Smart Sensing Systems
Pushing Technology Frontiers

Activity Report

Date: 05-0-2024 **Doc. No.:** 2407-EX-SMK-01

Report Title: Detailed description of the procedures to generate modulated signals on the SMW and viewing the demodulated signals using the FSW.
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Description: Signals with binary pulse shifts keying (BPSK), quadrature pulse shift keying (QPSK), frequency shift keying (FSK), and amplitude shift keying (ASK) modulation were generated from the signal generator (SMW) and demodulated using VSA and I/Q analysis modes of the signal and spectrum analyzer (FSW).
Objective: - *To generate modulated signals using the SMW and to view the demodulated signals using the FSW.*

A brief introduction to digital communication systems

Figure 1 shows the elements of digital communication systems. The first block of the block diagram is the information source. The source can be either an analog or digital source. Analog signals such as video or audio signals undergo the analog-to-digital conversion process producing a sequence of binary digits. A digital source output includes a computer's terminal generating ASCII codes.

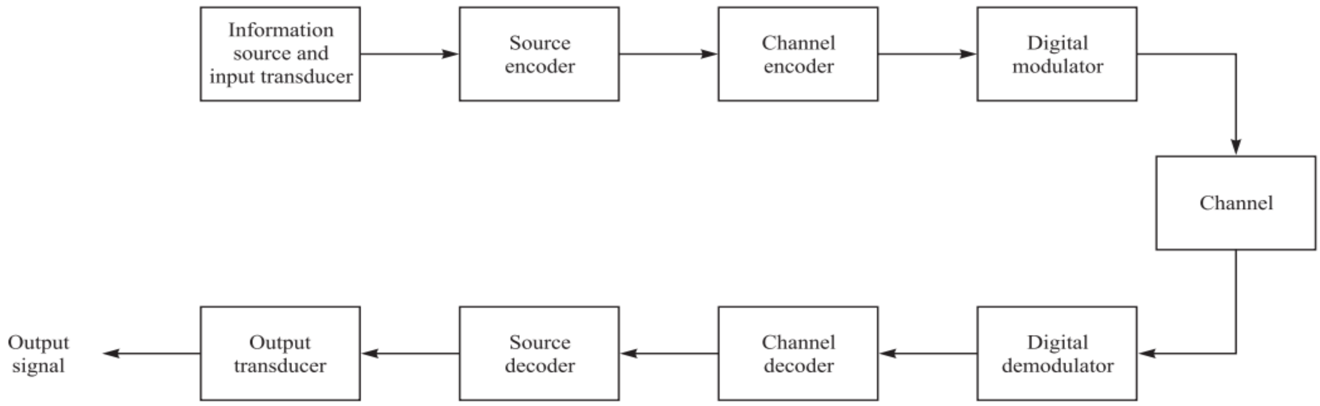


Figure 1. The functional block diagram of digital communication systems.

To efficiently represent the source, as few as possible binary digits must be used. The process of removing redundancy in the source output is called *source coding* or *data compression*. The output of the source encoder is passed to the channel encoder which then adds redundancy to the signal in a controller manner; this is to improve reliability of the received data and overcome noise introduced in the transmission of the signal through the channel. Moreover, the *digital modulator* maps the digital sequence to a signal waveform sequence to be transmitted over the channel.

The *channel* is a physical medium over which the transmitted signal travels. The channel could be the atmosphere (free space), optical fiber cables, or wire lines. At the receiving end, the *digital demodulator* converts the received waveforms into the transmitted data symbols.

The *channel decoder* reconstructs the original information sequence (removing redundancy) from knowledge of the code used by the channel encoder. Moreover, the *source decoder* also attempts to reconstruct the original source output from knowledge of the source encoding method used.

Configuring The SMW and FSW Communication System

This section discusses the procedures of generating modulated signals from the transmitter (SMW) and viewing the demodulated signals on the receiver (FSW).

