Chapter 2 – HF RADIO

High Frequency (HF: 1.6 MHz to 30 MHz) radio is unique in that it can provide reliable long-distance communications, using simple and inexpensive equipment, both within a country and internationally from isolated areas where the communications infrastructure is either non-existent or where access is denied by disaster or military conflict. It is the only practicable means of bridging long distances (up to thousands of kilometres) without the need for intermediate relay facilities, such as satellite or telecommunications line providers. HF radio also includes more localised coverage. One example is military mobile communications including long and short range links to man-packs, vehicles, ships and aircraft.

HF communications are able to provide the services most likely needed, be they voice, data or video traffic at very low cost and with little preparatory work to establish a network. It has these unique properties because of the existence of a natural resource available to virtually everyone on the globe, the High Frequency spectrum and the ionosphere that provides the conduit for the exchange of information.

2.1 CHARACTERISTICS

Besides direct wave propagation, the HF band exhibits ground wave and sky wave propagation characteristics not apparent in other higher frequency bands (Figure 2.1-1). At the lower frequencies near to the transmitter, the ground wave is the dominant mechanism. In this mode, the radio wave essentially follows the curvature of the Earth. The range depends on factors such as transmitter power, frequency (lower frequency gives greater coverage) and surface conditions (wet ground gives greater coverage, with the best conditions for these frequencies being over seawater). The ground wave attenuation is lowest for vertical polarization and highest for horizontal polarization; therefore the antennas for ground wave propagation should be vertically polarized.

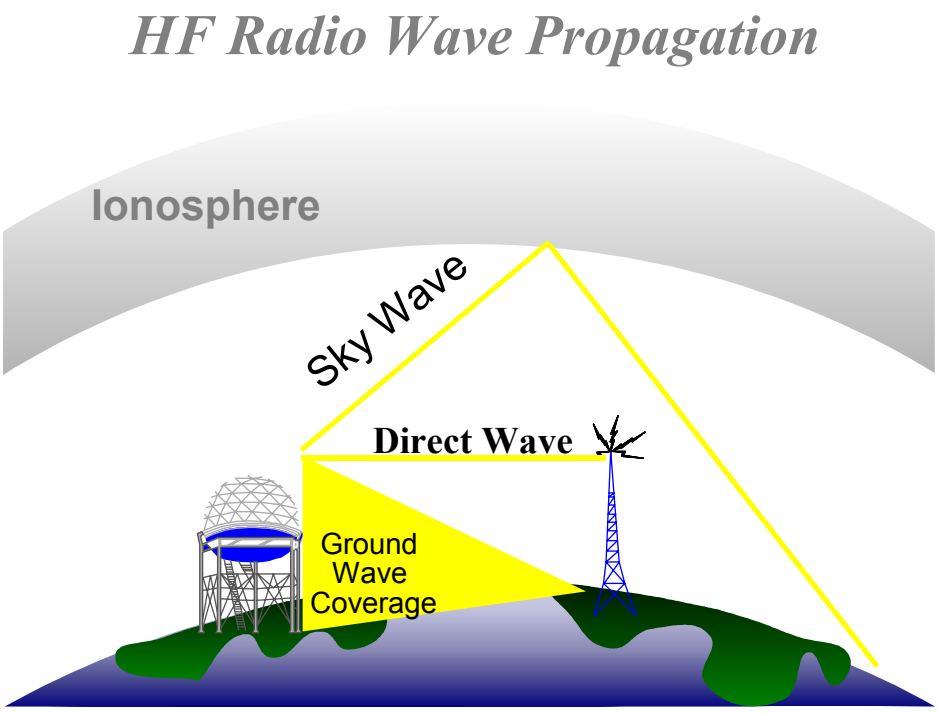

Figure 2.1-1: HF Radio Wave Propagation.

The dominant propagation mechanism in the HF band, where longer distances are involved, is the sky wave. In this mode, radio waves that enter the ionosphere (part of the upper atmosphere) are refracted back towards the earth (height between 100 km and 400 km). The exact amount of refraction depends on the frequency and ionospheric conditions which vary with geographic location, time of day, season and the 11-year sunspot cycle. Radio waves that are launched at high elevations may escape the atmosphere. However, at lower angles, the waves will be bent back down towards the earth and can travel very long distances, especially if they are reflected back up again off the Earth's surface for another 'hop'. Because of this, sky wave is ideal for international communications, including broadcasting. At the lower end of the HF band, virtually all radio waves are reflected back towards the Earth, which enables the use of Near Vertical Incidence Sky wave (NVIS). This is used for national broadcasting in some countries and also for some essential military purposes.

As sky waves change their polarization while propagating through the ionosphere (elliptical polarization) any linear polarization at the receiving antenna may be received. Often horizontally polarized receiving antennas are preferred because generally lower effort is required to obtain the same antenna gain compared to the vertically polarized case.

HF radio signal reception is limited by the ambient radio noise level (Section 2.3) underlying the same wave propagation conditions as the HF radio signals themselves. The variations of HF field strength at the receiving antenna as a function of transmitter power, gain and transmitting direction, frequency, ground conductivity, geographic locations of transmitter and receiver (including their distance), time of day, season (date), and sunspot number (SSN), as well as the ambient radio noise levels, have been extensively studied and are well understood (Sections 2.3 and 6). Modern technology has re-established HF as an important, reliable mode of communications.

The HF signal spectrum has two special features because of the excellent wave propagation conditions, an extremely high signal density (up to 600 signals within 1 MHz bandwidth) and a very high dynamic range (difference between the maximum and minimum signal levels at the input of a receiver, up to 120 dB). These features have to be considered when measuring the ambient radio noise level.

2.2 USERS

There are a number of important new developments that will ensure continued use of the HF spectrum. These involve automatic link establishment (ALE) as well as the replacement of conventional forms of modulation by new digital techniques that are optimised for the propagation characteristics of an HF radio path. These include a new digital broadcasting standard, Digital Radio Mondiale (DRM), which has been developed for high quality international HF broadcasting as well as for national Medium Frequency (MF) broadcasting. Other services such as military communications are using digital modulation techniques to provide reliable and secure long distance communications. A common characteristic to digital communication systems is that although most systems are resistant to interference from narrowband carriers, they are susceptible to interference from broad-band noise-like radio sources such as PLT and xDSL.

