USE OF A DIGITAL TONE EXTRACTOR FOR REAL-TIME PHASE ANALYSIS*

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ABSTRACT

With demands for increased accuracy and reliability for very long baseline interferometry (VLBI) experiments, single station phase calibration techniques are becoming a reality. The presence of phase calibrator tones within the VLBI band-pass make it possible, for the first time, to monitor accurately the health of the entire instrumental data path. The digital tone extractor, designed and built by the Jet Propulsion Laboratory is exactly such a device. This real-time VLBI system monitor is a safeguard against most instrumental breakdowns and operator errors.

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INTRODUCTION

A digital tone extractor which monitors the phase integrity of a VLBI recording system in real time has been developed at the Jet Propulsion Laboratory. This digital tone extractor monitors phase calibrator tones injected at the antenna and tracks their phase as a function of time. It is capable of maintaining 0.001 cycle phase accuracy over the course of a VLBI experiment in accordance with the accuracy requirements of centimeter VLBI work. This real-time VLBI system monitor is a safeguard against most instrumental breakdowns and operator errors.

IMPLEMENTATION

The digital tone extractor interconnects with the VLBI recording system to extract phase calibrator tones from the digital data stream. A typical VLBI system with a digital tone extractor is shown in figure 1.

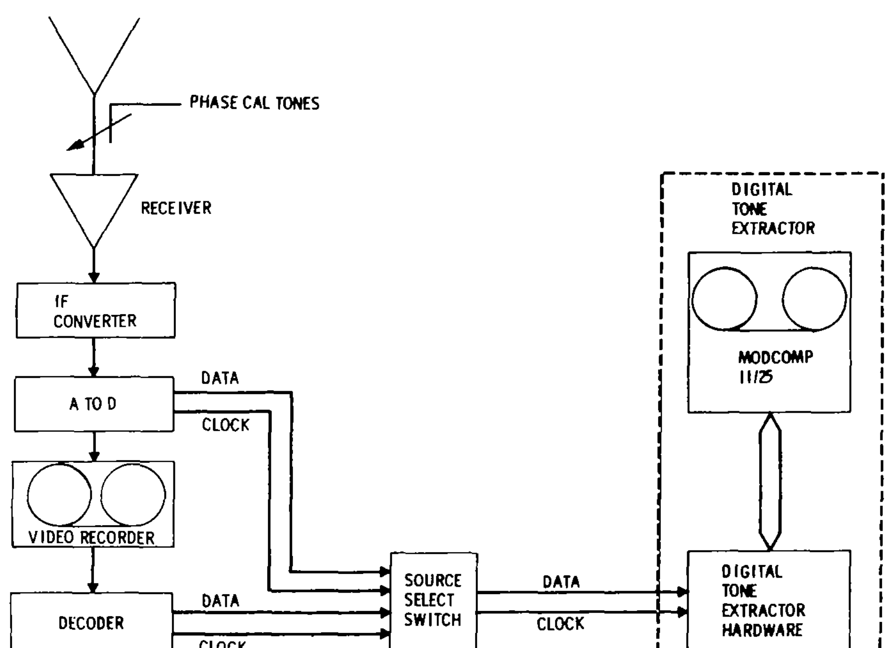

Figure 1. VLBI hardware configuration.

Stable tones from the phase calibrator are injected into the system at the antenna. From the antenna, the signals go through the front end of the receiver and are down-converted to baseband by the IF converter. A one-bit A to D converter digitizes the baseband data, after which it is formatted for recording on the video recorder.

The digital tone extractor can monitor the digital data stream either before or after it has been recorded on tape as selected by the SOURCE SELECT switch. When monitoring data recorded on tape, a decoder is used which is connected to the read-after-write head of the tape recorder. Along with the digital data, clock signals which are synchronous with the data are sent to the digital tone extractor.

The digital tone extractor synthesizes two tones in phase quadrature at the baseband frequency of a phase calibrator tone. These synthesized tones are cross-correlated with the incoming data and integrated to provide sine and cosine correlations. From these two correlations, the residual phase and amplitude of a phase calibrator tone is obtained.

A block diagram of the digital tone extractor is presented in figure 2. As shown, a programmable digital frequency synthesizer in the digital tone extractor synthesizes a tone at the baseband frequency of a phase calibrator tone. The clock that is brought in with the data is used to synchronize this synthesizer. Quadrature sine and cosine outputs of the synthesizer are cross-correlated with the incoming data, and the results are accumulated in two 32-bit registers. With 32-bit resolution, the hardware is capable of maintaining 0.001 cycle accuracy for up to 1 second of integration time. The integration time is controlled by a precision clock which is externally programmable. The sine and cosine accumulations are periodically sent to a MODCOMP mini-computer through a microprocessor. The phase of the frequency synthesizer is also updated by the MODCOMP. In the MODCOMP's software, 64-bit arithmetic is used which enables the digital tone extractor to maintain 12×10^{-6} degree accuracy over a 24-hour period.

The hardware of the digital tone extractor is controlled by the microprocessor which can store the phase and frequency of the tone synthesizer and the sine and cosine accumulations at any time and retrieve them at a later time. When these numbers are retrieved, the phase of the tone synthesizer can also be updated by the microprocessor. With this capability, the digital tone extractor can monitor time-multiplexed tones such as are encountered in time-multiplexed bandwidth synthesis experiments.

A typical output from a two channel bandwidth synthesis experiment is presented in figure 3. Each printout represents the results of 15 integrations of 12 seconds duration each. The average residual phase and average magnitude or amplitude are indicated in the last two lines. The slope of a line, which is a least squares fit to the 15 points, is indicated by the "Phase Drift." The scatter from this line is shown by the "RMS Phase Jitter."