The Transmitter Side

In this implantation, the transmitter is the signal generator (SMW). In this section, the procedures of configuring the SMW are paralleled to the functional blocks of the transmitter side of the digital communication system described above. Note that source and channel encoders and decoders are omitted.

* The Information Source/ Date Source

The information source, the first block of figure 1, can be configured by selecting the "Baseband" block shown in the SMW home screen, figure 2. From the list of options shown in figure 3, under the section "Misc", select "Custom Digital Mod…".

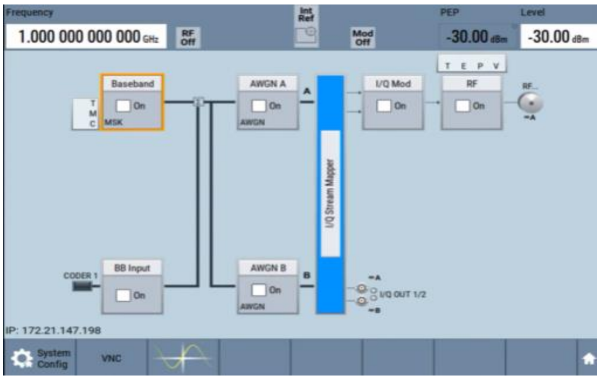


Figure 2. The SMW home screen.

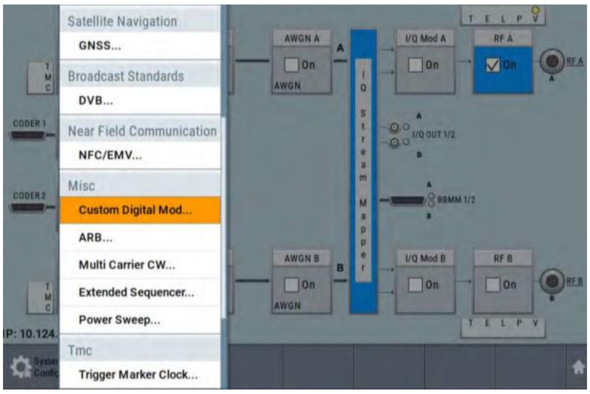


Figure 3. List of option upon selecting the baseband block.

On the "Custom Digital Modulation" dialog, select the data source tab as shown in figure 4. In this implantation, the PRBS (pseudorandom binary sequence) option was selected. The PRBS type selected was (PRBS 23), therefore, the sequence is repeating every 2^{23-1} bit.

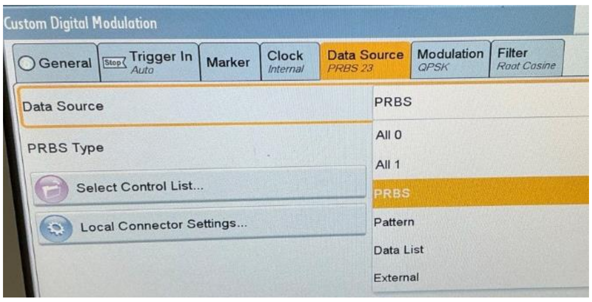


Figure 4. List of option upon selecting the baseband block.

*Digital Modulator

As mentioned above, the digital modulator maps the k binary symbols subsequence of the binary sequence into a signal waveform sequence $s_m(t)$, where $1 \leq m \leq M$, and $M = 2^k$. Figure 5 illustrates the block diagram of the digital modulator. The number of bits (k) per *symbol* is a function of the modulation scheme used.

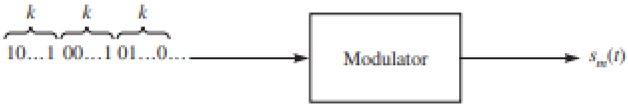


Figure 5. Block diagram of a digital modulator.

