INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION
INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
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SMR.380/5

COLLEGE ON THEORETICAL AND EXPERIMENTAL RADIOPROPAGATION SCIENCE

6 - 24 February 1989

IONOSPHERIC VERTICAL SOUNDINGS

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1. INTRODUCTION

After the first experiments in 1926 of E.V. Appleton and M.A.F. Barnett in England and G. Breit and M.A. Tuve in U.S.A. proving the existence of ionized layers on the upper atmosphere, predicted by Kennelly and Heaviside in 1901, the experimental method was improved and widely used to determine the characteristics of the ionospheric regions.

Starting from about 1930 the network of ionospheric vertical stations was expanded considerably and their data contributed to a better knowledge of the ionospheric phenomena at the same time that the Chapman theory (1931) of the atmospheric photo-ionization was developed.

While the first routine ionospheric sounding stations were set up primarily for scientific purposes to discover the characteristics and the causes of the reflecting and absorbing layers in the ionosphere, the great expansion of the network during the Second World War was brought about by the need to make predictions of ionospheric radio propagation conditions all over the world. However, the research carried out with this kind of measurements were still not adequate in order to understand the overall physical picture. During the International Geophysical Year more stations were added untill they reached a number of about 150; their geographical distribution is shown in fig. 1.
After this period a considerable uniformity was introduced into the scaling and reporting of ionospheric data, which has turned out to be valuable from the point of view of both radio communicators and scientists.

In addition to vertical sounding, other instrumental techniques were added such as rockets and satellites. However, these last methods cannot replace the space and time coverage obtained by ground based measurements.

The literature of ionospheric studies, shows the great importance of having a wide geographical distribution of stations to study the morphology of the ionosphere and the production of ionospheric maps for geophysical and radio propagation prediction projects.

Considering that the maintenance of an adequate network of stations for scientific and practical purposes depends on the cooperation of organizations involved in geophysical studies of the ionosphere or involved in studies concerning radio propagation problems, some international organizations such as the International Scientific Radio Union (URSI) or the Consultative Committee on Ionospheric Radio (CCIR) encourage investigations into the spatial and temporal variations of the electron density distribution of the ionosphere, to continue the operations of the ionospheric observatories and the exchange of the basic data through the World Data Centers.

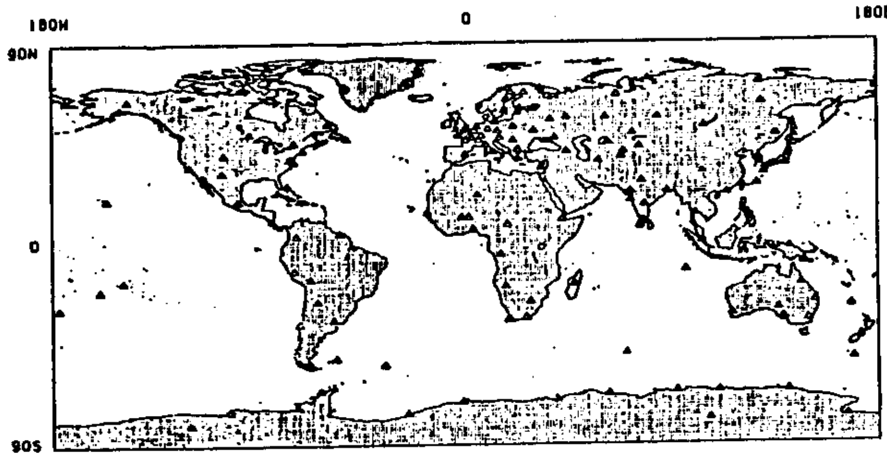

Fig. 1

2. IONOSPHERIC MEASUREMENTS

The method and the instrumentation utilized for the electronic density measure in the upper atmosphere are briefly described below. This method is based on the following principle: generally, when an electromagnetic wave penetrates vertically on the ionospheric plasma, reflection occurs at the level where the refractive index becomes zero. Reflection depends on the electronic density N (i.e. on the free oscillation frequency of the ionospheric plasma fN) and on the incident wave frequency. Radio waves with frequency higher than fN cross the ionosphere, while waves with frequency lower than fN are reflected (the maximal reflected frequency being equal to the plasma frequency fN).

$$f_N = \sqrt{\frac{e^2 N}{4\pi^2 \epsilon_0 m}}$$

Waves with frequency much lower than fN are absorbed by the lower ionospheric layer owing to the high frequency of collisions between electrons and neutral particles. In practice radio waves with frequency lower than 1 MHz are reflected and/or absorbed in the lower layer (D ionospheric region), radio waves with frequency in the range 1 to 15 MHz are reflected in the higher layers (E, F1, F2 regions). Up to 15 MHz radio waves cross the ionosphere. For this reasone, sounding instruments usually operate in the range 1 to 20 MHz.

2.1 The Ionosonde

From the beginning of fixed frequency ionospheric sounding many years have past, but the method is still the most commonly used in the field of systematic measurements of the electron density in the upper atmospheric region. The apparatus used for these measurements are called ionosonde and can be considered as a RADAR. The principles on which this is based will be described briefly. Radioelectric waves of increasing frequency and adequate power are transmitted upward by means a suitable antenna and propagate until reflection by ionospheric layers occurs. (Fig. 2).

