

Hardware Simulation Experiment to Study Radio wave Absorption by Ionosphere

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Abstract : *In a real multi frequency radio wave absorption experiment, very high power (30 kilo watts) radio wave pulses are transmitted vertically up and their echoes are received on the ground. The ionosphere height ranges from 60 km to 600 km. The amplitude of the echo received corresponds to absorption loss of 3 dB to 60 dB. This requires huge antennas and associated power amplifiers. It will also require very low noise and highly sensitive radio receivers. The Physics Department, Gujarat University had German equipment and the author has made absorption measurements during 1984-1985. It is not possible in a UG or PG laboratory to do this experiment.*

Therefore, we have fabricated a simple experiment using timer IC 555 as a stable and monostable multi vibrators to simulate above experiment. We have used 8 channel analog switching IC 4051 and 4 bit counter IC 4029 for multiplexing and de-multiplexing circuits to simulate 8 channel multi frequency radio wave absorption experiment.

This simulation hardware experiment is akin to RADAR in all the details. In fact real experiment is called ground based radio sounding of the ionosphere from bottom side. Similar to this there are airplane borne and satellite borne topside ionosphere radio sounding experiments.

I. INTRODUCTION

Study of Ionosphere is important for radio frequency communication and knowing the effect of solar emissions on the earth's environment. The ionosphere reflects back to earth radio frequency up to 30 MHz. Above 100 MHz the ionosphere is transparent and radio frequency travels into the space. The atmosphere is attached to the earth due to gravity and is very dense near the earth, becomes rarer at larger heights and extends up to about 600 km above the earth surface. The solar radiation is maximum at the top of Ionosphere (600 km). As the radiation enters the atmosphere it is absorbed and produces ions and electrons. Therefore intensity of solar radiation decreases towards the ground. On the other hand the ionisable material in the form of neutral atoms and molecules decrease in density as we go up. As a result of this, maximum ionisation is produced at a particular height. At higher heights there is less ionisable material but more radiation while at lower height there is more ionisable materials but insufficient (less) radiation. The above very simplified picture is true for radiation of one particular frequency and one particular type of ionisable material (atom and Gas Molecules). However the Earth's atmosphere contains a mixture of various gases and solar emissions contain very wide spectrum of electromagnetic waves and also massive particles like protons, neutrons, helium nuclei etc. As a result the ionosphere has got maxima in ionisation at various heights and valleys in between. These ionosphere layers are called D-region, E layer, Es layer (Sporadic), F layer- Sometimes split into F1 and F2 etc.

The ionisation produced is a result of solar emissions and therefore has all the cyclic variability like time of day & night, seasonal variation, yearly variation, effect of lunar tides and also 11 years sunspot cycle variation. Therefore critical frequencies of ionosphere layers vary and this has got profound impact on radio frequency communication on earth.

Ionosonde measurements to study structure and variability of ionosphere:

Ionosonde experiments are conducted at many places in the world. Electromagnetic waves in the frequency range 10 KHz to 30 MHz are swept continuously, echoes received are recorded and displayed in the form of Ionograms. These experiments are conducted every 15 minutes and give details of the ionosphere above particular location above the earth. Fig 1 shows such ionogram.

When an Electromagnetic wave is transmitted vertically upwards as it enters the ionised layer it goes on bending and finally it is reflected back to the earth by the process of total internal reflection. The refractive index in the ionosphere depends upon the electron density. The highest frequency which is totally internally reflected by a layer depends on maximum electron density occurring in the layer. This frequency is known as critical frequency of that layer.

$$f_c = 9 \sqrt{N_{max}}$$

where f_c is the critical frequency of the layer and N_{max} is the maximum electron density in the layer. The critical frequencies of various layers are f_oE , f_oE_s , f_oF_1 , f_oF_2 etc. The minimum electron density required to reflect a frequency "f" (in MHz) at vertical incidence is given by

$$N = 1.24 \times 10^4 \times f^2$$

Where N is the number of electrons per CC and f is frequency in MHz.