The Symbol Rate

The symbol rate is the number of symbols transmitted per second. To set the symbol rate, select the baseband block shown on the SMW's screen, then select "Custom Digital Mod…", as shown in figure 3. In the general tab of the custom digital modulation dialog, shown in figure 6, adjust the symbol rate as required. In this implementation, the symbol was set to 100 ksym/s.

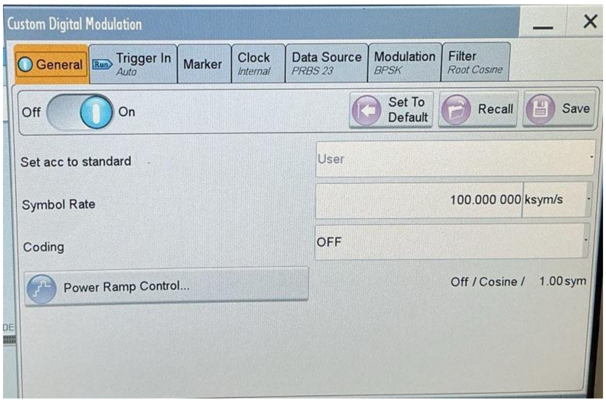


Figure 6. Custom digital modulation dialog, general tab.

Modulation

In this application, binary phase shift-keying (BPSK), quadrature phase shift – keying (QPSK), and amplitude phase shift – keying (ASK) modulation schemes were experimented.

Baseband up-conversion

For transmission of the baseband signal, the baseband signal must be modulated to an RF *carrier signal*. In this implementation the carrier *frequency* was set to 2.4 GHz, and the *power level* was set to -10 dBm.

Modulation Type

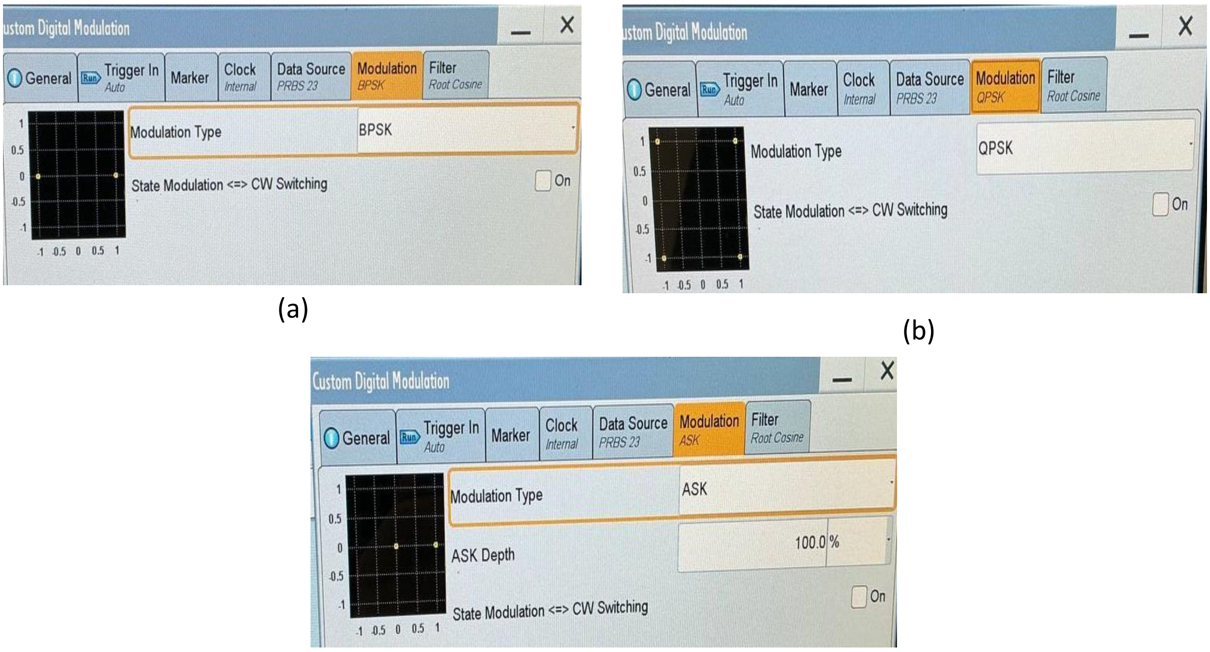
The signal waveform sequence $s_m(t)$ for phase shift -keying modulation is given by Eq.1; Where *g(t)* is the signal's pulse shape, f_c is the carrier frequency, and $\theta_m = 2\pi(m-1)/M$, m = 1, 2,..., M, is the M

