

RECOMMENDATION ITU-R F.1487*

**TESTING OF HF MODEMS WITH BANDWIDTHS OF UP TO ABOUT 12 kHz
USING IONOSPHERIC CHANNEL SIMULATORS**

(Question ITU-R 213/9)

(2000)

The ITU Radiocommunication Assembly,

considering

- a) that ionospheric radiocommunication in the HF bands is an economically effective transmission medium for many services requiring beyond line-of-sight operation;
- b) that simulation of the ionospheric propagation channel could reduce the time and expense of studying and testing the performance of such service systems;
- c) that some administrations have reported good correlation between the results of laboratory tests conducted on simulators and the results of tests of data modems in operation,

recommends

- 1 that for the simulation of HF ionospheric transmission for systems up to about 12 kHz, the methods described in Annex 1 are preferred;
- 2 that the method described in Annex 2 should be referred to for comparative testing of HF modems;
- 3 that when simulators are used to predict, in a quantitative sense, how well a particular modem may be expected to perform on HF circuits, the representative channel parameters listed in Annex 3 be considered on a provisional basis.

ANNEX 1

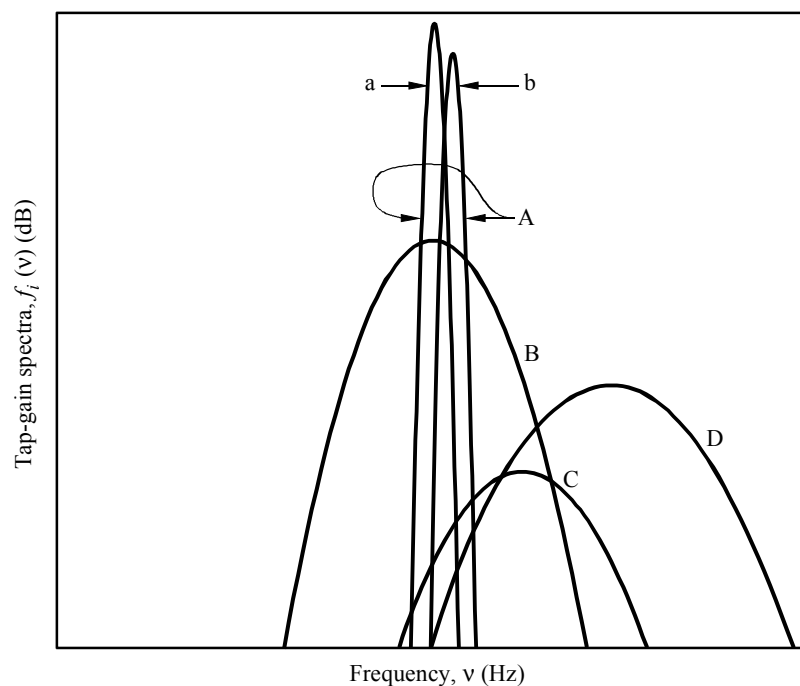
HF ionospheric channel simulations**1 Introduction**

HF ionospheric radiocommunication is typically characterized by multipath propagation and fading. The transmitted signal usually travels over several paths or modes to the receiver via single and multiple reflections from the E and F layers of the ionosphere. Since the propagation times over the paths are different, the signal at the receiving antenna may consist of several multipath components spread in time over an interval of up to several milliseconds. The average heights of the ionospheric layers may increase or decrease with time, which introduces different frequency (Doppler) shifts on each of the multipath components. The ionosphere is also turbulent which causes Doppler spread (fading) of each component and a resultant fading of the composite received signal. All of these effects produce multiplicative signal distortion and degradation of the performance of communication systems.

* This Recommendation should be brought to the attention of Radiocommunication Study Groups 3 (Working Party (WP) 3L) and 8 (WP 8B).

If a continuous wave (CW) signal is transmitted over an HF link the spectra of the received multipath components can appear as shown in Fig. 1. Four paths are present: one-hop E mode (1E), one-hop F mode (1F), two-hop F mode (2F), and a mixed mode (e.g. 1E + 1F). While the two magneto-ionic components (labelled a and b) in the 1E mode have about the same frequency spreads (fading rates), their frequency shifts are significantly different, allowing them to be resolved in frequency. On each of the other three modes, both the spreads and shifts of the magneto-ionic components are essentially the same and they appear as one. The short-term multiplicative distortion characteristics of the HF channel can thus be described in terms of the parameters that specify the signal losses, time-spread and frequency spread characteristics; i.e. the differential propagation times on the several paths, and the signal strengths, frequency shifts, and frequency spreads on each path. These parameters are subject to change on a diurnal and seasonal basis, as well as generally being different on different geographic circuits.

