

# **Two-Way Time Transfer Modem**

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## **Introduction**

NRL is developing a two-way time transfer modem that will work with very small aperture terminals (VSAT), commercial satellites, and an atomic clock. The two-way method has been chosen because of its performance and insensitivity to the position of the receivers and satellites. Precision, stability, accuracy, and versatility are the primary design considerations of this modem. The modem is designed to use many off the shelf components.

## **Design**

The modem can be broken up into several sections, analog box, digital card, and computer (Figure 1). The analog box handles the interface between the VSAT and the digital card. The 5 MHz and 1PPS interface are also implemented in the analog box. There are two digital and two analog test ports. The two digital test ports allow the user to monitor various signals in the digital card. Signals to be viewed are selectable through software. The analog ports are driven by a pair of 12-bit digital to analog converters (DAC). The DACs are driven by the computer.

The second section of the modem is the digital card. The digital card contains the hardware needed to track the carrier and code and make the time of arrival measurements. The card also handles the transmission of data and 1PPS.

The third section of the modem is a personal computer with a digital signal processor (DSP) that controls the digital card and analog box. The computer in this implementation is a MS-DOS compatible computer. The computer is configured as a keyboard, display, and storage interface for the DSP. The DSP used is Texas Instrument's TMS320C30 that runs at 16 MIPS and up to 33 MFLOPS. The DSP may seem to be overkill, but the reason for using such a powerful processor is to leave room for other functions that may be added later. Another reason for choosing this DSP was that a C compiler was available for it to make code writing much easier.

## **Acquisition**

The modem performs a two dimensional search to acquire a signal. One dimension is a time search. This search is to lock the receiver's code generator to the incoming signal's code. The other dimension is the frequency search. The frequency search is performed by reading 64 data samples at a high

rate from the correlators and performing a Fast Fourier Transform FFT on the data and storing the largest magnitude and the bin that it is in. Next, the code generator for the receiver is shifted and another frequency search is performed. This process is repeated over the entire code length. This process allows the modem to find the point where the codes and the frequency produce a maximum correlation. The next step is to match the codes and frequency offset. Once the largest peak is found the receiver's code is aligned with the incoming signal.

## Tracking

In the tracking mode, the numerically controlled oscillators used for the carrier and code are adjusted 608 times a second. The DSP first reads the correlators to determine the error signal. The information is then processed through the digital filters. The error information from the digital filters is then used to adjust the numerically controlled oscillators.

## Data Transmission

Information can be exchanged between modems. The DSP converts the data into a serial stream. The start of the data is synchronized to the 1PPS. Refer the 1989 PTTI paper for details on the data format.

## Time of Arrival Measurement

Data is sampled from the correlators at a 608 Hz rate. The code cycles at the same rate and generates an epoch pulse. Time of arrival measurements are made on each sample. As shown in Figure 2, the time of sample resolution is 40 ns. The time of arrival measurement (TOM) occurs on that boundary and the epoch occurs somewhere within the 40 ns. The slope of the line is the phase slope of the receiver's code. The phase 'y' is measured phase at 'TOM'. To determine the time of arrival (TOA), the TOM and y are measured at the occurrence of the epoch. The measurements, along with the known slope, are entered into the line equation (Figure 2) and the TOA is found. Of the 608 TOAs found, one of them occurred on the 1PPS. To better the resolution of the TOA, the 608 points are curve fitted with the 1PPS point in the middle. The curve fit helps reduce the noise in the measurements and gives the TOA for the 1PPS better resolution.

## Conclusion

One modem prototype is built and is being debugged. The modem has acquired and tracked signals and made time of arrival measurements. The next step is to get the communications software working and develop the control software for the system. The last step is to test the system and evaluate it.

