharing often involve the application of real time management of frequency use taking into account propagation, antenna directivity, transmitter power, time and geographical considerations.

The following factors are recognized in ITU-R work as relevant to inter-service sharing:

a) that several frequency bands between 4 and 30 MHz are allocated on a shared basis to various radio services including the mobile services;

b) that the efficiency of spectrum use will be improved by the use of frequency adaptive systems in the MF and HF bands shared by the fixed and the mobile services;

c) that use of the radio-frequency spectrum must take into account the dimensions of frequency, time, and space;

d) that dynamic real-time spectrum management techniques can facilitate inter-service sharing;

e) that the fixed and mobile services are currently using many of the same frequency bands between 4 and 30 MHz.

These crucial factors, especially the scope for a mixture of geographical, time and frequency sharing available at HF, counter-arguments which take a very pessimistic view about the feasibility of increasing the amount sharing in the HF bands, as means to satisfy the agenda item.

Such pessimistic views contradict the studies carried out in preparation for WARC-92 and after. This is perhaps, as a result of much of HF communications activity having become de-skilled, with past experience of operating techniques and conditions being forgotten. And it is important to note that HF use by the fixed service is much more homogeneous than when the WARC-92 studies were carried out. The fixed service bands supported a very wide range of commercial uses (e.g. public and private telecommunication links, news teleprinter services and high power ISB relays to broadcasting transmitters) in addition to governmental uses, which then included an extensive network of diplomatic wireless links to embassies as well as the major use seen now of defence related communications.

Impact of adaptive systems

A significant change in the sharing environment is the continued development and deployment of dynamic frequency selection techniques in the fixed and mobile services since WARC-92. Dynamic frequency sharing or real-time frequency management has proved to be a useful tool for providing communication circuits that are not otherwise possible because of interference constraints.

Regulatory changes and modified notification procedures were introduced at WRC-95 and WRC-97 to give full recognition to frequency agile systems, thereby facilitating the use of intelligent radiocommunication systems which can make more effective use of the radio spectrum. In parallel, the governing Recommendation ITU-R SM.1266 on adaptive MF/HF systems was developed for adoption in 1997. More recently, WP 9C has made an invaluable contribution to the introduction and deployment of frequency adaptive systems by developing the Handbook on Frequency adaptive communication systems and networks in the MF/HF bands.

The driving force for initiating the work on frequency adaptive systems was to overcome the difficulties imposed by a fixed band allocation structure under variable propagation conditions, thereby allowing more effective use of the available spectrum. Frequency agile systems test the quality of a specific circuit over a set of channel frequencies in real-time and provide the means for matching current propagation conditions over the circuit with the frequencies available.

One of the advantages foreseen was that, by being able to make a rapid response to changing propagation conditions, the adaptive systems would be ideal for sending short burst packet data transmissions. Channels could then be released for other potential users as soon as possible. This would also serve to overcome a major cause of concern at that time regarding channel blocking.

The prevalence of channels being occupied by idling signals for long periods of time was recognized as a severe impediment to relieving spectrum congestion, it being common practice then in the fixed service to run continuous tapes or keying to reserve access to frequency channels. Monitoring reports from the mid 1990s showed that over half of the identifiable transmissions contained no data traffic.

This concern is reflected in Recommendation ITU-R SM.1266 on adaptive MF/HF systems through *considerings* d) to f):

"d) that, in the MF/HF bands, voice traffic is increasingly being replaced by data traffic, which tends to require a high quality channel for short periods;

e) that use of adaptive systems, which release a radio channel when they have no traffic, will improve spectrum efficiency by allowance for frequency sharing;

f) that the use of adaptive systems, which monitor the propagation conditions in real time and release the channel to other users under time-varying propagation conditions, will increase spectrum efficiency;"

Although more recent technical studies in ITU-R on frequency adaptive systems and latterly their deployment, have tended to be linked with the introduction of digital modulation, as part of the general transition from analogue to digital systems, the supporting background work and studies on spectrum efficiency and sharing compatibility were already well advanced before WARC-92.

Several technical studies prior to WARC-92 recognized that, although few systems had come to market then, these ideas could help in the future to resolve HF spectrum congestion problems.

One of the contributions to the work of JIWP 10-3-6-8/1 noted that operational testing by that administration had shown that the fixed, mobile, and broadcasting services can make effective use of the same frequency bands through real-time frequency management and assignment procedures. Several CCIR Reports (911, 859 and 658) backed by actual operational experience were cited as being applicable to the allocation of broadcasting to certain bands in an arrangement that would allow access to the same HF spectrum by the fixed and mobile services. This access would be based on time and geographical sharing plus the varying operational characteristics of the three radio services. The conclusion was that "… experience indicates that a degree of compatibility in the same HF spectrum can be achieved between the fixed, mobile and broadcasting services, a compatibility that could easily be possible without adversely affecting the broadcasting service."

Service sharing and compatibility considerations

The conclusions of the JIWP Report on HF compatibility and service sharing support several types of sharing scenarios, even including possibilities for sharing between fixed and broadcasting. In addition, the following analyses on various sharing scenarios, draw on experience between WARC-92 and WRC-03.