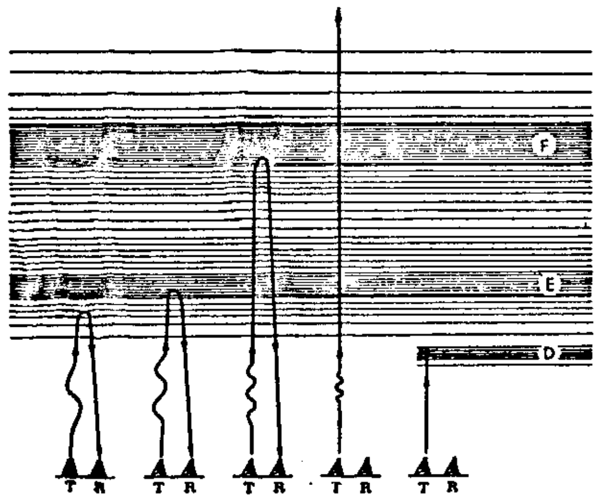

Fig. 2

A second antenna connected with a receiver, which is always tuned to the transmitted frequency, picks up the reflected waves as they return from the ionosphere. The time interval between the instant at which the radio pulse leaves the transmitting antenna and that at which the reflected one is received is a measure of the path length and determines the virtual height of the layer. We are able to calculate the height of the reflecting layer by the formula: h' = 150000 t (where h' is the virtual height). It is called virtual height because the velocity of the radiowave is assumed equal to the velocity of light.
The output of the ionosonde is called ionogram and is usually shown as a graph of the height versus frequency (fig. 3).

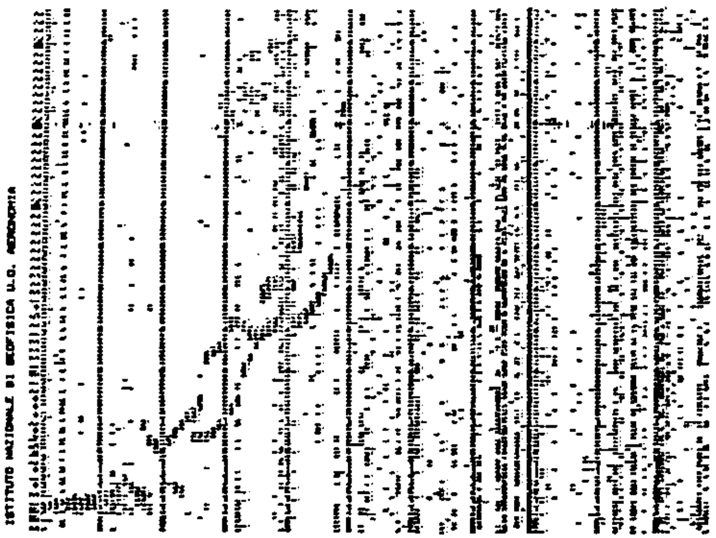

Fig. 3

Normally the results are presented an analogic form and the ionospheric feature are then scaled by operators. The data are digitalized and stored in magnetic memory for future applications. The modern apparatus are connected to a computer in order to have an autoscaled ionogram and to remove the need for an operator.

The main parts of the ionosonde are: the transmitter, the receiver, a frequency synthesizer, a control unit and antenna equipment. (Fig. 4).

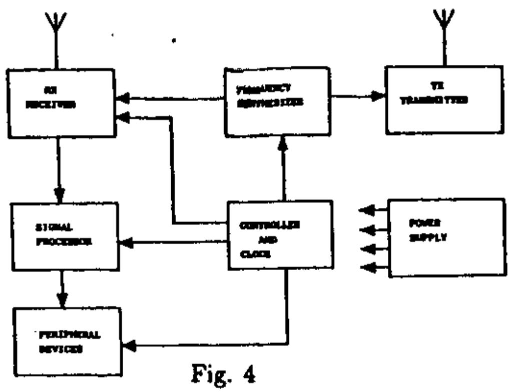

Fig. 4

Some peripheral devices such as plotters, tape recorders, or video screens can be interfaced with the ionosonde. The peripherals enable us to print data on paper, record on tape or, sometimes, transmit to remote sites by means of a suitable device. In its simplest version the ionosonde consists of a video screen (oscillograph) which, combined with a camera, produces ionograms on film. Each part of the ionosonde will be described later.

It should be remembered that we have two main categories of ionosonde, both reliable, the choice between which depends on the particular application: modulated amplitude pulses and low power frequency modulation.

The former is considered in this paper since it is more frequently used for its simplicity and also because it is suitable both for scientific and routine purposes. We have already mentioned the operating principle of the pulse ionosonde which includes: synthesis, transmission and reception and analysis of the radio pulses. Usually pulse duration is in the order of 100 microseconds; duration and pulse rate are limited by receiver selectivity height range and height resolution. In fact, shorter pulse length improves height resolution but is limited by band pass restriction and by the required fidelity of the reproduction. Longer time pulses affect the height resolution. The pulse rate (normally 50-100 Hz) is related to the height range in question. Radio wave takes 6.667 millisecond to reach 1000 Km altitude and come back to the same apparatus. Therefore the maximum pulse rate will be 1/6.667 mS i.e. 150 pulses/second. We need a high pulse rate in order to obtain a noise-free "true" signal. However too high a number of transmitted pulses affects the measurement since a longer interval of time is required; in this longer time period the precision of the measurement becomes dependent on the ionospheric dynamics. The received signal quality depends also on the signal/noise ratio and the peak power of the transmitted pulses. The transmitted pulse power is of the order of tenth of KW in order to overcome the problems arising from the absorption of the lowest ionospheric layer.

