Measurement of LHCD antenna position in Aditya Tokamak

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Abstract. To drive plasma current non-inductively in ADITYA tokamak, 120 kW pulsed Lower Hybrid Current Drive (LHCD) system at 3.7 GHz has been designed, fabricated and installed on ADITYA tokamak. In this system, the antenna consists of a grill structure, having two rows, each row comprising of four sub-waveguides. The coupling of LHCD power to the plasma strongly depends on the plasma density near the mouth of grill antenna. Thus the grill antenna has to be precisely positioned for efficient coupling. The movement of mechanical bellow, which contracts or expands up to 50mm, governs the movement of antenna.

In order to monitor the position of the antenna precisely, the reference position of the antenna with respect to the machine/plasma position has to be accurately determined. Further a mechanical system or an electronic system to measure the relative movement of the antenna with respect to the reference position is also desired. Also due to poor accessibility inside the ADITYA machine, it is impossible to measure physically the reference position of the grill antenna with respect to machine wall, taken as reference position and hence an alternative method has to be adopted to establish these measurements reliably.

In this paper we report the design and development of a mechanism, using which the antenna position measurements are made. It also describes a unique method employing which the measurements of the reference position of the antenna with respect to the inner edge of the tokamak wall is carried out, which otherwise was impossible due to poor accessibility and physical constraints. The position of the antenna is monitored using an electronic scale, which is developed and installed on the bellow. Once the reference position is derived, the linear potentiometer, attached to the bellow, measures the linear distance using position transmitter. The accuracy of measurement obtained in our setup is within +/- 0.5 % and the linearity, along with repeatability is excellent.

1. Introduction
A 3.7 GHz., 120 kW pulsed, Lower Hybrid Current Drive (LHCD) system [1] is being used on ADITYA tokamak [2] to drive the plasma current non-inductively. To drive the plasma current efficiently using lower hybrid waves, a good coupling between the plasma and the grill antenna, delivering rf power, is required. An efficient coupling of rf power to the plasma strongly depends on the plasma density near the mouth of grill antenna and is obtained by moving the antenna appropriately employing mechanical bellow, without breaking the tokamak vacuum. The movement of mechanical bellow, which contracts or expands up to 50 mm, provides the desired movement of antenna.

To determine the antenna position accurately, the antenna reference position with respect to machine/plasma position is derived and measurements are made using a mechanical and an electronics system. Here an alternative method has been adopted to measure the reference position of the grill
antenna with respect to machine wall due to poor accessibility inside the ADITYA machine. The paper is organized as follows. The test setup and details of the instruments is described in section-2. The results and discussion is presented in section-3 followed by conclusion in section-4.

2. Test setup and details of instruments
The setup for LH-antenna position measurement with LHCD system is shown in the figure 1. It is important to mention that bellow isolates the grounds of the transmission line (including antenna) and the machine. An elastomer seal is used to provide vacuum seal as well as isolation between the circular flange (connected to LH waveguides shown in figure 1) and the bellow collar. The linear potentiometer is connected with the LH-ADITYA bellow. The shaft of the linear potentiometer is attached to bellow with proper isolation using 5mm G10 sheet and appropriate mechanical structure for linear movements. The other instruments connected to linear potentiometer are position transmitter and indicator as shown in the figure 1. The detailed connection diagram for position measurement is shown in the figure 2.

![Figure 1. Position measurement setup with LHCD system](image-url)
The setup shows us the connection between linear potentiometer- 5 k ohm, position transmitter PT2004R, Indicator DPM-48 and 24V DC power supply. The detail of each component of setup is given below.

### 2.1. Position Transmitter, Model: PT 2004R

PT 2004R Position Transmitter is a panel mounting 2-wire Transmitter intended to sense any angular displacement with reference to a preset zero position and to transmit the signal in two-wire current loop. High stability linear potentiometric sensing element is used to achieve higher repeatability. The specification of the PT 2004 R position transmitter is listed in table 1.

### Table 1. The specifications of PT2004R position transmitter

| PARAMETER       | VALUES                                                                 |
|-----------------|------------------------------------------------------------------------|
| Range           | Maximum displacement: 0 to 180° with Internal Potentiometer. External Potentiometer minimum: 5000 Ω. |
| Output          | 4-20 mA. Through 2-wire current loop.                                   |
| Power Supply    | 12 to 40 V. D.C.                                                       |
| Loop Impedance  | \((V_{ps} - 12)/0.02\) [Ex. for 30Vps, Impedance = (30-12)/0.02 = 900Ω] |
| Transducer      | a). In-built Potentiometer.                                             |
|                 | b). External 3-wire Potentiometer (5KΩ).                                |
| Adjustability   | Zero & Span adjustable throughout the range.                           |
| Accuracy        | Max error : ± 0.2% of span.                                            |
| Repeatability   | Max. drift : ± 0.5% of span.                                           |
| Enclosure       | Rear Panel Mounting ABS Module (120mm(H) x 38 mm(W) x 115 mm(D))
2.2 Linear Potentiometer, Model: LMP-WW-200-B