Radio frequencies and frequency bands are allocated to different services within the ITU (International Telecommunication Union) Radio Regulations. The International Radio Regulations divide the world into three "Regions":

- Region 1 covers Europe, the "old USSR" areas, and all of Africa;
- Region 2 is North and South America; and
- Region 3 is the rest of the World.

The radio frequency allocations can differ between the three regions.

The current and future use of frequencies in the HF band in Europe may be taken from [2].

2.2.1 Military

In view of the new strategic concept with its increased emphasis on dialogue, crisis management and the prevention of conflict, NATO forces need to possess military attributes such as readiness, deployability and inherent Command and Control capabilities [3]. Also the incorporation of potential non-NATO contributions in contingencies not related to collective defence will have to be accomplished. In addition to the requirements of the operational task and of the single services, there may be other requirements which will generate Control Infra-Structure (CIS) requirements.

Modern HF technology with its specific technical attributes and features can meet the requirements derived from these new roles of the Alliance.

In conclusion, the development of both the doctrine concerning CIS planning for Crisis Response Operations (CRO) and the advancement in modern HF technology will equally contribute to the increasing importance of military HF communications in the future.

Modern communications in the HF band have specific attributes which make it a viable solution for military requirements:

- HF can provide both short-range and beyond line-of-sight communications.
- It is capable of supporting data rates up to about 10 kbps.
- It can support varying degrees of Electronic Protection Measures (EPM) ranging from protection from natural electronic interference to substantial protection from deliberate jamming.
- It is generally available, rapidly and readily deployable.
- It is the only fully military-controlled command system used for long distance secure transmissions, with easy frequency coordination and without additional costs.
- It can be integrated or used in conjunction with many commercial hardware products.

According to [3] “the experience in military missions shows, that HF communication is the only way to distribute missions and progress reports without delays and without the danger of signal jamming. In addition, in case of a nuclear explosion, SATCOM links will be disrupted. By contrast, the HF links will still be available. Disruptions on HF links will be only for a short time”.

In general, adaptive radio systems are used which automatically choose the best frequencies in relation to the propagation conditions for the highest data throughput possible at the actual ambient noise floor situation.

Besides these HF radio links, special units such as crisis reaction forces are using low power radios for their internal communications.

Additionally the Armed Forces are using installations for Communications Intelligence (COMINT: Detection, radiolocation and monitoring of mostly weak signals) within the entire band from 1.6 MHz to 30 MHz.

The use of the HF radio service by the individual military services is as follows:

2.2.1.1 Land Forces

Land forces need HF communications to ensure effective Command, Control and Communications, both within NATO and with PfP Nations. In addition, HF Combat Net Radio communications are used at lower echelons as primary or secondary means where terrain, distance, or mobility requirements preclude reliance on Tactical Area Communications Systems.

2.2.1.2 Air Forces

HF radio is used in the Air environment as the primary beyond-line-of-sight (BLOS) communication means to aircraft, land and maritime mobile platforms. Information is exchanged via HF radio in voice, message and data link formats.

HF communications are used between Air Command and Control ground elements and aircraft for exchanging mission control and surveillance/sensor data at extended ranges and when other communications are not available due to equipment failure or interference. HF is also used for Air Traffic Control (ATC) purposes when beyond the range of VHF facilities.

HF communications between Air Command and Control elements and ground elements mainly are used in a back-up mode when primary and higher capacity means are not available. This includes:

- Backup to NATO Communications Systems;
- Links to PfP and non-NATO elements;
- Links to deployed/mobile entities; and
- Links to tactical formations.

2.2.1.3 Maritime Forces

The NATO maritime community, due to its mobility, uses HF for BLOS communication requirements. Consequently, NATO is modernising its Broadcast and Ship Shore systems. Air/Ground/Air HF communications within the maritime environment are supported by the NATO CIS infrastructure. Within the maritime community, HF is widely fitted throughout NATO and PfP nations, and is common to virtually all warships. Where HF equipment is already fitted, only inexpensive enhancements such as a modem and a PC are generally required to achieve near error-free communications at user data rates significantly better than those used prior to the development of digital signalling techniques.

2.2.2 Broadcasting

The ITU Radio Regulations define the HF broadcast bands whose allocations will not become official until the 2007 World Radio Conference. Currently broadcast band allocations vary from country to country. The Broadcasting service in the USA is covering a total of 3130 kHz in 9 different bands and in Europe a total of 3970 kHz in 11 different HF bands shown in Table 2.2.2-1.

Table 2.2.2-1: Allocated Broadcast HF Radio Bands

Band Name	USA Frequency Range	Europe (EU) Frequency Range	Tropical Bands Receivable in EU
125 Metres	–	–	2300 – 2498 kHz
90 Metres	–	–	3200 – 3400 kHz
75 Metres	–	3950 – 4000 kHz	–
62 Metres	–	–	4750 – 4995 kHz
60 Metres	–	–	5005 – 5060 kHz
49 Metres	5950 – 6200 kHz	5900 – 6200 kHz	–
42 Metres	7100 – 7300 kHz	7100 – 7350 kHz	–
31 Metres	9500 – 9900 kHz	9400 – 9900 kHz	–
25 Metres	11650 – 12050 kHz	11600 – 12100 kHz	–
22 Metres	13600 – 13800 kHz	13570 – 13870 kHz	–
19 Metres	15100 – 15600 kHz	15100 – 15800 kHz	–
17 Metres	17550 – 17900 kHz	17480 – 17900 kHz	–
16 Metres	–	18900 – 19020 kHz	–
14 Metres	21450 – 21850 kHz	21450 – 21850 kHz	–
12 Metres	25670 – 26100 kHz	25670 – 26100 kHz	–

Frequency allocations globally are in a state of transition, so parts of the bands listed may not yet be officially fully available and new ones have been added.

Figure 2.2.2-1 shows measurements of the HF spectrum taken in Germany (FGAN) on 24 to 25 February 2003. All European bands (tropical included) were in use; the lower ones at night, the medium ones all the day and the higher ones only in the day. The levels of receivable HF signals differed up to 100 dB.

