Chapter 2

Techniques and Instrumentations

2.1 Introduction

In recent years scientists have realized that intelligent life may well be found throughout the universe and we are, perhaps, not the only civilization in our galaxy. The work suggests an alternative search strategy through sky noise windows emphasizing both the ‘water holes’ and the associated wavelengths. It also suggests that instead of pointing the antenna at known stars, an all sky search would be more appropriate for interstellar communication [1-3].

2.2 Established Methods for Detecting Extrasolar Planets

There are various methods to find the extrasolar planets. Out of many attempts so far the following indirect methods have revealed successful results. Established detection methods are: (i) Astrometric Method, (ii) Radial velocity methods and Doppler shift measurement, (iii) Dynamical perturbations, (iv) Gravitational Microlensing, (v) Transit Method, (vi) Pulsar Timing Method, (vii) Circumstellar Disks Method, (viii) Direct Imaging Method, (ix) Observations from Space and (x) MOP and Phoenix. Some of these methods are discussed here [4-6].

2.2.1 Astrometric Method

Astrometry is the method of measuring the position of a star in the sky and precisely observing how that position changes with time. One great advantage of this method is that it is highly sensitive to planets with large orbits. This makes astrometric method complementary to other methods that are most sensitive to planets with small orbits. However, long observation times required – may be years and even possibly decades [4, 7].
2.2.2 Radial Velocity Methods and Doppler Shift Measurement

The observed frequency of radiation emitted by a source \((v_{\text{obs}})\) moving at a constant velocity is different from that of a source stationary with respect to the observer \((v_{\text{source}})\). The relative frequencies, according to relativistic expression is given by the relation [8],

\[
\frac{v_{\text{obs}}}{v_{\text{source}}} = \sqrt{\frac{1-v/c}{1+v/c}}
\]  

(2.1)

When \(v \ll c\) the frequency shift \(\Delta v = v_{\text{obs}} - v_{\text{source}}\) can be expressed as

\[
\frac{\Delta v}{v_{\text{source}}} \approx -\frac{v}{c}
\]

(2.2)

More generally, for motion in an arbitrary direction the non relativistic expression becomes

\[
\frac{\Delta v}{v_{\text{source}}} \approx -\frac{v \cos \theta}{c}
\]

(2.3)

\(\theta\) is the angle between velocity vector and the line of sight to the observer. This is schematically shown in Figure 2.1.

Figure 2.1 A schematic illustration of the spectroscopic measurement of stellar wobble due to the presence of a planet

\[\text{(Wavelength)}\]
For a circular orbit coplanar with the observer’s line of sight then the maximum relative velocity is \( v = v_0 \), depending on whether the star is coming towards the observer (frequency increase, blue shift) or is going away from the observer (frequency decrease, red shift).

### 2.2.3 Dynamical Perturbations

Consider two objects in orbit about each other; one is a star and the other one is a planet of mass \( M_\star \) and \( M_p \) respectively. Let \( R_\star \) and \( R_p \) be their radii with respect to the centre of mass of the system. In general the orbital velocity of the star is given by

\[
\mathbf{v}_\star^2 = \frac{G(M_\star+M_p)R_\star^2}{R_p^3}
\]

(2.4)

Consider centre of mass coordinate system, we have \( M_\star R_\star = M_p R_p \) and assuming that \( M_p \ll M_\star \)

We obtained

\[
\mathbf{v}_\star^2 = \frac{G M_p^2}{R_p M_\star}
\]

(2.5)

This is schematically shown in the Figure 2.2

![Figure 2.2](image)

**Figure 2.2** An illustration of centre of mass for the discussion of dynamical perturbation, assuming \( M_\star \) greater than \( M_p \) [8]

### 2.2.4 Gravitational Microlensing

Gravitational microlensing happens in principle when the gravitational field of a star acts like a lens, magnifying the light of a distant background star. The effect occurs only when the two stars are almost aligned. Lensing events are brief, lasting for weeks or days, as the two stars and the
Earth are all moving related to each other. Gravitational lensing is the achromatic deflection of light due to gravity. A basic schematic of what happen is shown in the Figure 2.3. In this example the resultant image of the source is deflected by an angle $\alpha$.