During a VLBI experiment, excessive phase drift or rms phase jitter can alert the operator to a malfunction in the VLBI recording system. An alarm could be activated by the digital tone extractor software to warn the operator when these numbers become excessive.

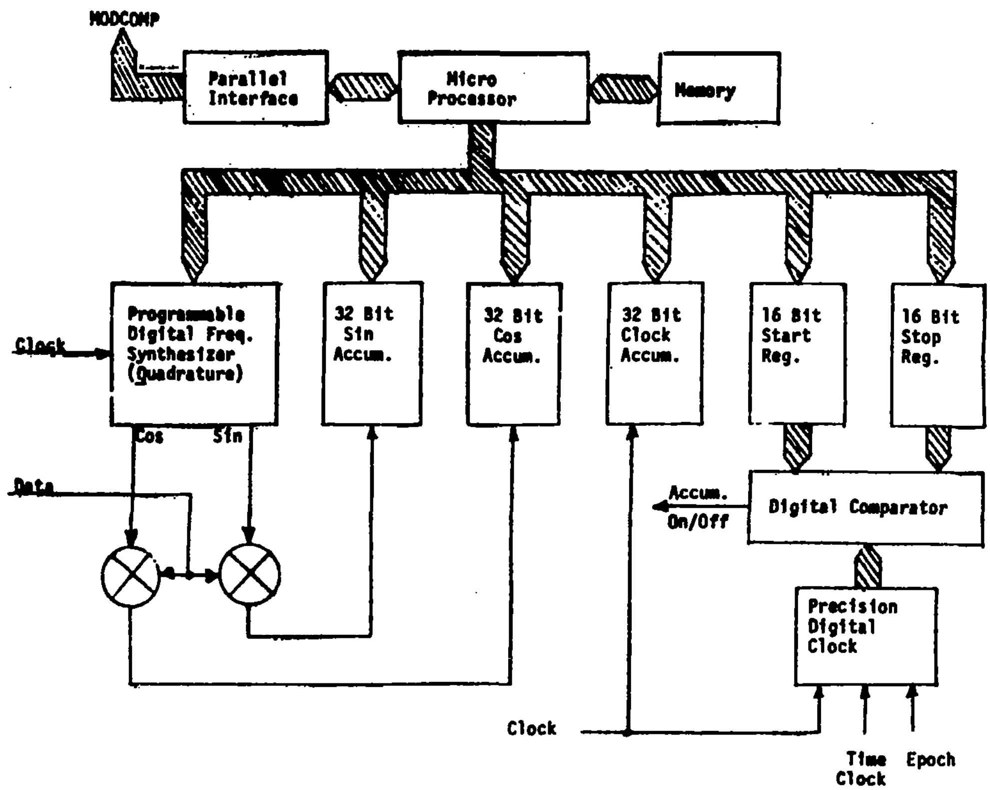

Figure 2. Digital tone extractor.

APPLICATIONS

The digital tone extractor performs, in real time, the same process on phase calibrator tones as the VLBI correlator. Since the digital tone extractor can monitor what is actually recorded on tape, it can indicate in real time the performance of the entire recording system. Thus, it can warn of an equipment malfunction when it happens and can save an experiment.

The digital tone extractor can also be used as a tool for debugging the VLBI system. It can look at data before and after it is recorded on tape to isolate faults in the recording system. In addition, a frequency synthesizer can be fed into a part of the VLBI system, and the phase can be monitored in order to isolate equipment with phase instabilities.

In addition to VLBI applications, the digital tone extractor has other uses which are of interest at the Jet Propulsion Laboratory. For example, it can be used to track spacecraft tones. The software can be programmed with a polynomial for frequency in order to track the frequency fluctuations of a spacecraft. Alternatively, an iterative software algorithm could be used to make the digital tone extractor follow the spacecraft frequency fluctuations and extract the Doppler shift of the spacecraft.

BASEBAND TONE NUMBER 1	CH. 1	PHASE DRIFT = -0.009 DEG/SEC 130:11:42:36 RMS PHASE JITTER = 1.096 DEG AVG PHASE = 152.01 DEG MAGNITUDE = 0.1354195785
	CH. 2	PHASE DRIFT = -0.012 DEG/SEC 130:11:42:36 RMS PHASE JITTER = 1.192 DEG AVG PHASE = -144.132 DEG MAGNITUDE = 0.0869244525
BASEBAND TONE NUMBER 1	CH. 1	PHASE DRIFT = 0.001 DEG/SEC 130:11:46:36 RMS PHASE JITTER = 0.662 DEG AVG PHASE = 151.525 DEG MAGNITUDE = 0.1355491886
	CH. 2	PHASE DRIFT = -0.003 DEG/SEC 130:11:46:36 RMS PHASE JITTER = 0.884 DEG AVG PHASE = -145.476 DEG MAGNITUDE = 0.0868894043
BASEBAND TONE NUMBER 1	CH. 1	PHASE DRIFT = 0.043 DEG/SEC 130:11:50:36 RMS PHASE JITTER = 3.661 DEG AVG PHASE = 154.289 DEG MAGNITUDE = 0.1361540671
	CH. 2	PHASE DRIFT = 0.035 DEG/SEC 130:11:50:36 RMS PHASE JITTER = 3.345 DEG AVG PHASE = -144.127 DEG MAGNITUDE = 0.0872003583

Figure 3. Digital tone extractor output.

ACKNOWLEDGMENTS

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