

## RECOMMENDATION ITU-R F.1610

**Planning, design and implementation  
of HF fixed service radio systems**

(Question ITU-R 205/9)

(2003)

The ITU Radiocommunication Assembly,

*considering*

- a) the need for HF radiocommunication services;
- b) that recent developments in HF system techniques make it possible to achieve the following:
  - a higher quality of service by combining the ability to exploit modern signal processing technology with advanced real-time control software;
  - a reduction in transmission times, thereby securing the most efficient use of the spectrum opportunity to decrease interference between users, and the capability to increase traffic density;
- c) that ITU-R has developed a Handbook on frequency adaptive communications systems and networks in the MF/HF bands which describes the nature of adaptive HF systems and their use;
- d) that the performance of the HF system depends on the engineering design and planning of the radio installation,

*recommends*

- 1** that users, who intend to deploy HF systems, should use the information contained in Annex 1 as a guide to planning, system design and implementation.

**Annex 1****Planning, design and implementation  
of HF fixed service radio systems****1 Introduction**

High operational flexibility, easy maintenance of equipment requirements make HF system techniques very useful in world communications; this is particularly emphasized in the case of large geographical areas with low density of telegraph, telephone and data traffic.

At the present time, the development of modern high capacity means of telecommunications, such as satellites and cables, has allowed a wide part of the RF spectrum between 3 and 30 MHz to be available for telecommunications systems, even while meeting the needs of the mobile services.

When the need for a new communications capability between two or more points is first envisioned, and HF radio is suggested as a possible solution, a feasibility study is required to analyse and define the whole system. This study will verify that HF is the appropriate means of communication for the set of system requirements pending, based on a comparison of technical and operational alternatives, and that the economic aspects for the new HF system are compelling.

## 2 Definition and analysis of requirements

A rigorous analysis of the expectations and requirements for the new system should show whether or not this communication medium is proper for this application. Some of the factors that support the use of HF radio over other means of communication are:

- distance
- reliability
- terrain
- message traffic requirements
- message priority requirements
- estimates
- solar cycle and available frequency set
- adequate sites.

A review of the above items will determine if the use of HF radio equipment is appropriate for the proposed application.

### 2.1 Preliminary system design and feasibility study

Once it has been determined that HF is a viable solution to the communications requirement, then a preliminary system design and feasibility study must be conducted. The items, which the system engineer must consider, make up the remainder of this item.

### 2.2 Trunking/routing plans

The trunking and routing plans in the design analysis provide information on the number and types of channels needed to interconnect each of the terminals within the HF system. If the radio system is to be a part of larger network of radios, the implementing engineer will work with the network manager to identify all the stations or nodes to be included in the network as well as their geographical locations. The routing plans have to consider the following factors:

- physical location of each node and the relationship to other nodes in the network,
- physical obstacles (i.e. mountains, buildings, antenna, etc.) between nodes,
- equipment located at each node, especially the power and antenna characteristics,

\*\*\*\*\*

- propagation paths between the stations involved,
- communication interfaces that are connected to each node,
- characteristics and volume and priority of the communications traffic.

### 2.3 Frequency plan

Planning must begin early in the project to secure an adequate list of frequencies to support each link in the HF radio system so that uninterrupted operations are possible both day and night, at any time of the year, and throughout the whole 11-year solar cycle. A frequency prediction program such as Recommendation ITU-R P.533 could be used determining frequency requirements in different conditions.

### 2.4 Personnel manning requirements

To ensure that each station in the network is operated and maintained properly, an analysis of the numbers, training and experience of the personnel that will be required to staff each of the nodes in the network during the required period of service should be conducted early in the planning process.

### 2.5 Support requirements

The system designer must select a site having adequate access roads, water and electrical power supply, fuel for generators, telephone service, post office, medical facilities, and adequate housing and shopping areas for site personnel. In the vast majority of cases, the radio site will be located near a city or large town, and the support considerations mentioned above, will normally be available. But in a few cases obtaining these services may require special logistics effort.

### 2.6 Modes of communications required (voice, data, and image)

The requirement specifications will specify what type(s) of traffic the HF station must be capable of handling. This may be voice only, both voice and data, or may indicate the need to handle other forms of information, such as image, facsimile, or encrypted voice. Each of these types of traffic will indicate additional pieces of equipment that must be considered by the system engineer.