Compatibility between the amateur, fixed, mobile and broadcasting service

The amateur service has allocations in the 3 500-4 000 kHz band which vary according to Region. In this band there is sharing between the amateur service and the fixed service and certain mobile services that, although not ideal, has proven to be generally acceptable over time. There is also inter-regional sharing, brought about by the differing allocations in the three Regions: The amateur service in Regions 2 and 3 shares frequencies with the broadcasting, fixed, and mobile services in Regions 1 and 3. Interference between these services is minimized because of the propagation characteristics of this band. During the daytime, the band is below the lowest usable frequency (LUF) for many paths. Daytime use is limited to shorter distances on the order of 500 km or less. At night, however, intra-continental propagation is excellent, while inter-continental propagation is marginal-to-good depending upon the season of the year, the latitude, and other factors. For the amateur service the freedom of operators to make a judicious selection of frequencies adds a further means of minimizing interference with other services.

The band 10 100-10 150 kHz is a primary fixed service allocation and secondary amateur service allocation that was made available by WARC-79. The secondary allocation does permit limited access to the band by amateur stations provided that interference to stations in the fixed service is avoided. This access has permitted the amateur service to use this band successfully for over 20 years.

Compatibility between the fixed, mobile and broadcasting service

The combination of Resolutions 729 (WRC-97), 351 (WRC-03) and 544 (WRC-03), involved in Agenda item 1.13 mean that the compatibility issues to be considered by WRC-07 have to include inter-service sharing between the fixed, mobile and broadcastings services and intra-service sharing between the maritime mobile service and general mobile use.

It would appear that sharing between the fixed, broadcasting, and mobile services would have limited possibilities because of the disparity in field strengths and signal-to-interference (*S*/*I*) ratios needed for adequate reception. In actual practice there are many instances where these services have access to the same frequency allocations and are able to function effectively to make efficient use of the HF spectrum.

Geographical and time sharing are feasible means for fixed and broadcasting services to coexist in many parts of the world. Propagation path and operational characteristics are prime factors that affect such sharing, and if appropriately taken into account, may allow coexistence. This is particularly true for frequency agile fixed service transmitters.

Article 5 of the Radio Regulations contains allocations that allow access to many of the same HF bands by the fixed, mobile, and broadcasting services. It is noted that No. 5.147 allows fixed service communications within any country, subject to not causing harmful interference to broadcasting in the bands 9 775-9 900 kHz, 11 650-11 700 kHz and 11 975-12 050 kHz, provided that total radiated power does not exceed 24 dBW.

HF band reuse over near vertical incidence skywave (NVIS) paths

Another well-established sharing scenario makes use of the natural time sharing opportunities between transmissions using oblique skywave paths and near vertical incidence skywave (NVIS) paths Successful NVIS operation is usually limited to no more than about 80% of the critical[2] frequency, in order to avoid problems caused by short term ionospheric variations. In contrast, the situation with the usual oblique skywave reflection mode is that the optimum frequency ranges from about 10% greater than the critical frequency, for a minimum sustainable range of around 200 km, up to around 3 times the critical frequency for the longest sustainable single hop paths.

Because of these circumstances it is possible to provide short range communications at frequencies below the critical frequency simultaneously with long to medium range communications above the critical frequency to or from the same general location/area. One example of such shared use is to be found in the bands 2 300-2 495 kHz (2 498 kHz in Region 1), 3 200-3 400 kHz, 4 750-4 995 kHz and 5 005-5 060 kHz covered by No. 5.113, where the broadcasting service has shared access with the fixed service in the tropical zone and usually operates using the NVIS mode in order to achieve localized broadcasting coverage. By extension, a similar time/geographical sharing scenario has been developed in the CPM Report concerning Agenda item 1.13 for WRC 2007 between the maritime mobile service and NVIS use by the fixed and mobile services within land masses.

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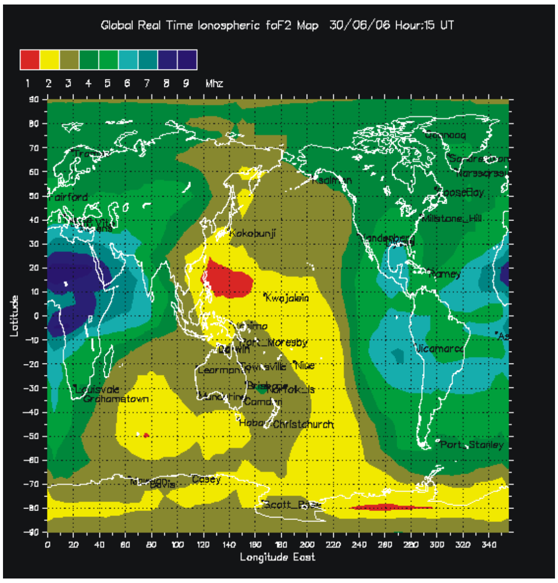
[2] Highest frequency that will be reflected vertically back to ground from the ionosphere at a particular time and location.

This approach exploits the possibility of coexistence between the fixed and land mobile services within land masses (utilizing NVIS) and the maritime mobile service in parts of the 4, 6 and 8 MHz Appendix 17 bands governed by footnote *p)*. This mode of sharing would increase the amount of spectrum available to support relatively short range fixed and land mobile HF communications over relatively short land paths. Moreover, it would provide a better overall balance in the amount and distribution of HF spectrum available to the fixed and mobile services. In Europe, over 70% HF communications in the fixed and mobile services are over relatively short land paths, typically using radiated powers of 1 kW or less.

