RECOMMENDATION ITU-R F.1821

Characteristics of advanced digital high frequency (HF) radiocommunication systems

(Question ITU-R 147/9)

(2007)

Scope

This Recommendation specifies the typical RF characteristics of advanced digital HF systems for use in sharing studies for two types of emerging advanced digital HF systems, token passing protocols and wideband modems. Wideband modems are further subdivided into two major systems, multichannel operations and Digital Radio Mondiale operations. A table of characteristics within the Annex to this Recommendation provides a summary of the values needed for sharing studies.

Acronyms

DRM	Digital Radio Mondiale
HFTP	HF token passing
HFWAN	High frequency WAN
ISB	Independent sideband
LSB	Lower sideband
NVIS	Near vertical incidence skywave
OFDM	Orthogonal frequency division multiplex
PSK	Phase-shift keying
QAM	Quadrature amplitude modulation
USB	Upper sideband
WAN	Wide area network
WTRP	Wireless token ring protocol

The ITU-R Radiocommunication Assembly,

considering

a) that there is an increasing use of the spectrum in the HF bands by advanced digital systems;

b) that such advanced systems are not standardized and may have different operational technical characteristics;

c) that the lack of uniformity, in the arrangement and designation of the channels in multichannel transmitters for long-range circuits operating on frequencies below about 30 MHz, may give rise to certain difficulties when one transmitting station has to work with several receiving stations, *recommends*

1 that the technical and operational characteristics of advanced digital HF systems described in Annex 1 should be considered representative of those systems operating in the HF frequency bands up to 30 MHz for use in sharing studies.

Annex 1

1 Introduction

HF systems have specific attributes that make them a viable solution for many radiocommunication requirements. They provide a highly versatile means of radiocommunications to a broad base of users and such equipment can be easily transported to remote and lightly populated areas. There are two technologies that are examples of advanced digital HF systems. This Recommendation specifies the characteristics of these types of systems.

For the purpose of this Recommendation spectrum efficiency is defined as an objective with two parts. The first is to achieve maximum throughput (bits/Hertz/s) and the second is to maximize the number of users, per frequency net. These objectives maximize the ability of fixed communications to achieve performance and mission goals.

2 Token passing protocols

Robust token management schemes are conducive for sharing data channels in HF networks where packet loss rates can be driven to extreme levels due to unforeseen variations in propagation. Network performance can be seriously degraded if nodes are out of contact. Data rates are degraded under these circumstances. Propagation perturbations can reduce efficiency in spectrum usage by HF networks.

Token passing can provide efficient medium access control in heavily loaded networks. However, it has been perceived to be too fragile for use in networks with non-negligible packet loss rates. In this Recommendation, a token management approach is presented that quickly recovers from common token loss and duplication scenarios, and deals efficiently with changes in network connectivity and membership.

Token passing protocols generally provide mechanisms for nodes to enter and leave the network. When token passing is to be used in a WAN, the characteristics of the wireless medium introduces additional token management issues:

– The node holding the token may lose connectivity to its successor, which can result in a lost token.
– The node holding the token can lose connectivity to the rest of the network. The network loses the token.
– A network may become partitioned. One subnetwork must create a new token.
– A node may be reachable only by one other node, so a ring topology is not possible if that node is to be included.

– Nodes from two or more rings using the same channel may come within range of each other. This results in interference unless the rings merge or change channel(s).

– Merging of rings or recovery from a lost token may result in multiple tokens in a ring.

The approach to recovery from connectivity problems places nodes that are not members of an active token-passing ring into a disconnected or floating state in which they either wait to be invited to join the remaining ring or periodically solicit other connected nodes to join with them.

The long link turnarounds inherent in fielded HFWAN technology result in token rotation times on the order of a minute. For example, if link turnaround times are 2 s and we allow each of N nodes to transmit for up to 8 s when it receives the token, we achieve a throughput efficiency of at most 80% with a token rotation time (latency) of up to $10N$ s.

If we limit solicitations to join the ring to one per token rotation, and rotate the authority to solicit among the nodes, each node will solicit once in N token rotations.

With ten nodes in a ring, use of the (non-HF oriented) wireless token ring protocol (WTRP) would result in disconnected nodes remaining out of the network for around 10 min (if there are no colliding responses to the eventual SOLICIT_SUCCESSOR); this is not an attractive mode of operation for a dynamic network in the fixed and mobile service.

The time required for WTRP to reform a new ring from the disconnected remains of two colliding rings would be at least that long: a small ring might emerge quickly, but the remaining nodes would then go silent and wait to be invited to join.

The recovery times for HFTP are more attractive. In the case of a lost link, HF requires N slots (whose duration equals a packet plus a turnaround time) to identify a relay. Thereafter, one additional packet time and turnaround time are required *in each token rotation*. In an example ten-node network, this amounts to a pause of less than 30 s while identifying the relay, and lengthening the token rotation time by a bit over 2%.