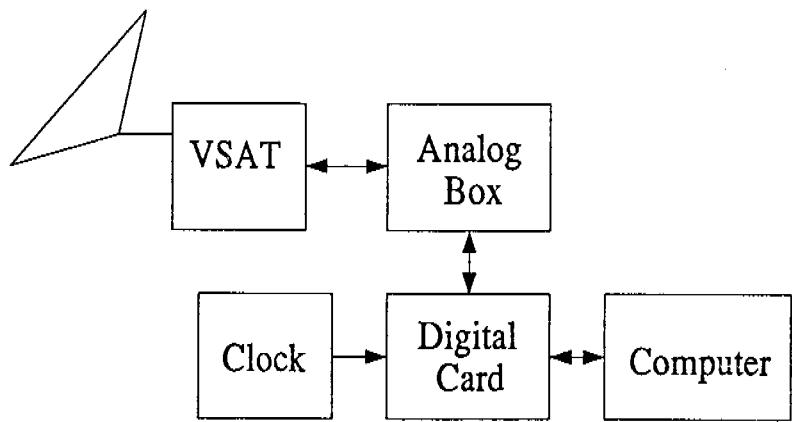


Figure 1 Modem Block Diagram

## Time of Arrival Measurement

$25 \text{ MHz} / 2.5 \text{ MHz} = 10 \text{ steps/sawtooth}$

$2.5 \text{ MHz} = 400 \text{ ns.}$

Resolution =  
 $400\text{ns} / 2^{12} \sim 100\text{psec}$

$$\text{TOA} = \text{TOM} - y/m$$

$m = \text{phase slope}$

$y = \text{phase at TOM}$

$\text{TOA} = \text{time of arrival}$

$\text{TOM} = \text{time of measurement}$

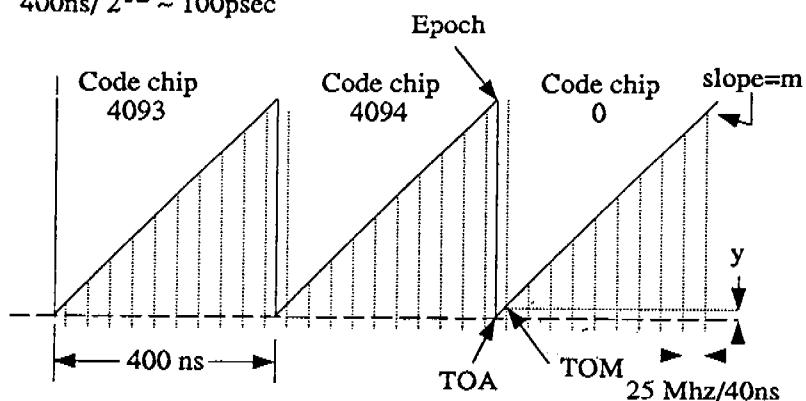


Figure 2 Time of Arrival Measurement

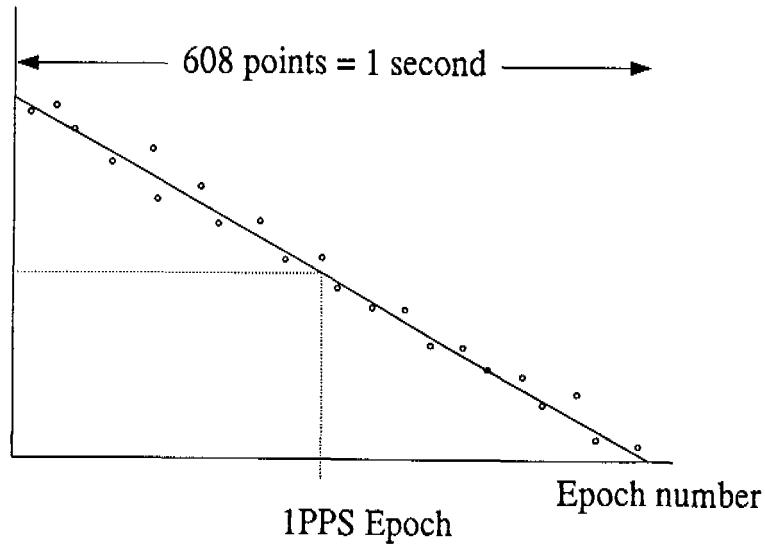


Figure 3 Curve Fit of TOA's