2.2 Transmitter

Due to the wide range of working frequencies a broadband transmitter (C class) is often used. Also a pulse power amplifier must be used in order to increase the efficiency. In an electronic tube amplifier, the pulse regime can be obtained with grid and/or anode control. In the digisonde a SCR driven by the control unit feeds grid and anode lines. There are several amplification stages because the output signal from the synthesizer has a power of few tenths of mW. The first stages (driver) are usually solid state and increase the signal power to about one hundred Watts. The last stage consists of electronic tubes which are more reliable than transistors at this order of magnitude (about 10 KW) of transmitted power. The anode and the screen grid are supplied by a proper pulse power supply, driven by control logic. The transmitter has a typical output impedance of 50 Ohm and is connected to the antenna by a coaxial cable. The antenna must be located near the transmitter device to avoid losing power along the line. Electronic tubes also are not affected by voltage due to lightning and other atmospheric discharges. The schematic diagram of the transmitter of the KEL IPS 42 ionosonde is shown in fig. 5.

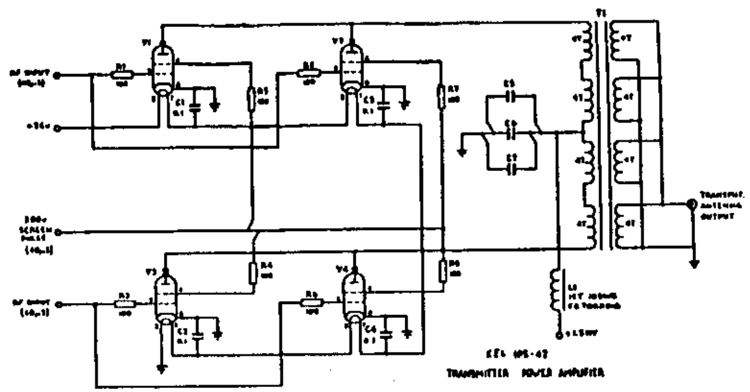

Fig. 5

A very good 10 KW distributed pulse amplifier is mounted in the digisondes. It is composed of 14 ceramic electronic tubes 4CPX250K (manufactured by Eimac). This amplifier gives an uniform response over the whole range of frequencies (fig. 6).

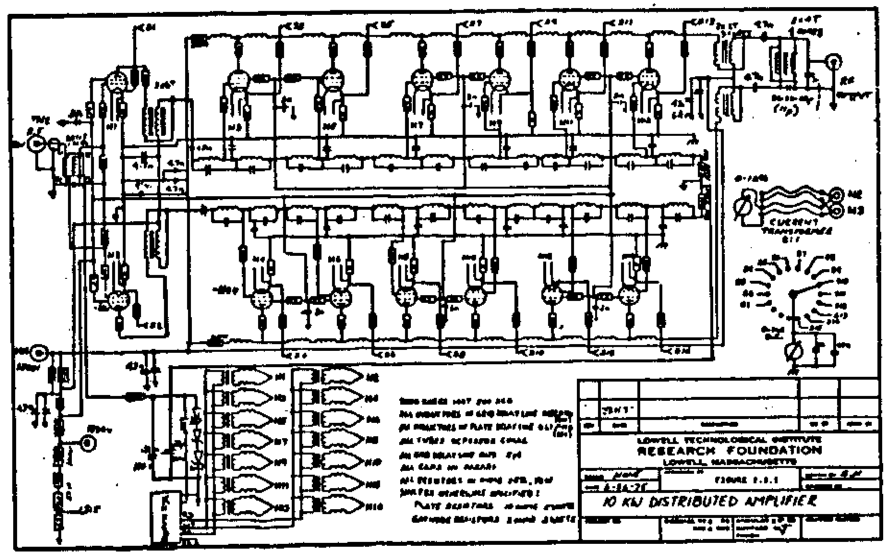

Fig. 6

2.3 Receiver

The receiver constitutes a very important part of a pulse ionosonde as its performance can affect the reproduciblity of transmitted pulses. Many factors must be considered in designing a receiver suitable for this purpose. Normally these receivers are a double or triple superheterodyne conversion, with IF very high frequency in order to eliminate unwanted frequencies such as image frequencies (see Kel IPS42 block diagram fig. 7).

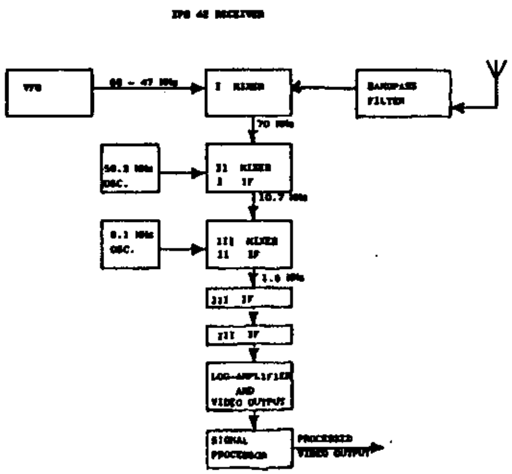

Fig. 7

A very sensitive receiver is required and so also the receiving antenna must be suitable. The insulation between the transmitting and receiving antenna should be about 25 dB. During the transmission pulse the receiver can be isolated electrically by means of the control logic. The ionosonde with a good performance during the sounding can achieve an insulation of 180 dB between transmitter and receiver. The sensitivity of receiving apparatus is, of course, related to signal/noise ratio, and is generally about 1 microvolt. In the block diagram the functions of all the modules are shown. The preselector located after the antenna is necessary to clean all the frequencies which are out of the working band of the ionosonde i.e. 1-20 MHz. A large number of IF stages is recommended in order to have a good detected output signal, without distortions by the detector itself and the following video amplifier. The beat frequencies for the second and third mixer are synthesized by separated oscillators, which must always be shielded. The output of last IF stage is about 100-200 KHz. The signal from this stage is sent to a logarithmic amplifier in order to increase receiver dynamics. Generally these receivers have a 60 dB dynamics. If the signal were not logarithmically compressed (linear scale) we would have a low level saturation and so a part of the information requested would be lost. We may have two different gain regulations: one managed automatically and the other by the controller (from the program) or manually. The output of the last IF of the receiver is sent to the detector and then, depending on the ionosonde type, it receives different treatment. In the ionosonde with a photographic recorder the signal is increased by an amplifier and sent to the cathode of the oscilloscope. The modern ionosonde perform a different kind of signal processing as will be described. In its simplest form the preselector may have either a control-band filter with passive elements only or several channels driven (switched on) by the control logic. The radiofrequency amplifier is often omitted and the signal sent directly to the first mixer, the tuning accordance to be accomplished in this step with variable frequency thus coming from VFO (variable frequency oscillator), which is always tuned to transmitter. (Scheme IPS42 fig. 8)