FIGURE 1
Example power spectra for the multipath components of a CW signal



- A: Path 1 (1E mode, a and b represent magneto-ionic splitting)
- B: Path 2 (1F mode)
- C: Path 3 (Mixed mode)
- D: Path 4 (2F mode)

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To compare the performance of two or more systems over real HF links, they must be run simultaneously because propagation or channel conditions vary uncontrollably and cannot be repeated at other times or over other links. The use of a channel simulator has the advantages of accuracy, regularity of performance, repeatability, availability, a large range of channel conditions, and lower cost. However, these advantages are limited if the channel model on which the simulator design is based is not valid. This Recommendation describes a stationary Gaussian scatter HF channel model. It is valid for use in 3 kHz channels, and may be applicable to bandwidths up to 12 kHz wide. A practical implementation of this model may operate at baseband (audio) frequencies and thereby act directly on the output of a transmitting HF modem and provide signals directly to a receiving HF modem. However, when considering the performance of HF systems the effect of other system components should always be taken into account (e.g. transmit and receive filters and level or gain control).

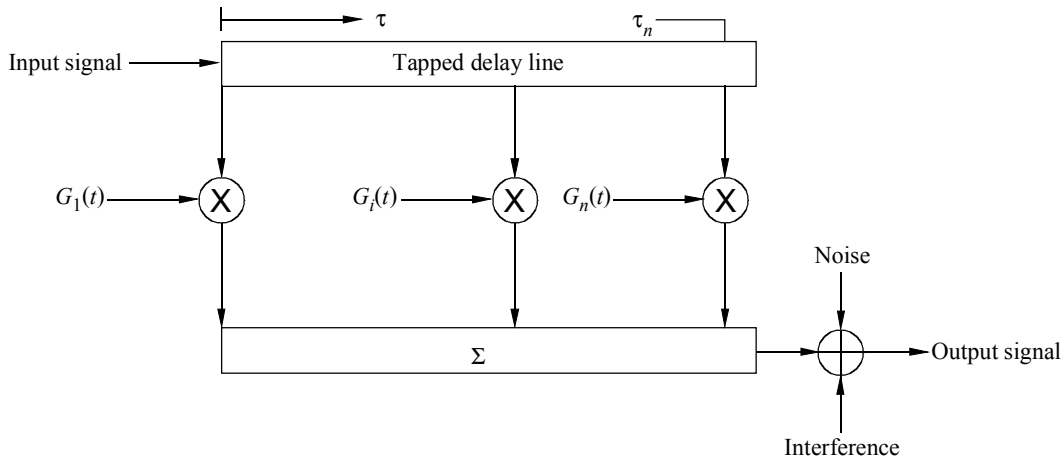
2 Gaussian scatter model

A block diagram of the stationary Gaussian scatter HF ionospheric channel model is presented in Fig. 2. This is commonly known as Watterson model. The input (transmitted) signal is fed to an ideal delay line and delivered at several adjustable taps, numbered 1, 2, ..., i , ..., n , one for each ionospheric propagation mode or path. At each tap, the delayed signal is modulated in amplitude and phase by an appropriate complex random tap-gain function, $G_i(t)$. The delayed and modulated signals are summed with additive noise (Gaussian, atmospheric, and/or man-made) and/or interference (unwanted signals) to form the output (received) signal. For the Gaussian scatter channel model each tap-gain function is defined by:

$$G_i(t) = \tilde{G}_{ia}(t) \exp(j 2\pi \nu_{ia} t) + \tilde{G}_{ib}(t) \exp(j 2\pi \nu_{ib} t) \quad (1)$$

where, the a and b subscripts identify the two magneto-ionic components that can, in general, be present in each mode or path. The tildes indicate that $\tilde{G}_{ia}(t)$ and $\tilde{G}_{ib}(t)$ are sample functions of two independent complex (bivariate) Gaussian ergodic random processes, each with zero mean values and independent real and imaginary components with equal r.m.s. values that produce Rayleigh fading (i.e. that they are Gaussian scatter functions). The exponential functions in equation (1) are included to provide the required frequency (Doppler) shifts, ν_{ia} and ν_{ib} , for the magneto-ionic components in the tap-gain spectrum.

