REPORT ITU-R F.2087

Requirements for high frequency (HF) radiocommunication systems in the fixed service

(2006)

1 Increased requirements in the HF fixed service

1.1 Introduction

Increasing requirements in the HF fixed and mobile services are driven by two factors. Firstly, other technologies do not meet all requirements. This is especially true in public protection and disaster relief operations. Ease of deployment and comparatively lower costs continue to make HF fixed and mobile applications desirable during the development of a crisis situation. The second factor is the emergence of HF advanced technologies which allow development of applications to exchange more information at higher data rates.

1.2 Disaster relief support by HF radiocommunication systems

HF radiocommunication systems and networks play a vital role in the support of relief efforts during disasters. Disasters may be local, regional, or, worst case, global in nature. Basic HF systems are vital during disasters, and, as shown in this Report, have recently supported a multitude of events. The categorization of global relief support provided by the optimal use of radio-frequency systems includes, in particular HF.

1.2.1 Background

Disaster relief operations using the HF spectrum provide emergency radiocommunications when the telecommunications infrastructure has been disrupted or destroyed for the exchange of critical and lifesaving information between administrations, private voluntary organizations (PVOs), non-governmental organizations (NGOs) and local public safety activities during crisis situations. Normally, HF channels supporting disaster relief activities are global in nature. The propagation characteristics of the HF portion of the radio spectrum make it most suitable for this type of operation. It offers a propagation medium in which reliable, long range and geographically expansive networks can be established, without the use of satellites, using inexpensive and easy-to-deploy equipment, which operate over a range of frequencies.

When a disaster occurs, personnel from surrounding areas, other administrations and international agencies provide first-responder support to local disaster agencies. HF radiocommunication offers radiocommunication supporting safety and security during these humanitarian relief operations, especially long-range communications when the telecommunications infrastructure is destroyed or disabled.

HF mobile radios provide both short- and long-range support for a variety of activities including various land, maritime and aeronautical radiocommunications while serving as an integral component in an extensive fixed and mobile network capability. Due to the unique characteristics of HF radio propagation, mobile radio use is able to support a wide variety of critical needs specific to these public protection and disaster relief responses.

Modern radiocommunications in the HF band have specific attributes that make it a viable and irreplaceable solution for many emergency response requirements:

– HF radiocommunication allows transmissions across national borders;

– HF radiocommunication can, and is often the only means to provide both local and beyond line-of-sight communications;

– in mountainous areas, it may be the only terrestrial radiocommunication technology that will overcome line-of-sight obstructions by way of near vertical incidence sky-wave (NVIS);

– it is capable of supporting low and medium transmission data rates and different modes of radiocommunication operation (e.g. voice/data/electronic messaging/e-mail);

– it is not dependent upon a relay (e.g. aircraft or satellite);

– its operational cost per bit of information transmitted is considerably less than alternative radiocommunication systems;

– it is generally readily available and easily deployable;

– it can be integrated or used in conjunction with many commercial hardware products;

– it is highly interoperable due to open standards.

Humanitarian relief operations that rely on the use of HF radiocommunication operation modes are evolving to encompass multinational organizations and treaties, responding to needs on a worldwide basis. This trend demonstrates the incalculable value and support HF radiocommunication use provides on a global basis for humanitarian purposes.

1.2.2 A case study in requirements surge: 2004 Indian Ocean Tsunami

A recent example of disaster relief operations was the multinational administration response to the Indian Ocean Tsunami. Extensive infrastructure damage combined with the need to rapidly provide relief supplies from many administrations provided a classic scenario for HF radiocommunications. Landline telecommunications were destroyed, and severe damage was done to all other forms of telecommunications. The only long-range communication means available were provided via satellite and HF radio. The up-front expense and lack of availability of satellite communications equipment and infrastructure limited their use.

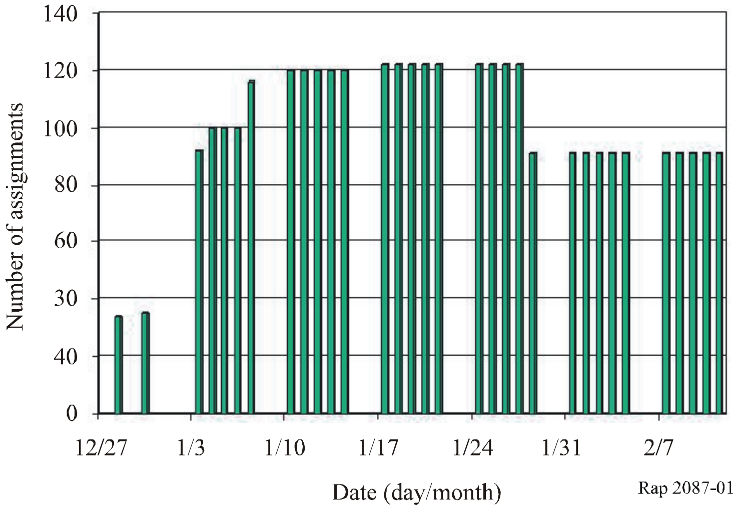
HF radiocommunication was a ready solution. Administrations that sent governments and private organizations to the disaster areas to provide relief supplies and support possessed sufficient HF radiocommunication equipment to establish telecommunications under extremely austere conditions. The emergent need for HF spectrum in this situation drove up spectrum demand. The following chart shows the increase in requirements for HF radiocommunications as administrations established organizations for the delivery of disaster relief supplies in several locations in the Indian and Pacific Oceans. The chart demonstrates how the demand for HF increases dramatically in a very short period of time to accommodate the need to maintain order and organization for the disaster relief effort as well as provide critical communications for those administrations struck by the disaster.

Each bar on Fig. 1 represents assignments for a single day.