Coexistence is possible in such an arrangement scenario because the properties of the ionosphere allow for compatible operation on a natural time sharing basis between long range maritime circuits and short range fixed/mobile circuits over land paths using near vertical incidence skywave (NVIS) techniques. Short range communications at frequencies below the critical frequency will be able to operate simultaneously with long to medium range communications above the critical frequency to or from the same general location/area. In particular, this combination of time and geographical discrimination will serve to limit any adverse impact on the maritime mobile service by NVIS communications on land. This effect is illustrated in Figs. 19 and 20 using two examples of real time world ionospheric maps.

FIGURE 19

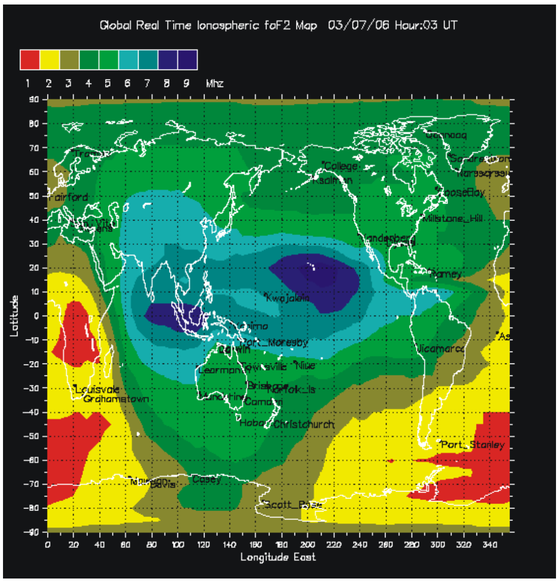


Transmissions between maritime HF stations on the coast, or inland, communicating to ships mid-ocean will use a maritime frequency band around twice the oblique mid-path critical frequency, e.g. around 6 MHz for the Pacific Ocean, or 12 MHz for the Atlantic Ocean at the indicated season and time of day 30 June, 1500Z.

At the same time NVIS communications within the continental land masses will be below the critical frequency, e.g. < 3 MHz for Australia, < 5 MHz Europe, Asia & N. America, < 6 MHz for S. America and a maximum of 8 MHz for equatorial Africa.

This time of day corresponds simultaneously to the highest daily expected ionospheric activity at 0° to 20° longitude and the lowest activity before dawn in the mid Pacific Ocean.

FIGURE 20



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Transmissions between maritime HF stations on the coast, or inland, communicating to ships mid-ocean will use a maritime frequency band around twice the oblique mid-path critical frequency, e.g. around 12 or 16 MHz for the Pacific Ocean, or around 6 or 8 MHz for the Atlantic Ocean at the indicated season and time of day 3 July, 0300Z.

At the same time NVIS communications within the continental land masses will be below the critical frequency, e.g. < 5 MHz for Australia, Europe & N. America < 6 MHz Asia, 2-4 MHz for S. America and no more than 1-2 MHz for Africa.

This time of day corresponds simultaneously to the highest daily expected ionospheric activity at 180° to 200° longitude and the lowest activity before dawn in the mid Atlantic Ocean.

Example of intra-service sharing to remove usage limitations within RR Appendices 17 and 25

Digital data exchange systems for the maritime mobile service are being deployed in parts of the RR Appendix 17 bands which are currently identified by the footnote *p)*. Some of the systems currently in use have the capability to select from a pool of frequencies. Further development of maritime data exchange systems will result in the deployment systems with dynamic frequency selection capabilities with full adaptive control. However, Resolution 729 (WRC-97) does not allow the deployment of frequency adaptive systems in bands allocated exclusively to the maritime or aeronautical mobile (R) services.

There is also further scope for improving the utility of the Appendix 17 bands by letting data exchange systems make use of the spectrum contained within those sub-bands also subject to the RR Appendix 25 Plan for analogue voice channels. The feasibility of reusing the Appendix 25 voice channels for data communications can be demonstrated by the results of band monitoring. Project Team FM22 of the CEPT has undertaken several monitoring campaigns related to this agenda item. Figure 21 shows spectrograms from the third FM22 monitoring campaign conducted in May 2005, which includes the following segments of the HF maritime mobile bands governed by Appendix 25:

4 065-4 146 kHz; 4 351-4 438 kHz;

6 200-6 224 kHz; 6 501-6 525 kHz;