### 2.7 Required $S/N$

The modes of communications required (i.e. voice, data, etc.) will determine the required  $S/N$ . Recommendation ITU-R F.339 can be used to determine what  $S/N$  is needed for the required grade of service (orderwire quality, marginal commercial grade, or good commercial grade), for the type of signal (analogue, digital).

### 2.8 Modulation types and data rates

Normally this information will be furnished in the system designer with the equipment specifications. Care must be taken to assure that equipment interfaced together operates at the same data rates and uses the same modulation types. For HF data transmission Recommendations ITU-R F.763 and ITU-R F.436 have suggestions for different techniques to avoid degradations resulting from the radio channel.

In the solution adopted by the ITU-R, a serial to parallel conversion of the high-speed signal (up to 1 200 bit/s) is effectuated giving 6-12 channels, FDM multiplexed. The low modulation rate (50-100 Bd) so obtained for each subchannel makes the digital signal practically free from multipath distortion. At the receiving side a data concentrator restores the original signal characteristics.

For higher signal speeds (up to 4 800 bit/s), systems based on differential phase keying with frequency shifted tones are sometimes used. In this case the information is derived from the relative difference of phase between two simultaneously transmitted tones. The multipath effects over the two tones are practically the same, because of the small difference value (about 40 Hz). An alternative technique is to transmit the data in serial form and utilize the adaptive equalizer in the receiver to remove the multipath distortion. HF modems for data rates up to 9 600 bit/s have been developed with these signalling formats.

The information is transmitted in analogue or digital form through the radio channel, the transmission types described in this section are defined in Table 1.

TABLE 1  
Types of modulation

| Designator | Modulation form      | Definition                                                                                                                                                                                                                                                                                                                                        |
|------------|----------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CW         | Continuous wave      | Defined as a radio wave of constant amplitude and constant frequency. As a modulation form, CW is defined as an interrupted continuous wave, which is on/off, keyed using Morse code                                                                                                                                                              |
| AM         | Amplitude modulation | A form of modulation in which the amplitude of a carrier wave is varied in accordance with some characteristic of the modulating signal                                                                                                                                                                                                           |
| FM         | Frequency modulation | Amplitude changes of the modulating signal are used to vary the instantaneous frequency of the carrier wave from its unmodulated value                                                                                                                                                                                                            |
| SSB        | Single sideband      | A form of amplitude modulation in which the carrier and one sideband are suppressed and the remaining sideband is transmitted. Also designated as USB and LSB, for upper and lower sideband                                                                                                                                                       |
| ISB        | Independent sideband | A method of double-sideband transmission in which the information carried by each sideband is different                                                                                                                                                                                                                                           |
| RTTY       | Radio teletypewriter | A teletypewriter used in a communication system using radio circuits. Mark/space teletypewriter signals are modulated on radio systems either by a two-frequency shift of the carrier wave, called frequency-shift keying (FSK) or by a two-frequency audio signal, called voice frequency telegraph (VFT) or audio frequency-shift keying (AFSK) |
| Data       | Binary digital       | Information that is represented by a code consisting of a sequence of discrete elements. Digital data is produced by teletypewriters, digital facsimile equipment and computer terminals among other sources. The signals are generally transmitted by digital-to-analog conversion to FSK or phase-shift keying (PSK)                            |

## 2.9 Required circuit reliability

HF circuits are able to provide circuit reliability of 80% (19.2 h/day) to 95% (22.8 h/day). Modern, adaptive equipment such as automatic link establishment (ALE) will operate near the high end of the reliability spectrum.

## 2.10 Terminal facilities required

The term terminal facilities are used here to describe all of the physical plant, primary and auxiliary power, and environmental control systems required to support the new HF system.

## 2.11 Required system lifetime of service

The length of time that the new HF system will be expected to be in service will have an impact on the selection of equipment. If the service is only for a short period of time (several months to a few years), it may be possible to operate with transportable or tactical equipment. Any longer life expectancy will usually require permanently installed equipment.

## 2.12 Facilities site requirements

Because of the long wavelengths involved with HF operations, large amounts of land are required for HF stations. A simple dipole antenna usually requires at least 0.5 hectares of ground, and a rhombic antenna can require from 2 to 7 hectares. If the new HF system cannot use an existing site, then planning must begin very early in the project to find and acquire a suitable location. Additionally, if operation is contemplated on several circuits or full-duplex operation on one circuit, then various antennas must be separated to prevent co-site interference. This antenna separation compounds the need for additional land.

