QUESTION 9/2

Identify Study Group Questions in the ITU-T and ITU-R Sectors which are of particular interest to developing countries

ITU-D STUDY GROUP 2 2nd STUDY PERIOD (1998-2002)

Report on frequency agile systems in the MF/HF bands

Telecommunication Development Bureau (BDT)

International Telecommunication Union

THE STUDY GROUPS OF ITU-D

The ITU-D Study Groups were set up in accordance with Resolution 2 of the World Telecommunication Development Conference (WTDC) held in Buenos Aires, Argentina, in 1994. For the period 1998-2002, Study Group 1 is entrusted with the study of eleven Questions in the field of telecommunication development strategies and policies. Study Group 2 is entrusted with the study of seven Questions in the field of development and management of telecommunication services and networks. For this period, in order to respond as quickly as possible to the concerns of developing countries, instead of being approved during the WTDC, the output of each Question is published as and when it is ready.

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1 Introduction

1.1 Regulatory provisions up to 1995

Until 1995, international agreements for frequency regulation and assignment for the HF fixed services were based on long-standing procedures. Proposals for new assignments were submitted to the ITU Radiocommunication Bureau (BR) (before 1993 to the IFRB). BR examined the proposal and submitted it to a technical examination for compatibility with existing assignments. If the result of the technical examination showed that the proposed use would not cause harmful interference to an existing assignment, the assignment was included in the Master International Frequency Register. The administration then proceeded to authorise the assignment.

This process was of dubious technical value at HF. The use of HF is governed by the variable nature of the ionospheric propagation so that the operating frequency has to be changed several times during a 24-hour period. There are also significant day-to-day changes in ionospheric conditions and interference may be caused by very distant transmissions. To assure satisfactory operation, real-time frequency changes may be undertaken by the circuit operators who have to amend frequency schedules according to current conditions, due to short-term changes in ionospheric conditions, or to the presence of interference. Thus frequencies actually in use may not be those predicted for that time. The propagation models used by BR in the technical examination were statistical in nature and could not include short-term considerations. Thus the frequency listing in the Master Register was an inadequate guide to actual occupancy. Moreover, it is well known that some assignments included in the Register have ceased to be used by operational systems and in some cases relate to circuits which have never been put into operation.

1.2 The World Radiocommunication Conference 1995

WRC-95 had amongst its tasks a consideration of the simplification of the Radio Regulations, to aid use by the Administrations, etc. and also to aid the efficiency of the work of BR. A simplified set of Regulations was agreed. However, by means of Resolution 23 (WRC-95), it was decided that BR, with immediate effect, would no longer make any technical examination of proposed frequency assignments in the unplanned frequency bands below 28 MHz.

Thus any proposals by Administrations for the registration of assignments in the Master International Frequency Register would take place without any check for incompatibilities, and countries which relied on this process to ensure satisfactory, interference-free communication would not now have that perceived safeguard.

The remaining Regulations following WRC-95 still require notification to BR and listing in the MIFR. However, without any checks, and thus without anything to be gained from registering the date of an assignment, it might be expected that the listing in the MIFR will progressively degenerate and that some new assignments would not be notified.

ITU also has the purpose of offering technical assistance to developing countries and of promoting the development of technical facilities and their most efficient operation. It may be considered that the withdrawal of a technical examination by BR would reduce the technical assistance available, despite the imperfections of the previous arrangements. Countries without the resources for their own monitoring and planning may be concerned that there is no longer any regular procedure which would enable them to maintain the quality of their existing services.

Another factor which is degrading the effective use of the HF spectrum is the shortage of skilled and experienced circuit operators. In the past experienced operators could assess the performance of the circuits which they were managing, and make effective decisions for real-time frequency management. Such skills are now disappearing with the result that the actual performance of many HF circuits is now becoming worse.