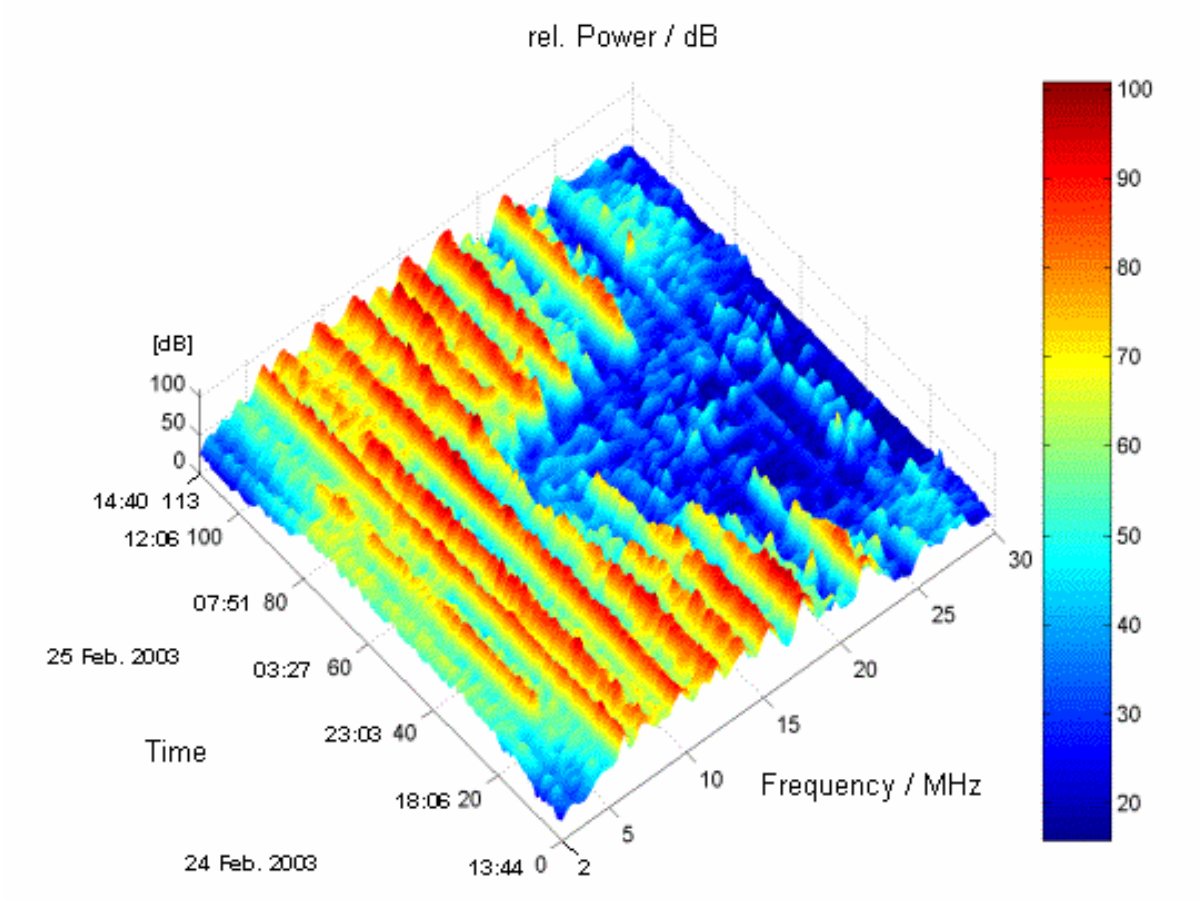

Figure 2.2.2-1: HF Spectrum Measured in Germany during One Day in February 2003 (2 – 30 MHz, measurement bandwidth 100 Hz).

Figure 2.2.2-2 shows similar measurements taken in Norway (by Norwegian Defence Systems Management Division) on 21 November 2004. Here, the measurement bandwidth was 9 kHz, and we see that the variation in measured noise level is 75 dB. This variation is 25 dB smaller than in the German measurements, illustrating the fact that a higher measurement bandwidth precludes measurement of noise only within the measurement bandwidth.

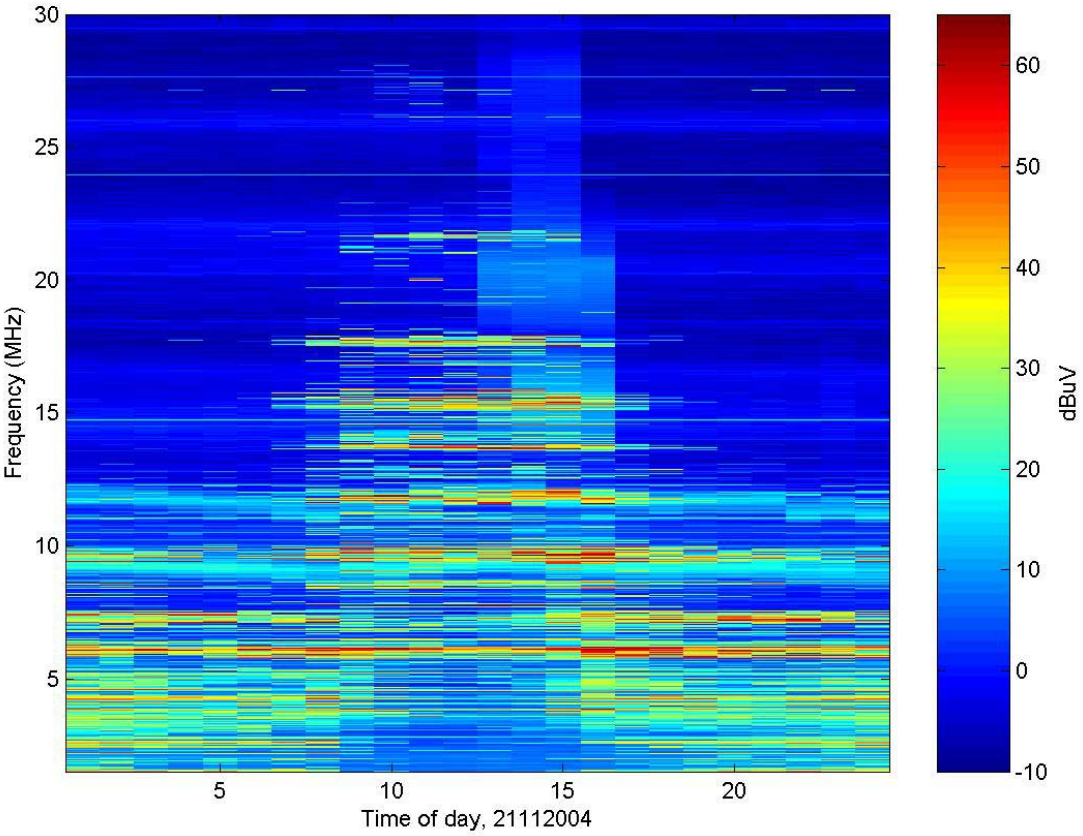

Figure 2.2.2-2: HF Spectrum Measured in Norway during One Day in November 2004 (2 – 30 MHz, measurement bandwidth 9 kHz, average energy measured over 10 ms intervals).