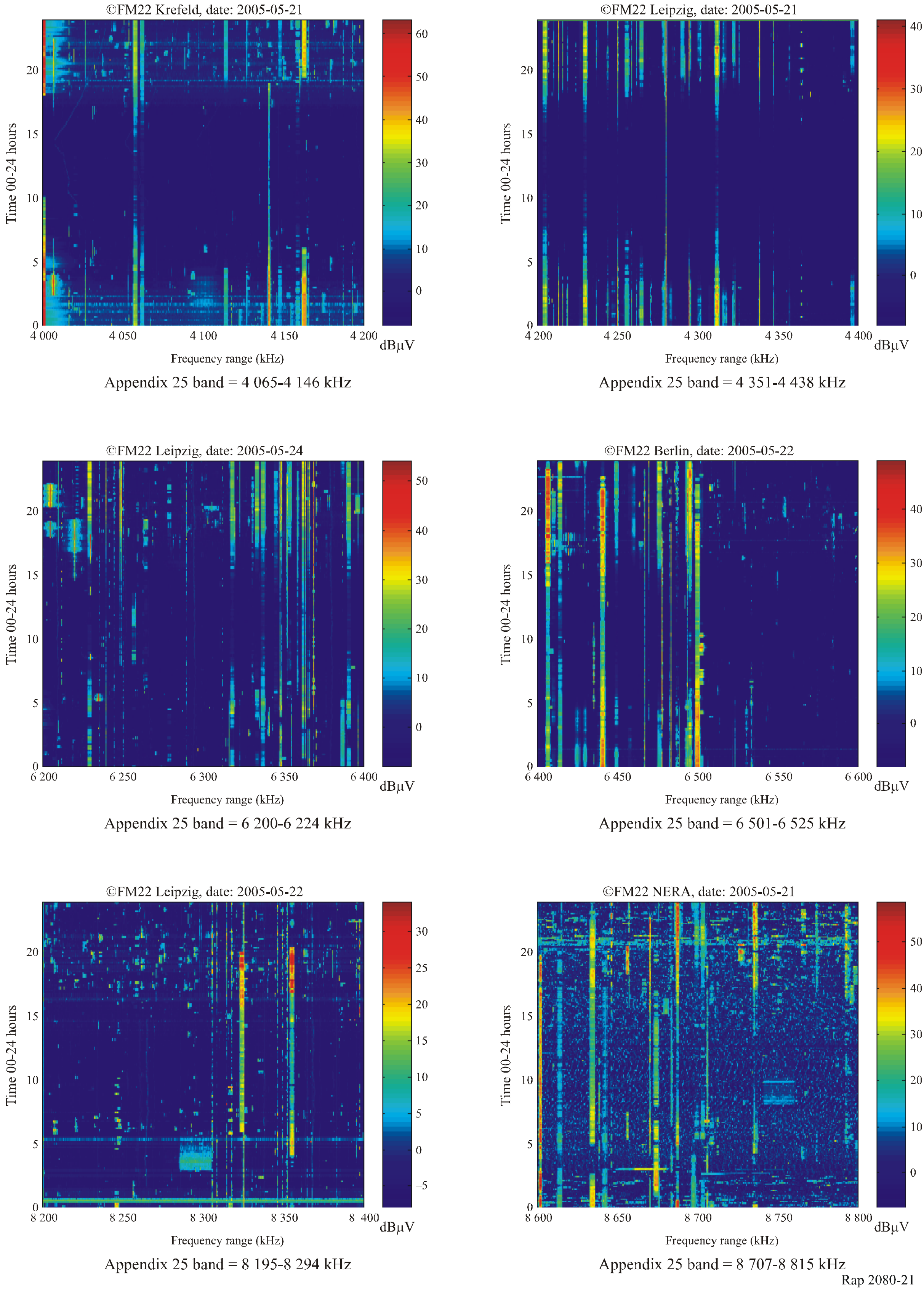
8 195-8 294 kHz; 8 707-8 815 kHz.

These representative results show that there is less activity in the Appendix 25 voice channels than in other parts of the Appendix 17 maritime mobile bands. In some cases, the gain of the recording equipment had to be increased so much that noise is triggering the machine. It is also worth noting that some of the strongest signals recorded in these spectrograms (visible as high field strength wide markings) are due to transmissions in the fixed and broadcasting services. The conclusion is that new data exchange services could be accommodated more readily in those parts of Appendix 17 governed by the Appendix 25 Plan than those which are not.

In order to allow frequency adaptive data exchange systems for the maritime mobile service to in all parts of the Appendix 17 bands that do not have to be reserved for distress and safety communications and legacy NDBP communications, including MSI broadcasts, it will be necessary to remove the restriction in Resolution 729 (WRC-97). The *resolves* 1.2 prevents the deployment of frequency adaptive systems for use by the maritime mobile systems in bands allocated exclusively to the maritime mobile service. The same restriction also applies to the aeronautical mobile (R) service in respect of the RR Appendix 27 bands.

FIGURE 21

Spectrograms of 4, 6 and 8 MHz maritime mobile bands



Annex 5

Spectrum sharing considerations in relation to WRC-07 Agenda item 1.13

Spectrum sharing

While this text is primarily intended to reflect the position in the HF bands below 10 MHz, the arguments put forward are more general and applicable to all frequency bands.

Unfortunately, there is insufficient radio spectrum available to allow every user to have a clear dedicated channel. The frequencies, or "channels", have to be used again and again − or shared − to carry as much traffic as possible using the limited spectrum available. All services must (or should) share spectrum within their allocation. This has been the practice for decades. Examples of how the broadcasting service shares channels are given in Examples 2 and 3.