The disaster relief operation for the December 2004 Tsunami utilized extensive radiocommunications, primarily HF in the early stages, although satellite communications became available for long distance communications as the work progressed. Two administrations involved in the disaster relief work made use of over 1 000 HF frequency channels between 2 MHz and 29.7 MHz for fixed and mobile communications for relief work in the disaster affected areas. Similar requirements may have been needed by other administrations involved in the relief work.

FIGURE 1

Assignments for Pacific Tsunami



Because of existing extensive usage of the HF bands in the disaster areas, it was not possible to provide all these channels in accordance with the provisions of the Table of Allocations in the Radio Regulations (RR), although in most cases this was achieved. For example the maritime mobile bands were primarily used for maritime mobile purposes; fixed/mobile bands were primarily used for fixed and mobile purposes, etc. Those frequency assignments that were made in derogation of the regulations, e.g. those in the amateur and broadcasting bands, were made under the provisions of RR No. 4.4.

Frequencies below 10 MHz can generally be used 24-h a day. Because of this 24-h availability they are preferred for use in disaster relief work for local communications, using single side band voice communications. Existing HF usage in the affected areas meant that some of the frequencies used for local communications had to be above 10 MHz, as there was insufficient spectrum available below 10 MHz to meet these requirements.

Frequencies generally above 10 MHz experience ionospheric propagation over long distances during daylight hours. Using these frequencies during daylight for groundwave communications in the disaster area carries with it the risk of causing interference to others or (of far more importance to those involved in the relief work) suffering from interference which may disrupt essential communications. For this reason, frequencies below 10 MHz are preferred for this type of work.

Frequencies in the higher bands were mainly used for long-distance digital communications to the home countries of these two administrations, although a portion was also used to supplement the lower bands to provide local voice communications in the disaster area as well. Initially, these HF circuits were the primary means of communications to the headquarters of the organizations undertaking relief work. As the work progressed, satellite communications became available, however the HF circuits continued to be used to carry a portion of the long distance traffic, as well as being retained as an essential back-up facility to the satellite circuits. Essential back up is required in areas where satellite communications can be interrupted by other factors such as by monsoonal weather conditions causing loss of communications through attenuation of signals caused by heavy rainfall.

Because some HF frequencies could be used simultaneously in the different countries affected by the disaster, a reuse factor of three was achieved, giving rise to an overall usage of around 1 000 kHz of HF for the disaster relief work.

1.2.3 Effect of bands identified in Resolution 544 (WRC-03)

The HF spectrum usage for Tsunami disaster relief work in different bands is shown in Annex 1.

Table 1 summarizes the number of frequency channels that would not have been available for fixed service usage (except under the provisions of RR No. 4.4) if the bands identified in Resolution 544 (WRC-03) were allocated to the broadcasting service on an exclusive basis. The broadcasting service usage would result in strong interfering signals in broadcasting bands. Some use of individual channels could be available for disaster relief work under RR No. 4.4, however, as interference free channels are needed for safety-of-life situations in disaster relief, this usage may not be compatible with sharing spectrum with the broadcasting service.

TABLE 1

Number of frequency channels affected if the bands identified in Resolution 544 (WRC-03) were allocated to the broadcasting service on an exclusive basis

Frequency range (kHz)	Number of affected frequency channels
4 500-4 650	1
5 060-5 250	13
5 840-5 900	1
7 350-7 650	25
9 290-9 400	7
9 900-9 940	1
TOTAL	48

Two hundred and seventy-four frequency channels (around 25% of the total) used were between 4 and 10 MHz during the disaster relief operation. Therefore, approximately 17% of the frequencies below 10 MHz used in the Tsunami relief work may have been unavailable depending upon the level of broadcasting usage at the time.

What cannot be estimated is the flow on effect on emergency communications a reallocation of some of these bands to the broadcasting service would have had on communications during the relief work for this disaster, or could have on relief work for future major disasters. If many of the domestic and international circuits presently using the bands identified in Resolution 544 (WRC-03) had been moved to other bands below 10 MHz, congestion in those bands would be greater than at present.

Additionally, if a similar response is required for a future disaster after 2009, the effect of the reallocations to the broadcasting service by WARC-92 and WRC-03 (with dates of effect in 2007 and 2009 respectively) would have to be taken into account in making frequency assignments for use in relief work.

Consequently, it may be much more difficult in future to find spectrum below 10 MHz for all the channels required for similar relief work communications. This will result in a higher percentage of circuits used in the disaster relief work being placed in bands above 10 MHz, which are not the preferred bands for this type of operation.

1.3 Emergence of advanced HF technologies

The lower parts of the HF spectrum represent an essential element of adequate frequency management and constitute an important basis for the reuse of HF resources. But already the spectrum available today does not support the full range of HF radiocommunication requirements and the great variety of capabilities of the equipment available. Because all fixed and mobile users want to increasingly take advantage of new HF technology available on the market. Propagation concerns make it essential that the frequency channels or sub-bands of an HF pool are evenly spaced in order to adapt to the daily and seasonal changes in the ionosphere.

1.3.1 Background

There has been a steady evolution of technology related to HF fixed systems driven by the growth of fixed service use of the HF bands as noted in Table 2. The data capabilities of HF modems has progressively advanced over the past 30-40 years and will continue its growth as new HF fixed applications are developed.

TABLE 2

The data capabilities of HF modems

Decade	1970	1980	1990	2000+
Data rate (bit/s)	50	2 400	9 600	19 200-64 000

Adaptive systems have not been adopted by all operators; however, second generation adaptive systems were developed in the 1980s and development of third generation systems in the 1990s provide faster link establishment, more robust algorithms and higher data rates.

HF adaptive systems must only be operated on frequency hopsets/frequency pools in order to ensure sufficiently interference-free conditions.