The recommendation ITU-R BS.703 sets out a specification of portable-receiver performance. For the HF band, it specifies that an audio signal-to-noise ratio (SNR) of 26 dB should be achieved for a signal of 40 dBµV/m with 30% modulation, and that the SNR will increase linearly to at least 40 dB as the field strength is increased [4].

Any increase in the 'noise floor' that a particular listener experiences correspondingly will reduce the audible SNR of the station that he currently receives. This effect can also be manifested as a reduction in the choice of available stations, as the weaker ones fall below an acceptable SNR. To put this into context, it may be noted that ITU-R BS.560 sets out *minimum field strengths* for broadcast signals to which full protection against interference from other signals should be provided. For HF, it is specified to be 34 dB above the greater of the level of *atmospheric* noise (given in ITU-R P.372, see Section 2.3), or the *intrinsic receiver nois*e, which it gives as 3.5 dBµV/m (presumed to be RMS).

Most of operational HF broadcasting is currently analogue, using double-sideband amplitude modulation (AM). A very few transmissions are made using single-sideband (SSB) AM, which was proposed (and recommended by the ITU-R) as a replacement for conventional AM. However, this has been overtaken by recent developments in digital techniques. A consortium of broadcasters, manufacturers and operators called *Digital Radio Mondiale* (DRM) has developed a system which is adapted to the various needs of all types of broadcasting in the bands below 30 MHz (long and medium wave, as well as HF). Using the regular 10 kHz of RF bandwidth, DRM delivers an audio signal whose quality is comparable to that of mono FM, without audible background noise or audible effects of fading. It also offers much greater ease of use and will revolutionize long range/wide area broadcasting in terms of quality and

economy. DRM has been approved in the recommendation ITU-R BS.1514. Operational broadcasts started in 2003 using all HF broadcast bands of Table 2.2.2-1.

Under present circumstances DRM will permit some reduction of transmitter power compared with AM operations. This is partly a simple matter of definition. DRM signals are rated by their *mean* power, whereas AM signals are rated by their *carrier* power. Each is in turn related to the *peak* power of the signal, but the relationship for DRM is different from that for AM. If an existing AM transmitter is converted to DRM, the rated DRM power will be less than the rated AM power. This is for two reasons. First, the peak power rating of the transmitter must not be exceeded, and second the interference caused to other existing AM broadcasts must be no greater than that caused by the existing AM transmission that is being replaced. The precise values for the reduction in rated power, and the SNR requirements of DRM, are still being refined by the ITU-R. However, the system is, in effect, designed to work with the same noise floor as AM; any increase in the noise floor will have a deleterious effect. The effect of inadequate SNR on DRM reception will be quite marked: on a steady Gaussian channel reception will cease fairly abruptly as the SNR falls below the necessary level, whereas for a fading channel the proportion of 'drop-outs' will increase first, followed by a complete loss of reception. This is a normal characteristic of digitally modulated systems; it is the trade-off involved in reception being very greatly improved compared with AM once the SNR is adequate. However, if the noise floor is raised significantly, an adequate SNR for DRM reception will no longer be ensured. This would have a severe impact on the likelihood of the new system being introduced into service, risking the loss of its many advantages [4].

2.2.3 Other Users

There are a lot of different other users of the HF spectrum shown in Table 2.2.3-1. Details to the different frequency bands allocated and their usage may be taken from [2] and [5].

Table 2.2.3-1: Further Users of HF Spectrum

User	Total Bandwidth	Power	Remarks
Aeronautical Mobile (OR)	EU 1125 kHz USA 845 kHz rest 875 kHz	Base station: 1 kW aeroplanes: 400 W	OR : off route service, non civil aviation, helicopters, incl. “safety of life service”; frequencies all over the HF band
Aeronautical Mobile (R)	EU 1301 kHz USA 1331 kHz		R: route service with aeroplanes, incl. “safety of life service” (ATC, SAR, etc.); frequencies all over the HF band
Amateur	EU 3190 kHz USA 3750 kHz rest 3450 kHz	few W; max. 100 W – 1000 W	bands heavily used: SSB voice (SNR 6 dB) and A1A morse (SNR –6 dB); incl. “emergency nets”; new: digital voice, data, image; frequencies all over the HF band
Amateur - Satellite	2700 kHz		frequencies within the Amateur bands, but >7000 kHz
Fixed	EU 14195 kHz USA 14129 kHz rest 14409 kHz		very limited civil use; embassies, Interpol, Red Cross and similar; news, weather reports; all over the HF band; intensive use by military
Industrial, Scientific and Medical (ISM)	EU 370 kHz USA 652 kHz rest 326 kHz		short range devices
Land Mobile	EU 2554 kHz USA 3213 kHz rest 2150 kHz		limited use in Europe, but more outside; frequencies used <8100 kHz and >24000 kHz
Maritime Mobile	5140 kHz	coast: 1 – 10 kW	incl. Global Maritime Distress and Safety System (GMDSS)
Meteorological Aids	500 kHz		at 27500 – 28000 kHz in all 3 regions, additionally at 2025 – 2045 kHz in EU
Mobile	500 kHz		incl. distress and safety service
Mobile except aeronautical	895 kHz		
Mobile except aeronautical (R)	3259 kHz		intensive use by military
Radio Astronomy	170 kHz		in rural areas at 13360 – 14410 kHz and at 25550 – 25670 kHz; need protection
Radiolocation	30 kHz		below 2170 kHz; need to be protected
Standard Frequency and Time	90 kHz EU: 84 kHz		at 2500 ±5(EU±2) kHz, 5000±5 kHz, 10000±10 kHz, 15000±10 kHz, 20000±10 kHz, 25000±10 kHz

2.3 NOISE LEVEL

In all radio communications, the limiting factor is the ability to receive weak signals against the background noise. However, because of the characteristics of the HF band, this background noise is not the noise generated in the receiver (as it is on VHF and higher frequencies), but the ambient noise in the external environment. In effect this noise enters the receiver via the antenna along with the wanted signals, so that the radio environment is part of the receiving process.

The **ambient noise environment** consists of two parts, the irreducible residual **ambient noise** which is more or less constant in any particular location, and **incidental noise** from local man-made sources. The combination of these two determines the minimum usable signal level.

