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AUTUMN COURSE ON GEOMAGNETISM, THE IONOSPHERE AND MAGNETOSPHERE

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IONOSPHERIC RADIOPROPAGATION

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2.1. Introduction

At present time there is a tendency to replace long distance HF communication links by others more efficient and stable. However, many applications and areas of the worlds still need the ionospheric communications. The co-existence of complex and simultaneous systems make necessary to develop techniques and methods to guarantee an adecuate utilization of the radio spectrum. The way to solve the problem is often the use of sofisticated electronic technology and a large number of frequencies. This way, in turn, introduces low efficiency, interference among systems and saturation of the spectrum. The correct approach is to develop adecuately the "spectrum engineering" to optimize the utilization and time sharing of the HF band. This is of great importance for regions like South America, where the use of the HF portion of the radio spectrum is still, and will be in future, very important to communicate small communities or isolated people with larger centers, or to send coded informations from unmanned sites. The main requirements in these cases are high reliability and security in the operation of the radio links.

Estimates of HF radiopropagation conditions are made on the basis of statistical prediction of the ionospheric parameters variations. Ionospheric effects on radiopropagation are characterized by a Transmission function and a Field Strenght Loss function. The first one is concerned with reflection of radio waves in the ionosphere and the second one with the absorption of the wave energy when crossing the ionized media.

The transmission function represents the probability of existence g(f) of an ionospheric propagation mode for a given frequency f. It generally decreases with increasing value of f and depends on the time, geographic, and geometric characteristics of the radio link. It is also a strong function of the solar activity. As frequency increases for given conditions, q(f) reaches a low limit below which the radio link is not possible. The corresponding frequency is the MUF or Maximum Usable Frequency. For it: q(f) = 5.

In field applications it is important to know when the field strength of the radio signal of a given frequency is high enough to allow intelligible communications. The function of field strength loss is then expressed by the probability of the field strenght of the signal to be higher than the radio noise at the given frequency. In other words, it is a function of the signal to noise

ratio or q(S/N), that depends upon geophysical and solar parameters, radiated power and minimun S/N required by the specific situation. It increases with the frequency and for this reason a lower limit in the useable frequencies exists, below which the probability of on acceptable S/N is too low. The corresponding frequency is called the LUF or Lowest Useful Frequency. At this frequency: q(S/N) = .5.

The MUF and the LUF for a given link, hour, month and year are the limits of the usable radio frequency band. In order to increase possibilities of establishing the radio link the upper limit is reduced to the value of frequency that corresponds to q(f) = .9. It defines the FOT or Optimun Working Frequency or Optimun Traffic Frequency.

In summary, the basis of the study of telecommunications in the HF band is given by the analysis of the functions q(f) and q(S/N). Fig. 2.1. (J.L. Verdile, private communication, like the other figures of this chapter) shows the typical form of this functions and the position of the characteristic frequencies defined above.

2.2. Ionospheric predictions in South America

2.2.1. Argentina:

In this country research and development groups active in radio propagation studies and applications are integrated in the National Programme of Radiopropagation (PRONARP).

2.2.1.1. Prediction services:

The Laboratorio Ionosférico de la Armada (LIARA) has developed a service of HF ionospheric predictions for the South American sector, using base data from 18 vertical sounding stations in all the continent and the Antartic peninsula. The main parameters given by computer output in different formats are:

- Maximun Usable Frequencies (MUF)
- Optimun Traffic Frequencies (FOT)
- Minimun Useful Frequencies (LUF)
- Field Strenght
- Reliability

The LUF is computed using a simplified version of the method given in the NBS Circular 462, from solar activity, radiated power and type of emission. Field strength and the reliability pertentage C are predicted by a computer program that contains the method of CCIR Report 252 including radio noise values of CCIR Report 322. For radio links terminals outside the South American sector, MUF values are computed using the method of CCIR Report 340. Public monthly services (six months in advance) affered by LIARA are:

LIARA A-1: MUF predictions between 2 and 30 MHz for any link in the South American sector.

