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Adaptive Compression of Transient Radio Astronomy Signals

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Astronomical signals are typically weak and dominated by Gaussian receiver noise. Over short time intervals ($\sim$ seconds), such a signal is stationary and can be quantized with 2-bits, without much loss in SNR [1]. An exception to this is bright Fast radio bursts, solar bursts and radio frequency interference(RFI). While the analog front end and the analog to digital converters (ADC) may have sufficient dynamic range to handle these signals, it is possible to incur a signal loss due to saturation post requantization in these scenarios (see Figure 1) when recording with reduced bit-width. Quantizing with more bits in such cases is sub-optimal as the rate of occurance of such bright bursts is low. Communications transmissions are similar and the Square Kilometre Array Mid requires at least eight-bits [2] to preserve signal fidelity in certain bands.

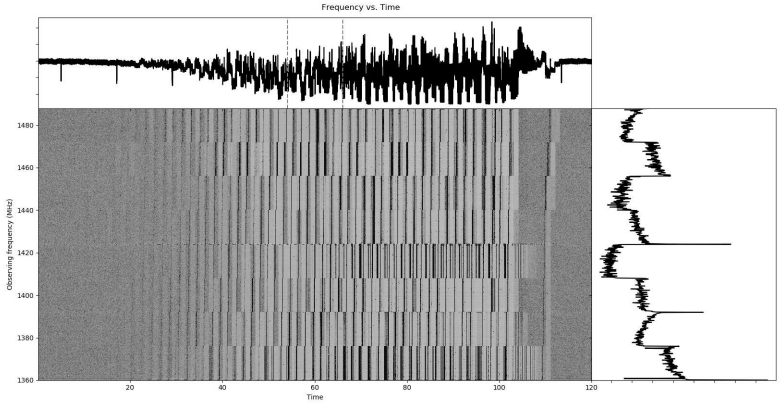

Figure 1. A dynamic spectrum showing the effect of a "simulated" transient signal on a 2-bit data recorder. This digitizer is pushed into non-linearity at power-levels $\approx$ -30 dBm, rendering it unsuitable for bright transients.(Image Courtesy: Franz Kirsten)

In this paper we present our work investigating schemes to adaptively compress non-stationary and transient radio-telescope signals, in order to minimize the bit rate required to preserve a desired information content. The developed receiver will be able to adaptively adjust quantization and bit-rate according to user input parameters. This will lead to efficient data recording, processing and storage for single dish/station observations. For large arrays, like the SKA or ngVLA, it will make more optimal use of data transfer bandwidth, processing and storage resources improving the telescope capability to dump voltage data, whose importance in study of transients cannot be understated.

We intend to develop this system in multiple stages, initially evaluating model schemes on computers and then testing performance on the Onsala 25m telescope using an FPGA based digitizer. While this work is targeted at radio-telescope signals, we expect it is relevant to the processing of non-stationary transient signal processing generally.

References

[1] B.F.C. Cooper, "Correlators with two-bit quantization," *Australian Journal of Physics*, **23**, 1970 pp.521-527.

[2] K. Caputa, S. Harrison, Z. Ljusic, M. Pleasance, and E. Zhao, "The SKA Mid SPFRx receiver/digitizer qualification model testing," *Ground-based and Airborne Telescopes IX*, **12182**, SPIE, 2022 pp. 1457-1475.