On the other hand, the number of frequencies in a hopset or in an adaptively used frequency pool is directly interrelated to the frequency re-visitation rate, the potential interference level, the interference tolerance of the potential victim (a co-channel or adjacent channel user) and to the operational performance of the own system.

As an example, for the operation of a standard medium hopper with 100-130 hops/ s, an ideal hopset should be composed of about 120 coordinated frequencies. The minimum size would be around 16-20 frequencies to allow hopping at all.

It is obvious that to fully exploit all these chances offered by modern technology, the availability of sufficient spectrum resources is crucial, and even more bandwidth beyond the present standard 3 kHz-channels must be available.

Based on recent developments, there are two HF very high data rate technologies identified which could be considered as technological protagonists:

The channel banding approach is based on the use of several 3 kHz channels. The advent of the first HF 64 kbit/s modem using this technology on the international market was appreciated as a technological highlight.

The wideband channel approach is based on the family of modulation schemes of the Digital Radio Mondiale (DRM) standard offering data rates up to 72 kbit/s for a 20 kHz wideband HF channel. The European Telecommunications Standards Institute (ETSI) has published this option in its “Data Applications Directory”.

A modern state-of-the-art HF radiocommunication system can be a reliable bearer for many data, fax, messaging, imagery and voice services. It has been demonstrated that HF e-mail is ideally suited for HF channels.

1.3.2 Establishing fixed and mobile usage considering advanced technologies

Statistical analysis of fixed and mobile HF usage is problematic after the Radiocommunication Bureau (BR) discontinued assessments of interference potential prior to documenting new frequency assignments.

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 ITU 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 (MIFR). The administration then proceeded to authorize the assignment.

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 MIFR and individual administrations keep track of their own assignments and coordinate with other administrations as necessary.

Most users are expected to experience the impact of a complete realignment of the fixed and mobile bands to include the users displaced by the assignments already made internationally to the broadcasting service for 2007 and 2009. This additional congestion will make it difficult for many users to successfully meet their required missions without encountering interference from other fixed and mobile users. Increased usage of adaptive technologies and advanced HF systems will ease this impact, but will unlikely solve it completely.

With the development and introduction of frequency adaptive systems, the MIFR no longer contains accurate information related to fixed service use and therefore the licensing and usage statistics in each administration provides the basis for demonstrating supply and demand of allocated spectrum. In addition to the information maintained by administrations, the evolution of HF fixed system technology is also a very good indicator of the growth of the HF fixed service demonstrating a demand for faster more robust systems.

Given the nature of HF propagation, the use of frequencies across the entire 3-30 MHz band is a requirement for most fixed and mobile users. At a given time of day, season, sun spot cycle, etc. only specific sub-sets of the HF spectrum will successfully propagate a signal through ionosphere refraction. These characteristics impact how the demands by the users are satisfied.

The benefits of advanced technologies are diligently being applied to maximize the use made by fixed and mobile users within the existing allocations under 30 MHz and, in particular between 4 and 10 MHz. This is essential to ensure that the general increased demands placed on the limited spectrum resources are satisfied effectively and efficiently within the existing allocations.

2 General information on HF usage

2.1 Introduction

This section addresses specific features and technical aspects related to the spectrum support for fixed and mobile service operating in the lower part of the HF range.

Typical technical parameters

Land mobile

Frequency range:	1.5-30 MHz
Power:	10-30 dBW
Emission designator:	3k00J3E (98%), 3k00J3A
Antenna height:	Maximum 2-15 m
Antenna gain:	Minus 10-2 dBi

Fixed stations

Frequency range:	1.5-30 MHz
Power:	30-40 dBW
Emission designator:	2k70J2B, 3k00J3E (98%), 3k00J3A
Antenna height:	10-60 m
Antenna gain:	5-10 dBi

2.2 Background

Ionospheric effects have a severe impact on the use of the HF range, constraining essential operations to the lower bands, i.e. below 10 MHz.

The next World Radiocommunication Conference planned for 2007 (WRC-07), will review the HF bands between 4 and 10 MHz in respect of their allocation to services, taking account of new techniques and, in particular, the spectrum requirements of the broadcasting service. In view of numerous exemptions from this review process, any expansion of the broadcasting bands may – again – have to be made at the expense of the fixed and mobile services.

2.3 Specific features of the HF range

The specific HF features have been well known for many decades. Typical types of propagation paths are:

2.3.1 Groundwave

In the case of groundwave, the path is up to line-of-sight (LoS) and beyond. This mode is normally used for path lengths up to 50-200 km. The frequencies required are not time dependent but the longer ranges (200 km) require lower frequencies. Therefore, many HF groundwave radiocommunications can only be operated if frequencies are taken from the lower part of the HF band, i.e. below 10 MHz.

2.3.2 Skywave

In the case of skywave, the path is not LoS but is affected via reflection at the ionosphere, 100-350 km above the Earth. Ranges of several thousands of kilometres are common. The majority of HF skywave paths also require frequencies taken from the lower part of the HF band, i.e. below 10 MHz.

Evidently, selecting frequencies for the HF skywave is difficult. Whether a frequency will propagate depends on the time of the day, season, the length of the link, etc. For the determination of suitable frequencies it is necessary to use programmes that take all the various factors into account and predict the range of usable frequencies for an HF skywave link.

Limiting factors are in particular:

– The window between maximum usable frequency (MUF) and lowest usable frequency (LUF). If the frequency chosen is higher than the MUF, the HF waves will pass through the ionosphere and will not be reflected to the receiver. If the frequency chosen is lower than the LUF, the HF waves will be extensively attenuated. The frequency is normally chosen in the area of 85% of the MUF and is called the frequency for optimal transmission (FOT).
– The antenna bandwidth which is about 1 MHz wide. If the bandwidth is made wider, the antenna efficiency tends to decrease, and also the antenna construction will be more complicated and expensive.