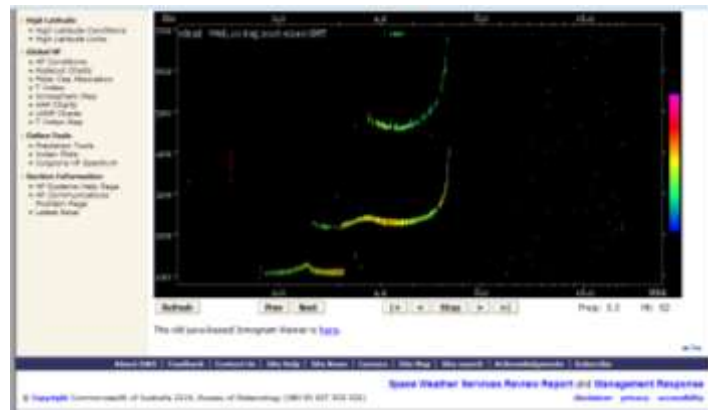


FIG 1: Ionogram showing various layers in the ionosphere.

Vertical incidence ionosphere absorption measurement experiment:

Multi-frequency very high power pulses of electromagnetic waves in the range 1.5 MHz to 6 MHz are transmitted vertically upwards and the echoes received are recorded. From the amplitude of the echoes and the height of reflection (Delay time required to receive echo) the absorption of radio waves in the ionosphere is calculated using the formula

$$\text{Loss (Day time), } L_d \text{ db} = E_n h_n / E_d h_d$$

Where, E_d = Echo during Day time
 h_d = Height during Day time

E_n = Echo during Night Time
 h_n = Height during Night Time

The ionosphere height ranges from 60 km to 600 km and the electromagnetic wave absorption is up to 60 db. Electromagnetic wave moving at a speed of light will require a time of 0.4 ms to travel to the height of 60 km and back. The radio wave will require 4 ms to travel up to 600 km and back. Hence the Echo will be delayed in the range of 0.4 ms to 4 ms corresponding to height 60 km to 600 km. If a 4 volt signal pulse is transmitted the amplitude of the echo received will be 2 volts to 3.8 microvolts corresponding to absorption loss of 3 dB to 60 dB.

Method and Circuit details

Innovative Hardware Simulation Experiment to measure radio wave absorption:

We have fabricated a simple experiment using timer IC 555 as astable and monostable multivibrator to simulate above experiment. We have used 8 channel analog switching IC 4051 and digital 4 bit counter IC 4029 for multiplexing and de-multiplexing circuits to stimulate multi frequency (8 different frequencies) electromagnetic radio wave ionosphere absorption experiment. The block diagram of transmitter is given in figure 2. Here for Multiplexing purpose MOSFET switching IC 4051 is used which can switch up to 8 analog channels. The transistor acts as open or closed switch depending on its biasing voltage. In this IC any channel (from 0 to 7) can be switched from input to output by selecting the three digital controlling inputs A, B, C (from 000 to 111)

Output square waves of IC 555 are applied to a binary counter IC 4029. The counter generates at the three binary digits - 000, 001, 111 and this cycle repeats. The outputs of the counter are applied to switching IC 4051 as digital control inputs A, B and C. Hence, IC 4051 will switch channels 0 to 7 one after another from input to output as the digital output as the digital output of the counter advances from 000 to 111.

At the receiver for Demultiplexing again the same IC 4051 is used. For proper synchronization the same clock signal from the transmitter section is applied in the receiver section. The receiver block diagram is given in figure 3. After demultiplexing, the signals, amplitude and delay time of the Echo are measured using CRO and also displayed. The ionosphere radio waves absorption values are calculated using the above measured values.

