

RECOMMENDATION ITU-R F.1337*

**FREQUENCY MANAGEMENT OF ADAPTIVE
HF RADIO SYSTEMS AND NETWORKS USING FMCW
OBLIQUE-INCIDENCE SOUNDING**

(Question ITU-R 205/9)

(1997)

The ITU Radiocommunication Assembly,

considering

- a) the need for highly reliable HF communication services;
- b) the limited amount of HF spectrum available for transmission of voice and data;
- c) the constraints of the time-varying ionosphere, which limits the number of usable channels within the available spectrum;
- d) that effective and efficient regulatory and frequency management techniques are essential to optimize use of the frequencies for fixed and some mobile services between 1.6 and 28 MHz;
- e) that experimental studies, as outlined in the Annex 1, have shown that substantial improvements in channel utilization can be achieved through the use of frequency and path diversity;
- f) that frequency modulated continuous wave (FMCW) oblique incident sounding schemes can provide an accurate real-time assessment of the HF channels available to a network thereby forming the basis of dynamic frequency management;
- g) that the FMCW “chirp” sounding method can be engineered to limit harmful interference, and can be implemented as an external process thereby eliminating reductions in system capacity,

recommends

- 1 that automatic and adaptive management schemes be considered for adaptive HF networks to include dynamic selection of optimum frequencies, the sharing of frequencies within a network, and adaptive selection of alternate network paths;
- 2 that FMCW “chirp” sounding be considered for use in dynamic frequency management schemes including:
 - as a real-time input data source for updating resource management and propagation prediction programmes;
 - as a means for updating the frequency scan lists of adaptive HF systems;
 - for modification and enhancement of the link quality analysis (LQA) matrices for adaptive HF systems;
 - as a complement to the exclusive use of in-band channel sounding, thereby increasing network communication capacity and reducing interference introduced by channel sounding;
- 3 that for adaptive HF networks in the fixed and mobile services, the information contained in the Annex 1 be considered for general spectral planning and in the design of network topologies;
- 4 that further studies are required to evaluate the advantages of sounding technology for frequency management of regional and global adaptive HF networks, emphasizing high latitude and equatorial regions during solar maximum conditions.

* This Recommendation should be brought to the attention of Radiocommunication Study Groups 1 and 8.

Long-term investigation of oblique incidence FMCW sounding as a method for dynamic frequency management of HF communication networks

1 Introduction

FMCW swept-frequency sounding has been used within centralized spectrum management networks to provide real-time channel evaluation (RTCE) for multiple HF circuits. Often referred to as “chirp” sounders, these devices provide the benefits associated with oblique incidence sounding, i.e. for use in the optimization of frequency utilization, improvement in circuit reliability, evaluation of signal-to-noise and interference ratios, and the measurement of ionospheric propagation parameters used by some adaptive HF systems. When linked to centralized spectrum management networks, these sounders can be operated in limited numbers on an intermittent, low-power basis, obtaining real-time spectrum management information for multiple users. This method decreases the need for sounding in general and also limits the total time that a sounder will operate co-channel with other HF transmitters. The net result is improved information to multiple users and a decrease in interference potential due to sounding.

2 System concept

Within centralized spectrum management networks, FMCW swept-frequency sounding information can be used to produce presentations, called ionograms, of received signal time delay versus frequency of transmission. Because the ionospheric channel may be comprised of multiple layers and scattering centres supporting HF communication, received signals at a given frequency will experience varying amounts of time delay distortion. Traces on the ionogram record are indicative of various ionospheric propagation modes which will support communication.

Ionograms are derived by processing a low power FMCW signal over a selectable frequency range, typically 2-30 MHz. The quality of these “chirp” ionograms is superior to those derived from pulse sounders for the same average power because the former employs a spread spectrum waveform characterized by processing gain which is applied against narrow-band interference effects. The nominal average power (and peak envelope power (PEP)) of these systems is 10-100 W or possibly less depending upon the circumstances.

FMCW sounding also reduces the amount of time when any particular frequency is occupied. The nominal rate at which these sounders sweep through the 2-30 MHz band is 100 kHz/s. Consequently, the entire HF band is sampled in about 5 min. The temporal separation between successive sweeps for a given transmitter, called the scan interval, is typically 15 min, but may be set at 30 min or longer. Therefore, the FMCW swept frequency transmitter not only uses modest power, but it has a momentary effect on other HF users within each scan, and the scan interval is relatively long. If a co-channel user is within the coverage pattern of the FMCW sounder, a typical 3 kHz channel may experience a 30 ms blip no more than twice an hour if the scan interval is 30 min.