$$\begin{aligned} s_m(t) &= \operatorname{Re}\left[g(t)e^{j\frac{2\pi(m-1)}{M}}e^{j2\pi f_c t}\right], \quad m = 1, 2, \ldots, M \\ &= g(t)\cos\left[2\pi f_c t + \frac{2\pi}{M}(m-1)\right] \\ &= g(t)\cos\left(\frac{2\pi}{M}(m-1)\right)\cos 2\pi f_c t - g(t)\sin\left(\frac{2\pi}{M}(m-1)\right)\sin 2\pi f_c t \end{aligned} \tag{1}$$

possible phases of the carrier. For amplitude shift-keying modulation, $s_m(t)$ is given by Eq.2, where A_m is the signal's amplitude.

$$
\begin{aligned}
s_m(t) &= \operatorname{Re}\left[s_{ml}(t)e^{j2\pi f_c t}\right] \\
&= \operatorname{Re}\left[A_m g(t)e^{j2\pi f_c t}\right] = A_m g(t)\cos(2\pi f_c t)
\end{aligned} \tag{2}
$$

To select the modulation type, on the custom digital modulation dialog, select the modulation type. Figure 7 shows the modulation tab for various modulation types.



(a) (b) (c)

Figure 7. Custom digital modulation dialog, the modulation tab.
(a) BPSK, (b) QPSK, and (c) ASK.

Setting the filter or g(t)

The pulse shape or filter used is a root of the raised-cosine filter with a roll off factor of 0.25 as results in minimum ISI (Inter symbol interference). On the custom digital modulation dialog select the filter tab, shown in figure 8. Select the root cosine filter and set the roll off factor to 0.25.

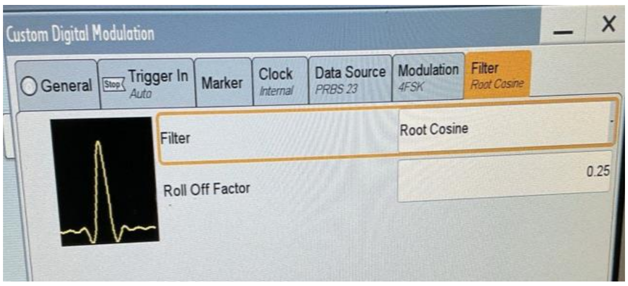


Figure 8. Custom digital modulation dialog, the filter tab.

Setting the coding

Coding is the assignment of k information bits to the $M = 2^k$ possible amplitudes for amplitude shift keying (and to 2^k possible phases for phase modulation). The most preferred coding method is called the *Gray Coding* where each adjacent signal amplitude (for ASK, and phase for PSK) varies by one binary digit only. The gray coding for BPSK, and QPSK is shown in figure 9. To set the coding in the general tab of the custom digital dialog, shown in figure 6, set the coding as required. In this implementation, the coding was set as "OFF". Also set the state to "ON" to enable the generation of the baseband signal.

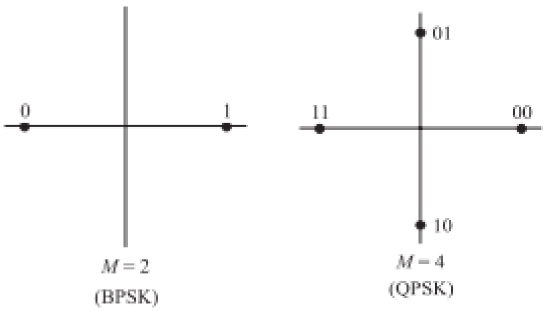


Figure 9. Constellation for PSK with Gray coding.