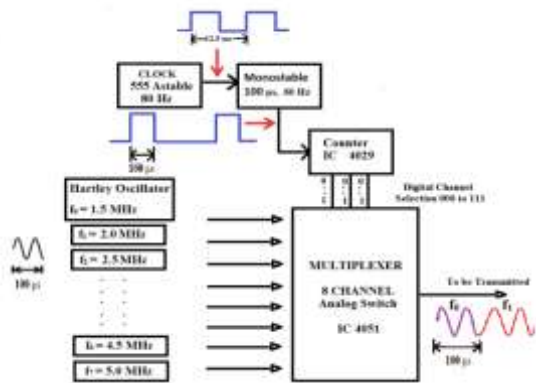


Fig: 2 Transmitter Block Diagram

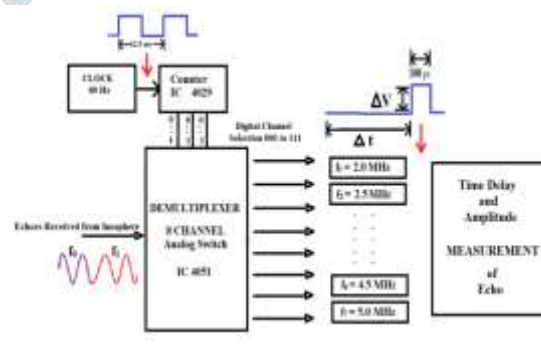


Fig: 3 Receiver Block Diagram

IV. RESULTS AND DISCUSSION

The simulation hardware experiment is akin (similar) to RADAR in all the details. In fact this experiment is called ground based Radio sounding of the ionosphere from bottom side. Similar to this, there are aeroplane borne and satellite borne topside ionosphere Radio sounding experiments. Just like RADAR, a radio pulse which is sent vertically upwards gets reflected from the ionosphere at a height where

there is particular electron density (the ionosphere layer serves as a target) and echo is received back on the ground. The distance of target in RADAR corresponds to height of ionosphere layer which is measured here.

This is simulation experiment only because we are not physically transmitting the radio wave pulses (1.5 MHz to 5 MHz Range) and receiving their echoes. This will require very huge power (of the order of 30 kilowatts peak output) to be transmitted which needs huge antennas and associated very high power amplifiers. It also requires very low noise and highly sensitive radio receivers. Due to these requirements it is not possible to perform the real experiment in undergraduate or post graduate laboratory. However photograph of the absorption measurement equipment and site showing the antenna is given in fig 5 and another photograph of actual echoes observed during day time and night time are included in fig 4 to get a feel of the real experimental setup and the observations obtained.