LIARA A-2: Usable frequency band (FOT-LUF) prediction for 54 tipical coastal radio links in Argentina.

LIARA A-3: Usable frequency band (FOT-LUF) for radio links between capital cities of the South American countries.

In addition more specific services of interest to other organizations in Argentina and special services on network planning are offered by LIARA.

It can be shown that the prediction of the complete set of parameters listed above allows a rational analysis of individual radio links and complex networks. Typical information obtained is concerned with the real importance of radiated power on the link reliability versus adecuate frequency election. Fig. 2.2. displais an example for the transecuatorial radio link Buenos Aires-Caracas. Reliability is given as a functions of power for different frequencies and hours of operation. From the graphs is easily seen that a power increase does not introduce important improvement of the reliability. They also show that 22 MHz is the more reliable frequency when used at 21.00 hours.

Fig. 2.3. displays an example of FOT-LUF chart produced by LIARA. Fig. 2.4. shows the computer output with the analysis of a small network with a set of three frequencies. The upper part of the figure gives the assigned frequencies and the computed percentage of utilization that totalizes only 85.6%. The lower part displays the maximun of use of 95.7% of the time.

LIARA produces also predictions for the ham radio on a regular basis and under special request like the service performed to the Radio Club of Cochabamba in Bolivia. Fig. 2.5. gives a tipical hamband prediction for this purpose.

2.2.1.2. Recent contributions to CCIR documents:

a) "Results of comparisons between measured HF field strength data and values estimated by the method of Report 252-2", (1978), by M. Perés. (These results have been included in Report 571).

b) "Results of comparisons between measured and predicted field strength for a modified version of the method of Report 252-2, Part I", (1980), by M. Perés and L. Filkenberg. (This paper is referenced in Report 571).

c) "Results of comparisons between measured and predicted field strength for a modified version of the method of Report 252-2, Part II" (1981), by M. Perés and L. Finkelberg.

d) "Proposal for the modification of Recommendation 534: Method for calculating sporadic-E sygnal strength "Document 6/221-S, june 1981. (This contributions shows the results of sporadic-E propagation on 47.6 MHz between Tucumán and Buenos Aires at a distance of 1060 km. The percentage of time observed with possible interference by sporadic-E propagation is larger-in particular during spring and summer- than predicted by Recommendation 543 for South America).

e) "Variability of the equatorial sporadic-E ionization" Document 6/220-S, June 1981 (This contributions to Reports 259-4 and 725, Study Programme 30B/6, and Question 25/6, is based on the results by Giraldez (1980a) and Giraldez (1980b) (see section 1.1.3.) on the seasonal variations of the latitudinal width of the equatorial Esporadic-E zone both in the Asiatic and American sectors).

f) "Proposal for the modification of Recommendation 534: "Method for calculating sporadic E signal strength" Document 6/197-S, may 1981. (This document proposes to include in Recommendation 534 a set of curves with E_s data for the South American sector).

g) "Technical aspects of the optimun use of the radio spectrum and time sharing of frequencies between 3 and 30 MHz; Project of Report for Questions 44/1 and 45/1". Documents 1/177-S and 3/71-S, July 1981 (This proposed Report is the result of the work on HF Spectrum Engineering carried out in Argentina).

2.2.2. Other countries:

The Instituto de Pesquisas Espaciais of Brasil uses the ionospheric parameters obtained by the vertical ionosondes in Cachoeira Paulista and Fortaleza to make comparisons with CCIR ionospheric predictions. MUF predictions are published by the Centro Técnico Aeroespacial and by the Instituto de Pesquisas da Mariña of Brasil one month in advance. Field strength computation are made with a simplified method derived from the CCIR Report 252-2, but they are not published.

In Chile the local Navy is producing MUF and FOT predictions but publications are not available.

Also Perú is obtaining MUF prediction without know open publication.

The author of these notes does not know of other prediction work be made in South America.

2.2.3. Figure Captions

Fig. 2.1. The probability function of existence of an ionospheric propagation mode q(f) and the probability function of the signal to noise ratio q(S/N).