Enabling the Digital Modulator

To enable the I/Q modulator, in the block diagram, select the "I/Q Mod" block. Navigate to the section "I/Q Mod In" and select the "Internal Baseband I/Q In" option, as illustrated in figure 10, and under the section "I/Q Settings", select, "I/Q Modulator…".

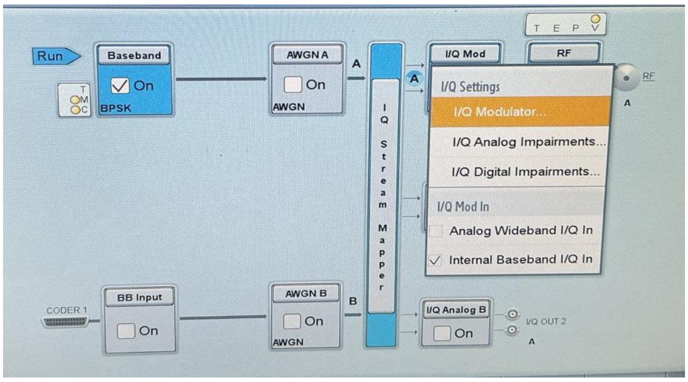


Figure 10. List of options upon selecting the "I/Q Mod" block.

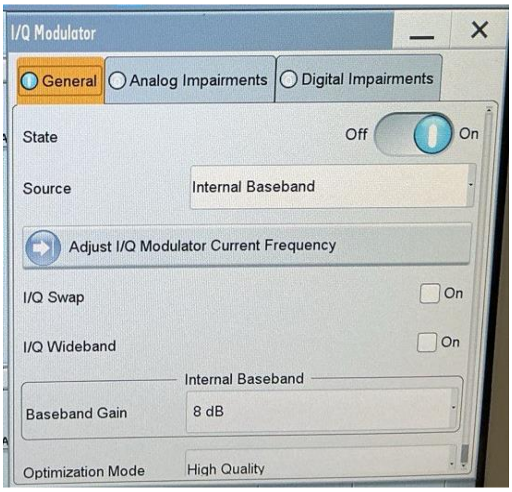


Figure 11. I/Q modulator dialog.

Figure 11 shows the "I/Q Modulator" dialog. Set the "State" to "On". Select the "Source" as "Internal Baseband" and close the dialog.

Previewing the generated signal

The generated baseband signal can be viewed by selecting the sine wave option at the bottom of the screen, shown in figure 12, which opens the "Graphic Generator" dialog.

In the " Graphic Generator" dialog, shown in figure 13, select "Mode ", and from the list of options select "Power Spectrum". Under the "Source", select "RF". Finally, select the "Add" shown at the bottom of the dialog. Figure 14 shows a preview of the BSPK modulated baseband signal using the graphic generator.

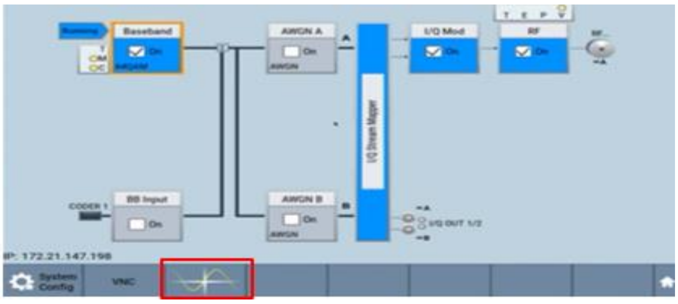


Figure 12. SMW screen, with red box at the sine graphic generator.