$$\alpha = \frac{4GM}{c^2R}$$ \hspace{1cm} (2.6)

$R$ is the impact parameter, $2GM/c^2$ is the Schwarzschild radius

![Figure 2.3](image)

**Figure 2.3** An achromatic deflection of light by a mass $M$ between the source and the observer; the fashion analogous to classical optics, the mass $M$ acts like a lens [8]

### 2.2.5 Transit Method

If a planet passes between the observer and its parent star then the light from the star will be attenuated as the planet passes across the stellar disk. Typically the attenuation will be significantly less than some 1-2% of the total starlight. The attenuation is the ratio of the planet and star visual disk areas

$$\frac{\Delta L}{L_*} \approx \left(\frac{R_p}{R_*}\right)^2$$ \hspace{1cm} (2.7)

The basic model for a planet transiting in front of its parent star is shown in Figure 2.4. In the upper plot the planet ($P$) can be considered to be moving along a linear path at a stellar latitude $\delta$. As it transit a fraction of the stellar light is blocked and the net luminosity of the system appears to drop. This is shown in the lower plot. The shape of the transit curve in this case is just due to geometric superposition of two uniform circular disks. The luminosity $L_*$ is reduced by $\Delta L$ during full transit [8, 9].
Figure 2.4 The basic model for a planet transiting in front of its parent star

The transit duration is given by

$$\tau = \frac{P}{\pi} \left( \frac{R_\ast \cos \delta + R_p}{a} \right)$$

Where $P$ is the orbital period, $a$ is the planet-star separation at transit and $\delta$ is the mean stellar latitude of the transit. Now, the duration $\tau$ can be directly measured, and the interval between transits also yields $P$ to high precision. The stellar radius $R_\ast$ can be estimated from the knowledge of stellar structure and the spectroscopy measurement of the star. $a$ can be determined from the Kepler’s 3rd law. $R_p$ can be measured from the attenuation $\Delta L/L_\ast$, and then the latitude $\delta$ of the transit can be estimated.

2.2.6 Pulsar Timing Method

A pulsar is a small, ultra dense remnant of neutron star. It is a star that has exploded as a supernova. Pulsars emit radio waves regularly as they rotate. As the intrinsic rotation of a pulsar is regular, slight anomalies in the timing of its observed radio pulses can be used for tracking its motion [5].

2.2.7 Circumstellar Disks Method

Disks of space dust (called debris disks), surround many stars. This dust can be detected as it absorbs ordinary starlight and re-emits it as infrared radiation. Even if the dust particles have a total mass sufficiently less than that of the earth, they can still have a considerably large total
surface area that they outshine their parent star in infrared wavelengths. The Hubble Space Telescope is capable of observing dust disks with the help of NICMOS (Near Infrared Camera and Multi Object Spectrometer) instrument [10].

2.2.8 Direct Imaging Method

Current Telescopes are capable of directly imaging planets, e.g. the Gemini Telescope, the Subaru Telescope and the VLT etc. Direct imaging is possible when the planet is especially large (considerably larger than the Jupiter) and widely separated from its parent star. A group of astronomers used the European Southern Observatory’s very large telescope array in 2004 and 2005 and also in 2007 to produce images of exoplanets.

Future Detection Methods are: (i) Observations from space, (ii) Eclipsing binary minima timing, (iii) Orbital phase reflected light variations and (iv) Polarimetry.

2.2.9 Observations from Space

Astronomical measurements from space can be more sensitive than measurements done from the ground, as the distorting effect of the Earth’s atmosphere is removed and the instruments can view in infrared wavelengths that do not penetrate the atmosphere. These space probes even have the capability of detecting planets similar to our Earth [4, 11-16]. NASA has cut funding for the Terrestrial Planet Finder in 2007 and the funding has gone towards the Kepler Mission. This is mainly because the transit method will be used by the Kepler Mission to scan a hundred thousand stars simultaneously and thus will be able to collect statistics on the numbers of planets around sun like stars [17].

