

RECOMMENDATION ITU-R F.1611*

**Prediction methods for adaptive HF system
planning and operation**

(Questions ITU-R 205/9 and ITU-R 147/9)

(2003)

The ITU Radiocommunication Assembly,

considering

- a) that the number of adaptive HF systems in operational use is growing, specifically automatic link establishment (ALE) systems;
- b) that Recommendation ITU-R F.1110 specifies the general characteristics of adaptive HF systems, and specifically recognizes that adaptive HF systems make it possible to achieve the following:
 - a higher quality of service by combining the ability to exploit modern radio frequency technology with advanced real-time control software;
 - to reduce transmission times, thereby securing most efficient use of the spectrum, reduced interference between users, and the ability to increase traffic density;
- c) that ITU has developed an adaptive HF Handbook which describes the nature of adaptive HF systems and their use;
- d) that frequency-adaptive HF systems are constrained to use the minimum number of active frequency channels in order to limit the potential for interference with other users;
- e) that Recommendation ITU-R F.1337 recommends that automatic and adaptive management schemes be utilized for adaptive HF networks;
- f) that frequency planning with an accurate HF performance prediction model will reduce the margins over which adaptive HF systems must be designed to adapt, with the result that operational procedures can reduce the potential for interference, and overall cost may be reduced;
- g) that Recommendation ITU-R P.533 (and its software program REC533) is the established ITU-R method for HF performance predictions, and is well-suited to be an umbrella for additional (related) prediction methods, some of which are currently used in the control of various quasi-adaptive HF systems and in the design of systems employing forms of ALE;
- h) that other related prediction methods, such as the IONCAP family of programs, are maintained on the same publicly-available Institute for Telecommunication Sciences' (ITS) website as is Recommendation ITU-R P.533;

* This Recommendation should be brought to the attention of Radiocommunication Study Group 3.

j) that all methods downloaded from the ITS website (including Recommendation ITU-R P.533, VOACAP and ICEPAC) have input/output methods that can be reconciled with some additional effort,

recommends

1 that administrations which intend to procure and deploy adaptive HF and ALE systems, based upon the information in Annex 1, should explore the use of HF performance prediction models such as those contained in Recommendation ITU-R P.533 and related models in advance of deployment to establish adaptivity bounds;

2 that the models contained in Recommendation ITU-R P.533, augmented by material such as that contained in the (optional) IONCAP family of programs, are preferred methods for the design of adaptive HF systems and for possible incorporation within software modules for real-time adaptation using recognized real-time channel evaluation (RTCE) technologies (i.e. in-band sounders, advanced channel probes, and out-of-band frequency modulated-continuous wave (FM-CW) sounding).

Annex 1

Adaptive HF system planning and operation using prediction methods

1 Introduction

The ionospheric channel provides the connectivity for the links in an adaptive HF radio circuit or network. To provide proper utilization of this resource the radio system must operate on the ideal frequency or as close to it as practical. This may be the same frequency for a simplex circuit or two different but closely related frequencies for a full duplex circuit. Frequency changes will be dictated by the natural cycles of ionospheric propagation; diurnal, seasonal and sunspot variations. Natural or man-made radio interference may dictate unpredicted changes in the operating frequency. Also solar flares and geomagnetic storms may cause communications disruptions which will also require changes in the operating frequency.

For the most part, the frequency adaptive HF radio system will detect link failure, find another usable frequency, bring the link up on the new frequency and re-establish communications without operator intervention. Several things can create intolerable outages even with the most sophisticated adaptive HF radio system. Equipment failure is one that is unavoidable over the life cycle of the system. It can be mitigated by fault detection, backup power supplies and equipment redundancy in the system design. However, most disruptions are attributed incorrectly to propagation failure. Only

under the most rare of ionospheric conditions should propagation failure occur. Most cases, where the signal power on any frequency across the band is unusable, can be directly traced to improper system design. The areas, which must be considered in the system design, will be discussed in the following paragraphs. Let it suffice to say at this point that the most common areas are:

- inadequate number of frequencies in the authorization list;
- underestimation of radio noise environment at the receive sites;
- antenna radiation patterns which do not match the takeoff and arrival angles of the ionospheric channel; and
- excessive losses in the transmission lines between the transmitter and the transmit antenna or the receiver and its antenna.

2 Frequency planning

Frequency planning begins early in the design phase of the HF radio system. For frequency adaptive HF radio systems, it is essential that the ionospheric model used for making the frequency predictions include as much knowledge as possible concerning the expected variation of the hourly maximum usable frequency (MUF) about the monthly median value (i.e. the MUF) for each of the probable modes on each link in the proposed radio system. The needed accuracy in the prediction model is directly related to the very low S/N s required for the sophisticated adaptivity techniques employed in the modern radio equipment and their associated modems.

We will now outline a sample procedure by which prediction methods can be used to design and operate adaptive HF systems. The discussion in this Annex is based upon the VOACAP procedure that is used within the United States of America administration, having some experience in its application for adaptive HF systems. It is likely that similar procedures could be developed for other methods such as the preferred ITU method, Recommendation ITU-R P.533. At this time the preferred programs in the IONCAP family are VOACAP and ICEPAC, which, along with Recommendation ITU-R 533, are maintained and available at no cost via the Internet from the US Department of Commerce (i.e. <http://elbert.its.bldrdoc.gov/pc-hf/hfwin32.html>). The Recommendation ITU-R P.533 computer program predicts the monthly median MUF. It currently does not explicitly give, as an output, the expected distribution of daily MUF values over the days of the month at that hour for the possible modes.

In evaluating an adaptive HF system, each link in the radio net needs to be evaluated using a recommended prediction program. (In this example, we specify VOACAP, which belongs to the IONCAP family of programs.) These prediction methods were originally developed for non-adaptive systems. However they can be utilized for adaptive system planning.

For conventional HF radio links, the optimum working frequency (OWF) would be determined by finding the most reliable frequency at each hour, season and for high and low sunspot activity. However, for frequency adaptive HF radio systems, the highest probable frequency (HPF) needs to be found. This is the frequency which would not be exceeded more than 10% of the days in the month at that hour and sunspot number; whereas the OWF is the frequency which is exceeded on