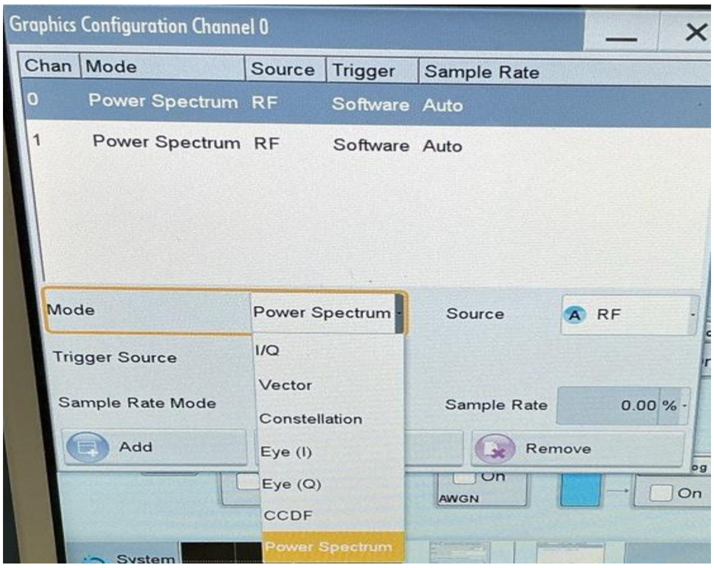


Figure 13. Graphics configuration dialog.

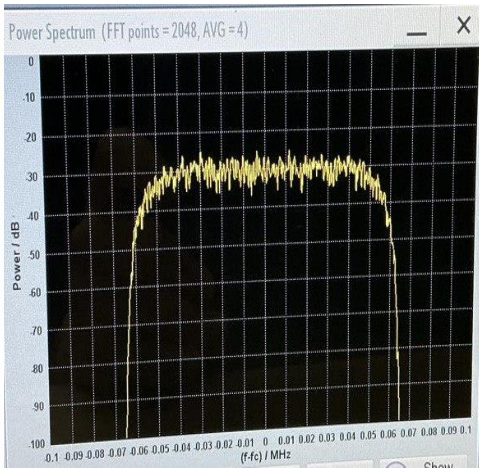


Figure 14. A preview of the BSPK modulated baseband signal using the graphic generator.

The Receiver Side

The receiver in this implementation is the signal and spectrum analyzer (FSW). To view the demodulated signal using the FSW's I/Q analysis and VSA modes, press the mode button at the bottom of the FSW, then select the modes I/Q analyzer and VSA. The I/Q analyzer tab screen is shown in figure 15. To display the IQ- Vector, magnitude, spectrum, or Real/ Imag (I/Q) screens, click on each block and drag and drop them to the desired configuration.

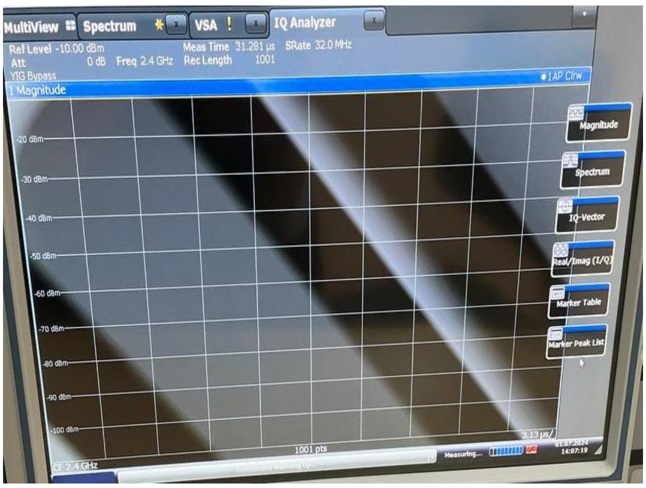


Figure 15. I/Q analyser tab.