There are two[3] basic methods for sharing a channel. The channel can be shared in time with one user having access at certain times and others having individual access at other times. The channel can also be shared in space. If there is sufficient geographical separation between the transmission paths used by the users, any one, the wanted one, can, typically ignore the other(s) if received signal levels are sufficiently different. The criteria for successful coexistence are embodied in "protection criteria". Much work has been done on this subject and much data and guidance exists.

It is intuitively obvious that different users can share a particular channel in time provided that each can coordinate the times when it wants to use the channel with the others. While, perhaps, not intuitive, it is similarly clear that suitably engineered systems with adequate protection can coexist if there is an adequate distance between them. Adequate protection means that the spatial attenuation is sufficiently large to allow unimpeded reception of the wanted signal. There is no technical reason why a channel should not be shared; the question is "how" rather than "if". It is a matter of coordination, management and administration.

Clearly, if transmissions from the same "service" can share spectrum, there is no technical reason why transmissions from different services should not similarly share. Where the different services use the same, or comparable, transmission characteristics, the protection criteria will be those that the individual services already use. The problem is easily solved. Where there are significant engineering differences between the transmission characteristics of the different services – as there are, for instance, between broadcasting and amateur transmissions – suitable protection criteria may have to be established. Importantly, the key to sharing remains in coordination and management and the will of the services jointly to administer the spectrum. Unless there are differing technical characteristics which fall outside existing protection criteria, sharing studies will predominantly be concerned with these administrative considerations. Where there are technical differences which are not adequately covered it may be necessary for sharing studies to encompass the formulation of the relevant protection criteria.

An example of two radically different services coexisting in the same part of the spectrum can currently be seen in the band 7.100 to 7.200 MHz where the amateur service has early access to spectrum occupied by the broadcasting service. Monitoring campaigns carried out by WG FM PT22 show that both the broadcasting and amateur services actually use this band. Further to this, the

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[3] A third method is possible where modulation schemes of very different types and with sophisticated error protection and correction schemes allow two signals to "overlap" if either one can separate itself from the "noise like" effects of the other.

broadcasting service is introducing digital transmissions into the HF broadcast bands. The technical characteristics of digital broadcasts are quite different from "conventional" analogue ones. To accommodate this, the existing protection criteria used to coordinate services within the broadcasting service have been extended to incorporate digital transmissions and their different technical characteristics.

Factors supporting generic banding/band sharing

There are several examples of managed frequency reuse on a band or a "per-frequency" basis embodied within the ITU-R. Foremost among these is the application of the Article 12 scheduling procedure for the broadcasting service. The management techniques supporting the Article 12 procedure allow for broadcasting frequencies to be shared between broadcasters on the basis of time and geographical separation. The result is a high degree of frequency reuse that is coordinated between broadcasters themselves. This analysis concludes with some specific examples how broadcast transmissions are coordinated to allow the same channel to be used many times.

A further example of frequency reuse is found in the RR Appendix 26 allotment plan for the aeronautical (OR) service, where each frequency has allotments available to several administrations. The studies on modern data exchange systems for the maritime mobile system in IMO and WP 8B have also revealed that a large proportion of maritime traffic using these systems is carried on frequencies outside the exclusive HF maritime bands, mainly in fixed service bands. The regulatory equivalence of a fixed service network and a mobile network where the subsidiary terminals operate under the umbrella of the protection accorded to a base station further reinforces the case that many fixed and mobile networks are difficult to distinguish from an operational point of view. Furthermore, examples of frequency time sharing between new maritime data exchange links and broadcasting have been noted of time managed sharing with broadcasting.

WARC-92 recognized the extent to which HF spectrum can be reused both within a service and between services by means of coexistence within common bands. Moving to more broadly defined band allocations was seen as providing maximum flexibility in spectrum use. Following WARC-92, it was also recognized that such improvements would depend on implementing adaptive communication techniques using dynamic frequency selection techniques incorporating automated channel conflict avoidance (*resolves* 2 and 3 of Resolution 729 (WRC-97) and the rapid release of channels after use to provide a greater chance of finding a reliable propagation path amongst competing users (Recommendation ITU-R SM.1266).

The situation now is one of increasing convergence between the operational characteristics of modern data exchange systems developed for fixed and mobile use in the HF bands. This is demonstrated by the fact that most of these new systems now employ orthogonal frequency division multiplexing (OFDM) as a common transmission standard. There is even convergence with HF broadcasting, since the Digital Radio Mondiale (DRM) system, developed to replace analogue modulation for MF/HF sound broadcasting, operates within an OFDM envelope.

A characteristic of OFDM based systems is that it is possible to tailor the transmission coding characteristics to give the best match to the service requirements and radio propagation factors at the time of transmission. The convergence in modulation and control techniques for modern fixed and mobile applications means that their operations will increasingly take place within a similar envelope of characteristics. Once circuit planning considerations, operational functions and characteristics have become so close as to be indistinguishable, the applications involved could coexist since their compatibility criteria will naturally be much the same. There is a high degree of regulatory equivalence that already exists in the treatment of fixed and mobile networks.

These circumstances complement the philosophy of *recommends* 1 of WRC Recommendation 34 (WRC-95) that future world radiocommunication conferences should, wherever possible, allocate frequency bands to the most broadly defined services with a view to providing the maximum flexibility to administrations in spectrum use, taking into account safety, technical, operational, economic and other relevant factors.

