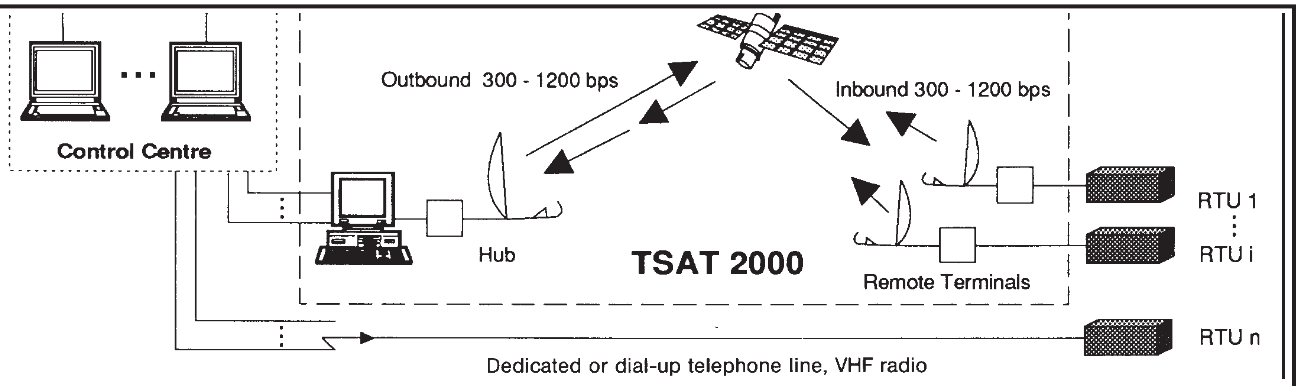
Viewing FSK-signals



Normarc a/s

Background

The company Normarc a/s (Oslo, Norway) is a manufacturer of communications equipment for telemetry and data transfer via satellite. For example data transfer of road traffic information from various sensors (traffic intensity, temperature, CO-concentration in tunnels etc) and control of e.g. traffic signs.

For data communication, Normarc uses a HF-carrier frequency, with a 300-1200 bps FSK-modulation or a 2400-9600 bps PSK-modulation. In this application note we will describe the FSK modulation (FSK=Frequency Shift Keying).

The carrier frequency is 70 MHz modulated with a small frequency shift every 3:rd ms. Four discrete frequencies are used for data coding, each separated approx. 300 Hz. The frequency transitions are filtered via a gaussian filter to avoid the sharp frequency changes that would otherwise generate harmonics and cause the signal to occupy valuable bandwidth. Due to this filtering, the frequency transitions are smooth, less distinct, but bandwidth “waste” is reduced.

The measurement problem

The measurement problem was to identify and view the small frequency shifts on the 70 MHz carrier, and check that the four discrete frequencies used were separated 300 Hz apart.

To view a 70,000,000 Hz carrier and simultaneously track rapidly changing 300 Hz shifts, is a very tough measurement task. Previously, it required extremely expensive tools. Nowadays this problem is solved, using a high resolution modulation domain analyzer, like for example the CNT-81 together with TimeView.

The measurement problem could simply be summarised: “*Sample the frequency fast enough to be able to view all frequency shifts, and do every individual measurement with a very high resolution*”.

Resolution requirements

The required resolution of each frequency measurement sample was $1x10^{-7}$. Since the carrier frequency is 70 MHz, this means a resolution of 7 Hz for each sampled frequency value.

To reliably follow all frequency shifts, at least two frequency samples per modulation clock cycle must be made. At 300 bps, the modulation clock has a period of approx 3.3 ms, which means that 1 sample every 1.6 ms with a 7 Hz (or $1x10^{-7}$) resolution is required. A very, very tough measurement!

To make this measurement, the CNT-81 and TimeView must be set up for free-running data capture. The measuring time for each frequency sample should be set to 1 ms. All other settings are the TimeView defaults. A 1ms measuring time in the CNT-81 gives a $5x10^{-8}$ resolution (3.5 Hz) and a sample rate of one measurement every 1.1 ms, i.e. well inside the requirements.

The measurement result in the modulation domain (frequency vs. Time) is shown in figure 1.

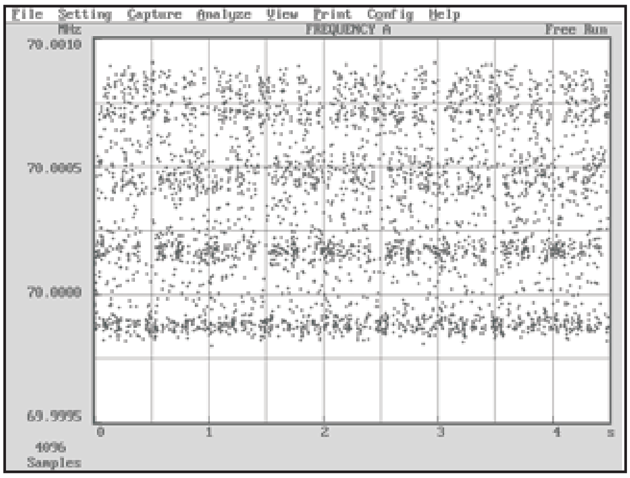


Figure 1 *The frequency vs time graph of a FSK-signal (4 frequency levels)*

Analyzing the frequency vs time graph

The frequency vs time graph in figure 1 shows that the frequency values are concentrated around four different frequency levels. This is clearly seen as the TimeView graph presentation mode was set to "dots", that is the individual measured value pairs [f(t), t] are *not* interconnected with lines. See figure 1.