2.4 Assessment of usage by one administration

One administration conducted a review and analysis of domestic spectrum use in certain bands between 4 and 10 MHz. In order to focus the analysis, this administration considered three issues, the incomplete re-accommodation of the WARC-92 expansion bands, the incomplete realignment and subsequent reallocation of HF spectrum in accordance with WRC-03 and consideration of Resolution 544 (WRC-03) in WRC-07, agenda item 1.13.

2.4.1 Background

There is a reallocation from WARC-92 that has not yet been fully implemented in one administration, affecting the current users of this spectrum. For this administration to adequately examine the impact of any future WRC proposals and more importantly proposals for reallocation of spectrum to the broadcast service, the impact to their frequency authorizations as a result of the WARC-92 reallocation must be taken into consideration. There are three bands affected by the decisions of WARC-92 that relate to agenda item 1.13. Any re-accommodation of the assignments in these three bands most likely will be in the remaining fixed service spectrum, which also contains preferred bands for reallocation consideration to the broadcast service at WRC-07. This reduces the spectrum available to the fixed service and must be collectively examined.

The WARC-92 bands scheduled for reallocation as of 1 April 2007, between 4 and 10 MHz are 5 900-5 950 kHz, 7 300-7 350 kHz and 9 400-9 500 kHz for a total of 200 kHz. A search of one administration’s spectrum management database was conducted to determine the impact to users. The list provided below includes both the number of assignments within each frequency band to best capture the spectrum impact.

– 5 900-5 950 kHz band (174 assignments)
– 7 300-7 350 kHz band (170 assignments)
– 9 400-9 500 kHz band (216 assignments).

As a result of WRC-03, 50 kHz is to be reallocated from the fixed service to the broadcast service in Region 2, with an implementation date of 29 March 2009. Fixed service users must be re-accommodated most likely in the 7 400-8 100 kHz band. As mentioned above, the broadcasters are looking for additional spectrum in the 7 350-7 650 kHz band, which will further reduce the band availability for the users currently in the 7 300-7 400 kHz looking for re-accommodation. Therefore, users with assignments in the 7 300-7 400 kHz band must assess their needs, both present and future, for re-accommodation, considering not only meeting their displaced requirements, but also the impact of further reduction of the band in response to agenda item 1.13.

– 7 350-7 400 kHz band (211 assignments)

The broadcasting service has indicated they require an additional 250 kHz to clear the co-channel collisions and up to 800 kHz to clear both the co-channel and adjacent channel collisions.

Resolution 544 (WRC-03) specifically notes preferred bands which sufficient allocations could be made to the broadcasting service. These bands are:

– 4 500-4 650 kHz
– 5 060-5 250 kHz
– 5 840-5 900 kHz
– 7 350-7 650 kHz
– 9 290-9 400 kHz
– 9 900-9 940 kHz.

In order to determine the impact to users that operate in the bands preferred by the broadcasting service, a search of one administration's spectrum management database was conducted to assist in evaluating the impact any further reduction of the fixed service bands would create.

– 4 500-4 650 kHz band (849 assignments)
– 5 060-5 250 kHz band (1099 assignments)
– 5 840-5 900 kHz band (272 assignments)
– 7 400-7 650 kHz band (896 assignments)
– 9 290-9 400 kHz band (216 assignments)
– 9 900-9 940 kHz band (114 assignments).

2.4.2 Requirements

One administration currently uses specific channels in the 4 to 10 MHz range in support of critical aircraft communications for public protection. In addition this administration uses spectrum in the 4 to 10 MHz range as part of extensive emergency HF networks.

These networks support critical communications between offices across the country, offices on islands in the Atlantic and Pacific Oceans and headquarters when other capabilities do not exist, are inadequate or are temporarily disrupted. This use is on a constant ongoing basis and spectrum demand fluctuates in response to specific needs such as ongoing public protection and specific disaster relief situations.

Maritime HF functions include public protection and disaster relief functions. This administration relies on HF radiocommunications to provide critical safety-of-life-at-sea missions, ship and air unit operational command and control, and distress alert. By treaty there is a requirement to perform distress alerts using digital selective calling, and distress, urgency and safety communications over narrow-band direct printing and radiotelephone[1]. Additionally, broadcasts of worldwide navigational warnings are provided and weather warnings and forecasts by voice, data, and facsimile[2]. These operations are vital to international shipping.

This administration also has a requirement for long-path communications using HF systems. NVIS communications can be used in specific situations but does not meet the normal requirements of most users in this administration. It is common for HF links to be established between the East and West coasts of this administration, which can only be accomplished using long path skywave links. Given the nature of HF propagation the "footprint" of the HF signal after any given ionosphere refraction is quite large. These footprints can be over 3 000 km in the direction of the required signal. This makes it likely that many fixed or mobile communications long-path signals will overlap international shipping lanes. Therefore, it is unlikely that sharing would be feasible between

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1 These requirements are documented in Chapter IV of the Safety of Life at Sea Convention.

2 These requirements are documented in Chapters IV and V of the Safety of Life at Sea Convention.

the fixed or mobile (aeronautical/land) services and the maritime service. Given the safety nature of maritime communications it is imperative that any solution that would call for sharing between the fixed and mobile (aeronautical/land) services and the maritime service provide detailed sharing studies showing the feasibility of such sharing. This administration is currently studying this issue and will provide the results in a separate contribution.

HF channels below 10 MHz are commonly required for NVIS and long-haul radiocommunications at night time, and during long periods of the solar cycle when sunspot numbers are relatively low. For that reason, any corruption of the lower part of the HF band, e.g. with noise, will severely curtail standard HF radiocommunications during these times.