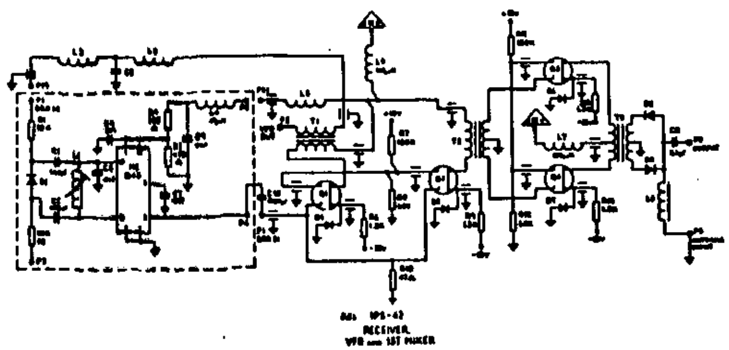

Fig. 8

The values of the first intermediate frequencies are kept relatively high (40-70 MHz) to avoid interference by unwanted frequencies which are always present in the antenna. The selectivity obtained by means of many IF amplification stages is 15-25 KHz. These values are fixed by taking into account two opposite necessities.

It is known that the noise increases by raising the width of the passing band. With a fixed number of amplification stages, if the amplitude of the passing band is decreased (by increasing the selectivity) it is possible to increase the sensitivity. But this results in an impaired accuracy of pulse reproduction. By increasing the band width all the Fourier components are reproduced with higher fidelity without phase distortion. The latter modifies the pulse shape and causes others echos.

2.4 Control Unit

One of the most important parts of the modern ionosonde is the control unit, which was practically non-existent in older ionosondes. It consists in a programmer (operated by keyboard or by a series of switch), a numerical display or a video screen that shows the set of ionospheric sounding parameter. This unit also contains the control of the sweep frequency synthesis. The "master oscillator" provides the necessary functions for the frequency synthesizer, thus enabling the lines of programmable counters. It is always possible, even with the above mentioned limitation inherent in the pulse sounding technique to choose ionospheric sounding parameters in order to obtain an optimal measure. This in the case for variations of ionospheric conditions or in order to solve other kinds of measurement problems. These settable parameters can be: range and step increment of the frequency, range and step increment height, pulse rate and pulse duration, receiver gain, signal processing control, etc.. Frequency and height marks, combined with the chosen parameters, are usually reported on the ionogram (fig. 3). In the programmer unit it is possible to store some programs so that the ionosonde can be operated automatically. A quartz crystal must be used to control the frequency of the oscillator by utilizing the quartz to provide the resonant circuit that determines the frequency oscillator. To achieve frequency stability other special circuits are used to eliminate thermal drift. (Fig. 9) There are also several bufferized outputs that are implemented with digital counters. All ionosonde function quality depends also on the precision and the stability of the quartz oscillator. As will be seen, the reference frequency for the frequency synthesizer, other functions concerning the duration and pulse rate, as well as the clock functions and the timing control start, are originated from the master oscillator in the control unit. The controller also provides the signal processing (sampling, cleaning, analog to digital conversion ADC, character generation etc..). Peripherals are enabled in the correct way in order to have several devices connected to the ionosonde.

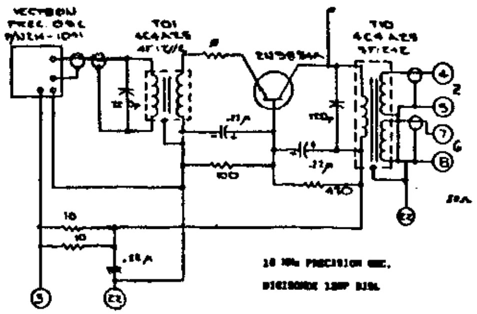

Fig. 9

2.5 Frequency Synthesizer

The frequency synthesizer is controlled by the control unit and is the part where the sweep frequencies are originated. A automatic mechanical system used to provide this function in old the ionosondes. It was hard to match transmitter and receiver without anyother device of fine tuning. Modern ionosondes utilize a digital synthesis and control apparatus. The frequency synthesizer dictates ionosonde quality, because the frequency range, the increment step, the scale (linear or logarithmic), are very important functions that can affect measurement precision and quality. The most recent vertical sounding apparatus utilizes a digital variable frequency oscillator (VFO). These devices are able to generate a wide range of frequencies (for instance 30-300 MHz range) with high precision, utilizing the Phase Locked Loop (PLL) technique. The flow diagram of this kind of frequency synthesizer shows three main blocks when it is operated at fixed frequencies. (Fig. 10).