Contributing to the ambient noise environment are:

Natural Noise Sources:

- Atmospheric noise, a major source of which is almost continuous lightning activity around the equator (ca. 100/s have been measured) from which interference is propagated to the rest of the world by ionospheric reflection. The overall noise level depends on frequency, time of day, season of the year, sunspot number and location. In temperate zones, noise from this source is relatively low, compared to the equatorial zone, although there will be short bursts of noise from local electrical atmospheric activity (thunderstorm) at certain times.
- Cosmic noise originates from outer space. The main generator of radio noise is the sun, along with atmospheric gases and star clusters. In the HF band the cosmic noise reaching the antenna depends on the screening effect of the ionosphere. At lower HF frequencies (<10 MHz) it is impractical to distinguish between cosmic noise and the general background noise from other sources.

Man-Made Noise Sources:

Man-made noise derives from electrical, electronic or radio equipment and exhibits two effects. Firstly, there is the contribution from a large number of relatively distant sources. This noise is effectively "white" and one of the constituents of the ambient noise floor. Secondly, there is incidental noise from local sources the level of which varies, depending on the type of environment. Environments are classified as business, residential, rural and quiet rural [6],[85],[86]:

- "Business" areas are defined as any area where the predominant usage throughout the area is for any type of business (e.g., stores and offices, industrial parks, large shopping centres, main streets or highways lined with various business enterprises, etc.).
- "Residential" areas are defined as any area used predominantly for single or multiple family dwellings with a density of at least five single family units per hectare and no large or busy highways.
- "Rural" areas are defined as areas where dwellings are no more than one every two hectares.
- Carefully selected quiet receiving sites in "Quiet Rural" areas were selected for measurement of the "minimum" man-made noise.

From the radio users' point of view, the difference between these environments is the level of the noise and the length of time for which it persists. Experience has shown that in industrial or business locations, HF communications is very much impaired by incidental noise which may be present at a high level all the time. In residential locations, the percentage of the time that severe incidental interference is evident on any particular band of frequencies is much less and HF communications is practical, though conditions are not ideal. In rural and quiet rural locations, incidental noise is rare and HF communications is optimal.

Figures 2.3-1 and 2.3-2 show the "natural noise" and the "man-made noise" according to measurements performed in the USA in the 1970s and recommended by ITU [86]. These are **median** values of the external noise figure F_a (F_{am} in Figure 2.3-2) for a short vertical monopole antenna above perfect ground. "For the atmospheric noise curves (Figure 2.3-1), all times of day, seasons and the entire Earth's surface have been taken into account." The median values of man-made noise power (Figure 2.3-2) are averaged over all times and a lot of different locations. The lower and upper decile deviations of the noise power with time are about –5 dB and +10 dB respectively, and the corresponding deviations with location are about ±7 dB (Table 2 in [86]).

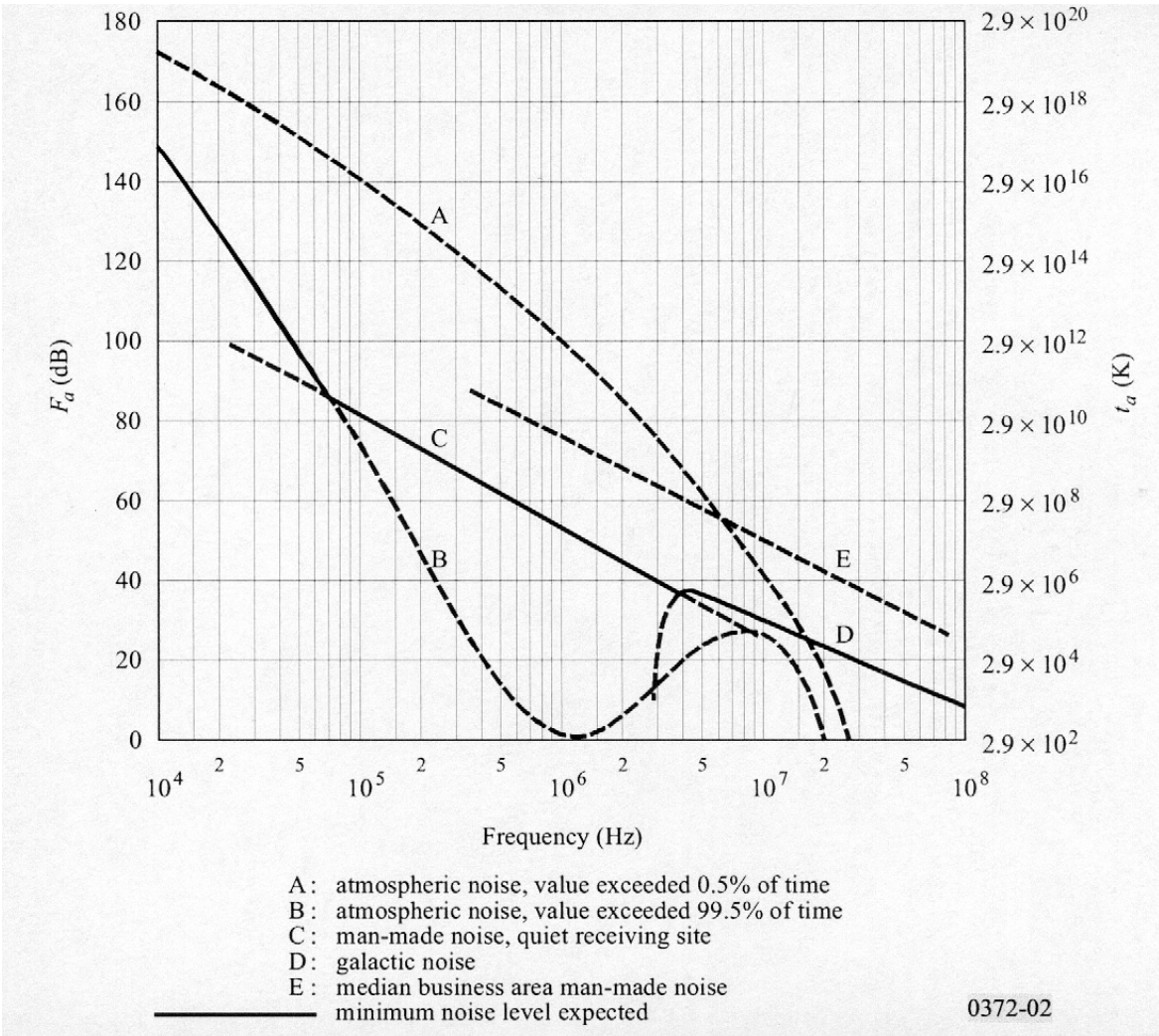

Figure 2.3-1: Median Values of Natural Noise Power for a Short Vertical Lossless Grounded Monopole Antenna.