1.3 The use of modern technology

Fortunately, modern technology now permits another solution to the HF problem. Automatically controlled radio systems which evaluate the circuit performance during operation and change the operating frequency, or other circuit parameters, to optimise the performance are now feasible and are in use for some high-quality circuits. Whilst the use of frequency agile systems may not necessarily use the minimum number of frequencies, the assurance of reliable communication given by such systems should result in more efficient operation, together with the avoidance of situations where interference might be caused.

Moreover, the assurance of circuit availability when required for traffic, should result in a reduction of idling transmissions which are used to maintain a channel when there is no current traffic; this should result in an increase in efficiency of spectrum utilization. A recent monitoring study showed that 41% of transmissions were not being used for the transmission of traffic.

2 Recommendation 720 (WRC-95)

At WRC-95 the possible use of intelligent frequency agile systems was identified. Recommendation 720, entitled “The flexible and efficient use of the radio spectrum by fixed and some mobile services in the MF and HF bands using block allocations for adaptive systems”, recognises “that further studies are essential to permit the introduction of frequency agile equipment coupled with the power of digital signal processing for frequency control and error correction techniques” and goes on to instruct the Director, BR, “to ensure, in consultation with the Study Group Chairmen, that the studies now in hand are completed as a matter of urgency and in time for WRC-97”.

3 ITU-R Studies

The 1995 Radiocommunication Assembly adopted two new Questions which are relevant for the HF fixed services. These are: Question ITU-R 204-1 “Block allocations for adaptive Systems in the HF Band”; and Question ITU-R [Doc. 9/40] “Technical and Operational Implications of using Discrete Blocks of Spectrum by Adaptive HF Systems”. Both these Questions had the same purpose – to provide justification for a new regulatory environment at HF. As envisaged, the Study Groups have completed a steady series of studies extending over the last four years so as to reach firm conclusions on the merit of such systems.

The work in ITU-R Study Group 1, on spectrum utilisation aspects, has been completed with the preparation of Recommendation ITU-R SM.1266. This recommendation includes the basic reasons for the use of system adaptivity and lists the various system parameters which may be adapted in response to changes in the channel:

Transmission: data rate; coding scheme; transmitting power; antenna pattern; modulation method.

Link: frequency management; real-time channel evaluation (RTCE) (channel sounding, link quality analysis, etc.).

Network: routing and flow control; protocol handling; data exchange; network reorganisation.

System: resource management; multimedia options; bridge to isolated nodes.

Frequency adaptation and agility at the link level is the most obvious and most widely used technique to combat ionospheric variability and interference, although some systems may now dynamically adapt the modulation method and the data rate.

In ITU-R Study Group 9, Working Party 9C, studies have been undertaken for some years. In 1995 Recommendation ITU-R F.1192 was approved which deals with the "Traffic Capacity of Automatically Controlled radio Systems and Networks in the HF Fixed Service". Although this is a first version which would still merit further improvements, the Recommendation does give methods for quantifying traffic capacity and would be equally valid for similar applications in the mobile services.

A second version of Recommendation ITU-R F.1110-2 was approved in 1997 which deals with "Adaptive Radio Systems for Frequencies below about 30 MHz". This Recommendation describes adaptive systems and has a number of annexes which give brief details of some specific systems. This Recommendation will be further revised in November 1999. It was also decided to prepare a Handbook on frequency adaptive systems and Professor Les Barclay was appointed as Rapporteur. The draft version of the Handbook was approved at the October 2000 meeting of WP9C, and is with BR for publication.

A more detailed description of frequency agile systems is given in the Annex.

4 Results of WRC-97

4.1 Definition

At WRC-97 a definition was adopted in the Radio Regulations, paragraph S.1.109A:

adaptive system: a radiocommunication system which varies its radio characteristics according to channel quality.

Although the use of frequency adaptive systems was allowed previously, with the registration of all frequencies in transmitter complement, for the first time this specifically identifies this new capability of technology. The definition is general and has applications also in other frequency bands.

4.2 Resolution 729 (WRC-97)

WRC-97 also adopted Resolution 729 which sets out the way in which MF and HF Adaptive systems should be used.