The need for fixed and mobile HF radiocommunications within this administration expands as the situation warrants. The scale of such expansion is a function of the number of assets involved, the communications capabilities of other nations participating in operations, availability of infrastructure, and the requirement for long-range communications between different users. Since each situation is different, HF usage prediction is untenable, although a general trend can be determined that shows an increase in spectrum demand for the fixed and mobile service. This demand is being met in this administration with the application of a variety of techniques (e.g. narrow-band emissions) to maximize the use of existing allocations that support *inter alia* the introduction of advanced HF services. This upward trend will continue for the foreseeable future based on the characteristics of HF radiocommunications and the reliability it provides for public protection and disaster relief.

Advanced HF services can be summarized in three broad groups:

1) Electronic messaging

2) Large file transfer

3) Internet

These type of systems demand more bandwidth than typical HF systems (including adaptive technologies). This need can be met in the short term by using multiple HF channels to support a single mission. The larger bandwidth is offset by the increasing speed and complexity of communications capabilities, which allow multiple current missions to be met by a single communications channel. Therefore, the designation of wider bandwidths internationally needs to be investigated further.

Adaptive technologies have been used successfully for many years. These technologies leverage existing channel assignments and frequency plans to provide robust radiocommunications around the world. In fact, adaptive techniques are becoming the standard communications means in many administrations for HF radiocommunications based on their reliability and cost factors. The lack of a need for highly qualified operators is another beneficial point when considering deploying such systems.

2.5 Assessment of usage by another administration

The use of the frequency range between 4 and 10 MHz in one administration has essential differences from that of the majority of other states in its region. It is caused first of all by the sizes of territory where it is necessary to provide radiocommunication (the length of radio links can reach several thousand kilometres). Territory includes very large sparsely populated, remote, difficult-to-access areas, and also areas of the North where it is extremely difficult to deploy the mobile communications of traditional kinds, such as trunking or cellular radiocommunication.

Besides, in order to provide short-distance radiocommunication in high altitudes operators have to use relay stations located in lower altitudes that leads to doubling of used frequencies.

An effective (and in some cases the only possible) solution for the problem of providing the radiocommunication in these areas can be found on the basis of using multihop communications in the frequency bands between 4 and 10 MHz, arranged within the framework of fixed and land mobile services. At present, within the framework of these services, a great number of terrestrial stations operates. The average density of frequency assignments to medium and high-power stations in the frequency bands between 4 and 10 MHz amounts to 105 assignments per 10 kHz of spectrum. All in all within the fixed and land mobile services about 60 000 frequency assignments to stations of medium and high-power operate, including about 30 000 frequency assignments in candidate bands. Typical characteristics of these stations are presented in Table 3.

TABLE 3

	Station M1	**Station M2**	**Station M3**	**Station M4**
Operation band (MHz)	1.5-30	3-30	1.5-30	2-30
Power (kW)	5	15	5	15
Path length (km)	3 000	6 000-7 000	3 000-4 000	6 000-7 000

Many more frequency assignments are used by the low-power stations. The preliminary estimations show that in the candidate bands more than 100 000 frequency assignments of low-power stations operate. Typical parameters of low-power stations are presented in Table 4.

TABLE 4

	Station N1	**Station N2**	**Station N3**
Operation band (MHz)	1.5-29.0	1.5-29.0	1.5-29.0000
Power (W)	1; 10	310; 100	10; 50
Path length with symmetrical dipole antenna (km) not less	300	350	350

The majority of these stations do not employ adaptive frequency management methods.

2.5.1 Frequency sharing scenario

Consider a frequency sharing scenario between fixed, land mobile and maritime mobile services. The radio path length in fixed and land mobile services in one administration can reach 7 000 km as it follows from Table 3. It allows to make a conclusion that a frequency sharing scenario between fixed, land mobile and maritime mobile services turns out unacceptable to one administration and that it is necessary to arrange further study in order to develop the frequency sharing scenario, suitable for medium and long radio links.

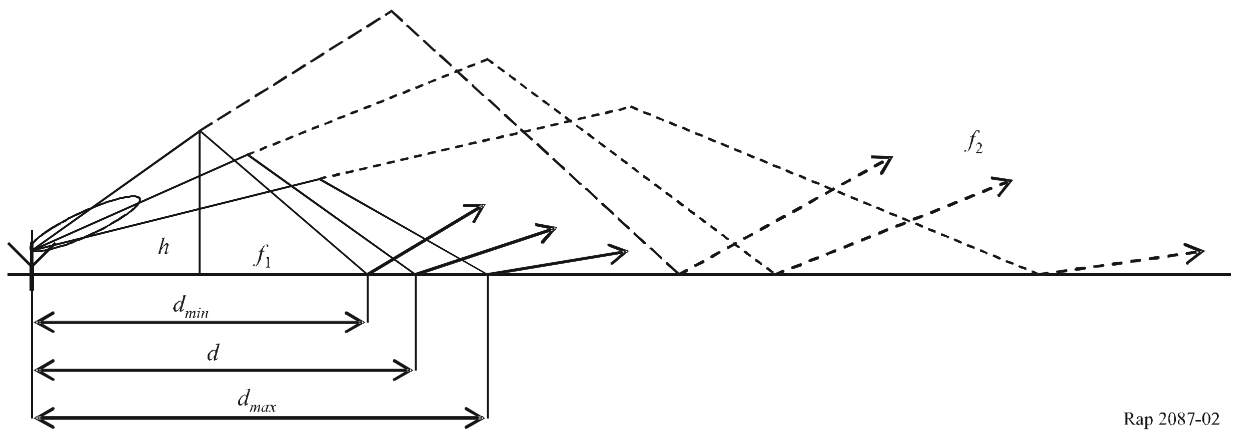
2.5.2 Impact of frequency change on radio links operation in the range 4-10 MHz

The peculiarity of wave propagation in this frequency range is that it propagates by multiple reflections from the ionosphere and the Earth’s surface. Electromagnetic wave paths for various frequencies are outlined in Fig. 2.