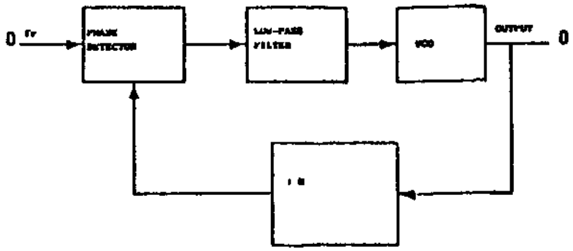

Fig. 10

The voltage frequency oscillator generates a frequency proportional to the input voltage. A phase detector compares the output phase from the VCO Φu with a reference phase Φr. The output voltage of the phase detector (error tension Vu) is proportional to the phase difference Vu = k(Φu - Φr). This voltage filtered through a low-pass filter is used to correct the VCO output frequency. One of the most common methods used to variate the VCO's frequency is to vary the capacitance of the LC block utilizing the capability of the varactor (or varicap) diode junction that modifies its capacitance when the applied voltage varies. This method is mostly utilized in electronic tuning. With this system to get an output frequency fu that is an integer multiple N of the reference frequency fr when there is a divisor by N at the end electronic chain. The main difference between a digital synthesizer (square wave output) and an analogic synthesizer (sinusoidal wave output) is due to the type of phase detector. The first utilizes a comparator, the second a double balanced mixer. The low-pass filter can be a simple RC filter, but better results are obtained using active filters. The one just described is a fixed synthesizer of frequency, but it is possible to transform it into a variable frequency oscillator varying the dividing factor N of the divisor placed at end of the electronic chain. The N1 dividing block is necessary because phase comparators behave when they work at the low frequency (about 10 KHz). Stability and precision are provided using a quartz oscillator. In practice frequency reference fr is extracted from the output of the control unit oscillator. The proposed flow-diagram is similar to that of the KEL IPS42 frequency synthesizer. (Fig. 11).

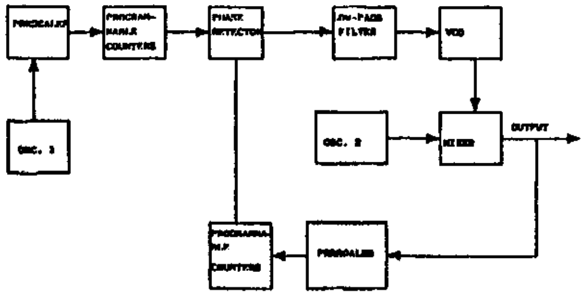

Fig. 11

This ionosonde uses a MC 1648 Motorola integrated circuit as VCO. To produce an output frequency in the range of 69 to 47 MHz, the VCO is driven by a comparator and some form of "steering" (such as an active low-pass filter). This frequency will be heterodyned by a 70MHz fixed frequency oscillator to get a mixer output frequency in the range of 1-23 MHz. The mixer output frequency is divided by a prescaler followed by a programmable counter. The comparator "compares" the output phase from this last circuit with a phase of a reference oscillator output. Also the reference oscillator output is processed through the prescaler and a programmable counter chain. 8 to -10 V direct voltage by a steering circuit is applied to the varactor diode connected to the input of the MC 1648 VCO.

2.6 Signal Processing

It is necessary to clean up the received signal from disturbances and interferences due also to other transmitter stations. Several strategies can be adopted, they base on the natural distribution of the noise. Low level noises are eliminated by the receiver sensitivity setting. Noises with power level of the same order of magnitude as the signal are eliminated by applying the above mentioned principle. For instance in the KEL IPS42 ionosonde the signal is sampled only in suitable time windows, and the comparator output (TTL level) is sent to a shift register and compared with the following pulse signal. If a high bit is produced by the reflected signal, the following bit, probably high, outcoming from the receiver output is compared to the memorized bit and taken as reflected signal. On the contrary if the stored bit in the shift register is produced by a disturbance, the following bit is, probably, a low bit (owing to the random distribution of the noise), the comparison produces a negative result and the bit is refused. This operation is repeated three times for each frequency sounding channels. Other more sophisticated ionosondes (digisonde Bibl 128P and 256P) take average of a greater number of pulses using more sophisticated techniques.

2.7 Antennas

The range of frequencies covered by the ionosonde is so wide (2-20 MHz) that resonance antennas are not suitable. Therefore wide band antennas, e.g. log-periodic delta and rhombic antennas must be used. The log-periodic antennas are too big and so a good efficiency also at low frequencies is questionable.
The true a-periodic antennas are the delta, V and the rhombic; they are of long wire type and of a size n times the half wavelength ($l = n\lambda/2$).

Normally in the vertical sounding stations the rhombic or delta antennas are used, ending with a load resistor which raises the directional gain toward the termination and gives a good response over a wider frequency range. Typical radiation antenna are reported in fig. 12.

Rhombic antennas show the highest directional gain. Their load resistance is about 600 Ohm and is equal to the radiation resistance of the antenna.

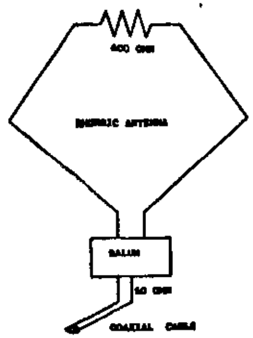

Fig.12

The resistor must generally be antiinductive in order to avoid any modification of the features of the antenna. In this range of frequencies, the sides of the rhombic antenna must have decametric dimensions. Furthermore the antenna must be located on a plane which, for the vertical ionospheric sounding, is perpendicular to the plane of the land. In vertical sounding, the antennas (receiving and transmitting) lie on perpendicular planes to avoid coupling between them. In practice the transmitting antenna is like the receiving antenna with the exception that the resistor must have an appropriate power dissipation. If the feedline has the same impendance as the antenna this is connected directly. Generally modern apparatus has an output impendance of 50 Ohm and the feed lines are made with a coaxial cable of the same impedance. This makes it necessary to add a device known as balun (balanced unbalanced) which is able to couple an unbalanced device, such as the coaxial cable line, with a balanced one such as the antenna. A rhombic antenna fed by two-wire transmission line is balanced with respect to the ground, provided the two halves of the antenna have the same orientation and placement with respect to the ground. In the balanced mode the two halves of the antenna are at potential +V and -V from the ground. In this case the current on the two wires of the transmission line is the same. When an antenna is connected to a coaxial trasmission line the two halves of the antenna will be at different potential levels with respect to the ground, and the potentials of the two conductors of coaxial lines are different. The consequence in this case is that undesired currents might be exited on the external conductor and the current in the two halves of the antenna will not be the same. The radiation from the coaxial line will interfere with the radiation from the antenna, modifying the performance of the antenna system. Furthermore problems caused by reflected power throughout the line may arise.