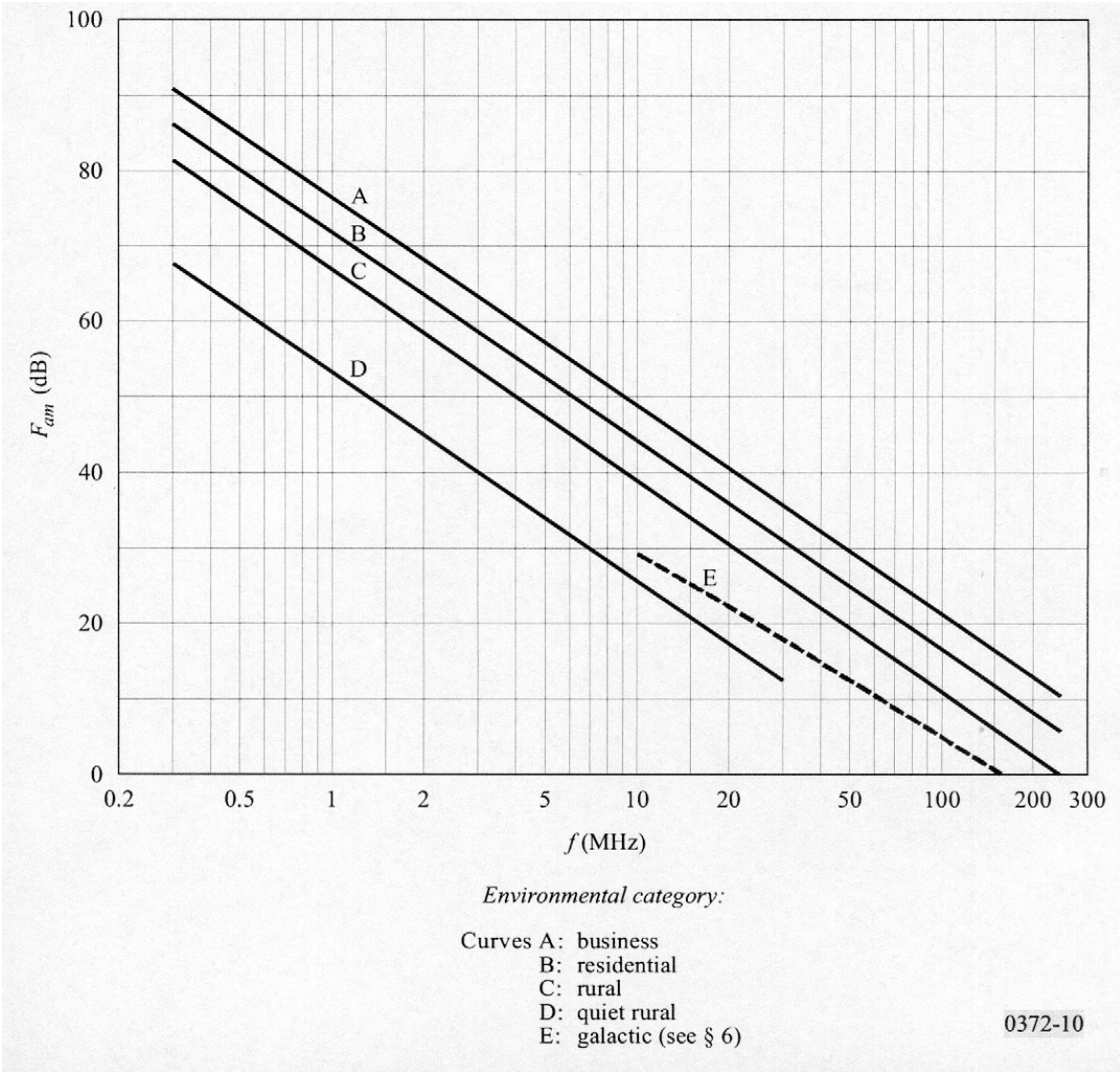

Figure 2.3-2: Median Values of Man-Made Noise Power for a Short Vertical Lossless Grounded Monopole Antenna.

The external noise figure is defined as:

$$F_a = 10 \cdot \log_{10} f_a \text{ dB} \tag{2-1}$$

with the external noise factor f_a defined as:

$$f_a = p_n / (k \cdot t_0 \cdot b) \tag{2-2}$$

p_n: available noise power from an equivalent lossless antenna

k: Boltzmann's constant = $1.38 \cdot 10^{-23}$ J/K

t_0: reference temperature (K) taken as 290 K

b: noise power bandwidth of the receiving system (Hz)

Equation (2-2) can be written:

$$P_n = F_a + B - 204 \quad \text{dBW} \tag{2-3a}$$

where:

$P_n = 10 \cdot \log_{10} p_n$ available power (W)

$B = 10 \cdot \log_{10} b$

and $-204 = 10 \cdot \log_{10} (k \cdot t_0)$

The available noise power spectral density can hence be written

$$P_n = F_a - 174 \quad \text{dBm/Hz} \tag{2-3b}$$

For a short ($h \ll \lambda$) vertical monopole above a perfect ground plane, the vertical component of the RMS field strength is given by [86]:

$$E_n = F_a + 20 \cdot \log_{10} f_{MHz} + B - 95.5 \quad \text{dB}\mu\text{V/m} \tag{2-4}$$

where:

E_n : field strength in bandwidth b,

and f_{MHz}: centre frequency (MHz).

Similarly for a half-wave dipole in free space [86]:

$$E_n = F_a + 20 \cdot \log_{10} f_{MHz} + B - 99.0 \quad \text{dB}\mu\text{V/m} \tag{2-5}$$

The atmospheric noise is modelled as shown in Table 2.3-1 [3]:

Table 2.3-1: Formulas Reflecting the Level of the Atmospheric Noise, 99.5% Value Exceeded

Frequency Range	Formulae
1.5 – 10 MHz	$F_a = 27.8 - 0.35 \cdot (8.2 - f_{MHz})^2$
10 – 15 MHz	$F_a = 46.4 - 1.98 \cdot f_{MHz}$
15 – 20 MHz	$F_a = 66.8 - 3.34 \cdot f_{MHz}$
20 – 30 MHz	0

These formulas were derived from Rec. ITU-R P 372-8 using a graph that represents the 99.5% of time value exceeded situation and f is frequency in MHz.

