Toward 64 Gbps Wideband Digital Backend Design for the Event Horizon Telescope

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A broad international collaboration is building the Event Horizon Telescope (EHT). The aim is to test Einstein's theory of General Relativity (GR) in one of the very few places it could break down: the strong gravity regime right at the edge of a black hole. The EHT is an earth-size VLBI array operating at the shortest radio wavelengths that has achieved unprecedented angular resolution of a few tens of μarcseconds. For nearby supermassive black holes (SMBH) this size scale is comparable to the Schwarzschild Radius, and emission in the strong GR regime at the edge of the event horizon can be directly observed.

The EHT combines existing submillimeter radio telescopes across the Earth. In 2015 the EHT will add several new stations including the South Pole Telescope (SPT), the Large Millimeter Telescope (LMT) in Mexico, and the IRAM 30m dish in Spain. The sensitivity and UV-coverage of the interferometer will be vastly improved with these stations, and it may become possible to make an event-horizon-scale image of emission from the black hole. Adding more sites also significantly increases the complexity of operating the EHT, thus we are standardizing equipment across the heterogenous telescope array. To this end, in 2015 a newly designed 4 GHz bandwidth (16 Gbps) digital backend (DBE) will be used on many of the new and existing single dish sites. Ultra-fast analog-to-digital converter (ADC) technology is used to achieve this bandwidth without excessive analog expense and complexity.

The new DBE has been designed based on the Reconfigurable Open Architecture Computing Hardware, Generation 2 or ROACH2 This "ROACH2 DBE" is designated the R2DBE. It was developed at the Harvard-Smithsonian Center for Astrophysics (CfA) and built on earlier 4 Gbps systems such as the "RDBE" based on ROACH1. The R2DBE uses open source hardware, firmware, and software provided by the open source Collaboration for Astronomy Signal Processing and Electronics Research (CASPER). Researchers at CfA have been active in CASPER for about 8 years. Leveraging the collaboration's shared technology has helped us meet schedule and budget goals which would otherwise not have been possible. In four months the R2DBE was developed and demonstrated with fringes obtained on the sky at centimeter wavelengths.

The first R2DBE based system was deployed at the SPT in November 2014. We present the tests and results achieved with this system and discuss current and future developments that improve performance, increase automation and sophistication, and move the EHT toward an era of turn-key operation. Additionally, we discuss how the EHT will be scaled to 64 Gbps in the next three years, adding dual-pol, dual-sideband 4 GHz capabilities to each single dish element in the EHT array.