The benefits of moving towards an arrangement of generalized allocations in the HF bands to cover fixed and mobile operations, except for reserved safety related functions for aircraft and shipping, were further recognized at WRC-03. On 29 March 2009, the first allocation changes along these lines will come into effect as a consequence of action to satisfy WRC-03 Agenda item 1.23 on the re-alignment of the bands around 7 MHz. After that date, the bands 6 765-7 000 kHz, 7 400-7 450 kHz (Region 2) and 7 450-8 100 kHz will become available for general use by the fixed and mobile, except aeronautical (R), services.

The principle benefit of spectrum sharing between different services is the availability to both services of a greater frequency range and hence a greater number of channels. This gives more scope for finding the best channel at a particular time. The reliability of any HF communication network improves as a wider range of frequencies becomes available, thereby giving a better chance of being able to select the optimum frequency for the purpose and to respond to the constantly changing propagation conditions, resulting from the natural diurnal and seasonal changes in the properties of the ionosphere. Having a larger ensemble of frequencies available does not detract from efficient use of the spectrum. Indeed, Recommendation ITU-R SM.1266 on adaptive MF/HF systems is based on the recognition that communication systems which monitor the propagation conditions in real time and release channels to other users under time-varying propagation conditions will increase spectrum efficiency. It must, however, be remembered that congestion is brought about primarily by traffic volumes and the relative urgency of any particular message.

Adaptive systems are constantly being developed to "automate" the coordination process (in real time) to better effect and hence progressively reduce the need for human administrative work. Indeed, Resolution 729 (WRC-97) resolves that:

– frequency adaptive systems shall automatically limit simultaneous use of frequencies to the minimum necessary for communications requirements and

– with a view to avoiding harmful interference, the system should evaluate the channel occupancy prior to and during operation.

Adaptivity here can encompass frequency agility and variation of the technical and operation characteristics of transmitters, receivers, antennas, etc. to optimize the use of available resources.

It is currently difficult for the broadcasting services to make extensive use adaptive techniques because there is typically no control over the receiver. However, broadcasters do make extensive used of highly directional antennas, and a diverse range of potential transmission paths[4] in order to minimize the interference to and from other transmissions. Further, the advent of digital broadcasting holds the promise of a limited adaptivity in the receiver itself.

Circumstances may exist where many current implementations of frequency adaptive systems do not offer truly autonomous dynamic frequency sharing. From a statistical perspective, a wider generic band, covering several narrower service exclusive bands, will offer each user from the services involved more opportunities to select one or more frequencies for immediate use. This is where poorly conceived frequency selection protocols can result in problems when moving to generic banding/band sharing. To avoid persistent and irresolvable collisions the frequency selection process has to be carried out on a random basis, even to the extent of allowing unlikely choices from a propagation perspective. This is because, as in any lottery situation (the aim here

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[4] Distribution of HF broadcast programming from its point of origination (in a studio centre) to a specific transmitter is usually carried out by satellite. The programme can be taken off the satellite distribution system more or less anywhere.

being to select “winning” frequencies over a large number of trials), a predetermined selection will perform less well over time.

So as not to take the lottery analogy too far, the “winning” strategy will be to select frequencies that establish a functional link without colliding with another user. This is a much more open situation than matching a draw in a real lottery. The important factors are the extent of frequency choice and the probability of finding a suitable channel. A diversity of adaptive links (with differing operational requirements) making frequency selections from a wider generic band are more likely to find functional channels than several users (from a single service) trying to meet similar objectives from a narrower band. However, it is a necessary part of this strategy that users do not dwell on a selected frequency longer that necessary. If they do the choice available for other users will be restricted as the benefits of being able to make and test random selections will be lost.

Statistical analysis of lottery results and strategies shows that a non-random predetermined choice can easily result in no success at all, or will lead to choices that are also popular with other contestants and therefore result in having to share any winnings − in this case experiencing repeated collisions on the “popular” frequency choices. Thus, if different sets of users try to pre-empt frequency choices, then no suitable choices may be left available to set up a new link. The same effect will occur if a number of channels are concatenated to form a single wide-band channel – this is another form of dwelling on a pre-empted choice of frequencies. Moreover, if two or more users try to use the same frequencies from a pre-determined pool all the time, and there is no possibility for the systems to rearrange their choices in real time, then persistent conflicts will result. The natural reaction of users to dwell on “their” frequencies, in an attempt to protect them, will further exacerbate the situation.

The perceived problems with the band sharing approach for solving Agenda item 1.13 are in fact the result of focusing on inefficient spectrum management strategies. This can be corrected to the benefit of all users.

The correct strategy is to use a pseudo random real-time selection technique, which allows transmitter and receive sites to stay in step and to pass over choices with conflicts. In addition, a transmission should never dwell on a channel longer that necessary because that decreases choice for other users. This confirms the guidance already contained in Recommendation ITU-R SM.1266 on releasing channels to other users in a timely manner. As reported to the 10^{th} International Conference on Ionospheric Radio Systems and Techniques held in London, during 18-21 July 2006, such systems are already under test. The other dimensions of adaptivity such as adaptive power control adaptive null-steering on antennas and adapting data rates and modulation protocols to traffic requirements and propagation conditions offer further flexibility to make the most effective use of the available spectrum.