2.2.10 MOP and Phoenix

The main objectives of the Microwave Observing Program [11, 18-19] abbreviated as MOP, were the following: (i) “Targeted Search” Program, (ii) 800 Specific nearby Stars & General Sky Survey, (iii) Radio Dishes associated with NASA and (iv) A 43-meter dish at Green Bank. Signals were to be analyzed by Spectrum Analyzers each with a capacity of 15 million Channels.

On the other hand, Project “Phoenix” (1995) was largely engaged in: (i) “Targeted Search” Program, (ii) Studying about 1000 nearby Sun-like Stars, (iii) Phoenix conducted observation at
the 64-meter Parks Radio Telescope in Australia and (iv) A 140-ft Telescope of the National Radio Astronomy Observatory in West Virginia, USA. The project observed 800 Stars over the available channel in the frequency range from 1200 to 3000 MHz.

2.3 Recording Techniques

In our laboratory there are some radio receivers, which are 1420 MHz Hydrogen line Spectra-Cyber receiver, 406.7 MHz Solar Radio telescope, Log Periodic Dipole Array Antenna operates on 50 MHz to 300 MHz, 40 kHz VLF atmospheric Receiver and 92 MHz VHF receiver.

2.3.1 1420 MHz Hydrogen Line Spectra-Cyber

1420 MHz Hydrogen Line Spectra-Cyber receiver is used for receive a signal which coming from in the intergalactic space. The receiver is briefly discussed here.

2.3.1.1 Description of the Radio Telescope

The Radio Telescope is comprised of two units; one called the front end the other the backend. The front end contains the low noise amplifier and the Receiver Backend contains the converter and signal processing circuitry. Both are powered by +12 Vdc, which is supplied by the backend and the external power supply. This low noise system is constructed with the latest, microwave component technology and, is state of the art for amateur radio astronomy. The 1420 MHz converter is a dual conversion unit, which converts the 1420 MHz. hydrogen region down to the 70MHz. IF frequency. The backend contains a high gain IF amplifier, square law diode detector, computer controlled DC amplifier, programmable integration control, adjustable offset, and a 12 bit A/D converter, power supply, all controlled by a Basic Stamp II micro computer! Interface to the outside world is by RS-232 link to an IBM compatible computer on com port #1 or #2. Presently, no other com ports are supported [20-22].

2.3.1.2 Single Antenna Hookup

The feed horn should be mounted at the focus of the dish in whatever manner you choose (The focal point of your antenna should be at the mouth of the horn, not inside at the monopole). The LNA should be connected to the feed horn. A weather proof box should be used to house the front end module (LNA) [23-25].
2.3.1.3 Interferometer Hookup (Two Antennas)

For two antenna systems, two feed-horns are supplied as well as two LNA’s. Mounting of the feed-horns and placement of the LNA’s are the same as above. A weather proof box should be used to house the front end module (LNAs). NOTE: Suggested antenna placement should not be more than 25 - 50 feet apart. If more distance is required, a pair of in-line booster amplifiers may be required. The separate antenna cables are connected via a power combiner, which also routes the combined signal to the receiver backend. It cannot be stressed enough that any outside modules (LNA), which comprises part of the radio telescope front end, are not fully weather proof! The low noise amplifier must be housed in an additional weather proof box, simply painting will not keep the elements out. Damaged electronics may result if these instructions are not followed! Power for the LNA is obtained from the backend via the power cable. The RF output of the LNA is connected to the coax cable and run into the observation area, to the backend unit. The backend unit is meant to be kept in a shirt sleeve environment such as, a habitable room. This unit is not resistant to the elements and must be kept free of temperature extremes and high humidity. Keep in mind that this unit will be connected to a computer (user supplied), which is also very sensitive to environmental conditions [26].