Fig. 2.2. Analysis for the radio link Buenos Aires-Caracas. Variation of the reliability as a function of radiated effective power for two conditions of solar activity (R = 10 and R = 120) and three frequencies (14.7, 17.6 and 22 MHz). Time of operation in hours is given in brackets.

Fig. 2.3. Example of FOT and LUF prediction map for head station Buenos Aires and given month and time.

Fig. 2.4. Example of computer output with the analysis of a small network using three frequencies (see text).

Fig. 2.5. Example of radio wavelenght bands prediction chart for the head station Cochabamba.

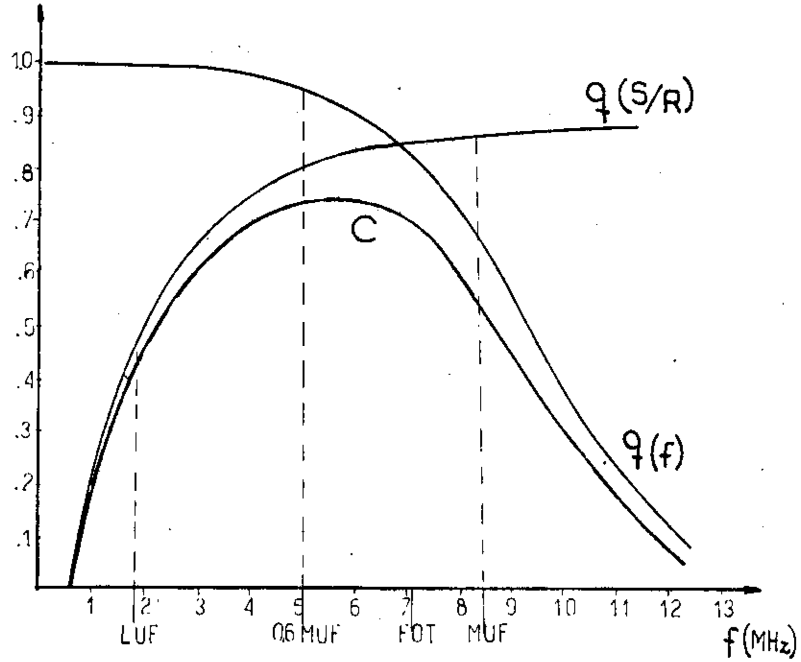

Fig. 2.1

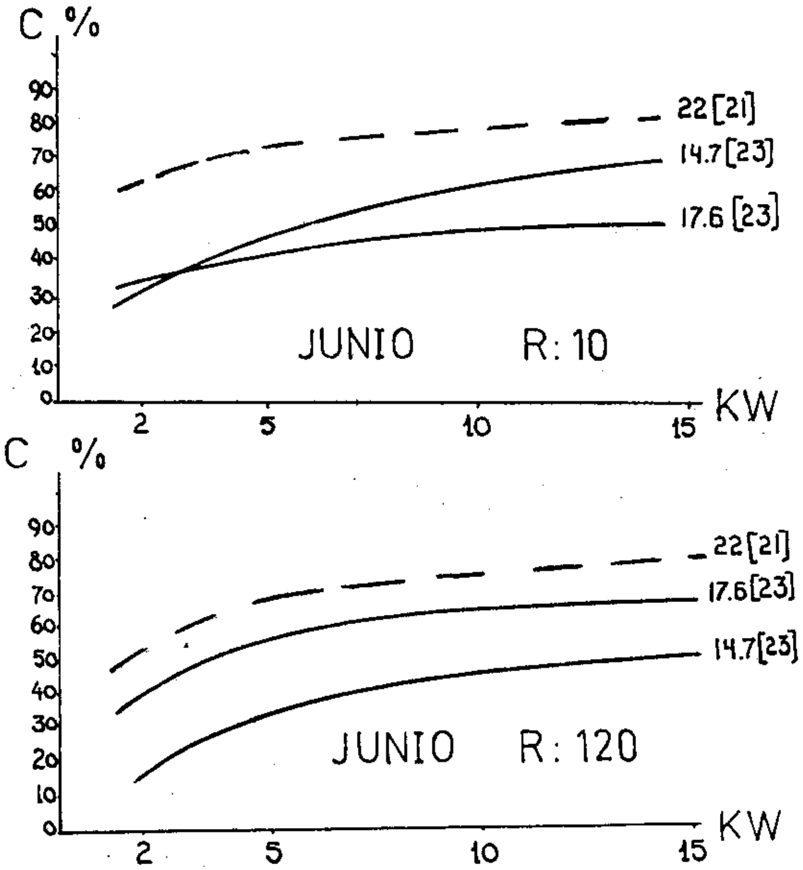
C %
22 [21]
14.7 [23]
17.6 [23]
JUNIO R: 10
KW
C %
22 [21]
17.6 [23]
14.7 [23]
JUNIO R: 120
KW