One area where sharing, while still technically possible, is not advisable is where “safety of life” is involved. The critical nature of such transmissions and the inability to coordinate with other transmissions in advance means that certain channels have to be kept clear at all times for emergency traffic.

Frequency reuse in the broadcasting service

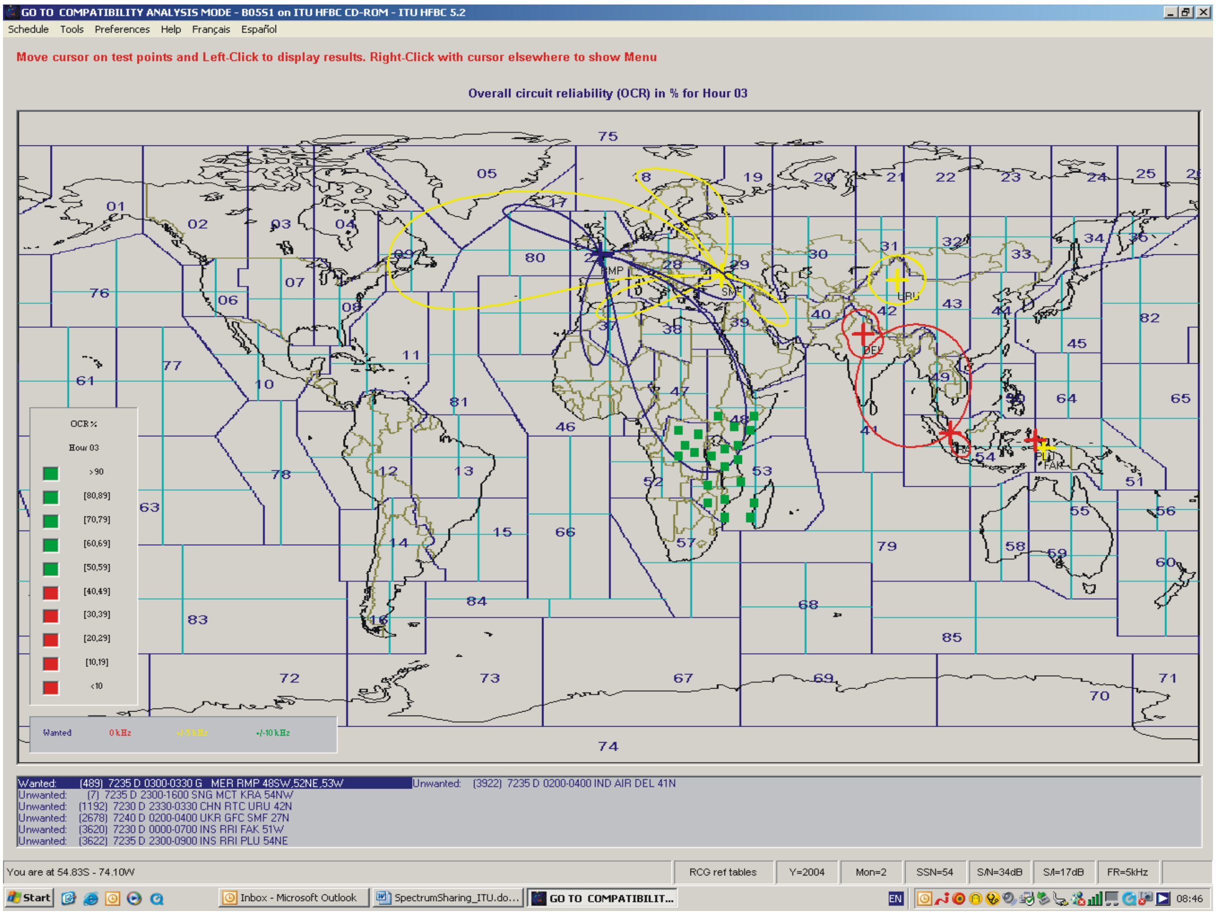
Example 1: Analogue broadcast protected from analogue broadcast

Protection criteria for analogue to analogue transmissions for the HF broadcasting service are given in Recommendation ITU-R BS.560. This suggests that the co-channel RF protection ratio for HF broadcasting transmissions should be 27 dB to give an overall reception quality of 4 on the 5-point scale. Experience over many decades has shown that this figure of 27 dB can be reduced to allow more transmissions to share the available spectrum without serious impact on received audibility. In application of RR Article 12, a co-channel protection ratio of 17 dB is used. This value can be varied by the user to see the impact of other transmissions on their own transmission.

Broadcasting is a point to area service so it is often difficult to visualize the impact of one transmission on another over the whole of the wanted service area. Fortunately, nowadays there are many tools that can help with this. As part of the implementation of Article 12, the ITU BR has developed a graphical tool that allows the display of a wanted requirement together with all unwanted requirements. The map shown below in Fig. 22 is an example of such a graphical presentation. It shows a wanted transmission from Rampisham (United Kingdom) to Africa and other transmissions both co- and adjacent channel. The test points in the wanted area are coloured depending on the calculated value of the overall broadcasting reliability which includes the impact of possible interference from all of the other transmissions indicated. In this case, it shows that the OBR is greater than 50% over the whole of the wanted service area indicating an acceptable level of reception.