2.3.1.4 Instrument Employed for the Present Study

The Radio Telescope we have used is composed of a front-end unit which includes the low noise preamplifier and a cylindrical feed horn for 1420 MHz. It is constructed and developed by Radio Astronomical Supplies (RAS), USA. The frontend is connected to the backend rack unit by user supplied low loss coaxial cable with type "N" connectors. In addition, 18 Gauge, four conductor (shielded) power wire is used for external LNA power. We implemented a "very low loss” cable LMR-400 flexible cable to minimize a loss of 6 dB or less at 1420 MHz. The arrangement is shown in Figure 2.5.
Depending on the length of cable run, it was necessary to add an additional low noise preamp in the line. Extremely low loss hard line allowed running over 100 feet with no additional preamplifier. The feed line carries the low noise amplified signals to the telescope backend. The back end is powered by a 220 V AC supply which produces a nominal +/- 12.5 V DC as well as a rear panel output to power the preamplifier and an optional noise source. The instrument communicates with an IBM compatible CPU via an RS-232 dB9 connector. The 1420 MHz signal from the frontend (LNA) enters the rear panel (Receiver Backend) and is fed to a 1420 to 70 MHz dual conversion (Internal) down converter. This converter has 8 MHz bandwidth with the Hydrogen rest frequency at 70.0 MHz. This 8 MHz wide IF signal is passed through a programmable gain IF amplifier and then split between the continuums square law detector and the spectrometer third conversion mixer. The programmable gain IF amplifier is used to compensate for feed line losses and to place the signal in optimum range for the square law detectors [26-27].

The software has been designed and tested on XP and a SVGA (800 x 600) monitor. The software provides a control and hardware setting interface to the spectrometer. The software includes features to enable the user for playing data movies of hundreds of scans at a time, select time coordinate systems for the data files, set the computer clock to within 500 milliseconds of WWV via the internet, and change graphical features such as background or the amplitude axis on the data plot. Final modifications include a frequency shifting for equipment that can shift
frequencies around 1420 MHz to a 70 MHz IF, displayed on the X axis. In practice, we can run a single scan and save it to produce the bmp. The 13 k bmp can be converted to a 6 k gif file with graphic software package. This bmp or gif graphics file can be used for data plots [29].

2.3.2 406.7 MHz Solar Radio Telescope

406.7 MHz Solar Radio Telescope is used to received a signal, which coming from solar coronal regon. The radio telescope used for recording the data is basically comprised of two units, one called the front end and the other the backend. The front end contains the low amplifier and the 406.7 MHz internal converter. Both are powered by +12 V dc, which is supplied by the backend and the external power supply. This low noise system is constructed with the latest microwave component technology. The 406.7 MHz converter is a dual conversion unit, which converts the 406.7 MHz down to 70 MHz IF frequencies [29-34]. The block diagram of the experimental setup including the dipole antenna mounting system is exhibited in Figure 2.6.

![Diagram](image)

Figure 2.6 Block diagram of the experimental setup including the dipole antenna

2.3.3 Log Periodic Dipole Array Antenna

The log-periodic dipole array (LPDA), is a multi-element narrow-beam antenna, which is used conveniently for the reception of solar burst. The antenna array has impedance and radiation characteristics that are periodic as a logarithmic function of the excitation frequency. It can
accommodate a suitable range of frequencies with moderate gain and directionality. Our receiving systems linked to two LPDAs successfully to receive solar signal. Here we use two low noise amplifiers (LNA) to reduce the local noises significantly and thereafter the signal is fed to high frequency amplifier (VHF) to amplify the received signal [35-39]. A schematic diagram of the whole arrangement is shown in Figure 2.7.

![Figure 2.7 Block diagram of Log Periodic Dipole Array](image)

### 2.3.3.1 Data Storage Techniques

The received signal through the amplifier is fed either to the digital storage oscilloscope (DSO) connected to the master computer or to the spectrum analyzer for video recording by a digital video camera. When the storage oscilloscope is used for recording we observe constantly varying signal voltages along the vertical axis ('Y' axis), against the horizontal time axis ('X' axis). Although an oscilloscope displays voltage on its vertical axis, other physical quantity that can be converted to a voltage can be displayed as well [40].