The linear potentiometer is used as the sensing element (transducer) for the position transmitter. The specification of the linear potentiometer is listed in table 2.

| PARAMETER               | VALUES                  |
|-------------------------|-------------------------|
| Resistance              | 5 kΩ                    |
| Linearity               | Better then ± 1%        |
| Resolution              | 0.048%                  |
| Insulation Resistance   | 500 MΩ @ 500VDC         |
| Maximum Working Voltage | 200VDC                  |
| Stroke(Shaft) length    | 200 mm                  |
| Housing                 | 32 mm square aluminium housing with 6 mm SS shaft |

Table 2. The specifications of linear potentiometer

In our case, the effective stroke length is 160 mm and the resolution is 0.048%, which corresponds to resistance resolution of 2.4 Ω. The potentiometer of value 5k is linearly distributed along the length of 200 mm and covers the value of \((5000 \times 160 / 200) = 4000k\) for 160mm effective stroke length. Thus the resolution in the mm range is about \((2.4 \times 160 / 4000) 0.096 \text{ mm} \) or approximately 0.1mm.

2.3 Indicator/meter, Model: DPM- 48, Make: KEW

To show the reading in the mm range the digital indicator is used, which takes 4 - 20mA current as a input. This Indicator is connected with power supply and transmitter in the loop-powered configuration as shown in the figure 2. Its main specification is shown in table 3.

| PARAMETER               | VALUES                  |
|-------------------------|-------------------------|
| Range                   | 0 – 160mm               |
| Input                   | 4 – 20 mA DC            |
| Auxiliary power supply  | 200 – 250 VAC           |
| Accuracy class          | 1.0 (1% accuracy)       |

Table 3. Specifications of indicator/meter

2.4 24VDC Power Supply

Power supply requirement for the PT 2004 R position transmitter is 12 – 40 VDC. The power supply Schematic for 24V DC output is shown in figure 3.

Figure 3. 24V DC power supply
Here we feed line voltage 230VAC to the transformer 15–0–15. The output of the transformer is connected to bridge rectifier as shown in figure 3. To minimize the ripple and for stable 24VDC output, 2200uF electrolytic capacitor, IC LM7824 and combination of 10uF electrolytic capacitor with 0.1uF ceramic capacitor is used. LED indicates the power supply status. The system is calibrated on experimental table before being installed on the main system.

3. Results and discussions

As mentioned earlier, a unique method, employing plate-rod mechanism was devised, as shown in figure 4, to establish the reference position of the antenna. A 3 mm thick straight aluminium plate is bent in L-shape and is joined to ~3m long square aluminium pipe (to be used as handle for remote maneuvering through port no. 7 of ADITYA machine), employing M6 nut-bolts. From one port (port no. 7), it was inserted inside the ADITYA tokamak to reach the LH port (port no. 14).

![Plate-rod mechanism](image)

**Figure 4.** Plate-rod mechanism

![ADITYA-LH antenna inside ADITYA-LH port](image)

**Figure 5.** ADITYA-LH antenna inside ADITYA-LH port

The principle on which this method works is very simple and is as follows. A straight plate is kept on ADITYA-LH port wall inside tokamak (port no. 14 on which LH antenna is mounted) such that it touches the upper and lower edges of the circular port from inside the machine, as the cross section of ADITYA vessel is rectangular (see figure 5 for reference). As mentioned earlier the machine and the antenna is isolated and shows electrical discontinuity when they are connected externally. The LH-ADITYA antenna is slowly pushed into the vessel till it touches the plate. At this position the antenna and the port wall (inner side) is same and they touch each other, through straight plate. At this location the electrical isolation is lost and external connection (multimeter) shows continuity between the antenna and the vessel, as both are on separate ground. Since the location of the port is precisely known, therefore the antenna position is also derived very accurately.

Before starting the position measurement experiment, the initial reading between outer to outer bellow flange was recorded using the scale/vernier (265mm). A linear potentiometer is attached with bellow, which measure the linear distance using position transmitter.

From the initial position (265mm on scale and 60.0mm on indicator/meter), the LH antenna is retrieved back (towards the LH waveguide side) by expanding the bellow. The readings are obtained at each 10.0mm expansion of bellow. The measurements obtained during the process, both on the meter and on scale are shown in figure 6.
At the end point (meter reading = 0.4mm) the antenna tip, at both ends (bottom and top), are in flush with vessel wall and electrical continuity is immediately obtained. The flushing of LH-antenna, LH-port and the plate-rod mechanism is shown in figure 7. A slight retrieval of antenna (meter reading around 0.3mm) resulted in electrical discontinuity (open circuit). This process was repeated several times to establish the repeatability of the measurements.

4. Conclusions
A unique method for measuring the LH-antenna position is employed and the reference position of the antenna with respect to the inner edge of the tokamak wall is established. An electronic scale is developed and installed on the bellow to measure the movement of the antenna position. Once the reference position is derived, the linear potentiometer, attached to the bellow, measures the linear distance using position transmitter. The experiment shows the good measurement accuracy along with excellent repeatability.

References
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