MWC Experiment 5

Shivani Bhat

BE EXTC A
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Aim:

To perform GMSK on GNURadio

Theory:

1. BPSK (Binary Phase Shift Keying)

- **Concept**: Simplest form of Phase Shift Keying (PSK). Uses two distinct phases (0° and 180°) to represent binary **0** and **1**.
- **Signal Representation**:
  [
  s(t) = \sqrt{\frac{2E_b}{T_b}} \cos(2\pi f_c t + \pi b)
  ]
  where (b \in {0,1}).
- **Key Concepts in Implementation**:
  - **Mixers & Oscillators**: For carrier generation and phase shifting.
  - **Coherent Demodulation**: Receiver must be synchronized with transmitter phase.
  - **Bit Error Rate (BER)**: High robustness in noise but lower data rate.

2. QPSK (Quadrature Phase Shift Keying)

- **Concept**: Extends PSK by using **4 phase states** (0°, 90°, 180°, 270°), each representing **2 bits per symbol**.
- **Advantage**: Doubles data rate compared to BPSK with the same bandwidth.
- **Signal Representation**:
  [
  s(t) = \sqrt{\frac{2E_s}{T_s}} \cos(2\pi f_c t + \phi)
  ]
  where (\phi \in {0, \pi/2, \pi, 3\pi/2}).

- **Key Concepts in Implementation**:
    - **I/Q Modulation**: Splitting signal into In-phase (I) and Quadrature (Q) components using mixers.
    - **Symbol Synchronization**: Required for correct bit mapping.
    - **Constellation Diagram**: Four equidistant points on a circle.

3. GMSK (Gaussian Minimum Shift Keying)

- **Concept**: A **continuous-phase frequency modulation** scheme derived from MSK (Minimum Shift Keying), but with a **Gaussian filter** applied to input data to smoothen phase transitions.
- **Advantages**:
    - Bandwidth-efficient (narrow spectrum).
    - Constant envelope (good for nonlinear RF power amplifiers).
    - Widely used in GSM cellular systems.
- **Key Concepts in Implementation**:
    - **Gaussian Filter**: Shapes the baseband data pulses before modulation.
    - **VCO (Voltage Controlled Oscillator)**: Implements continuous-phase frequency shift.
    - **Nonlinear PA Compatibility**: Since envelope is constant, no distortion in high-power RF amplifiers.

Basic Comparison:

- **Phase Modulation (BPSK, QPSK)** vs. **Continuous Phase Frequency Modulation (GMSK)**.
- **Carrier Generation & Mixing** (oscillators, mixers, PLLs).
- **Baseband Filtering** (Gaussian filter in GMSK).
- **Synchronization** (phase & symbol timing essential in BPSK/QPSK).
- **Spectral Efficiency**: GMSK > QPSK > BPSK.

1. **Why is GMSK used in cellular communication systems?**
   Spectral Efficiency
    - GSM channels are only **200 kHz wide**.

    - GMSK uses a **Gaussian filter** to smooth the input bitstream, reducing out-of-band radiation.
    - This minimizes adjacent channel interference and allows tight **frequency reuse**.
2. **Constant Envelope**
    - The output signal has **constant amplitude**, so nonlinear but **power-efficient RF amplifiers** (like Class C) can be used in mobile phones.
    - This lowers power consumption and extends **battery life**.
3. **Robustness in Mobile Environment**
    - **Continuous phase** means no abrupt signal transitions → lower susceptibility to multipath fading and Doppler shift.
    - Good **BER performance** in noisy cellular channels.