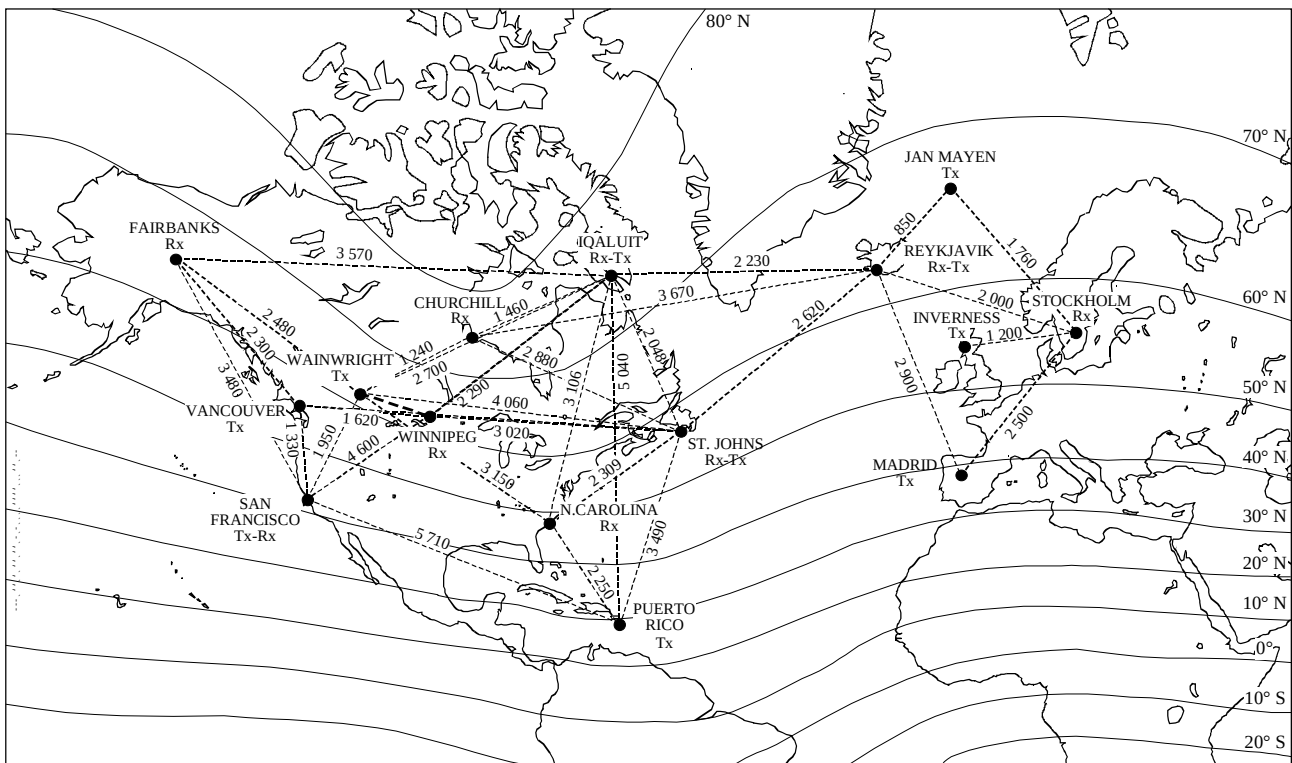
When used within a centralized spectrum management network, the number of sounders can be limited while providing regional or worldwide coverage to a large number of users. This process eliminates the need for individual HF operators to perform their own sounding thereby decreasing the total amount of sounding needed to support a number of users. Channel sounding by individual transmitters, though providing useful information, can add to the congestion of the HF frequency range. FMCW swept-frequency sounding used in conjunction with centralized spectrum management networks can greatly decrease the potential for interference due to sounding.

3 Experimental implications of relevance to the Recommendation

Many experiments have been conducted over the years using FMCW swept-frequency oblique incidence sounders. An extensive experimental program of the potential of frequency and path diversity was conducted between 1993 and 1996, a period of low solar activity. The program was conducted using ten sites in the Northern hemisphere. Figure 1 provides

the geometry. The investigation was directed toward resolving problems associated with adaptive HF communication systems with special emphasis on automatic digital data communication. Other issues of concern included those of radio propagation, frequency management, and system architecture. Paths that were examined have provided information related to circuits within the polar cap, auroral zone, high-latitude trough, as well as mid-latitude channel environments.

FIGURE 1
Geometry of the propagation experiments
 Distances between the transmitter and receiver sites are given in kilometres. Data were obtained between 1993 and 1996.



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Transmitter powers used in the experiments ranged between 10 and 100 W, and the sounder scan interval was set at 30 min. Over 40 path-years of data were collected and analysed, providing estimates of link and star-net communication availabilities under a variety of frequency and station diversity conditions.

Not only was the information significant derived from the data taken during the experiments, but the extensive long-term operations provided evidence of the decreased potential for interference resulting from the used of FMCW sounders with centralized spectrum management networks. During the entire period of operation of these FMCW sounders associated with the experimental activity conducted between 1993 and 1996, there were no reports of interference.

The following conclusions are based upon the analyses of the data collected. Some of the conclusions flow directly from axiomatic principles of HF propagation and the ionospheric interaction.