3. IONOGRAMS: INTERPRETATION AND PRESENTATION OF THE DATA

The principal routine work of every standard station, as defined in the well known URSI Handbook of Ionogram Interpretation and Reduction edited by W.R. Piggott and K. Rawer, is

a) To monitor the ionosphere above the station.
b) To obtain significant median data to evaluate long-term changes.
c) To study phenomena peculiar to the region.
d) To study the global morphology of the ionosphere.

Of course these objectives need a set of standard techniques and conventions applicable to the general interpretation of the ionospheric measurements in orde to make a more phenomenological description of the ionogram also to give a sim plified description of the ionosphere over the station.

This set of conventions and rules of scaling the ionograms are exhaustivel described in the Handbook mentioned before and recently also in the "Manual (Ionogram Scaling" edited by the Japanese Ministry of Posts and Telecomunica tions (Radio Research Laboratory).

3.1 The Ionogram

The ionogram is a record produced by the ionosonde which shows the variatio of the time t of the vertical incidence propagation, that is the delay between th transmission time and the received echo from the ionospheric layer, as a functio of the radio frequency f.

Considering the well known relation

$$\Delta t = \frac{2}{c}\int_0^h \frac{dh}{n} = \frac{2}{c}h'$$

with c the velocity of e.m. wave in the free space and n the refraction index phase this delay Δt is correlated to the virtual height of reflection h' that is th height where it should be the reflection if the radiowave was propagated with th same velocity as in the free space.
Since the signal always travels more slowly in the ionosphere and in the receive than in free space, the heights observed exceed the true heights of reflections. the frequency of the signal is increased the virtual height increases more rapidl than the true height. When the level of the maximum electron density in the laye is reached the virtual height becomes infinite.
This frequency is called the critical frequency of the layer (fig. 13).

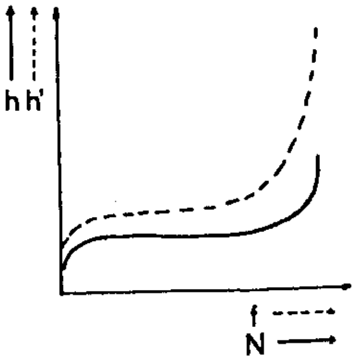

Fig. 13

Another important effect of the propagation of a radio signal is the double refraction due to the interaction between the electrons in the plasma and the magnetic field. The two waves reflected independently in the ionosphere, known as magnetoionic components, are called, by analogy with optical double reflection, the ordinary and the extraordinary wave (fig.14).

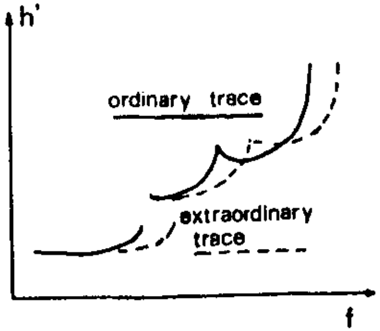

Fig. 14

For a simple description of the ionosphere by the vertical sounding it is convenient to consider the ionosphere as schematically divided into the conventional layers D, E and F.

In figure 15 is represented an ideal daytime ionogram where the ordinary and the extraordinary traces, related the layers E, Es, F1 and F2, are present with their own parameters.

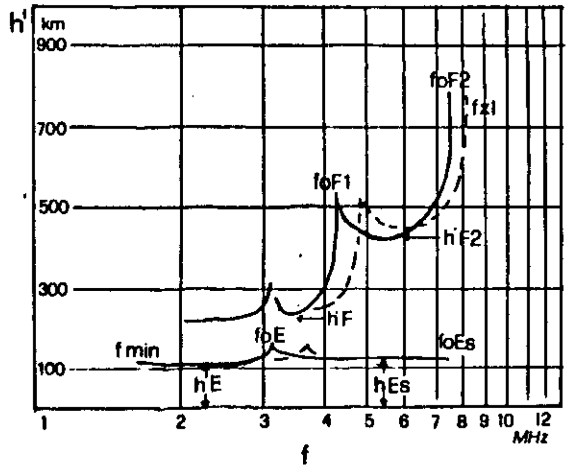

Fig. 15

F layer

foF2 Critical frequency of the ordinary wave in the highest layer of the F region called F2 .

fxI The highest frequency recorded by a reflection from the F region.

foF1 Critical frequency of the ordinary trace in the F1 region when it is present.

h'F2 Minimum virtual height of the ordinary wave in the F2 layer.

h'F Lowest virtual height of the ordinary wave in the F region.

E layer

foE Critical frequency of the ordinary wave in the E region.

h'E Minimum virtual height of the ordinary wave in the E region.

Es layer

foEs Top frequency of the ordinary wave of the continuous Es traces.

h'Es Minimum virtual height of the Es ordinary trace.

fbEs Blanketing frequency of the Es layer.

fmin Lowest frequency recorded in the ionogram.