FIGURE 2

Electromagnetic wave paths as a function of frequency

(Note: $f_2 > f_1$)



Analysis shows that in typical cases communication between stations is feasible only within some area with the size defined by antenna pattern width and the angle on main lobe inclination toward horizon. Long-distance communication occurs through multiple reflections of waves between Earth surface and ionosphere. Size of illuminated areas and distance between them are determined by state of ionosphere, antenna pattern width and working frequency.

It follows from the above-mentioned that the development of sharing scenario associated with the change of frequency necessitates taking into consideration the peculiarities of wave propagation in 4-10 MHz and potential economic and procedural consequences.

2.5.3 Spectrum effectiveness

It is specifically true for the systems which provide long-range radiocommunication (at distances from 7 000 km to 12 000 km) in East-to-West or West-to-East directions. It is associated with the need to use both night and daytime frequency designations and availability of intermediate stations providing emission frequency transformation.

For systems with long-range links a number of used frequency designations taking into account information available should be more than a number of stations combined into an ALE system. Otherwise when a large number of stations concurrently needs to transmit signals a situation could occur when some stations need to wait in a queue to result in reduction of promptness in data transfer. In some cases (e.g. for systems providing radiocommunication in extreme situations, specifically in inaccessible or distant areas) it would be unacceptable due to potential irreversible consequences.

2.5.4 Reduction of transmitting stations power

An ALE system can adapt and may find better propagation conditions, thereby establishing a link with lower power levels. The above statement would be reasonable when all stations in an ALE system are deployed in an area with a similar propagation environment. Such conditions could occur when all stations in a system are deployed in the same time zone or in adjacent ones. But if a system consists of stations located in the opposite (daytime and night) sides of the globe and they are linked using a multi-hop technique then operators have to establish a communication between them at the lowest of accessible frequencies. Often in such cases emissions of increased power level should be used. The way out of the situation is in deploying additional stations of such ALE system in the radio path and division of the whole network into sub-networks each capable of operating at the frequency optimal for its area. The above situation could be typical for countries with extensive and expansive territory. It could also occur at deploying long-range radiocommunication systems with radio paths of 7 000-1 000 km.

2.5.5 Irregularity of frequency allocations

It is noted that frequency adaptive systems are already in successful operation using the existing frequency allocations. ITU-R has not yet obtained any results showing that uniform relocation of frequencies would result in improving the spectral resource effectiveness as compared with the case when the frequency adaptive systems operate in the current frequency allocations.

Annex 1

The HF spectrum usage for Tsunami disaster relief work in different bands is shown in the table below (frequencies are in kHz). Shaded rows indicate bands that Resolution 544 (WRC-03) identified as preferred bands from which allocations could be made to the broadcasting service. The number in brackets in the first columns of the table represents the number of channel frequencies that would have not been available for fixed service usage if the Resolution 544 (WRC-03) preferred bands were exclusively allocated to the broadcasting service.

<table>
<tr><th rowspan="2">Number of Assignments</th><th colspan="3">Allocation to Services</th></tr>
<tr><th>Region 1</th><th>Region 2</th><th>Region 3</th></tr>
<tr><td>8</td><td>2 194-2 300
FIXED
MOBILE except aeronautical mobile (R)

5.92 5.103 5.112</td><td colspan="2">2 194-2 300
FIXED
MOBILE

5.112</td></tr>
<tr><td>4</td><td rowspan="3">2 300-2 498
FIXED
MOBILE except aeronautical mobile (R)
BROADCASTING 5.113

5.103</td><td colspan="2" rowspan="2">2 300-2 495
FIXED
MOBILE
BROADCASTING 5.113</td></tr>
<tr><td></td></tr>
<tr><td></td><td colspan="2" rowspan="2">2 495-2 501
STANDARD FREQUENCY AND TIME SIGNAL (2 500 kHz)</td></tr>
<tr><td></td><td>2 498-2 501
STANDARD FREQUENCY AND TIME SIGNAL (2 500 kHz)</td></tr>
<tr><td></td><td>2 501-2 502</td><td colspan="2">STANDARD FREQUENCY AND TIME SIGNAL
Space Research</td></tr>
<tr><td></td><td rowspan="2">2 502-2 625
FIXED
MOBILE except aeronautical mobile (R)

5.92 5.103 5.114</td><td colspan="2">2 502-2 505
STANDARD FREQUENCY AND TIME SIGNAL</td></tr>
<tr><td>2</td><td colspan="2" rowspan="3">2 505-2 850
FIXED
MOBILE</td></tr>
<tr><td>2</td><td>2 625-2 650
MARITIME MOBILE
MARITIME RADIONAVIGATION

5.92</td></tr>
<tr><td>6</td><td>2 650-2 850
FIXED
MOBILE except aeornautical mobile (R)

5.92 5.103</td></tr>
<tr><td></td><td>2 850-3 025</td><td colspan="2">AERONAUTICAL MOBILE (R)

5.111 5.115</td></tr>
<tr><td>10</td><td>3 025-3 155</td><td colspan="2">AERONAUTICAL MOBILE (OR)</td></tr>
</table>

<table>
<tr><th rowspan="2">Number of Assignments</th><th colspan="3">Allocation to Services</th></tr>
<tr><th>Region 1</th><th>Region 2</th><th>Region 3</th></tr>
<tr><td>2</td><td colspan="3">3 155-3 200
FIXED
MOBILE except aeronautical mobile (R)

