RadioAstron Mission: Tracking Stations

Tracking stations (TS) will provide two-way information contact with the space radio telescope (SRT) during scientific experiments over major portion of the elliptical orbit during all operational time of the Mission (not less than 5 years). Tracking stations will be selected in accordance with the schedule issued daily by the General Operative Control Group (GOCG) in Lavochkin Association with the gaps in operations during spacecraft contact with the control stations (CS). The schedule will determine the TS operation mode and the pointing of special communication antenna (dish with the diameter greater than 12 m) to the SRT. Communication frequencies (carrier): high data rate information transmission downlink from the SRT – 15.000 GHz; uplink synchronization – 7.2075 GHz; downlink synchronization – 8.400 GHz. TS may have gaps in operation during spacecraft contact with the control stations (about one hour per day). Every TS will have communication facilities with the GOCG, processing and ballistic centers.

Orbit parameters: inclination 52 degrees, maximum apogee height 380000 km, minimum apogee height 1000 km, mean period 9.5 days. Orbit apogee is located in the southern hemisphere. To provide continuum tracking (less than 10% losses in operation time) with the minimum redundancy we need 2-3 tracking stations located at different longitudes in the Northern hemisphere together with 2-3 tracking stations located at different longitudes in the Southern hemisphere. In our current plan there are only three TS: NASA in Australia, NRAO in Green Bank, and Russian TS in Pushchino.

TS must be compatible with the on-board High Data Rate Information (HDRI) radio complex, and TS must perform the following functions:

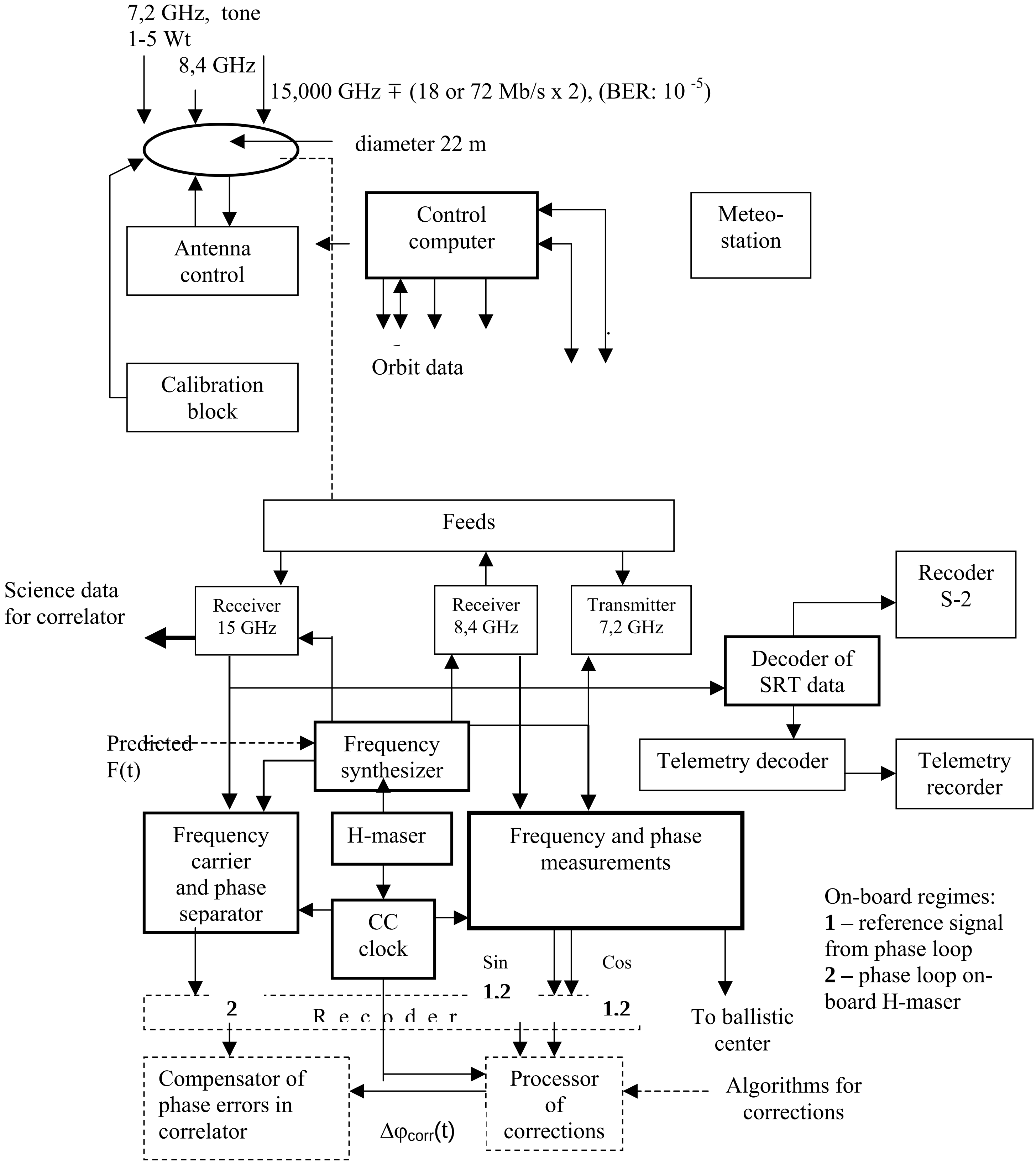
1) To receive and to encode digital data streams with the rate of 2x18 or 2x72 Mbit/s. To record the encoded data streams together with the information on accurate local time onto dedicated digital devices.
2) To separate headers from data stream and to recode the headers for subsequent transfer of the information to GOCG.
3) To provide phase synchronization of the SRT operation by transferring to the SRT (uplink) the stable reference signal formed from the Hydrogen frequency standard with the predicted Doppler frequency shift, and by receiving responded coherent signal (downlink) continuously measuring phase difference between uplink and downlink signals with high accuracy of less than 3 degrees. The measurements will be carried out with the sampling frequency of 400 Hz (in both quadrature components), and the results will be recorded in digital format for the subsequent transfer to GOCG, processing and ballistic centers.
4) To determine Doppler shift and phase behavior for the carrier of HDRI data transfer in the mode of operation using on-board Hydrogen frequency standard with the same accuracy and sampling frequency as mentioned in the previous item for the subsequent transfer to GOCG, processing and ballistic centers.

TS operating from its hydrogen frequency standard will continuously measure phase difference between transferred and received tone signals (taking into account predicted Doppler shift). Such operation will provide small phase fluctuation of reference signal at any SRT height due to high communication potential of up-down link loop (SNR greater than 35 dB in a frequency band of about 1 Hz) and due to fast sampling of measurements (sampling time is a few ms). The disadvantage of this technique is that any failure in the loop will cause the loss astronomical dater until the synchronization will be reestablished. Besides, synchronization loop inevitably introduces some errors due to asymmetry of transferred and received signals, since during the propagation time from TS to the SRT and back (30 ms – 2 s for RadioAstron orbit) troposhphere and ionosphere delay may change; some errors may by caused by the difference in uplink and downlink frequencies. To avoid these disadvantages we have other mode of operation using on-board hydrogen frequency standard.

Functional diagram of TS in Pushchino is shown in Figure1. Existing TSs are constructed according to the same diagram. Diagnostic correlator indicated at the bottom of the diagram (as desirable, optional) can carry out two important functions:

1) Near-real-time monitoring of the quality of interferometric measurements when the TS can receive simultaneously scientific data from the SRT and from the ground radio telescope located nearby.
2) In radiometer mode (during boresighting) data averaging will increase the sensitivity.

Shematic Diagram of the Pushchino Tracking Station



Facilities shown in dashed squares are related to the processings center