The man-made and galactic noise is modelled as:

$$F_{am} = c - d \cdot \log_{10} f_{MHz} \tag{2-6}$$

with values as shown in Table 2.3-2 for c and d:

Table 2.3-2: The Constants c and d in Equation (2-6) for Various Types of Area

Type of Area	c	d
Business	76.8	27.7
Residential	72.5	27.7
Rural	67.2	27.7
Quiet Rural	53.6	28.6
Galactic (10 – 30 MHz)	52.0	23.0

The ambient noise floor has been **measured** by several organisations including the ITU, the British BBC, DERA (Defence Evaluation & Research Agency, now QinetiQ) and RSGB (Radio Society of Great Britain) and the German TST (Telefunken Systemtechnik). Making these measurements requires great care. In particular it is essential to select a radio frequency that is not occupied by an existing radio signal. It is almost impossible to find spot frequencies where there is a 9 kHz band without any signals. Because of this congestion, sweeping the HF band using an EMC measuring receiver with a 9 kHz bandwidth does not measure the background noise level. Additionally, measurements made with a typical loop EMC measuring antenna will be limited by the noise of the receiver system, not the environmental noise.

To carry out a swept measurement of the true ambient noise floor at HF, a much narrower bandwidth than 9 kHz – something in the order of 100 – 200 Hz – should be used (compare Figures 2.2.2-1 and 2.2.2-2), and the noise produced by the measuring system itself has to be lower than the ambient noise to be measured. The results of the noise measurement are then converted to a 9 kHz bandwidth for comparison purposes with field strength limits (see Section 2.4) which rely on that bandwidth in the HF-range.

Usually, it is impractical to measure the ambient noise floor in industrial or business locations where the man-made noise will exceed the natural noise floor. The best locations for measuring the ambient noise floor without being influenced by man-made noise will be in rural or in quiet rural areas.

In interpreting published plots of the ambient noise floor, it is important to take into account the conditions of measurement, particularly the bandwidth and the detector used, peak, quasi-peak or average, and the type of antenna.

Figure 2.3-3 shows low natural noise measured in Germany at night and in the day. The measurements with 200 Hz measurement bandwidth were done in July 1971 (SSN = 80, medium), October 1979 (SSN = 180, high) and April 1985 (SSN = 20, low) in the same quiet rural area. There had been no remarkable change of the minimum noise level, so only the results of the measurements 1985 are shown.

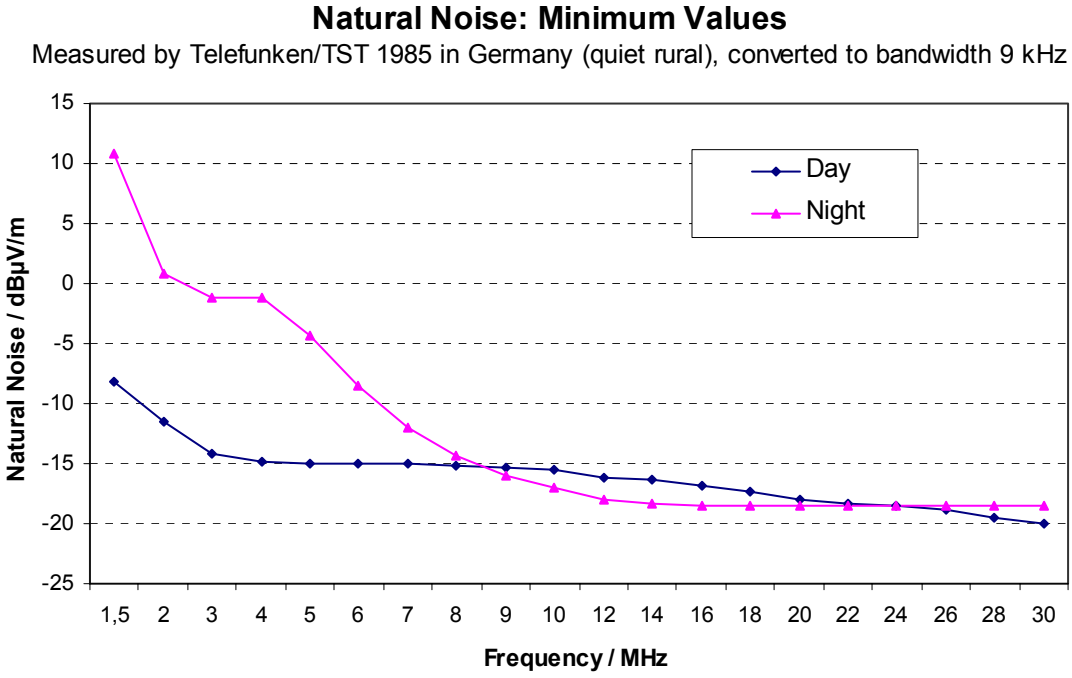

Figure 2.3-3: Low Natural Noise Measured in Germany.

In the lower HF-range the natural noise substantially differs between day and night because of the absorbing D-layer of the ionosphere (height ca. 60 – 90 km) missing at night. The signal absorption in this layer in the day decreases with increasing frequency.

The natural noise in the day should be fundamental to the protection requirements for HF-receivers (see Section 2.4).

Recently, European representatives of different interests, in presentations and discussions have argued (without being able to prove it) that the ITU Recommendations based on measurements carried out in the 1970s (Figures 2.3-1 and 2.3-2) are no longer valid, as the man-made and the ambient noise levels have increased since that time to considerable higher values (by up to 30 dB). Contrary to that, different noise measurements in Germany (1971, 1979 and 1985 by TST, as well as 2003 by the University of Karlsruhe [7],[87]) and in Great Britain ([4], Appendix N, Figure 2.3-4) have proven that the ITU Recommendations for natural and man-made noise in the HF-range are still valid in Europe. Figure 2.3-4 shows minimum field strengths measured in 1985 (and in the 1970s) in North Germany compared with corresponding measurements of 2001 in Southern Britain. There is no remarkable difference between the measurements, specifically **no increase of the ambient noise within the last 30 years**. The noise measurements by the University of Karlsruhe 2003 in rural zones in South-West Germany also indicated no increase compared to ITU-R P.372-8 (curve C in Figure 2.3-2). Figure 2.3-4 also shows median ambient noise field strengths recommended by the ITU for Central Europe in summer and winter in the day, as well as median man-made noise field strengths. These median values are about 5 – 10 dB higher than the measured minimum values, which is in accordance with ITU-R P.372-8 (Figures 17a/b/c – natural noise in Winter; Figures 29a/b/c – natural noise in Summer; and Table 2 – man-made noise). Thus, there is no increase in the ambient HF noise level actually measured in UK and Germany compared to the ITU Recommendations (based on measurements of the 1970s).