5.116 5.117</td></tr>
<tr><td>3</td><td colspan="3">3 200-3 230
FIXED
MOBILE except aeronautical mobile (R)
BROADCASTING 5.113

5.116</td></tr>
<tr><td>3</td><td colspan="3">3 230-3 400
FIXED
MOBILE except aeronautical mobile
BROADCASTING 5.113

5.116 5.118</td></tr>
<tr><td>6</td><td colspan="3">3 400-3 500
AERONAUTICAL MOBILE (R)</td></tr>
<tr><td>2</td><td rowspan="2">3 500-3 800
AMATEUR
FIXED
MOBILE except aeronautical mobile

5.92</td><td>3 500-3 750
AMATEUR

5.119</td><td rowspan="3">3 500-3 900
AMATEUR
FIXED
MOBILE</td></tr>
<tr><td>6</td><td rowspan="4">3 750-4 000
AMATEUR
FIXED
MOBILE except aeronautical mobile (R)

5.122 5.125</td></tr>
<tr><td>2</td><td>3 800-3 900
FIXED
AERONAUTICAL MOBILE (OR)
LAND MOBILE</td></tr>
<tr><td></td><td>3 900-3 950
AERONAUTICAL MOBILE (OR)
5.123</td><td>3 900-3 950
AERONAUTICAL MOBILE
BROADCASTING</td></tr>
<tr><td>1</td><td>3 950-4 000
FIXED
BROADCASTING</td><td>3 950-4 000
FIXED
BROADCASTING

5.126</td></tr>
<tr><td>4</td><td colspan="3">4 000-4 063
FIXED
MARITIME MOBILE 5.127
5.126</td></tr>
<tr><td>21</td><td colspan="3">4 063-4 438
MARITIME MOBILE 5.79A 5.109 5.110 5.130 5.131 5.132
5.128 5.129</td></tr>
</table>

Number of Assignments	Allocation to Services		
	Region 1	Region 2	Region 3
5 (1 affected)	**4 438-4 650** FIXED MOBILE except aeronautical mobile (R)		**4 438-4 650** FIXED MOBILE except aeronautical mobile
	4 650-4 700	AERONAUTICAL MOBILE (R)	
6	**4 700-4 750**	AERONAUTICAL MOBILE (OR)	
1	**4 750-4 850** FIXED AERONAUTICAL MOBILE (OR) LAND MOBILE BROADCASTING 5.113	**4 750-4 850** FIXED MOBILE except aeronautical mobile (R) BROADCASTING 5.113	**4 750-4 850** FIXED BROADCASTING 5.113 Land Mobile
13	**4 850-4 995**	FIXED LAND MOBILE BROADCASTING 5.113	
	4 995-5 003	STANDARD FREQUENCY AND TIME SIGNAL (5 000 kHz)	
	5 003-5 005	STANDARD FREQUENCY AND TIME SIGNAL Space Research	
	5 005-5 060	FIXED Mobile except aeronautical mobile 5.113	
13 (13 affected)	**5 060-5 250**	FIXED Mobile except aeronautical mobile 5.133	
14	**5 250-5 450**	FIXED MOBILE except aeronautical mobile (R)	
	5 450-5 480 FIXED AERONAUTICAL MOBILE (OR) LAND MOBILE	**5 450-5 480** AERONAUTICAL MOBILE (R)	**5 450-5 480** FIXED AERONAUTICAL MOBILE (OR) LAND MOBILE
10	**5 480-5 680**	AERONAUTICAL MOBILE (R) 5.111 5.115	
3	**5 680-5 730**	AERONAUTICAL MOBILE (OR) 5.111 5.115	
3 (1 affected)	**5 730-5 900** FIXED LAND MOBILE	**5 730-5 900** FIXED MOBILE except aeronautical mobile (R)	**5 730-5 900** FIXED Mobile except aeronautical mobile (R)
6	**5 900-5 950**	BROADCASTING 5.134 5.136	
	5 950-6 200	BROADCASTING	

Number of Assignments	Allocation to Services		
	Region 1	Region 2	Region 3
6	**6 200-6 525**	MARITIME MOBILE 5.109 5.110 5.130 5.132 5.137	
3	**6 525-6 685**	AERONAUTICAL MOBILE (R)	
2	**6 685-6 765**	AERONAUTICAL MOBILE (OR)	
6	**6 765-7 000**	FIXED MOBILE except aeronautical mobile (R) 5.138 5.138A 5.139	
3	**7 000-7 100**	AMATEUR AMATEUR SATELLITE 5.140 5.141 5.141A	
	7 100-7 200	AMATEUR 5.141A 5 141B 5.141C 5.142	
4	**7 200-7 300** BROADCASTING	**7 200-7 300** AMATEUR 5.142	**7 200-7 300** BROADCASTING
1 (1 affected)	**7 300-7 400**	BROADCASTING 5.134 5.143 5.143A 5.143B 5.143C 5.143D	
11 (11 affected)	**7 400-7 450** BROADCASTING 5.143B 5.143C	**7 400-7 450** FIXED MOBILE except aeronautical mobile (R)	**7 400-7 450** BROADCASTING 5.143A 5.143C
43 (13 affected)	**7 450-8 100**	FIXED MOBILE except aeronautical mobile (R) 5.143E 5.144	
16	**8 100-8 195**	FIXED MARITIME MOBILE	
37	**8 195-8 815**	MARITIME MOBILE 5.109 5.110 5.132 5.145 5.111	
6	**8 815-8 965**	AERONAUTICAL MOBILE (R)	
4	**8 965-9 040**	AERONAUTICAL MOBILE (OR)	
14 (7 affected)	**9 040-9 400**	FIXED	