The Resolution considers:

- 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;
- that trials of frequency adaptive systems which have been undertaken during the past 20 years have demonstrated the feasibility of such systems and their improved spectrum efficiency;

- that such improved efficiency is attained through:
  - shorter call set-up and improved transmission quality by selection of the most suitable assigned channels;
  - reduced channel occupancy, permitting the same channels to be used by different networks, yet decreasing the probability of harmful interference;
  - minimization of the transmitter power required for each transmission;
  - continued optimization of the emissions owing to the sophistication of the systems;
  - simple operation by the use of intelligent peripheral equipment;
  - reduced need for skilled radio operators;
- that following Resolution **23 (WRC-95),** the Radiocommunication Bureau no longer undertakes examination with respect to the probability of harmful interference caused by new assignments recorded in the Master International Frequency Register (MIFR) in the non-planned bands below 28 MHz;
- that frequency adaptive systems will actively contribute to the avoidance of interference since, when other signals are observed on the channel, the frequency adaptive system will move to another frequency,

The Resolution then resolves:

- that, in authorizing the operation of frequency adaptive systems in the MF and HF bands, Administrations shall:
  - make assignments in the bands allocated to the fixed and mobile services;
  - not make assignments in the bands:

    (a) allocated exclusively to the maritime or aeronautical mobile (R) services;

    (b) shared on a co-primary basis with the broadcasting service, radio-determination service or the amateur services;

    (c) allocated to radio astronomy;

    (d) avoid use which may affect frequency assignments involving safety services made in accordance with Nos. **S5.155**, **S5.155A** and **S5.155B** of the Radio Regulations;

    (e) take into account any footnotes applicable to the proposed bands and the implications regarding compatibility;
- that frequency adaptive systems shall automatically limit simultaneous use of frequencies to the minimum necessary for communication requirements;
- that, with a view to avoiding harmful interference, the system should evaluate the channel occupancy prior to and during operation;
- that frequency adaptive systems shall be notified to the Bureau in accordance with the provisions of Article **S11**.

Thus the intention of this Resolution is to ensure that frequency adaptive use will be confined within those bands which are allocated for the fixed and mobile services, avoiding those bands allocated exclusively to the maritime and aeronautical services or to other services. It is also intended to ensure that the simultaneous use of frequencies is minimised and that interference should not be caused by monitoring for channel occupancy prior to transmission.

The Resolution also called on the ITU-R to continue its studies, and instructed the Director of the Radiocommunication Bureau to make the necessary arrangements, as soon as practicable, for the notification of frequency assignments to adaptive systems and for their recording in the MIFR, taking into account the studies already undertaken.

This has now been done, and the new TeraSys system for the notification of frequency assignments includes a special form for notification, T17, for adaptive MF and HF systems. This form allows the centre frequency of a band, together with the width of the band to be notified.

4.3 WRC-2000 and future WRCs

This topic was not included in the Agenda of the World Radiocommunication Conference (WRC), Istanbul 2000, so that the provisions continue as indicated above. However, topics proposed for the Agenda of the next two WRCs in 2003, and probably in 2006, included consideration of frequency allocation issues at HF where the impact of the use of frequency agile systems will be taken into account.

5. Conclusion

With the adoption of Resolution 729 (WRC-97) together with the procedures for frequency registration under TeraSys, now enables adaptive systems to be readily brought into use. The Resolution sets a number of provisions to ensure that such use is contained within suitable bands, and to ensure that interference is minimised. When such systems become more widely used , there should be an improvement in spectrum utilisation which will benefit both the users of adaptive systems ads well as those who continue to use non-adaptive systems. The capability of modern technology and of powerful digital signal processors would now permit the manufacture of economical equipment which would allow many types of radio use to take advantage of the improved quality possible with this type of operation.

ANNEX

HF Agile systems

1 Introduction

The first generation of adaptive MF and HF systems were developed in the late 1970s/early 1980s. At that time, control equipment was becoming available at reasonable costs and processing power, and the latest generation radio equipment was computer controllable (mainly intended for enabling remote control capability). This generation of equipment could only establish a radio link by selecting one traffic frequency among a small number of pre-set frequencies. The link was then handed over to the operator.

