2-IV A3

LONG RANGE PROPAGATION STUDIES OF HF SIGNALS EMITTED BY A SATELLITE

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An HF signal emitted by a satellite can propagate over very long distances around the earth in spite of the low radiated power, due to a low loss propagation mode. Such fact can be explained only by the existence of a kind of ionospheric channeling mechanism causing the signal to be ducted inside the ionosphere.

The subject has stimulated a number of experimental and theoretical works, a review of which is presented in a paper by Carrara et alii[1]. The main theoretical efforts for understanding this propagation mechanism were based on ray-tracing procedures. The general method is concerned with the integration of the ray canonical equation which govern the ray path in an anisotropic non-homogeneous medium, as given in spherical form by Haselgrove[2]. Such equations originate from Hamilton optics and allow the earth's magnetic field and the electron density's space variations, within the limits of geometrical optics, to be taken into account.

The results of this analysis demonstrate the possibility of such a type of ray guidance and evidence the main factors influencing the long range ducted propagation.

However the static model of the transmission medium is not sufficient to describe the actual configuration of the guiding channel. To study more realistically the phenomenon of the guided propagation, also for practical application, the above mentioned research methods must be integrated with an investigation on the role played by the irregular structure of the ionosphere and by its time fluctuations.

For this purpose the medium can be taken as a randomly variable medium. The attenuation can fluctuate and the various path lengths too. In addition the multipath and the Doppler effect complicate the propagation mechanism. The analysis of these characteristics can be developed by using the concept of linear filter theory in terms of the time-varying transfer function. Following this approach, the filter random modifications, that is the modification of the transmission channel, can be assumed to be quasi-stationary.

By considering the time-frequency autocorrelation function:

$$R(\alpha,\beta) = H^*(f,t)\, H(f+\alpha, t+\beta)$$

of the complex envelope H(f,t,) of the received signal corresponding to the transmission of a unity monochromatic signal, the two-dimensional Fourier transform of $R(\alpha,\beta)$ represents the power density function in the time and frequency domain, that is the so called "scattering function" $\sigma(\tau,\nu)$. The scattering function makes evident the time spread of the different possible energy paths and the frequency spreading due to the medium fluctuations along the various propagation paths.

At the IROE (Istituto di Ricerca sulle Onde Elettromagnetiche - Firenze) the data of the long range propagation experiment[3] of the San Marco 2* satellite were used for the analysis of the "frequency scattering function" $\sigma(\nu)$.

The function:

$$\sigma(\nu) = \int \sigma(\tau,\nu)\, d\tau$$

was evaluated in time intervals of 0.2 sec. for variuos cases of quasi antipodal paths, which occur very frequently as shown for example in Fig.1. In addition to the power spectrum, the autocorrelation function and the amplitude distribution were also computed.

The analysis of the evolution of these functions permits the study of the configuration of the propagation channel; an example is shown in Fig.2. The data obtained will be taken into account for the final project of a new propagation experiment[4] conceived to determine the complete scattering function $\sigma(\tau,\nu)$.

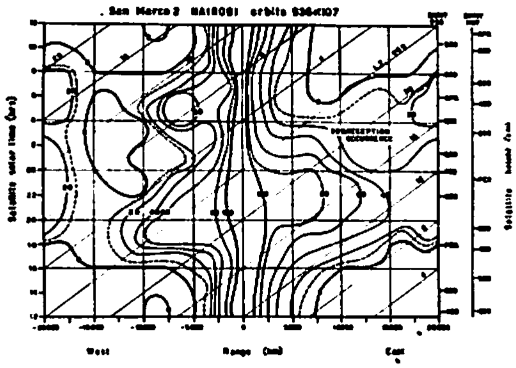

Fig.1 - San Marco 2 long range propagation experiment: reception occurrence at Nairobi station versus satellite-station range. Reception occurrence greater than 20% can be noted at antipodal distances.

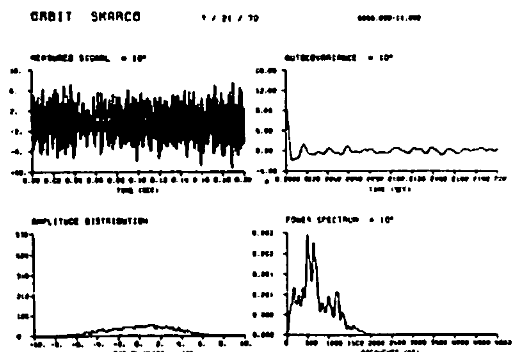

Fig.2 - Autocorrelation function, amplitude distribution and power spectrum of the San Marco 2 signal received in Nairobi during orbit 938 when the satellite was 17,000 Km west of the station. Two different main paths can be noted corresponding to the two measured peaks of the power spectrum.

<u>References</u>

[1] N.Carrara, M.T.de Giorgio, P.F.Pellegrini - Space Science Reviews 11, 160, 1970.

[2] J.Haselgrove - The Physics of the Ionosphere - The Physical Society London, p. 355, 1955.

[3] P.F.Checcacci, P.F.Pellegrini - Report of the Joint Satellite Studies Group (Addendum) JSSG Report N.3 - edited by the Auroral Observatory Tromsø, Norway p.181, 1968.

[4] P.F.Pellegrini - Acts of the Symposium on the Future Application of Satellite Beacon Experiments, Lindau Harz, Germany, in press.

* The long range propagation experiment of the San Marco 2 satellite was performed during June-July 1967. The emission was at 20.005 MHz with an output power of about 0.7 W. The signals received by four stations, Nairobi, Quito, Lima, Firenze, were converted on 1 KHz center frequency and recorded on magnetic tape. The orbit inclination was 2.9 degrees, the perigee and the apogee were 213 and 635 Km respectively.