In the case of colliding rings, HFTP networks will experience packet collisions until one of the nodes initiates the ring merger, while WTRP nodes will go silent as soon as they detect the foreign ring. However, once a MERGE_RINGS request is received and accepted, the merging rings will resume normal data transfers after $(N + 1)$ packet + turnaround times (i.e. after the SET_SUCCESSOR and the fast token rotation of the DOUBLE_TIME_TOKEN). This amounts to less than 30 s in an example ten-node network.

3 Wideband modems

3.1 Multichannel approach

3.1.1 Independent sideband (ISB) operation

There are modems that convey data in multiple independent sidebands simultaneously. Such modems contain independent PSK/QAM modulators for each audio channel (for information on modulation see Recommendation ITU-R F.763-5, Annex 6), but employ a single forward error correction encoder, whose output bit stream is distributed over the individual channels for transmission. When these channels are carried by contiguous frequencies, the S/N of the channels tend to be similar, although channel errors are not perfectly correlated. Thus, some improvement in output is achieved using receiver diversity.

3.1.2 Operation in non-contiguous channels

When contiguous channels are not available in sufficient quantity to support data requirements, operation in non-contiguous channels is necessary. In this case, channel *S*/*N* values may vary significantly so the distribution of a single coded bit stream over the complete set of channels is not optimal. Instead, separate coded bit streams are generated for each set of channels. Flow control operates independently for each set of channels so that overall data throughput is maintained near the maximum possible for the frequencies in use.

3.1.2.1 Single-channel HF equipment

One nominal 3 kHz channel USB or LSB (selectable).

3.1.2.2 Multichannel HF equipment

Multiple channelling arrangements are possible as shown below:

– Two nominal 3 kHz channels in the USB or LSB (two independent channels in the same sideband – sideband selectable).

– One nominal 6 kHz channel in the USB or LSB (selectable).

– Two nominal 3 kHz channels in the USB and two in the LSB (four independent 3 kHz channels – two in each sideband).

– One nominal 6 kHz channel in the USB and one in the LSB (two independent 6 kHz channels – one in each sideband).

– One nominal 12 kHz channel in the USB or LSB (selectable).

– One nominal 3 kHz channel in the USB and one in the LSB (two independent 3 kHz channels – one in each sideband).

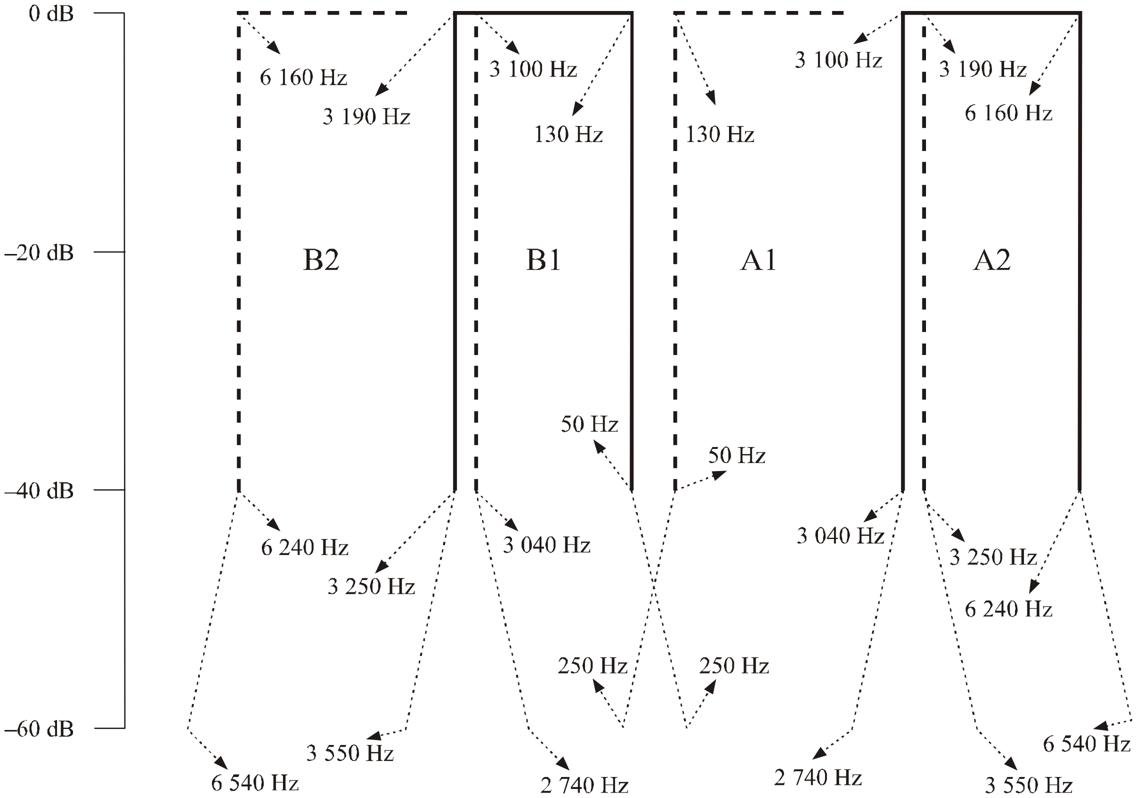
When four-channel independent sideband operation is required, the four individual 3 kHz channels should be configured as shown in Fig. 1, which also shows the amplitude response for these four channels. Channels A2 and B2 should be inverted and displaced with respect to channels A1 and B1 as shown in the figure. This can be accomplished by using subcarrier frequencies of 6 290 Hz above and below the centre carrier frequency, or by other suitable techniques that produce the required channel displacements and inversions.