Fig. 2.2

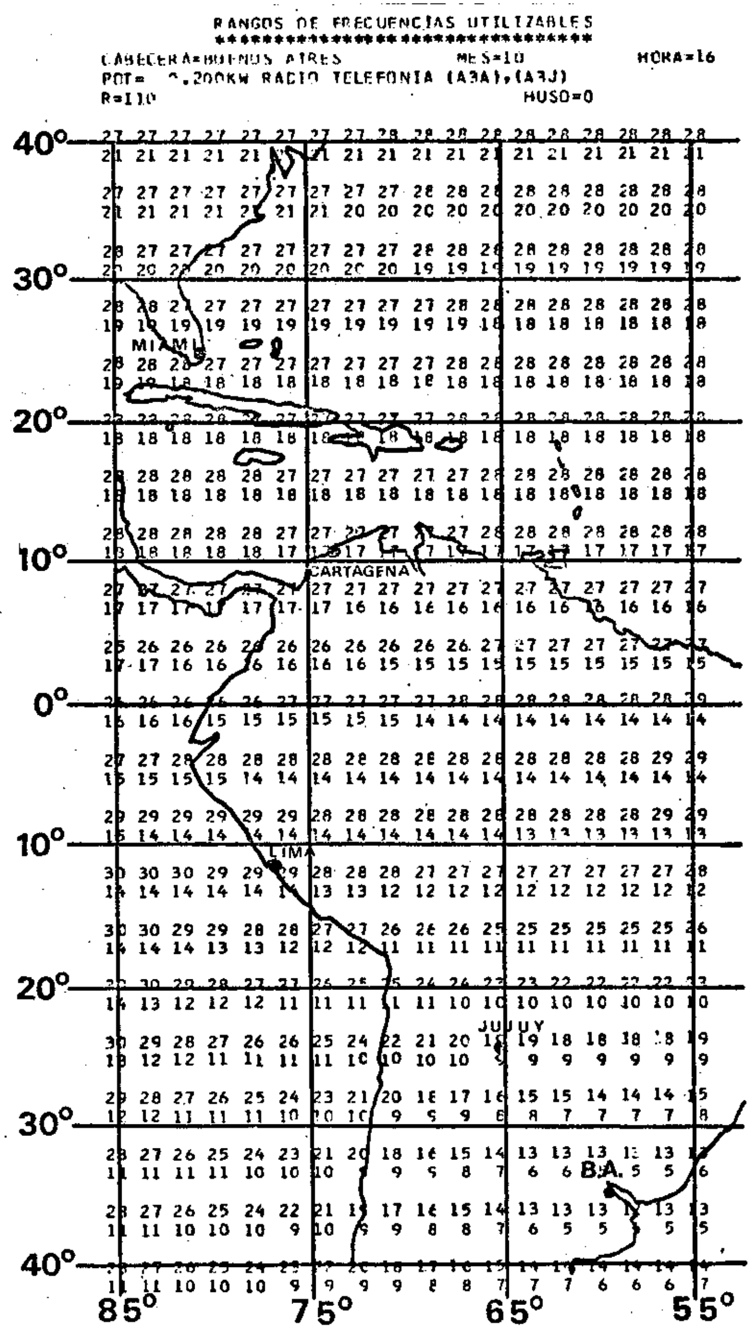
RANGOS DE FRECUENCIAS UTILIZABLES
CABECERA=BUENOS AIRES MES=10 HORA=16
R=110 HUSO=0
MIAMI
CARTAGENA
LIMA
JUJUY
B.A.