Digital Storage Oscilloscope of GDS-1000 Series we used for recording purposes. In the Digital Storage Oscilloscope (DSO), vertical input is digitized by an analog to digital converter to create a data set which is stored in the memory of a microprocessor. The data set is processed and then sent to the LCD flat panel display. The data set can be sent over a WAN or a LAN for processing or archiving. The screen image can be directly recorded on paper by means of an attached printer or plotter, without the need for an oscilloscope camera. The DSO’s own signal analysis software
can extract many useful time-domain features (e.g. rise time, pulse width, amplitude), frequency spectra, histograms and statistics, persistence maps, and a large number of parameters meaningful to engineers in specialized fields such as telecommunications, disk drive analysis and power electronics [41].

The received data from LPDA through DSO are subsequently transferred over a LAN for computer simulation. We have also fed the receiving signal to the input of the spectrum analyzer. The data so recorded in the spectrum analyzer are then analyzed either by computer simulation or by video camera [42].

2.3.4 40 kHz VLF Atmospheric Receiver

The receiver employed for the observations at 40 kHz is an imported one from Radio Astronomical Supplies (RAS), USA. It is designed in such a manner so that it can successfully handle variation of field intensities due to atmospherics originating due to meteorological disturbances. The unit has tuned r.f. stages followed by a detector and D.C. amplifier which in turn feed the recorder where a master computer is used for recording the atmospherics data in digital form. The type of antenna used with the receiver is governed by the nature of polarization of the signal to be received and also occasionally by the direction of arrival of the wave while the dimension of the antenna with horizontal part 30 ft and vertical part 10 ft largely depends on the wavelengths, the ratio of the signal picked up by the antenna to the inherent receiver noise. The polarization of the atmospheric field is mainly vertical in the designated frequency range. In our observation we used an inverted-L antenna whose vertical part would receive this field with an omni directional azimuthal pattern. The function of the horizontal part is simply to add to the top capacitance of the antenna causing an increase of current to the vertical part. In order to further mention the technical part of the instrument it may be pointed out that the receiver is composed of a very sharp double tuned filter and three stages of amplification in cascade. The gain of the cascade stages is set by a single potentiometer. The output of the amplifiers is fed to a diode detector and then to a 10 second integrator. Figure 2.8 depict the block Diagram of VLF Receiver [29, 43-45].
2.3.5 92.7 MHz VHF Receiver

We set our experiments to study the propagation effect of radio signal at VHF transmitted at 92.7 MHz from Kolkata. A super heterodyne receiver used to receive this transmitted signal at Kalyani round-the-clock. Measurements have been made by recording audio frequency output of the super heterodyne receiver. In the experimental arrangement we designed the circuit in such a manner that after receiving the electromagnetic waves transmitted by the antenna, the identical voltage is transferred to the receiver input which is amplified by the circuits. The carrier frequency \( f_c \) and the frequency of the local oscillator \( f_o \) are fed to the mixer whose output provides the intermediate frequency \( f_i = f_c - f_o \) which is then amplified by the IF amplifier whose output is fed to the detector. Finally, the audio output voltage is fed to pen recorder wherein the radio signal is received after proper calibration. Figure 2.9 shows a block diagram of the super heterodyne (FM) receiver whose ultimate output is properly tuned at 92.7 MHz. RF voltage amplifier designed for amplification of narrow band of frequencies using tank [46-47].

![Figure 2.8 Block Diagram of VLF Receiver](image)

**Figure 2.8 Block Diagram of VLF Receiver**

![Figure 2.9 Block diagram of the VHF receiver used to receive FM radio signal](image)

**Figure 2.9 Block diagram of the VHF receiver used to receive FM radio signal**
References


42. J. E. Mellor, *Advanced Digital Electronics – 4H Course Notes*