***Digital Demodulator** - Baseband Down-Conversion*

By inputting the *center frequency* information in the FSW, the received signal can be demodulated to the lowpass equivalent signal. This is done to alleviate the high sampling rate requirement for filtering.

Matching the Symbol Rate, Filter, and Coding

To maximize the received signal, the output of the digital demodulator must be sampled at the transmitter's symbol rate, and filter by a filter matching the transmitter's filter. The transmitted signal information is inputted by selecting the "Signal Description" option on the top right side of the VSA tab screen. Under the "Modulation" section of the signal description dialog, set the symbol rate, filter, and coding as previously set on the SMW. The dialog for BPSK modulation is shown in figure 16.

The VSA and IQ analyzer screens for BPSK modulation are shown in figures 17, and 18.

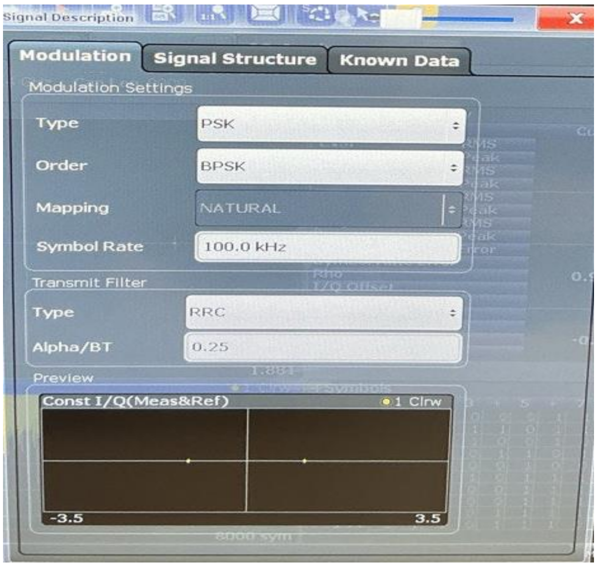


Figure 16. Signal description dialog for BPSK modulation.

Figure 17. VSA tab for BPSK signal demodulation.

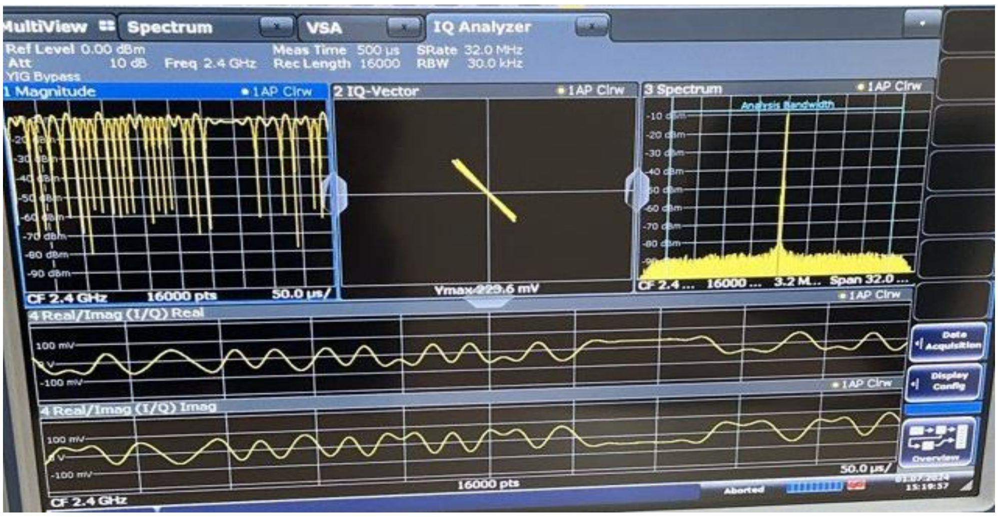


Figure 18. I/Q analyzer tab for BPSK signal demodulation.

(References: (1) Digital Communications by John G. Proakis, and Masoud Salehi. (2) Satellite communications by Dennis Roddy.)