## 2.13 Environmental impact assessments

Frequently, the construction of an HF radio site, or the upgrade of an existing site, will require environmental impact assessments. If towers in excess of 50 m are anticipated, or if the site is to be located near an existing airport or heliport, then notification of the aviation authorities is required.

## 2.14 Required operational date

The date that the station is required to be operational (or the new equipment is required to be operational) may be given in the original statement of requirements, or it may require negotiation with the operational agency. Some of the major system components may have delayed delivery times, so their delivery schedule should be factored into the plans for an operational date.

## 3 Practical aspects

Development of a new or expanded HF radio capability includes more than just the estimates for the equipment. This section contains the direct and indirect project estimates including details about:

- start-up;
- equipment;
- installation.

### **3.1 Start-up**

#### **3.1.1 Project management estimates**

Estimates must include direct and indirect labour for the project manager and any staff, for the time spent monitoring and managing the project. Also included are other items, such as travel.

#### **3.1.2 System engineering estimates**

Estimates must include direct and indirect labour for the system engineer and any assigned staff, for time spent reviewing the project requirements, and the time devoted to system design work. These estimates may also include other direct items such as travel, printing, drafting, etc.

#### **3.1.3 Real estate/land acquisition estimates**

If the site for the new HF station(s) is/are not owned by the operational agency, the site(s) must be acquired through purchase or lease. These acquisition estimates include all estimates associated with the acquiring of the land for the site(s), including the purchase, yearly lease, legal fees, and any taxes that apply.

#### **3.1.4 Site preparation**

These include estimates associated with levelling or grading the land, constructing fences, digging trenches for antenna cables, constructing concrete piers for antenna towers.

#### **3.1.5 Construction or modifications to equipment building(s)**

If the site is a new one, then an equipment building/control facility must be constructed to house the equipment and to provide a place for the site's personnel to operate. If the site is an existing one, then it may be necessary to construct additional rooms for the site building(s) to house the new capability.

#### **3.1.6 Construction or modifications to the site's primary and auxiliary power system**

The HF system requires a.c. power, from the local power company grid to run the HF equipment and site to provide support for equipment such as heating, ventilation, and air-conditioning. If the site is an existing one, this power may be already provided, but in many cases the power distribution system may have to be upgraded with larger transformers, and additional circuit breakers. The engineering plan may also call for the installation of an auxiliary power source, such as a gasoline- or diesel-powered electrical power generator for emergency use.

### **3.2 Equipment**

#### **3.2.1 Equipment in general**

The estimates of the HF system equipment may or may not be the largest item of the project, depending on how many circuits are required, what power levels the transmitters require and the distances between sites. Equipment is usually purchased through one supplier or vendor, although it is not uncommon for multiple vendors to support a large contract. The usual process is for the operating agency to notify all qualified vendors of intent to purchase equipment and/or services.

through the request for proposal (RFP). The interested vendors respond to the RFP with their proposed solution to the customer's need, and with an estimate. The customer can then choose among several competing solutions, and choose the one that best meets their needs. The vendors, often will propose a turnkey solution, whereby they will provide not only all the required equipment, but will also provide or subcontract the installation and site-preparation work as well. The following is a listing of the most common components of an HF radio system:

- transmitter/receiver or transceiver;
- antenna components;
- antenna switches;
- transmission lines;
- terminating devices;
- multicouplers, filters, preselectors, crossover networks, matching devices;
- RF patching;
- terminal equipment;
- voice terminals;
- audio patching equipment;
- d.c. patching facility;
- spare parts facility;
- test equipment, dummy loads, RF power/field strength meters.

### 3.2.2 Transmitter/receiver or transceivers

Depending on the power levels required, the station might be equipped with either transceivers or separate transmitters and receivers. For low-power to medium-power operations, say from 100 W to 1 000 W, it is the usual practice to use transceivers (a combination of transmitter and receiver in the same package). For high-power operation, >10 kW, the standard practice is to run a split site, with the transmitters at one location and the receivers at another. This configuration allows for full-duplex operation, if required.

### 3.2.3 Antenna components

Antennas used in the HF radio operations range from a simple, thin wire, half-wave dipole to large, fixed, or rotatable log-periodic antennas or rhombic antennas, covering many hectares of land. The selection of antennas depends on the number of frequencies to be covered, the RF power levels used, and the circuit reliability requirements. Whether or not the antenna has an omnidirectional or directional pattern is a function of where the stations to be contacted are located. Additional antenna subsystem components that may be needed are transmission line (balanced or coaxial), antenna switching matrix, multicouplers, terminating devices, impedance matching networks, and high- and low-level RF patching.