But how are these four frequency levels distributed? From figure 1 it may be difficult to actually quantify the "frequency density", that is how often the signal stays at one or the other frequency level. TimeView can give a thorough answer to that too.

A closer look at the four shifted frequencies

The TimeView statistics analysis mode shows the frequency distribution histogram, and verifies that the frequency samples can be grouped into four "frequency clusters", see figure 2.

By moving the two cursors to the centre of each cluster, you can read the mean value of each cluster. See figure 2 where the text: "δx=300.08..Hz" underneath the graph equals the frequency difference between the cursors, in the centre of cluster 1 respectively 2.

Analyzing individual clusters

The histogram can also be used to verify the fitness of the gaussian filter. Too little filtering, and you are wasting bandwidth. Too much and the clusters will overlap too much at the foothills, and data may be wrongly interpreted.

A measure of the filter characteristics is found by analyzing the distribution in each cluster. Standard deviation must be well below 150 Hz to assure a good communication.

Figure 3 shows, as an example, a zoom-in of the first (=lowest frequency) cluster. As can be seen in the greyed box in the upper right corner, the calculated standard deviation for this cluster is 24.4 Hz.

Instrument requirements

To be able to make this frequency versus time measurement with the required sampling rate and resolution, you must combine both a very high resolution and a very high measurement speed in the same instrument. The CNT-81 offers both the highest resolution and the highest measurement speed available in any timer/counter today.

Of course, this type of measurement can not be handled by oscilloscopes or spectrum analyzers. The strength of those instruments is to measure *amplitude* variations over time or frequency, not *frequency* variations over time. That is the purpose of a modulation domain analyzer, likeTimeView plus CNT-81.

Not even all expensive dedicated modulation domain analyzers will do this measurement with the required resolution. E.g. the 53310A from Hewlett-Packard would fall short, because of insufficient frequency resolution ($2x10^{-7}$ for 1 ms measuring time instead of the required 1x10-7).

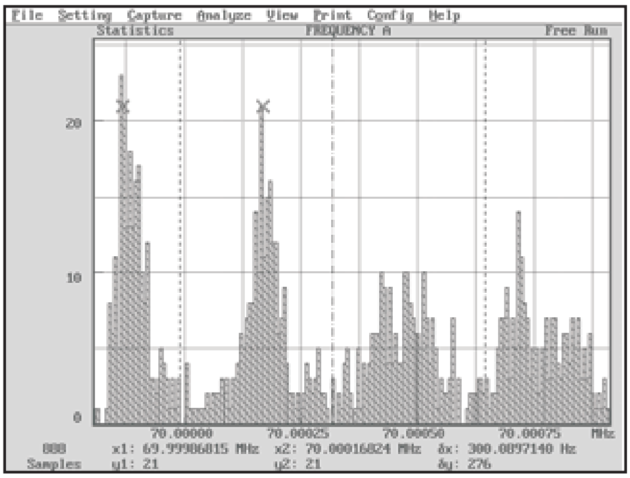


Figure 2 *The distribution of the frequency samples obtained from fig.1*

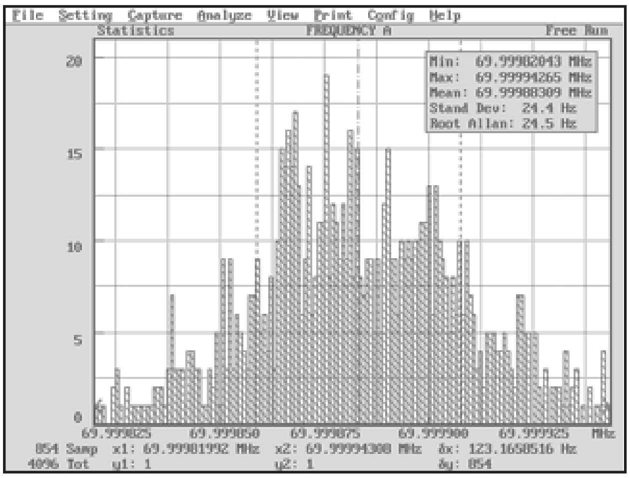


Figure 3 *The distribution of frequencies in the first cluster only*