LETTER TO THE EDITOR

Some comments on diurnal change of lower ionosphere equivalent height

(Manuscript received July 4, 1968)

The diurnal variation of the height of the upper boundary of the earth-ionosphere spherical waveguide for VLF (very-low-frequency) waves was discussed in a previous paper (Kaufmann, Souza & Mendes, 1968—a work that will be referred as paper I) being shown that the effect could be approximately understood with the use of the waveguide mode propagation theory (Wait, 1959; Wait & Walters, 1963; Watt & Croghan, 1967), invoking the presence of the second mode of propagation during nighttime, and considering the ficticious height change due to the dirunal variation of the mean conductivity gradient of the lower ionosphere—being 0.5 km^{-1} at nighttime, and 0.3 km^{-1} at daytime.

Another experiment was carried on this effect, consisting in the simultaneous reception of transmissions from NAA (Cutler, USA, wavelength $\lambda_1 = 16.8$ km, distance $d_1 = 7.9$ Mm) and from NSS (Annapolis, USA, $\lambda_2 = 14.0$ km, $d_2 = 7.6$ Mm), at Campos do Jordão (São Paulo, Brazil) by two tracking stations, controlled by an atomic frequency standard. The period of observation was from 11 April to 26 April 1968, and the experimental results are shown in Fig. 1. It was very interesting to consider that both propagation paths were practically at coincident directions, presenting similar lengths (being both a 4-hop path). Thus, a number of assumptions on the earth-ionosphere waveguide configuration differences for the two paths were not necessary to be considered in this analysis.

The measured phase advances were of 0.884 cycles for NAA and of 1.295 cycles for NSS. The assumption of the presence of a dominant first-order mode of propagation during nighttime (which reference height was assumed as 90 km) leads to apparent height changes of 16.6. km and 23.2 km, respectively (after Wait, 1959), unconsistent with that hypothesis. Considering now the ficticious height variation for the first-order mode (Wait & Walters, 1963; Frisius, 1966, and paper I)

$$m\frac{\lambda}{4\pi}\{(\alpha_2)_D-(\alpha_2)_N\}, \tag{1}$$

where the indices D and N are for daytime and nighttime conditions, m is the number of hops along the path, α_2 is a term correspondent to the phase lags upon reflection in the ionosphere for highly oblique incident waves (Wait & Walter, 1963); the contributions found were of the order of 17.1 km for NAA and of 18.2 km for NSS. This do not explain yet the difference between the height variations found, nor their order of magnitude. The presence of the second-order mode of propagation during nighttime must be then considered, in order to estimate the actual phase advance only for the first-order mode.

Following the same approach mentioned in paper I, estimating the relative values for nighttime mode I and mode 2 electric phasors, after Bates & Albee (1964) and Watt & Croghan (1967)—being $E_1/E_2 \simeq 2.58$ for NAA and $E_1/E_2 \simeq 0.44$ for NSS—it was found that the mode 1 phase advance from nighttime to daytime should be of 1.359 cycles for NAA and of 1.625 cycles for NSS, corresponding to mode 1 apparent height change of 25.6 km and of 27.4 km, respectively. Discounting the ficticious height variation effect, estimated with (1), the equivalent height variation for the lower ionosphere was of the order of 8.5 km and 9.2 km, respectively—a somewhat lower value than found in paper I, but keeping the same order of magnitude and favouring reason-

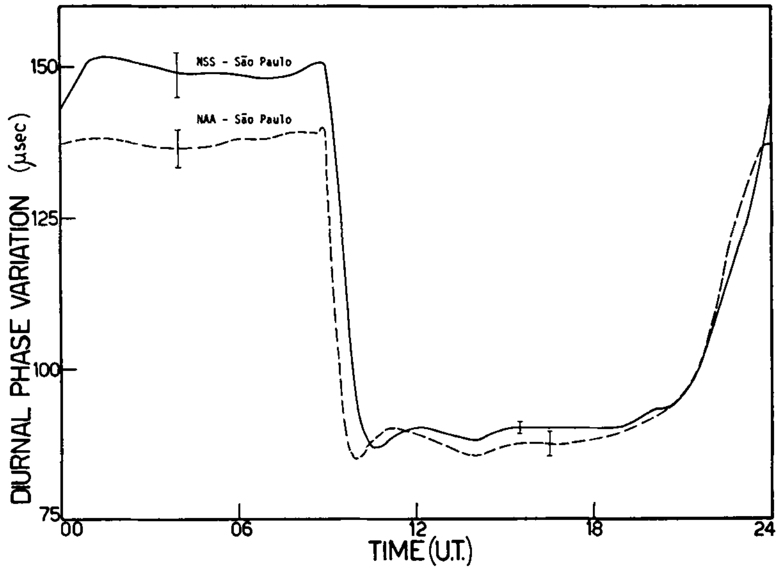

Fig. 1. Diurnal phase variations averaged for the period selected, of transmissions received from NAA and NSS, at São Paulo (Campos do Jordão). Vertical bars indicate the standard deviation ranges during nighttime, and during daytime.

ably the used approach—recalling that these values may suffer a dependence on the season. Finally, we should like to emphasize that certain parameters, necessary for the calculations, are only approximately known, and can constitute a significant source of errors. This is the particular case of the calculation of nighttime values for the electric phasors, which is based on the roughly estimated transmitters' radiated power.

Acknowledgements.—We are indebted to Maria Helena Paes de Barros for help in the calculations, and to Olivetti Industrial SA that made available a Programma 101 computer used in this work. This research was supported by the US Army Element, Defence Research Office, Latin America, grant no. DA-ARO-49-092-65-G77, Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) and Conselho Nacional de Pesquisas (CNPq).

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