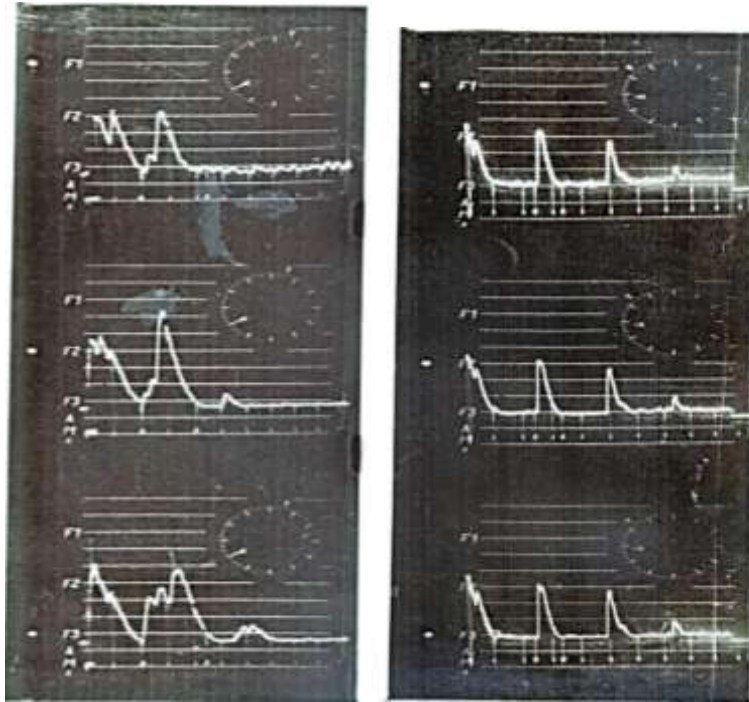


Fig. 4 (a) Day Time

Fig. 4 (b) Night Time

Photographs of Echoes Recorded during Day Time and during night time

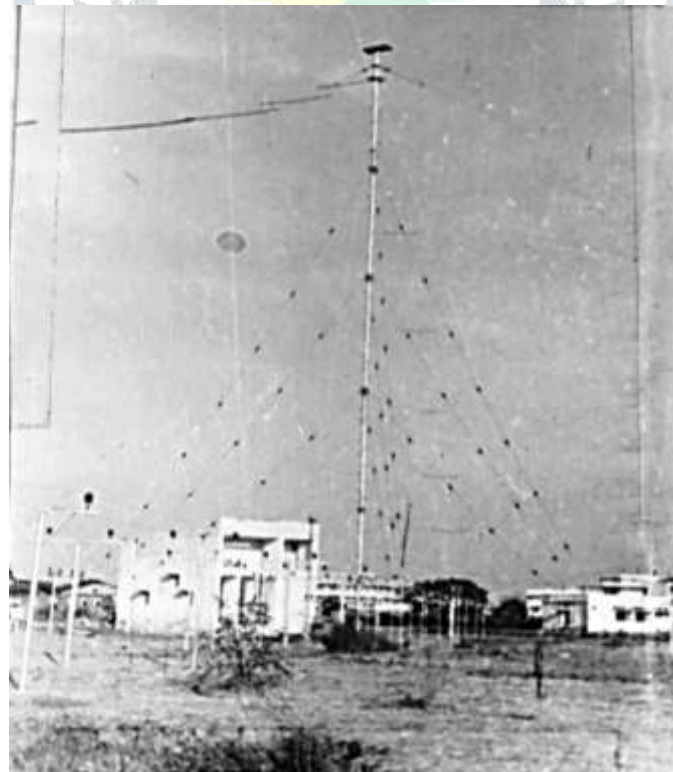


Fig. 5 (a) Photographs of Experiment Site and Antenna

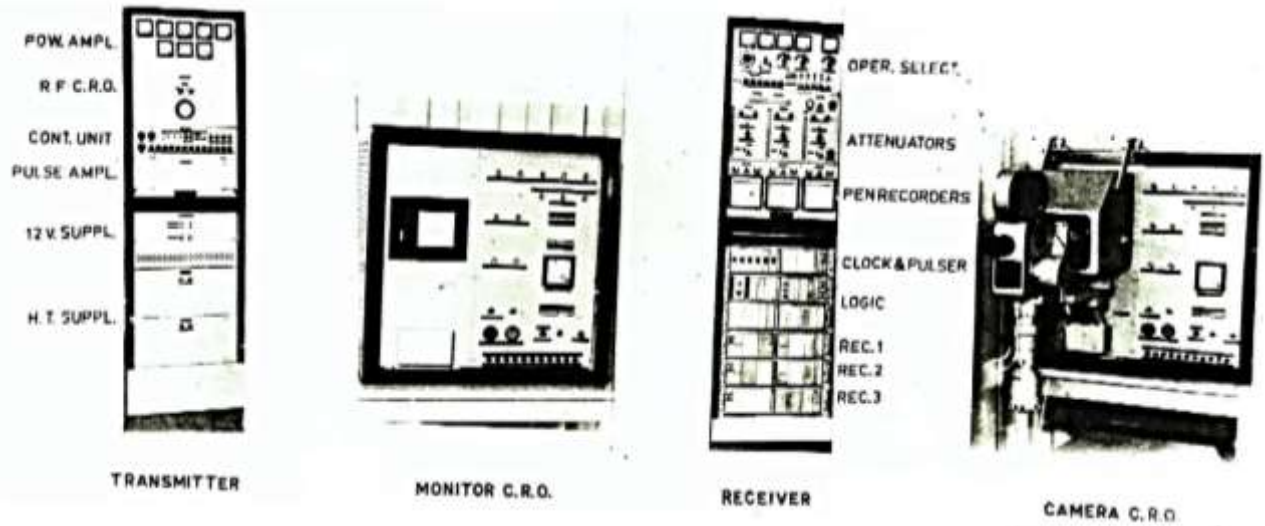


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II. ACKNOWLEDGMENT

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