Fig. 2.3

FRECUENCIAS ACTUALES	PORCENTAJE UTILIZACION
5.0 - 5.5	56.7
12.0 - 12.5	17.8
8.0 - 8.5	11.1

PORCENTAJE TOTAL DE UTILIZACION 85.6

FRECUENCIAS RECOMENDADAS	
7.0 - 7.5	3.3
3.5 - 4.0	2.8
8.5 - 9.5	2.2
4.0 - 5.0	0.6
6.5 - 7.0	0.6
9.5 - 11.5	0.6

PORCENTAJE MAXIMO DE UTILIZACION 95.7

Fig. 2.4

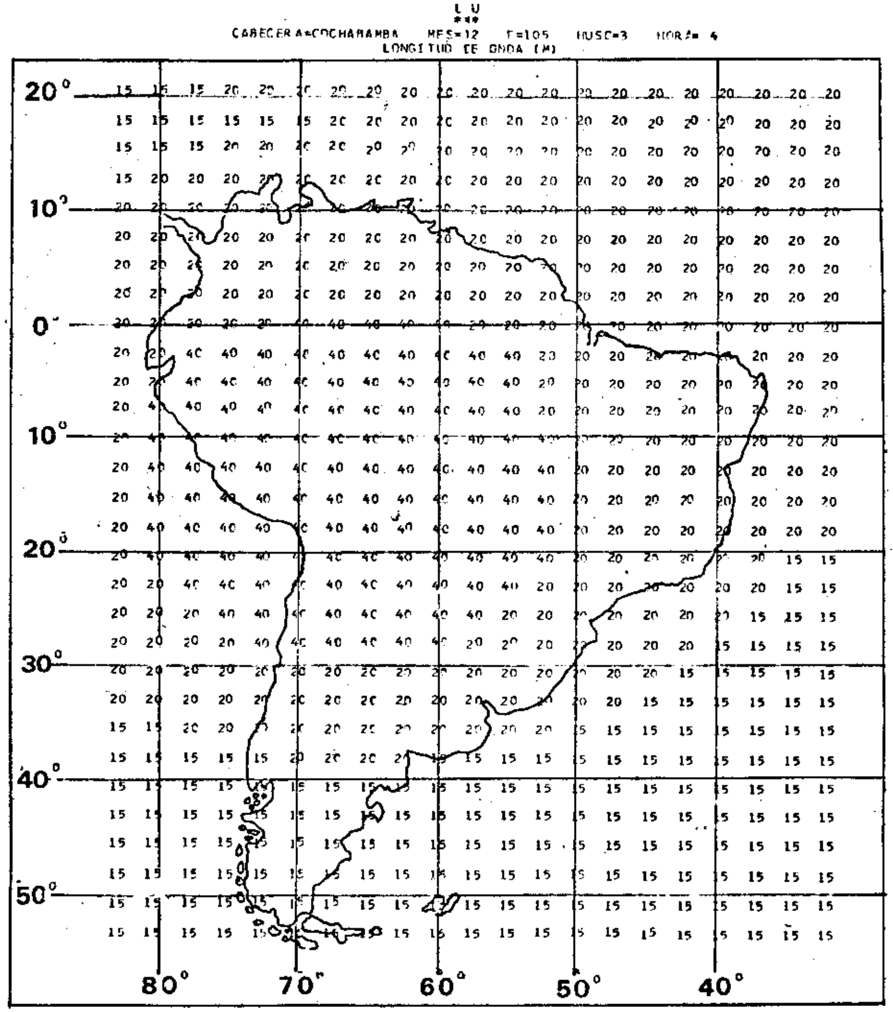

Fig. 2.5