The suppression of any subcarriers used should be at least 40 dB below the level of a single tone in the A2 or B2 channel modulating the transmitter to 25% of peak envelope power as shown in Fig. 1. The RF amplitude versus frequency response for each ISB channel is within 2 dB between 250 Hz and 3 100 Hz, referenced to each channel’s carrier (either actual or virtual). Referenced from each channel’s carrier, the channel attenuation should be at least 40 dB at 50 Hz and 3 250 Hz, and at least 60 dB at 250 Hz and 3 550 Hz.

Group delay distortion should not exceed 1 500 μs over the ranges 370 Hz to 750 Hz and 3 000 Hz to 3 100 Hz, and 1 000 μs over the range 750 Hz to 3 000 Hz and 150 μs for any 100-Hz frequency increment between 570 Hz and 3 000 Hz. Absolute delay should be less than 10 ms over the frequency range of 300 Hz to 3 050 Hz. Measurements are from end-to-end (transmitter audio input to receiver audio output) with the radio equipment configured in a back-to-back configuration.

FIGURE 1

Four-channel independent sideband operation



Note 1 – Frequencies shown are at the filter dB breakpoint levels in Fig.1

3.2 Digital Radio Mondiale (DRM)

DRM systems (see Recommendation ITU-R BS.1514-1) have undergone experimental demonstration trials for fixed and mobile use.

The DRM system is a narrow bandwidth orthogonally coded digital data transmission system that has the capability to tailor its transmission characteristics to match the service requirements and radio propagation factors. Each of the various subcarriers is modulated using quadrature amplitude modulation (QAM) in order to carry the information content, which also incorporates forward error correcting code elements. Two primary QAM constellations are used: 64-QAM and 16-QAM. In addition, a quadrature phase-shift keying (QPSK) modulation mode is available for highly robust signalling. The data is also interleaved in time over the subcarriers in order to counter time and frequency selective fading. The European Telecommunications Standards Institute has published the DRM option in its “Data Applications Directory” which can be accessed at http://pda.etsi.org/pda/queryform.asp. In the search function for this webpage enter “data application directory.”

3.3 Characteristics

TABLE 1

Characteristics of advanced digital HF radiocommunication systems

Parameter	Propagation mode		
	Ground wave	Sky wave	
		NVIS	Oblique incidence
Frequency band (MHz)	2-10	2-10	3-30
Approximate service area	Up to 80 km	Between 80 and 200 km	Greater than 200 km
Antenna polarization	Vertical	Horizontal	Vertical/horizontal
Transmitting antenna gain (dBi)	1-3	1-6	6-15
Maximum e.i.r.p. (dBW)	1-29	10-32	16-55
S/N (dB)[1]	SSB 17 DRM 18	SSB 25 DRM 26	SSB 26 DRM 26
Necessary bandwidths and types of emission[2]	SSB/ISB: 3, 6, 9 and 12 kHz 3K00J2D, 6K00J2D, 9K00J2D and 12K0J2D		
	DRM: 3, 4.5, 5, 9, 10 and 20 kHz 3K00J2D, 4K50J2D, 5K00J2D, 9K0J2D, 10K0J2D, 20K0J2D		

NOTE 1 – More detailed information on required S/Ns can be found in Recommendation ITU-R F.339.

NOTE 2 – For emission type the last letter (D) refers to data transmissions. If emission is not data (D), substitute (E) for voice, (C) for facsimile, (W) combination or (X) for cases not otherwise covered.

4 Conclusions

HF radio offers beyond-line-of-sight wireless radiocommunications for applications ranging from extended line-of-sight within a small region to global coverage supporting commercial aviation and maritime distress and e-mail messages. The long-haul links available using transportable HF equipment also provide quick communications into disaster areas where the terrestrial infrastructure may have been severed or destroyed.

Despite this ability to communicate beyond line-of-sight, vagaries of propagation and other environmental effects can sometimes produce outages on some HF links while leaving others intact. Thus, reliability in HF networks is enhanced when indirect routing is supported. Most routes in an HF network usually require only a single link. However, in cases where multiple routing options are necessary to maintain quality of service, a single-relay routing mechanism should be useful.

When multiple HF nodes wish to share a channel for efficient one-to-many as well as one-to-one communications, a channel access protocol is needed. One approach uses a token passing protocol. The narrow-bandwidth, high-delay, and high-loss characteristics of the HF channel place especially stringent requirements on such a protocol.

When data transmission requirements exceed the rates that can be achieved in nominal 3 kHz allocations, mechanisms that spread the data transmission over a multitude of such channels may be employed. Wideband modems are available which significantly increase data throughput of a network. Independent sideband operation can support multichannel operation to increase bandwidth while maintaining spectral efficiency.