FIGURE 22

Example of graphical output from ITU HFBC CD-ROM



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Example 2: Analogue broadcast protected from digital broadcast

With the introduction of digital modulation in the HF broadcasting service, additional protection criteria were required. These were developed by Task Group 6/7 and are contained in Recommendation ITU-R BS.1615. However, since this Recommendation was approved, it was found that the protection ratios given in Recommendation ITU-R BS.1615 may not be applicable for all cases of analogue transmissions protected from digital transmissions. Consequently, WRC-03 developed Resolution 543 giving interim values of protection ratio to be applied to the HF broadcasting service together with correction values to be applied for different values of parameters used for both analogue and digital transmissions from those assumed in Recommendation ITU-R BS.1615. WRC-10 has on its provisional Agenda item 2.6 concerning the verification of the protection ratios to be used in the broadcasting service. ITU BR has already included the relevant protection criteria for digital transmissions in the application of Article 12.

Conclusion

The conclusion therefore remains that band sharing or coexistence for fixed and mobile applications will result in more flexible and effective use of spectrum. However, as was always envisaged, this will not happen by accident and will require effective management of the spectrum through real time dynamic frequency selection techniques and the rapid release of channels after use. These measures will provide a greater chance of finding a reliable propagation path amongst competing users. The move to compatible digital modulation schemes and packet based protocols in new digital data exchange systems will further assist in making optimum use of shared bands.

Annex 6

Considerations regarding a primary fixed service or mobile service allocation and secondary amateur service allocation within the same band

1 Introduction

This annex addresses considerations related to a primary fixed service or mobile service allocation and a secondary amateur service allocation within the same band.

2 Background

There is no worldwide allocation to the amateur service between 3.8 MHz and 7 MHz provided for in the Radio Regulations. Depending on time of day, season and other propagation factors, the maximum usable frequency (MUF) is often such that access to spectrum around 5 MHz is essential for amateur stations to carry out their communications functions. Pursuant to RR 4.4, on a non-interference basis, some administrations have made available fixed frequencies (channels) in the 5 MHz band for amateur radio emergency traffic and related training.

Portions of the 5 MHz band are also being contemplated for the broadcasting service under Resolution 544 (WRC-03) (5 060-5 250 kHz and 5 730-5 900 kHz). In addition, the band 5 900-5 950 kHz is fixed service primary only until 2007, after which time it will be broadcasting primary. Unencumbered access to the 5 MHz spectrum by fixed adaptive systems is crucial to maintain long range communications.

At WRC-03, the fixed service also lost 50 kHz of spectrum worldwide in the band 7 350-7 400 kHz and an additional 50 kHz in the band 7 400-7 450 kHz, in R1 and R3, to the broadcasting service to accommodate amateur service harmonization at 7 100-7 200 kHz (making fixed service ionosphere long-range intercontinental communication links impossible in that portion of the band).

3 Considerations

3.1 Amateur service secondary allocation

The band 10 100-10 150 kHz is allocated to the fixed service on a primary basis and the amateur service on a secondary basis, but in some countries, the band is allocated to the amateur service on an exclusive basis.

Amateur service operators in most administrations need an operator certificate but do not need to approach their administration to obtain a clear (interference free) frequency and a licence to operate on a particular frequency within the amateur service bands. Amateur service operators listen and use an available frequency if there is no traffic. If there are cases of interference, administrations would be in a very difficult position to rapidly isolate and terminate the interference.

In designing an HF fixed system, network designers generally try to avoid the use of adjacent channels. If the amateur service operator finds a clear channel, adjacent to an existing fixed or mobile service channel, their out of band emissions may cause harmful interference.

3.2 Weak fixed service signals

An amateur service site, near a fixed service site receiving a weak signal, may not be able to detect the weak fixed service signal that the fixed antenna systems are designed for, thus creating interference to the fixed service.

3.3 High speed data sounds like noise

It is difficult to detect high speed data transmissions from the sound of demodulated audio as compared to voice transmissions.

3.4 Low power near vertical incidence skywave (NVIS)

Prior to transmission, amateur service operators may not detect fixed and mobile systems using low power (25 to 250 W) for ground waves links or NVIS operations for short distance links or links across large obstacles.

3.5 Point-to-multipoint transmission

Frequent use of one way point-to-multipoint transmission of data is utilized by the fixed service. If a secondary amateur user does not detect that the channel is occupied, they may transmit and could cause harmful interference to fixed service receivers. However, responsible amateur operators using HF over long distances can rarely hear both ends of a communication and therefore listen for a prolonged period before transmission.

3.6 Frequency adaptive systems

Adaptive systems do not typically have an operator monitoring channels to identify sources of interference and they cannot differentiate between primary and secondary users in a band. If a frequency occupied by an amateur service transmission is selected by an adaptive system that implements Recommendation ITU-R F.1778 – Channel access requirements for HF adaptive systems in the fixed service, the adaptive system would attempt to change the frequency of the established link and suffer from loss of throughput, reduced spectral efficiency and a reduced frequency pool, thus potential loss of FS link.