Number of Assignments	Allocation to Services		
	Region 1	Region 2	Region 3
13	**9 400-9 500**	BROADCASTING 5.134 5.146	
5	**9 500-9 900**	BROADCASTING 5.147	
1 (1 affected)	**9 900-9 995**	FIXED	
	9 995-10 003	STANDARD FREQUENCY AND TIME SIGNAL	
	10 003-10 005	STANDARD FREQUENCY AND TIME SIGNAL Space Research 5.111	
	10 005-10 100	AERONAUTICAL MOBILE (R) 5.111	
4	**10 100-10 150**	FIXED Amateur	
115	**10 150-11 175**	FIXED Mobile except aeronautical mobile (R)	
4	**11 175-11 275**	AERONAUTICAL MOBILE (OR)	
	11 275-11 400	AERONAUTICAL MOBILE (R)	
26	**11 400-11 600**	FIXED	
3	**11 600-11 650**	BROADCASTING 5.134 5.146	
	11 650-12 050	BROADCASTING 5.147	
10	**12 050-12 100**	BROADCASTING 5.134 5.146	
20	**12 100-12 230**	FIXED	
28	**12 230-13 200**	MARITIME MOBILE 5.109 5.110 5.132 5.145	
8	**13 200-13 260**	AERONAUTICAL MOBILE (OR)	
	13 260-13 360	AERONAUTICAL MOBILE (R)	
	13 360-13 410	FIXED RADIO ASTRONOMY 5.149	

Number of Assignments	Allocation to Services		
	Region 1	Region 2	Region 3
17	**13 410-13 570**	FIXED Mobile except aeronautical mobile (R) 5.150	
	13 570-13 600	BROADCASTING 5.134 5.151	
3	**13 600-13 800**	BROADCASTING	
2	**13 800-13 870**	BROADCASTING 5.134 5.151	
13	**13 870-14 000**	FIXED Mobile except aeronautical mobile (R)	
3	**14 000-14 250**	AMATEUR AMATEUR SATELLITE	
	14 250-14 350	AMATEUR 5.152	
59	**14 350-14 990**	FIXED Mobile except aeronautical mobile (R)	
	14 990-15 005	STANDARD FREQUENCY AND TIME SIGNAL (15 000 kHz) 5.111	
	15 005-15 010	STANDARD FREQUENCY AND TIME SIGNAL Space research	
	15 010-15 100	AERONAUTICAL MOBILE (OR)	
9	**15 100-15 600**	BROADCASTING	
33	**15 600-15 800**	BROADCASTING 5.134 5.146	
44	**15 800-16 360**	FIXED 5.153	
20	**16 360-17 410**	MARITIME MOBILE 5.109 5.110 5.132 5.145	
21	**17 410-17 480**	FIXED	
5	**17 480-17 550**	BROADCASTING 5.134 5.146	
3	**17 550-17 900**	BROADCASTING	
3	**17 900-17 970**	AERONAUTICAL MOBILE (R)	
	17 970-18 030	AERONAUTICAL MOBILE (OR)	

Number of Assignments	Allocation to Services		
	Region 1	Region 2	Region 3
	18 030-18 052	FIXED	
	18 052-18 068	FIXED Space research	
	18 068-18 168	AMATEUR AMATEUR SATELLITE 5.154	
44	**18 168-18 780**	FIXED Mobile except aeronautical mobile	
	18 780-18 900	MARITIME MOBILE	
5	**18 900-19 020**	BROADCASTING 5.134 5.146	
20	**19 020-19 680**	FIXED	
3	**19 680-19 800**	MARITIME MOBILE 5.132	
30	**19 800-19 990**	FIXED	
	19 990-19 995	STANDARD FREQUENCY AND TIME SIGNAL Space research 5.111	
	19 995-20 010	STANDARD FREQUENCY AND TIME SIGNAL (20 000 kHz) 5.111	
42	**20 010-21 000**	FIXED Mobile	
	21 000-21 450	AMATEUR AMATEUR SATELLITE	
3	**21 450-21 850**	BROADCASTING	
	21 850-21 870	FIXED 5.155A 5.155	
3	**21 870-21 924**	FIXED 5.155B	
	21 924-22 000	AERONAUTICAL MOBILE (R)	
27	**22 000-22 855**	MARITIME MOBILE 5.132 5.156	
6	**22 855-23 000**	FIXED 5.156	
3	**23 000-23 200**	FIXED 5.146A AERONAUTICAL MOBILE (OR)	

Number of Assignments	Allocation to Services		
	Region 1	Region 2	Region 3
	23 200-23 350	FIXED 5.156A AERONAUTICAL MOBILE (OR)	
3	**23 350-24 000**	FIXED MOBILE except aeronautical mobile 5.157	
12	**24 000-24 890**	FIXED LAND MOBILE	
	24 890-24 990	AMATEUR AMATEUR SATELLITE	
	24 990-25 005	STANDARD FREQUENCY AND TIME SIGNAL (25 000 kHz)	
	25 005-25 010	STANDARD FREQUENCY AND TIME SIGNAL Space research	
3	**25 010-25 070**	FIXED MOBILE except aeronautical mobile	
	25 070-25 210	MARITIME MOBILE	
9	**25 210-25 550**	FIXED MOBILE except aeronautical mobile	
	25 550-25 670	RADIO ASTRONOMY 5.149	
	25 670-26 100	BROADCASTING	
	26 100-26 175	MARITIME MOBILE 5.132	
	26 175-27 500	FIXED Mobile except aeronautical mobile	
12	**27 500-28 000**	METEOROLOGICAL AIDS FIXED MOBILE	
3	**28 000-29 700**	AMATEUR AMATEUR SATELLITE	
	29 700-30 005	FIXED MOBILE	