More functionality was added during the 1980s, enabling fully automatic link establishment, link maintenance during message transfer and link disconnection. Such systems could react adaptively to changes in link conditions, e.g. by changing the traffic frequency, the transmitter power and/or the modulation format. Since manufacturers developed their own specific systems, the capability to interoperate with systems from other manufacturers was at best limited.

In the United States, this resulted in a joint effort between customers and manufacturers to develop a standard, thereby fulfilling the prime objective within the US governmental authorities, i.e. inter-operability between systems from different manufacturers. This US standard, defined in its military version as MIL-STD-188-141A and in its civilian version as FED-STD-1045A, commonly referred to as the ALE standard (Automatic Link Establishment), has more or less become the *de facto* standard around the world. A recent survey revealed that at least 15 000 ALE systems have been established so far. The US HF Industry Association (HFIA), an open-to-all organization focusing on promoting and developing the ALE standard, is predicting a growth from 15 000 systems in 1996 to more than one million systems early next century.

Today, several different types of adaptive systems are in operation or under development. NATO has developed a standard (STANAG). The strategy selected for another automatic adaptive system KV 90, used by the Sweden, will probably be adopted for several of the more advanced defence systems under development or procurement. KV 90 is able to operate in two modes: the US ALE mode, and the KV 90 internal synchronous mode. The ALE mode will be used when communicating with other adaptive MF and HF networks and the synchronous mode will enable high performance communication within the network, giving faster link establishment times and higher user data rates.

The term adaptive HF systems has become synonymous with the current generation of automatic HF systems. In order for the regulatory framework not to set unintentional restraints on the future development of these type of HF systems, a new term (not identifiable with a particular generation or system) has been suggested: frequency agile HF systems, which only defines the frequency usage of the HF frequency spectrum by these HF systems.

2 Benefits for developing countries

Adaptive systems will offer special benefit to developing countries as well, for both commercial and government users. This will include lower-cost access to global or regional communications. Some countries have limited wire structure, and they can save money by using HF instead of satellite communications in many cases. Adaptive systems makes HF radios as easy to use as many telephones or satellite communications.

With the modern equipment already available or under development, the need for skilled radio operators can be completely dispensed with, because any frequency agile system will automatically select the optimal working frequency at any given instance, and perform the requested communication in an interference-free environment and with the highest possible degree of accuracy. By this system, the whole radio frequency spectrum will always be available to any operator who needs to use it in a timely manner.

It should be emphasized that allocation of radio frequency spectra to this mode of operation, at the national level, is always under the full authority of each government.

3 Technical description of some operational systems

3.1 Main characteristics

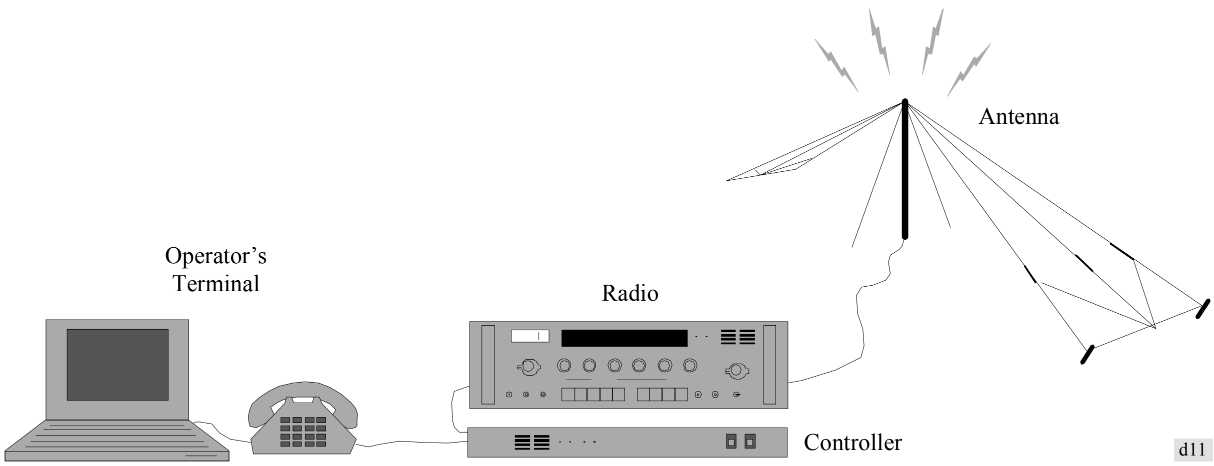
The salient features of the adaptive MF and HF systems are:

- Easy to use – the adaptive systems will establish, maintain and disconnect the MF and HF link without the need for an operator to interact technically. This alleviates the requirement for using trained radio personnel.
- Increased reliability – the percentage of time in which the adaptive systems will provide a high quality service is much higher than traditional fixed frequency systems. This is ensured by the use of adaptive frequency selection, automatic repetition on request and more robust modulation waveforms.
- Flexibility – an adaptive system will continuously analyse and update link quality assessment information making it possible to select the most suitable traffic frequency for each particular time instant. This adaptive behaviour minimises the time periods in which a mobile station cannot communicate with another mobile station or a fixed station. It also increases the possibility that a low-power mobile station will be able to make contact with another station.

3.2 General description

The following describes a common set of functions that are embedded in most of the various types of systems that have been developed. “Common” in this respect does not necessarily mean that they have been implemented in the same way thus enabling inter-communication. It only means that the same type of functionality has been implemented. A more thorough description can be found in ITU-R Rec. F.1110, “Adaptive Radio Systems for Frequencies below about 30 MHz”.

An adaptive station, here defined as being able to provide the operator with a radio link, consists of the following elements:



The main functions of the controller unit in an adaptive system are frequency management and link quality assessment, link preparation and establishment, link maintenance and disconnection.

3.3 Frequency management and link quality assessment

All frequencies that can be used at any given instant are stored in a frequency pool. Some adaptive systems may differentiate between transmitter and receiver frequency, others may use the same frequency for both transmission and reception. In general, five to ten frequencies are stored in a frequency pool, but some adaptive systems have the capability to store and use up to several hundred frequencies.

When there is no traffic, a station will scan the frequencies of the pool, dwelling on each frequency for a specific time period sufficiently long as to ensure that an incoming call can be detected. Some systems will simultaneously perform a passive channel analysis by measuring the interference level on each frequency.

Link quality assessment information is collected after a link has been disconnected. The information is used to select appropriate traffic frequencies between the stations in a net. If little traffic is passed within the net, an automatic sounding function may be activated to provide link quality assessment. A station will then at regular intervals perform a special sounding call consecutively on each frequency from the frequency pool. All other stations in the net detecting this sounding call will update their individual link quality assessment table.

3.4 Link preparation and establishment

The operator will order a link to be initiated either by using the ordinary telephone or via the operator terminal. When a station is ordered to establish a link, it will select the assumed most suitable frequency in the frequency pool. The receiver is set to that frequency, and the controller unit will measure the interference level on that frequency. If the interference level is above a certain threshold, the frequency is rejected and the controller will test the second best frequency. If a usable frequency cannot be found, a "failure" status report will be issued to the operator. Otherwise a call will be initiated.

When a called station detects a call, it automatically responds and reports the call to its operator. The calling station confirms the reception of the response, and messages can than be transferred or alternatively the link can be handed over to the operators for voice operation.

3.5 Link maintenance and disconnection

A link is under control of a controller unit, e.g. when passing text or data messages, it may react adaptively to changes in link conditions. If, for example, the link degrades, a change to a new frequency may be initiated automatically.

Either operator is able to disconnect the link. The controller unit will then issue the appropriate commands to ensure that both stations disconnect the link in an orderly manner. The stations will thereafter resume scanning the frequencies in the frequency pool.