Synopsis

One of the major problems in modern cosmology is to determine the distribution of matter on large scales in the universe and understand the large scale structure (LSS) formation. Redshifted 21 cm ($\sim 1420\,\mathrm{MHz}$) radiation, from the cosmological neutral hydrogen (HI) distribution, is present as a minute component in the background radiation in all low frequency radio observations. Observations of this radiation are one of the most promising future probes of the Universe starting from the dark ages to the present epoch. It is currently perceived that a statistical analysis of this radiation holds the greatest potential. The fluctuations, with angle and frequency, can be directly related to fluctuations in the properties of the HI distribution in space. The mapping is a little complicated due to the presence of peculiar velocities which moves spectral features along the frequency direction. The precise measurement of the power spectrum of the radiation would provide a wealth of information. In this thesis we have studied several issues related to this. The thesis consists of six chapters whose contents are summarized below.

Chapter 1 **: Introduction**

We briefly review the evolution of the neutral hydrogen starting from the Dark ages to present epoch through the epoch of reionization and the progress on theoretical predictions of the redshited 21 cm signal. The motivational aspects why we are interested in observing redshifted 21 cm radiation is discussed. We also highlight some challenging issues in the context of future HI observations and discuss further research directions.

Chapter 2: **The CMBR fluctuations from HI perturbations prior to reionization**

We investigate in detail the angular power spectrum of brightness temperature fluctuations for redshited 21 cm radiation produced by the HI inhomogeneities prior to reionization. These signal will probe the dark matter power spectrum down to very small scale $k < 500\,\mathrm{h\,Mpc^{-1}}$ prior to first structure formations. The brightness temperature fluctuations arise from two sources: (1.) spin temperature fluctuations (2.) HI optical depth fluctuations, both of which are caused by density perturbations. We investigate in detail the evolution of the spin temperature and the gas temperature in the presence of HI fluctuations. We incorporate two effects namely (1.) gas temperature fluctuations produced by density fluctuations and (2.) redshift space distortions, which will contribute to brightness temperature fluctuations. We find that the former effect increases the brightness temperature fluctuations $\sim$ by 10 % below the redshift $z < 100$ and for the latter effect it is more than 50%.

Chapter 3: **On using visibility correlations to probe the HI distribution from the dark ages to the present epoch : Formalism and the expected signal**

We discuss the nature and the magnitude of the HI signal expected across the entire redshift range starting from the dark age to the present era through the epoch of reionization. Complex visibilities at different baselines and frequencies are the primary quantity measured in radio interferometric observations. We develop the visibility correlation formalism, including peculiar velocities , which directly probes the power spectrum of HI at the epoch where the radiation originated. In the reionization era the HI has a patchy distribution. It has a distinct signature where the signal is determined by the size of the discrete ionized bubbles. At other epochs, the HI signal traces the underlying dark matter fluctuations. The signal is stronger for smaller baselines and an optimal strategy would preferentially sample these baselines. In the frequency domain, for most baselines the visibilities at two different frequencies are uncorrelated beyond $\Delta\nu \sim 1\,\mathrm{MHz}$, a signature which in principle would allow the HI signal to be easily distinguished from the foregrounds contamination. Here we also briefly discuss the signal to noise ratio and the approximate integration time required to detect the HI signal.

***Chapter 4*: Probing the bispectrum at high redshifts using 21 cm HI observations**

We study how three visibility correlations can be used to study the HI bispectrum at redshifts $z < 6$, where it is reasonable to assume that the large scales HI distribution traces the dark matter with a possible bias. Here we estimate the magnitude and nature of the three visibility correlated signal in angular and frequency domain. We also compare this with the two visibility correlated signal. The magnitude of the signal from the bispectrum is predicted to be comparable to that from the power spectrum. It allows us to detect both signal in roughly the same integration time. Here we also consider the possibility of using observations of the HI bispectrum to determine the linear and quadratic bias parameters of the HI.

***Chapter 5*: What will anisotropies in the clustering pattern in redshifted 21 cm maps tell us ?**

We investigate the expected anisotropies in the clustering pattern in redshifted 21 cm map for the epoch of reionization and the post-reionization era. The anisotropies arise due to two distinct reasons, the Alcock-Paczynski effect and the peculiar velocities of HI, both of which are sensitive to the cosmological parameters. We use simple models for the HI distribution for both the epochs to ask whether the observations of the anisotropy tell us more about the background cosmological models or the details of the HI fluctuations. We find that such observations will probably tell us more about the HI distribution than the background cosmological model. The observations of the anisotropies in HI map can be used to constrain the background cosmological model if the bias parameter can be determined by independent means.

***Chapter 6*: Foregrounds for redshifted 21 cm studies of reionization: GMRT 153 MHz observations**

We have carried out 150 MHz observations using the Giant Meterwave Radio Telescope (GMRT). We describe the data reduction process. The final calibrated visibility data is used to produce a continuum image where a large number of discrete sources are seen. For the subsequent analysis we use visibility-correlations technique to quantify the statistical properties of the data. We also discuss the expected uncertainties or statistical fluctuations in our visibility correlation estimator. We compare our observational results with the theoretical predictions of existing foreground models and discuss their implications for separating the HI signal from foregrounds in future HI observations.