How It Works

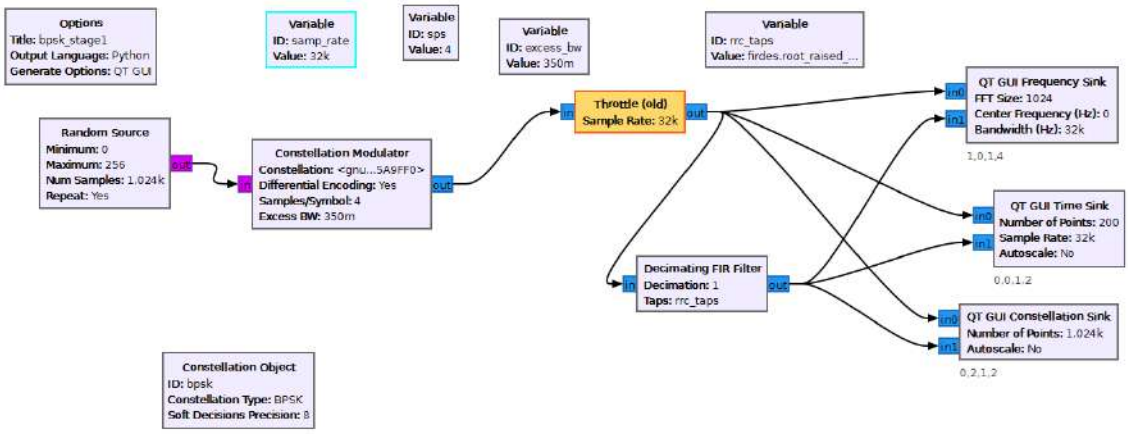
- **Step 1**: Input binary data is filtered by a **Gaussian low-pass filter**.
- **Step 2**: Filtered bits control the frequency of a **VCO (Voltage Controlled Oscillator)**.
- **Step 3**: Output is a smooth, continuous-phase waveform with minimal spectral side-lobes.
- **BT product (Bandwidth × Time)** for GSM = **0.3**, a compromise between bandwidth efficiency and intersymbol interference.

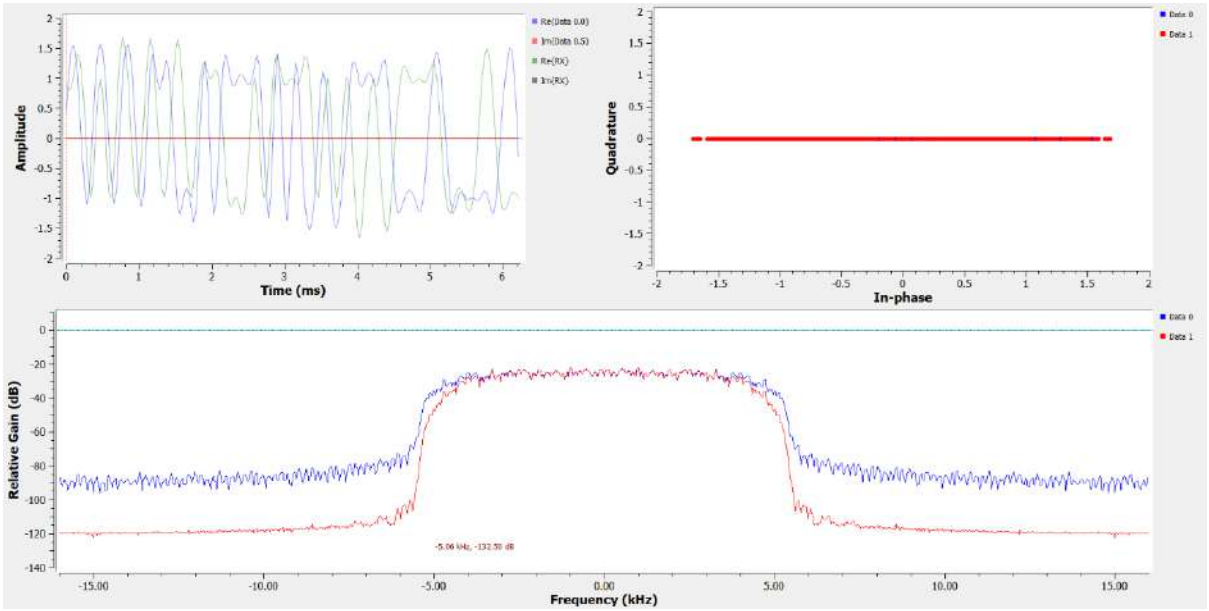
Advantages of GMSK for GSM

- Fits strict channel spacing (200 kHz).
- Allows reuse of frequencies in nearby cells without severe interference.
- Reduces handset complexity → cheaper, power-saving designs.
- Reliable performance in mobile environments with fading and interference.