3.2 The Maximum Usable Frequency Factor M

The M factor is a conversion factor to obtain the Maximum usable frequency over a given oblique propagation distance. The M factor for a standard distance of 3000 Km is called M(3000), this parameter, related to the MUF(3000) and to the critical frequency fo by

$$M(3000) = MUF(3000)/f_oF2$$

is very useful for practical ionospheric radio propagation predictions.

The Maximum usable frequency factor can easily be obtained directly from the ionograms. There is a well known relationship between an oblique frequency fob and the equivalent vertical frequency fv at an equivalent virtual height h' for a given distance D:

$$f_{ob} = f_v \sec\varphi_0$$

where φ_0 ,the angle of incidence, is, for a curved earth and a flat ionosphere,

$$\varphi_0 = \arctan\frac{\sin\Theta/2}{1 + h'/R - \cos\Theta/2}$$

with Θ the angle at the center of the earth subtended at the distance D and R the earth's radius. Fig. 16.

From this relation it is possible to draw, for a given oblique frequency fob, a curve as a function of h' and fv, known as the trasmission curve, which was introduced for the first time by N. Smith.

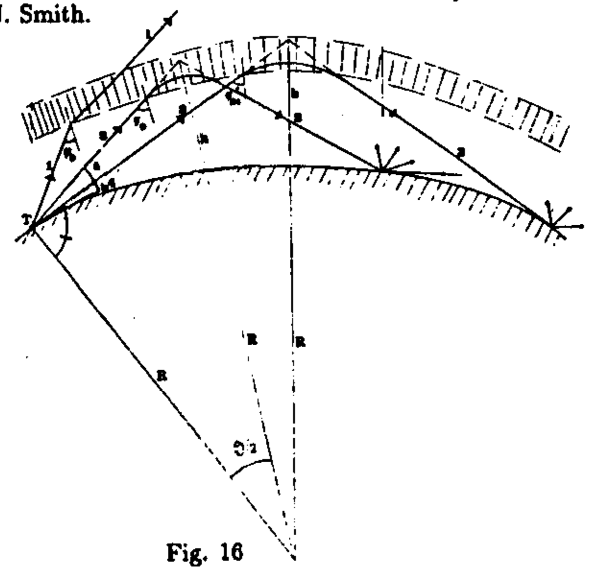

Fig. 16

The intersection of this curve with the curve h'fv of the ionogram gives the graphical solutions of the two equations, that is the two virtual heights of reflection of a transmission with two ways of propagation, points a and a' of the figure 17.

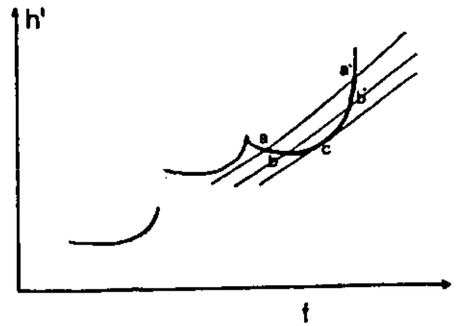

Fig. 17

By then increasing the given oblique frequency we can obtain other transmission curves that intercept the ionogram's curve at increasingly close points, b and b', until they become tangential as point c. At this point only one way of propagation is possible and the oblique frequency, corresponding to the tangent transmission curve, is the Maximum Usable Frequency (MUF) for that distance.

In practice by drawing a family of transmission curves on a transparent slide, mantaining of course the same scale for the frequency and the virtual eight, as in figure 18, and laying it on the ionogram, it is possible to read the MUF(3000) directly.

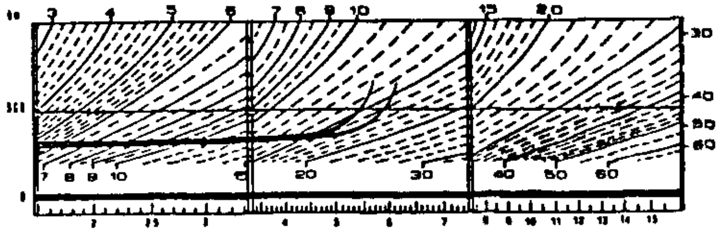

Fig. 18

In a real situation both the ionosphere and the earth are curved and also the virtual height of reflection depends on the electron density profile. However for practical purposes it is sufficient to correct the secant law with

$$f_{ob} = k f_v \sec\varphi_0$$

where K is a correction factor function of the distance and of the real height of reflection, it varies from 1. to 1.2.

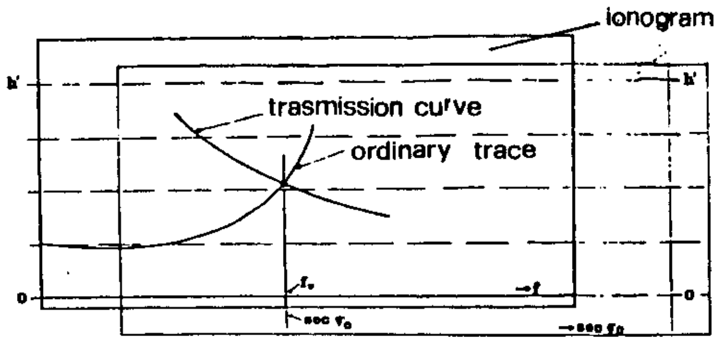

Fig. 19

For ionograms with a logarithmic frequency scale another similar procedure is generally used. When a transparent slider, where a standard transmission curve h'-sec φ_0 is drawn, is laid on the ionogram, the values of fv and sec φ_0 of one point of reflection are easy to read on the two different abscissae (fig. 19).
The procedure may be faster if the ionogram has a logarithmic scale and if the standard transmission curve is drawn with an inverted logarithmic scale. Infact, considering that

$$\lg f = \lg f_v + \lg \sec\varphi_0$$

it is possible to obtain the result of this sum by reading the value on the ionogram frequency scale directly at the point where the sec φ_0 scale is equal to 1. Moving the slider on the frequency axis when the transmission curve is tangential to the ordinary trace of the ionogram it gives directly the value of the MUF(D) and then the M factor (fig. 20).