### 3.2.4 Antenna switches

Antenna switches are found where there are multiple antennas or where different antennas are to be used for different circuit paths. The switch allows the radio operator to switch antennas by a manual switch, located in the radio room, or electrically, from a control console.

### 3.2.5 Transmission lines

Transmission line is used to connect the transmitters/receivers to the antenna. They are selected during the detailed engineering phase, based on the transmitter power, system impedance, and possibility of coupling with other nearby lines, line loss, economic aspects, and atmospheric environment. In general, low- to medium-power transmitters (100 W to 1 000 W) use some form of coaxial cable for transmission line, while high-power stations (>10 kW) use open wire, balanced transmission lines.

### 3.2.6 Terminating devices

Terminating devices are used with no resonant antennas, such as long wires, Vees, and rhombics to make them unidirectional. There are two types of terminating devices: a lumped constant (no reactive resistance) and a distributed constant (lossy transmission line) terminating device. These terminating devices are provided in the characteristic impedance of the particular antenna, and must be capable of dissipating (at least) the average power of the transmitter.

### 3.2.7 Multicouplers

Multicouplers are devices used to permit two or more receivers or transmitters to share the same antenna. In general, only low-powered transmitters use multicouplers, due to the amount of isolation required between transmitters.

### 3.2.8 RF patching

Low-level RF patching is used to interconnect equipment when frequency synthesizers or exciters are used with linear power amplifiers. The output of the synthesizers or exciters is usually on the order of a few milliwatts. High-level RF patching is used to interconnect low powered transmitters (100 W to 500 W) to linear power amplifiers.

### 3.2.9 Terminal equipment

For the purpose of this Recommendation, terminal equipment will include all other ancillary equipment, such as voice terminals, audio switchboards and patching, d.c. patching and teletype terminals, multiplexers for voice-frequency carrier telegraph, facsimile equipment, HF data modems, and crypto devices.

### 3.2.10 Voice terminals

Voice terminals provide the interface between the customer's equipment and the transmission system, call signalling, electrical isolation between the transmit and receive paths, and signal conditioning.

### 3.2.11 Audio patching equipment

Every HF terminal station should have some form of audio patching. It can be as simple as a single jack strip or many jack strips. The purpose of this patching facility is to give the station personnel the ability to have access to all of the audio circuits for:

- emergency traffic routing;
- switching or substituting equipment;
- monitoring the signal quality;
- circuit test and maintenance.

All incoming, outgoing, and most of the intra-station audio circuits will appear on the audio patch. For small installations, the audio patch may be located with the other equipment. In larger sites the audio patch will be separately located and manned, and may even be in a separate building. The audio patch plugs and jacks must be a different size from the d.c. patching equipment to prevent patching errors.

#### *d.c. patching facility*

A d.c. patching facility is required if teletypewriters or other d.c. equipment is present. This patch may be a single- or multiple-jack strip, and is usually co-located with the other ancillary equipment.

#### *Spare parts*

The mission of the site may dictate at what level spares are kept. If the station has a 24-h/day mission it may need to keep not only spares such as fuses, coaxial jumper cables, etc. but may also need to have spare equipment available to swap out with defective equipment, to keep the station operational agency policy or regulations may also dictate the storage of additional spare parts.

### **3.2.12 Installation**

Other items to be included in the estimate deal with the installation process. These may include the following:

- a) bill of materials for installation;
- b) estimates for outside consultants/professional engineers;
- c) estimates of installation labour;
- d) estimates of acceptance testing;
- e) training of site personnel;
- f) lifecycle estimates.

#### **a) Installation bill of materials (IBoM)**

The IBoM is a list of every piece of equipment and parts needed to construct (or upgrade) the HF station(s). In addition to the major items, such as antennas, transceivers, etc., the IBoM includes such things as wire, cable circuit breakers, cable trays, screws, nails, etc. The IBoM is finalized only after the detailed engineering has been completed. Rules of thumb or previous projects may provide estimate data for the initial stages of system planning.

#### **b) Estimates of outside consultants/professional engineers**

Consultants or professional engineers are frequently employed for specialized tasks, such as locating suitable sites or measuring the local electrical noise levels (both man-made and natural).