THE NEW 1420 MHZ DUAL POLARISATION INTERPLANETARY SCINTILLATION (IPS) FACILITY AT EISCAT

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ABSTRACT

The EISCAT 930 MHz antennas have for many years been used for interplanetary scintillation measurements of solar wind parameters. To augment the EISCAT IPS capabilities, the Swedish and Finnish antennas were recently equipped with 1400 MHz dual polarisation receiver systems, which in addition to the total signal power can also measure phase and amplitude scintillations simultaneously. This is potentially very important, as amplitude scintillation measurements provide better information on solar wind velocity while phase scintillation measurements are a particularly powerful method of studying the solar wind turbulent-scale microstructure. The first 1400 MHz IPS campaign is planned for May 2002.

INTRODUCTION

Measurements of the fluctuation in apparent intensity of compact radio sources when viewed through the solar wind - the technique of Interplanetary Scintillation or IPS - have been used to determine solar wind parameters for almost 40 years [1], [2]. In the last 10 years improvements in experimental technique - particularly the use of simultaneous observations from two widely (200-500 km) separated antennas - and improved analysis methods have transformed the capabilities of IPS (e.g. [3], [4]). It is now regarded as an essential tool for the study of the solar wind and inner heliosphere.

The EISCAT facility in northern Europe (Norway, Sweden and Finland) is one of the finest IPS instruments in the world. Its operating frequency of ~930 MHz allows it to probe the solar wind over a range of heliocentric distances from 15-25 solar radii (R) out to around 100 R, covering the region in which co-rotating interaction regions (CIRs) begin to develop and in which the interaction between coronal mass ejections (CMEs) and the background solar wind develops [5], [6]. The EISCAT field-of-view therefore covers the region in which the structure of the innermost solar wind (as seen in coronagraph observations) begins to be transformed into the structure seen in-situ at 1 AU [7], [8]. The wide spacing of the EISCAT sites - offering baselines of up to 390 km with exceptional timing accuracy - makes it capable of resolving two streams of solar wind with different velocities in a single observation, something which is not possible with smaller antenna separations (e.g. [9]).

THE SPECTRUM ISSUE

When EISCAT started operation in 1980, the entire 918 - 948 MHz frequency range was available for scientific use. For many years, EISCAT IPS observations were made using the full 30 MHz bandwidth and a square law detector, producing excellent quality data. In recent years, however, the capabilities of EISCAT as an IPS system have been eroded by the encroachment on its frequency band of several cell-phone and communications services, leading to reduced bandwidth available for observations, increased interference and severe receiver non-linearity problems.

This development culminated in 2001, when the Finnish EISCAT receiver site lost all spectrum, except the 929.0 - 930.5 MHz range, to a new GSM operator [10]. The remaining 1.5 MHz is not wide enough by far to get the time resolution required for meaningful IPS work. For this reason it was decided to examine whether it would be possible to modify the EISCAT receiver sites to allow observations in the 1410-1427 MHz protected radio astronomy band.

ADAPTING THE UHF ANTENNAS FOR 1400 MHz WORK

The EISCAT UHF antennas are 32-m Cassegrain dishes, fed by large circular corrugated horns. While the antenna optics is optimised for good aperture efficiency and low spillover at 930 MHz, it also provides acceptable main reflector illumination at 1400 MHz [11]. This is fortunate, as the feed horns are very large and heavy and it would be extremely impractical to routinely swap them with dedicated 1400 MHz horns. However, the waveguide-to-coax orthomode transformer (OMT) and waveguide-to-coax transitions used to couple into the receiver at 930 MHz are oversized, overmoded and badly mismatched at 1400 MHz.

To solve the matching and coupling problems, a two-section, circular waveguide Chebyshev transformer covering 1300-1450 MHz has been designed [12]. The transformer bolts directly onto the feedhorn flange and feeds into a circular-waveguide-to-coax transition with dual probe coupling. A prototype has been constructed and tested on the Kiruna and Sodankylä antennas. A very good impedance match (better than -20 dB reflection coefficient) is observed over the 1420-1427 MHz band. Pattern measurements using strong calibrator sources show a main beam (-3 dB) width of 0.44 degrees and first sidelobes about -17 dB down, roughly consistent with a fully illuminated main aperture and aperture efficiency in the 65 % range. This should be compared to a 0.6 degrees half- power beamwidth at 930 MHz. The antenna contribution to the system noise temperature is in the (25 – 30 Kelvin) range, indicating that the spillover is somewhat larger at 1400 MHz than at 930 MHz but still acceptable. Overall system noise temperature using uncooled HEMT preamplifiers is about 65 Kelvin. The G/T at 1400 MHz with this receiver is thus comparable to that at 930 MHz using the cooled front end. No signals have been observed either in-band or in adjacent bands at either site, so transmitter-generated wide-band noise and receiver overload problems will no longer be an issue.

Operational dual polarisation 1400 MHz feed adapters are now being manufactured for the Kiruna and Sodankylä antennas. Receiver performance will be enhanced through the addition of a second phase-coherent 6.5 MHz wide i.f. channel, providing a total receiver bandwidth of 13 MHz. The two i.f. signals will be digitised to 14 bits of resolution, rounded to 8 bits and processed by the Sun Enterprise 450 servers normally used for radar signal processing.

SCIENTIFIC GAINS AND TRADEOFFS, 1400 MHz VS. 930 MHz IPS

After moving the EISCAT IPS operation to the 1400 MHz band, observers will be able to enjoy 27 MHz of protected, interference-free spectrum. This can potentially improve the IPS statistics by one order of magnitude compared to the best performance of the non-bandwidth-restricted 930 MHz system. On the other hand, the flux densities of most sources used for IPS are significantly less at 1400 MHz than at 930 MHz, which negates part of the gain.

However, operation at 1400 MHz brings a number of other benefits, e.g.

1) to correctly interpret the level of scintillation and the variation of scintillation index with the orientation of the baseline with respect to the source, it will be necessary to have very high-resolution maps of radio brightness across the source. Many such maps are available at 1400 MHz from the VLA. None are available at 930 MHz,

2) by going to 1400 MHz, observations can be made slightly closer to the Sun than at 930 MHz yet still remain in the weak scattering regime, so improving the ability of EISCAT to study the outer regions of the acceleration region of the solar wind (e.g. [3], [13], [14]),

3) the move to observing at 1400 MHz will also increase the region of overlap between EISCAT IPS measurements and white-light measurements from the LASCO C3 coronagraph on the SoHO spacecraft, permitting direct comparisons of the drift speeds of structures with scale sizes of ~10000-100000 km and ~100 km (e.g. [13], [15]),

4) for a given scale of irregularity the Fresnel distance at 1400 MHz is only 43% of the Fresnel distance for 930 MHz. This means that the fairly arbitrary correction for the transition from Fraunhofer to Fresnel along the line of sight, which is made in the analysis routine, is less critical,

5) in addition to total-power processing of each polarisation, the 1400 MHz system will also have the capability to measure phase and amplitude scintillation simultaneously, something that to our knowledge has not been done before with a single system. This is, potentially, of great importance as amplitude scintillation measurements provide better information on solar wind velocity while phase scintillation measurements are a particularly powerful method of studying the turbulent-scale microstructure of the solar wind, e.g. [16],

6) since preamplifier overload and intermodulation will no longer be an issue, the data quality is expected to be much improved.

The first full-scale 1400 MHz IPS campaign is planned for Spring 2002. Preliminary results will be reported at the General Assembly.

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