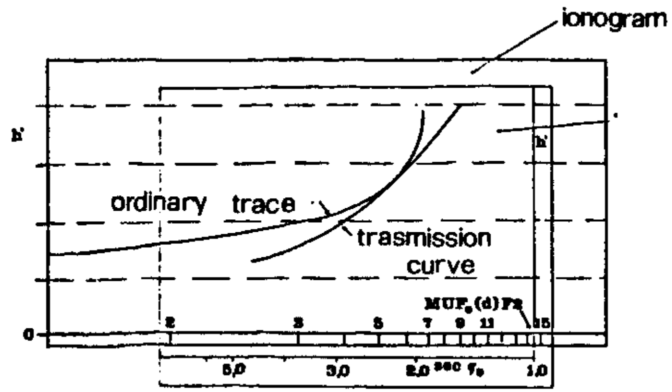

Fig. 20

3.3 Presentation and Processing of Ionospheric Data.

The measures of the principal ionospheric characteristics coming from scaling the ionograms are reported in daily and monthly tables (fig. 21 and fig. 22).

For every characteristic, two letters, the first qualificative and the second descriptive, contribute to providing a complete interpretation and description of the ionograms. In the monthly tables of the hourly ionospheric data are reported also the computed values of the median and of the upper and lower quartile. These tables, obtained by automatic procedures, form the monthly bulletin of the ionospheric vertical sounding station mailed to the World Data Centres and to other scientific Institutions.

Also the scaling of an ionogram can be obtained by a semiautomatic and, for the last Digisonde 256, by a completely automatic procedure.

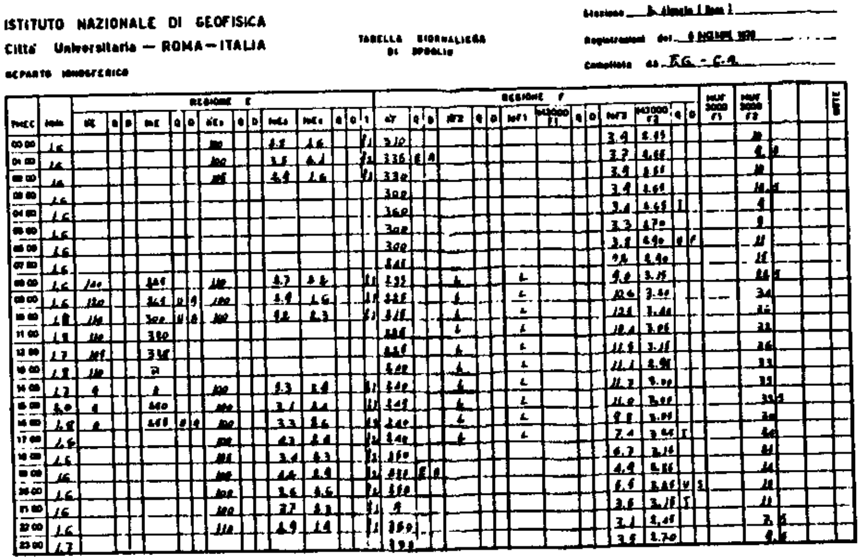
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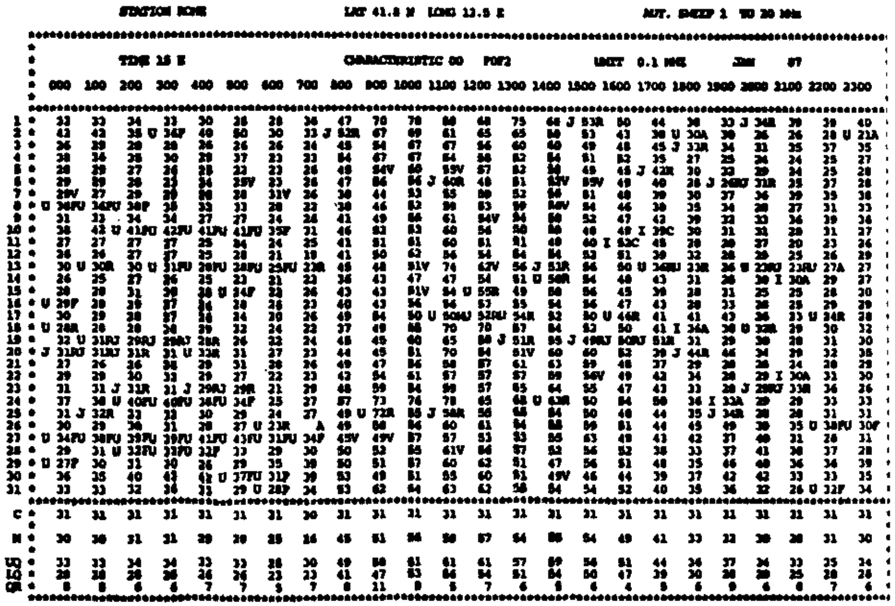
Fig. 21


STATION ROME LAT 41.8 N LONG 12.5 E AUT. SWEEP 1 TO 20 MHz

TIME 15 E CHARACTERISTIC 00 FOF2 UNIT 0.1 MHZ

000 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300

Fig. 22

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