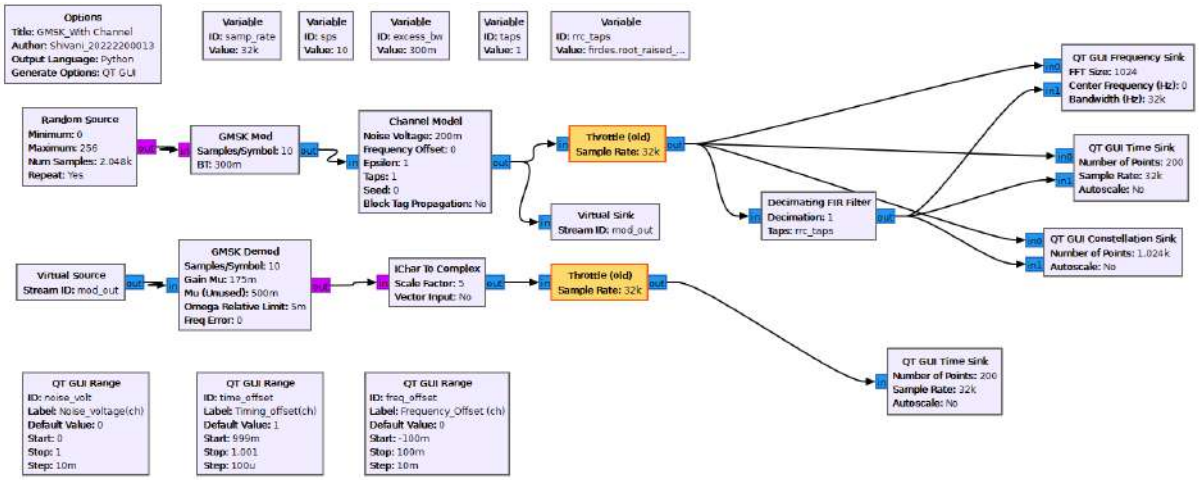
GNURadio Simulations:

