A PC-BASED INTERFEROMETER
FOR
RADIO ASTRONOMY

A Thesis
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INTRODUCTION

1.1 Interferometry

Interferometry is now a well established experimental technique of considerable importance in science and technology. In these *nearly* ten decades of its existence, interferometry has advanced greatly, almost in step with the advances in electronics, optics and related fields. While the first in*terferometer* was developed by Michelson in 1890 *[1]* to estimate stellar diameters, more recent developments in interferometry have taken its application areas into other branches of science, such as radio astronomy, spectroscopy, etc. To the astronomer, interferometry provides a means of measurement of stellar diameters; and more recently a powerful tool in high resolution radio astronomy, both implying studies of the angular distribution of radiation on the sky. For the spectroscopist, it facilitates measurement of *spectral* distributions and represents a new technique for high resolving power and increased sensitivity. To the optical designer. it is a method of testing lenses and. to the biologist it is a new branch of microscopy. To the meterologist and the engineer, it is now an important means of converting the international standard of length into a practical *scale*. The field of interferometry has advanced in such a way that in each of these fields, the user is *familiar* with the techniques and applications relevant to the field.

1.2 Interferometry in Radio Astronomy

Interference occurs when radiation follows more than one path from its source to the point of detection. It may be described as the departure of the resultant intensity from the laws of addition. This is because as the point of detection is moved, the intensity oscillates about the sum of the separate intensities from each path, leading to maxima and minima in the intensity pattern. These are generally called interference *fringes*. The technique of interferometery is derived from these interference patterns. And today, it has evolved into one of the most important methods of experimental physics, with applications extending to many branches of science and technology, as indicated earlier.

The first use of interferometry in radio astronomy was reported in 1947 [2]. Since then, there have been many radio interferometers developed and used in astronomical studies. The first radio interferometer made use of the reflections from the surface of the sea to provide the second path; but later instruments were developed making use of two separate antennas in the system.. The powerful technique of aperture synthesis was a spin-off from radio interferometers [3]. This technique has formed the basis for several new radio telescopes that were built in later years, with resolutions, until then thought of as unrealisable [4,5,6]. Some of these interferometers are now operating over a wide range of Radio Frequencies (RF) for a variety of astronomical applications all over the world. In the last over four decades, there has been considerable development and improvement in the techniques employed, and the electronics involved in realising these interferometers. Major advances in interferometry in recent years have largely been influenced by:

a) Progress in electronics

b) Advances in computers; and

c) Wider range of applications.

While the advances in electronics during this period have greatly influenced the development of better and better instrumentation for the radio interferometer, progress in digital computers has contributed a great deal in the field of analysis of observed data. This is particularly important as the study of the distribution of radiation over the sky involves manipulation of a large database. However, more recently, as the cost of computers has begun to decrease and their functionality to greatly increase, they have also been used for data acquisition in radio interferometry. As a result, there is now a wide variety of main-frame and mini-computers in use all over the world in radio astronomy applications. However, there are some limitations suffered by these radio interferometer systems:

a) Lack of standardisation in data structures

b) Incompatibility of secondary storage media

c) Multiplicity of programs for the same type of analysis in different systems

d) Need for two separate computers viz.,

   (i) data acquisition

   (ii) data analysis

This has resulted in the data acquired at one location not being easily analysed at another location leading to problems in free exchange of unprocessed data from one observatory to another. This has also resulted in lack of flexibility that is so much needed in this important field. Also there is a need for preliminary on-line data analysis, to monitor it for interference, which is especially predominant at low frequencies. This would avoid the collection of unnecessary data, thereby saving data storage space. Considering these limitations, and keeping in view the recent developments in Personal Computers (*PCs*) and their possible uses in instrumentation, it was decided to conduct a detailed investigation on the use of *PCs* to radio interferometer applications. As the Raman Research Institute already had a plan of developing a new radio interferometer at 150 MHz, it was decided to try out the new ideas resulting from this investigation in the system design and implementation of this new interferometer. This interferometer, which can be aptly termed as an intelligent instrument, would, not only solve the problem of data transportability but also incorporate a real-time Data Acquisition System (*DAS*) in it. This would enable on-line data acquisition, interference monitoring and storage, as well as off-line data analysis all in the same system. The result of this investigation is the development of a **PC-based radio interferometer,** which is described in detail in this thesis.

1.3 Thesis Organisation

The thesis is organised in five Chapters. Following this introductory Chapter, Chapter *II* reviews existing radiotelescopes historically, leading to different approaches in radio astronomy for the improvement of resolution. The radio interferometer forms the basic building block in these radio telescopes. A typical interferometer is then described in detail, drawing attention to the various limitations in present-day systems. This is followed by a brief discussion on the approach leading to the need of PC-based instrumentation in these applications.

Chapter *III* presents the detailed specifications of the overall PC-based interferometer system designed and developed at the *Raman **Resarch Institute.*** As the PC-based ***DAS*** is ***an*** innovation in radio interferometry, much of the discussion here is directed to the PC-based DAS for use in the radio interferometer. However, system design aspects of the total radio interferometer are also ***briefly*** touched upon here.

Chapter *IV* describes the experimental work done to ***realise*** the overall radio interferometer system ***including*** the system integration. The details of the various experimental setups for evaluating the performance of the different building blocks along with their corresponding results are also given here. This is followed by the testing and evaluation of the overall PC-based radio interferometer system. The results of simulation tests and the final radio source observations are then presented to clearly demonstrate the performance of the ***overall*** system.

Chapter V is the concluding Chapter which reviews the entire work and also indicates the scope for future studies and investigation in this area.

References to published literature are then listed followed by four Appendices covering supplementary *information.*