FIGURE 2
Block diagram of HF ionospheric channel model



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Each tap-gain function has a power spectrum, $f_i(\nu)$, that in general consists of the sum of two magneto-ionic components, each of which is a Gaussian function of frequency, ν , as specified by:

$$f_i(\nu) = \frac{1}{\tilde{A}_{ia} \sigma_{ia} \sqrt{2\pi}} \exp\left[-\frac{(\nu - \nu_{ia})^2}{2\sigma_{ia}^2}\right] + \frac{1}{\tilde{A}_{ib} \sigma_{ib} \sqrt{2\pi}} \exp\left[-\frac{(\nu - \nu_{ib})^2}{2\sigma_{ib}^2}\right] \quad (2)$$

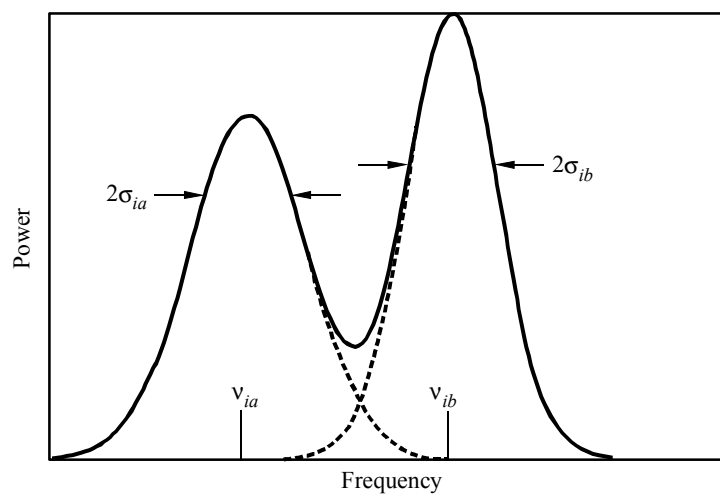
where, $\tilde{A}_{ia}$ and $\tilde{A}_{ib}$ are the component attenuations, and the frequency spread on each component is usually determined by $2\sigma_{ia}$ and $2\sigma_{ib}$. Equation (2) is illustrated in Fig. 3a). Six independent parameters specify a tap-gain function and its spectrum: the two attenuations, $\tilde{A}_{ia}$ and $\tilde{A}_{ib}$, the two frequency shifts, ν_{ia} and ν_{ib} , and the two frequency spreads, by $2\sigma_{ia}$ and $2\sigma_{ib}$.

The tap-gain function described by equations (1) and (2) is general in that it applies when the spectra of the two magneto-ionic components are significantly different and the difference in their delays is negligible. Only one of the two terms in equations (1) and (2) is required in the following cases:

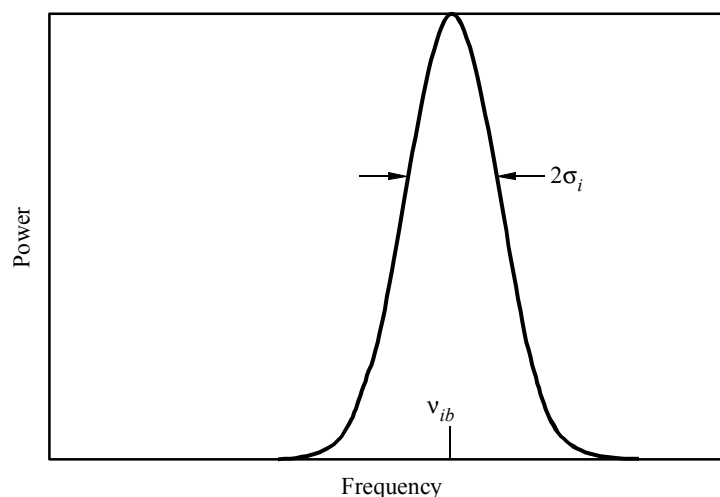
- when the frequency shifts and frequency spreads of the two magneto-ionic components are nearly equal, their spectra nearly match, and a single term can be used with the tap-gain spectrum in Fig. 3b);
- when the two magneto-ionic components have a significantly large difference in delay. In this case, separate delay line taps with appropriate spacing should be used, with each of the two corresponding tap-gain functions and spectra consisting of a single term, again as illustrated in Fig. 3b).

FIGURE 3

Tap-gain power spectra in Gaussian scatter model



a) Two Gaussian scatter power spectra



b) One Gaussian scatter power spectrum

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