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HIGH FREQUENCY COMMUNICATIONS PROBLEMS II

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High Frequency Communications problems

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IONOSPHERIC INFLUENCES

A radio wave is specified in terms of five parameters : its amplitude, phase, direction of propagation, polarisation and frequency. The ionosphere modifies these parameters as follows:

Refraction

The change in direction of propagation resulting from the traverse of a thin slab of constant ionisation is given approximately by Bouger's law in terms of the refractive index and the angle of incidence; a more exact specification must include the effects of the Earth's magnetic field. The refractive index is a function of the electron density and electron-collision frequency, together with the strength and direction of the Earth's magnetic field, the wave direction and the wave frequency. The dependence on frequency leads to wave dispersion of modulated signals. Since the ionosphere is a doubly-refracting medium it can transmit two waves with different polarisations. The refractive indices appropriate to the two waves differ. Refraction is reduced at the greater wave frequencies.

Change in phase-path length

The phase-path length is given approximately as the integral of the refractive index with respect to the ray-path length. Ignoring spatial gradients, the change in phase-path length introduced by passage through the ionosphere to the ground of signals at VHF and higher frequencies is proportional to the total-electron content. This is the number of electrons in a vertical column of unit cross section.

Group delay

The group and phase velocities of a wave differ because the ionosphere is a dispersive medium. The ionosphere reduces the group velocity and introduces a group delay which for transionospheric signals at VHF and higher frequencies, like the phase-path change, is proportional to the total-electron content.

Polarisation

Radio waves propagating in the ionosphere are split into characteristic ordinary and extraordinary waves. In general these are elliptically polarised, the polarisation ellipses have the same axial ratio, orientations in space that are related such that under many conditions they are approximately orthogonal, and electric vectors which rotate in opposite directions. The polarisation ellipses are less elongated the greater the wave frequency. The phase paths of the ordinary and extraordinary wave components differ, so that in the case of trans-ionospheric signals when these components have comparable amplitudes, the plane of polarisation of their resultant slowly rotates. The effect is known as Faraday rotation.

Absorption

Absorption arises from inelastic collisions between the free electrons, oscillating under the influence of the incident radio wave, and the neutral and ionised constituents of the atmosphere. The absorption experienced in a thin slab of ionosphere is proportional to the product of electron density and collision frequency, inversely proportional to the refractive index and inversely proportional to the square of the wave frequency. Normal absorption is principally a daytime phenomenon. At frequencies below 5 MHz it is sometimes

so great as to completely suppress effective propagation. The absorptions of the ordinary and extraordinary waves differ, with in the range 1.5-10 MHz the latter being significantly greater.

Amplitude fading

Fading arises from movements or fluctuations in ionisation. The principal causes are : variations in absorption, movements of irregularities producing focusing and defocusing, changes of path length among component signals propagated via multiple paths, and changes of polarisation, such as, for example, due to Faraday rotation. These various cases lead to different depths of fading and a range of fading rates. The deepest and most rapid fading occurs from the beating between two signal components of comparable amplitude propagated along different paths. In the tropics flutter fading leads to fading rates of about 10 Hz but at temperate latitudes fading rates rarely exceed 1-2 Hz.

Frequency deviations

Amplitude fading is accompanied by associated fluctuations in group path and phase path, giving rise to time and frequency dispersed signals. When either the transmitter or receiver is moving, or there are systematic ionospheric movements, the received signal is also Doppler- frequency shifted. Signals propagated simultaneously via different ionospheric paths are usually received with differing frequency shifts. Frequency shifts for reflection from the regular layers are usually less than 1 Hz but shifts of up to 20-30 Hz have been reported for scatter-mode signals at low latitudes. Frequency spreads at mid-latitudes are a few tenths of a Hertz for each propagation mode, but at high latitudes on auroral paths total spreads of several tens of Hertz can occur.

Reflection, scattering and ducting

Reflection may take place over a narrow height range as at LF or rays may be refracted over an appreciable distance in the ionosphere as at HF. Weak incoherent scattering of energy occurs from random thermal fluctuations in electron density, and more efficient aspect-sensitive scattering from ionospheric irregularities gives rise to direct backscattered and forward-scatter signals. Ducting of signals to great distances can take place at heights of reduced ionisation between the E- and F-regions, leading in some cases to round-the-world echoes. Ducting can also occur within regions of field-aligned irregularities above the maximum of the F-region.

Scintillation

Ionospheric irregularities act as a phase-changing screen on transionospheric signals from sources such as Earth satellites or radio-stars. This screen gives rise to diffraction effects with amplitude, phase and angle-of-arrival scintillations.

COMBATING TECHNIQUES

At HF there are needs to improve the performance of radiotelephony and radiotelegraphy circuits, both by better system design and with better operating procedures. Objectives must include the integration, via automatic control, with other circuits of the general telecommunications network.

Diversity

Diversity systems provide a means of improving reception quality. Space diversity is most common, but other forms such as polarisation diversity, frequency, time and wave-arrival-angle diversity can all have merit. Channels may be switched or combined, for example by linear or quadratic addition. The optimum configuration depends on the received signal characteristics and there is scope both for improving the specification of these and for determining which systems perform best. For example, optimum separations in space, frequency or time under different conditions remain to be quantified.

Frequency agility

There are particular advantages, except for sound broadcasting where flexibility is denied, in introducing real-time channel evaluation techniques. These can form part of the communication link or be implemented independently. They may involve low-power idle tones or consist of coded transmissions sent from the normal receiving site to the transmitter containing information on channel occupancy, as in the CHEC system operated over air-ground links. Otherwise, use can be made of oblique-path sounders which sweep the whole HF band. The early hopes of limited networks of sounders providing information to control large numbers of circuits have not been fulfilled, largely because of the extreme spatial variability of the ionosphere; the optimum way ahead is not clear. Certainly with microprocessor control, frequency-agile systems can now be implemented fairly readily.

Error-correction coding

There is much work in progress in the study of error control techniques providing forward error correction. The need is for error correcting codes which detect errors and automatically call for repetition (ARQ). Block codes with a burst error correction capability, adaptive convolution codes and soft-decision techniques are all under investigation.

Adaptive antennas

The use of directional antennas is clearly important to improved signal/noise ratio. Additionally, if unimode reception can thereby be achieved, this provides some fading suppression. On the other hand there may be greater advantages sometimes in interference rejection with adaptive receiving antennas producing steerable nulls. The next few years seem likely to see the operational exploitation of adaptive antennas on practical radio circuits.

Variable data rates

Variable data-rate systems, adapted to changing ionospheric conditions, are expected to be evolved. Although fixed data transmission rates of up to 2.4 kbit/s are now being used with differential phase shift keying, mention should be made of the particular advantages of other modulation systems. Multi-frequency shift-keying synchronous systems such as Piccolo provide very low error rates without error coding, even for low signal/noise ratios. There is current interest in spread-spectrum techniques and a 300 bit/s system within a 3 kHz channel has been successfully implemented in Canada. Spread-spectrum systems have the advantages of being resistant to narrowband interference, and immune from selective fading, multipath intersymbol interference and Doppler shifts. Further study of both narrowband and wideband prospective systems seems desirable.

In the field of radiotelephony there are obvious advantages in the introduction of band compression techniques involving SSB with reduced or suppressed carriers, both in order to provide greater interference rejection and so as to minimise selective fading effects. Lincompex companders consist of a compressor and expander linked by a control channel separate from the speech channel. With the increasing use of vocoders for digital telephony, the need is for optimum syncompex systems involving a synchronised digital control channel.