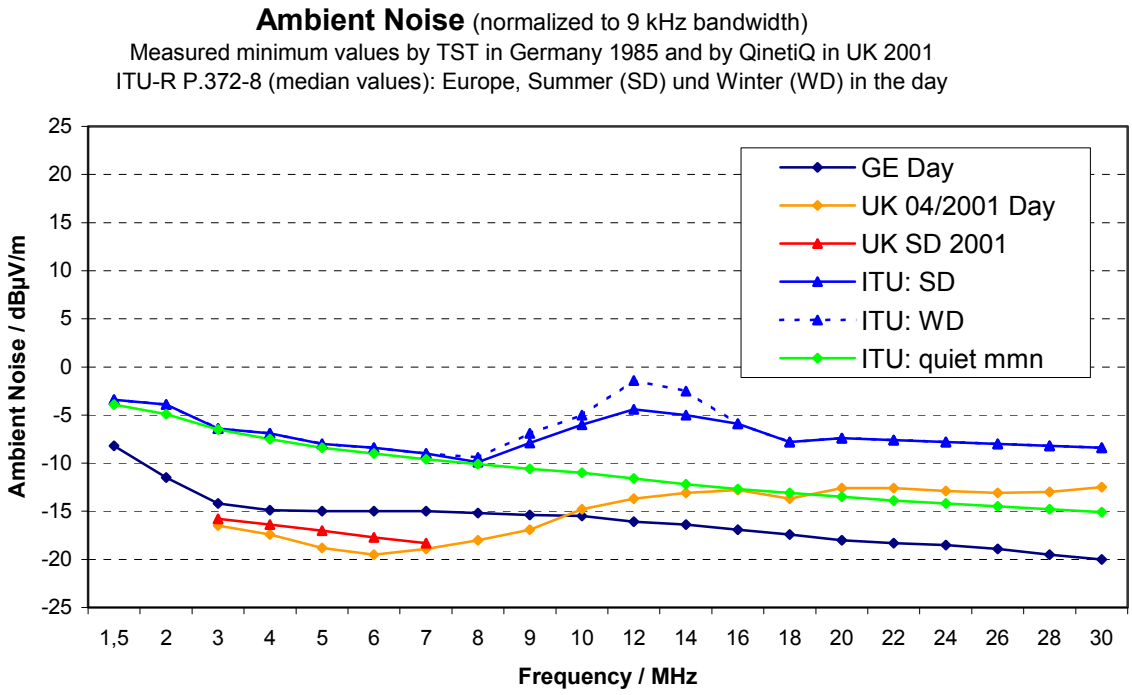

Figure 2.3-4: Minimum Natural Noise Measured in Germany 1985 and in UK 2001 and ITU-Recommendations for Median Natural and Man-Made Noise in Europe (mmn: median man-made noise in quiet rural areas).

2.4 PROTECTION REQUIREMENTS

The various HF radio services possibly affected by unwanted radiation from the new broadband wire-line telecommunication networks are described in Section 2.2.

As the sensitivity of HF receiving systems in general is determined by the ambient noise, the protection requirements are derived from the ambient noise levels specified in ITU-R P.372-8, as well as from the minimum noise measured in Europe.

PLT and xDSL will cause unintentional RF emissions which may increase the established radio noise floor directly nearby or by cumulative propagation far away from many such sources. This type of emission is quite different from that produced by electronic devices and equipment: it is broadband noise, most of the time with a high level, and extending over the HF band.

The incidental noise generated even by devices and equipment compliant with relevant EMC standards can greatly exceed the existing noise floor. Then, reception of low-level HF signals is possible only because of the statistical nature of this incidental noise. Many devices radiate near the limit of their standard on only a few discrete frequencies, or on a narrow band of frequencies. In addition most incidental noise is relatively short lived. HF communication services are opportunistic, i.e., frequencies and time are chosen to optimise the probability of a satisfactory signal-to-noise ratio. If incidental noise prevents communication at any particular time, the transmission is repeated at a later time when the interference has ceased. In automatic systems this is built into the operating protocol, but it doesn't work with a broadband noise floor steadily increased by PLT and/or xDSL.

Protection of HF radio-communications and -intelligence from interference by broadband wire-line telecommunications may be realized by limiting their emissions (Section 4). From the perspective of NATO, it is desirable that these limits be harmonized, for the following reasons:

- Emissions from wire-line communications travel long distances and past international boundaries, therefore, differences in emission limits introduce additional difficulties to the interference assessment and mitigation functions; and
- Different emission levels, thus different PLT-induced increases in ambient noise levels, have the potential to affect interoperability within NATO.

Therefore, it is necessary to find worldwide harmonized standards covering EMC aspects of wire-line telecommunication networks including their in-house extensions. These standards should ensure that broadband wire-line telecommunications will not degrade HF radio reception directly in the immediate vicinity of the wire-lines, as well as far away from mass-deployed telecommunication networks by cumulative interference.

Regarding possible increase of the existing HF noise floor by widespread use of PLT and/or xDSL, the minimum noise levels measured in Europe (Figure 2.3-4) should be fundamental to the protection of sensitive HF receivers. This is supported by UK conclusions from measurements ([4], Appendix N) that state: “An increase above 3 dB over the existing noise floor will reduce the availability on HF circuits and is likely to cause severe problems (… confirmed by the MoD)”. Based on above measurement results, the cumulative interference field strengths far away from telecommunication networks should not be higher than **–15 dBµV/m** (9 kHz bandwidth) across the entire HF-range, if no measurable increase in minimum noise levels are to be tolerated. The Task Group will refer to this criterion as the **Absolute Protection Requirement**. It should be noted that this value is in the range of 10 to 1 dB below the ITU-R Quiet Rural noise curve, which are median values, across the HF band (Refer to Figure 8.2.1-1).