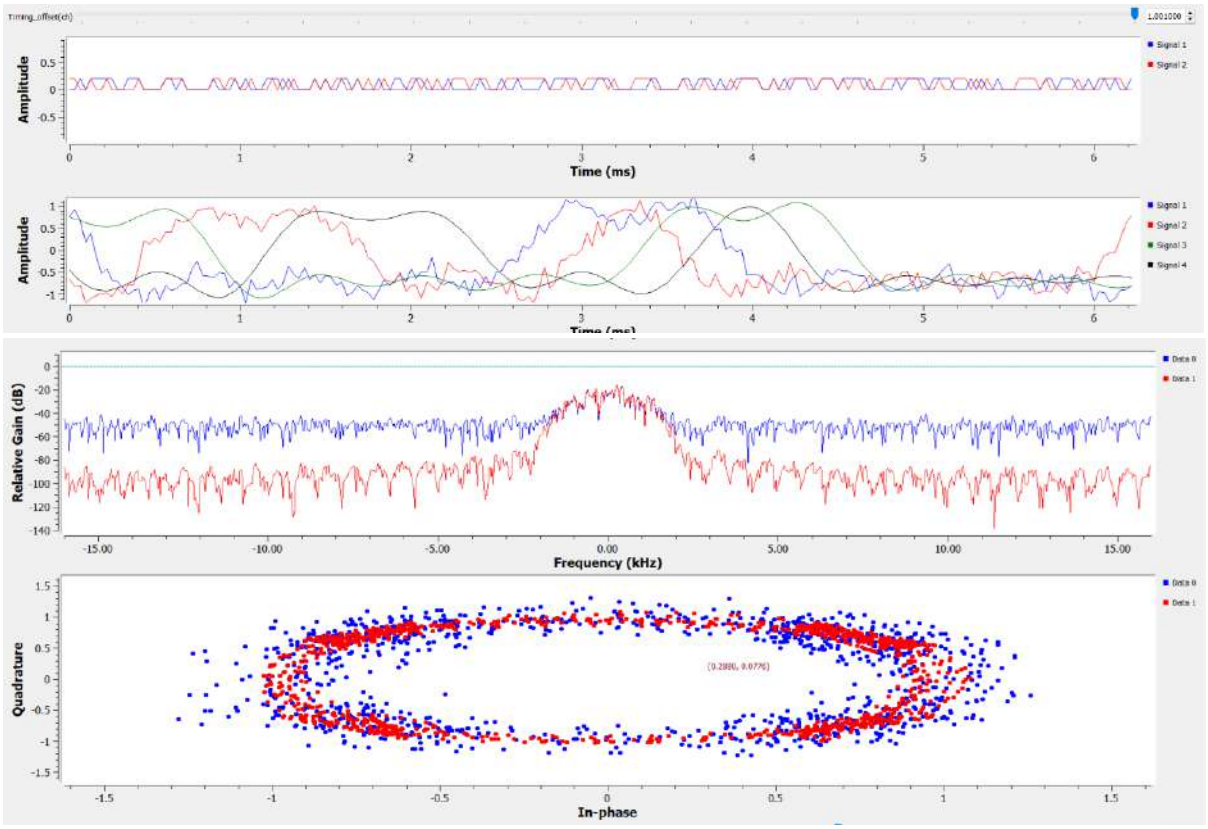
1. BPSK



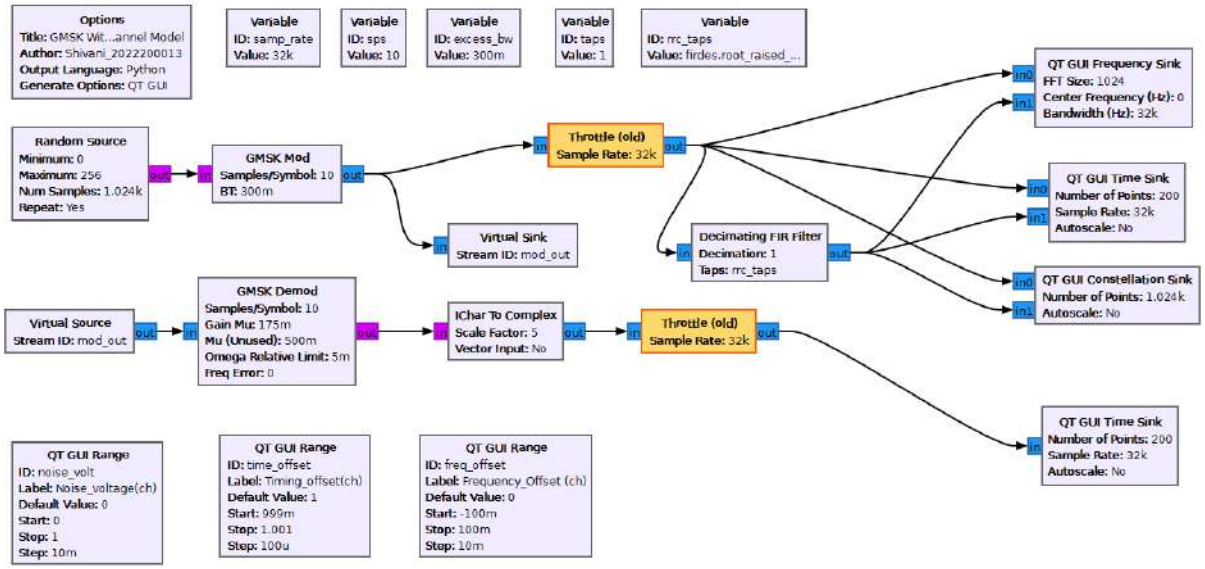


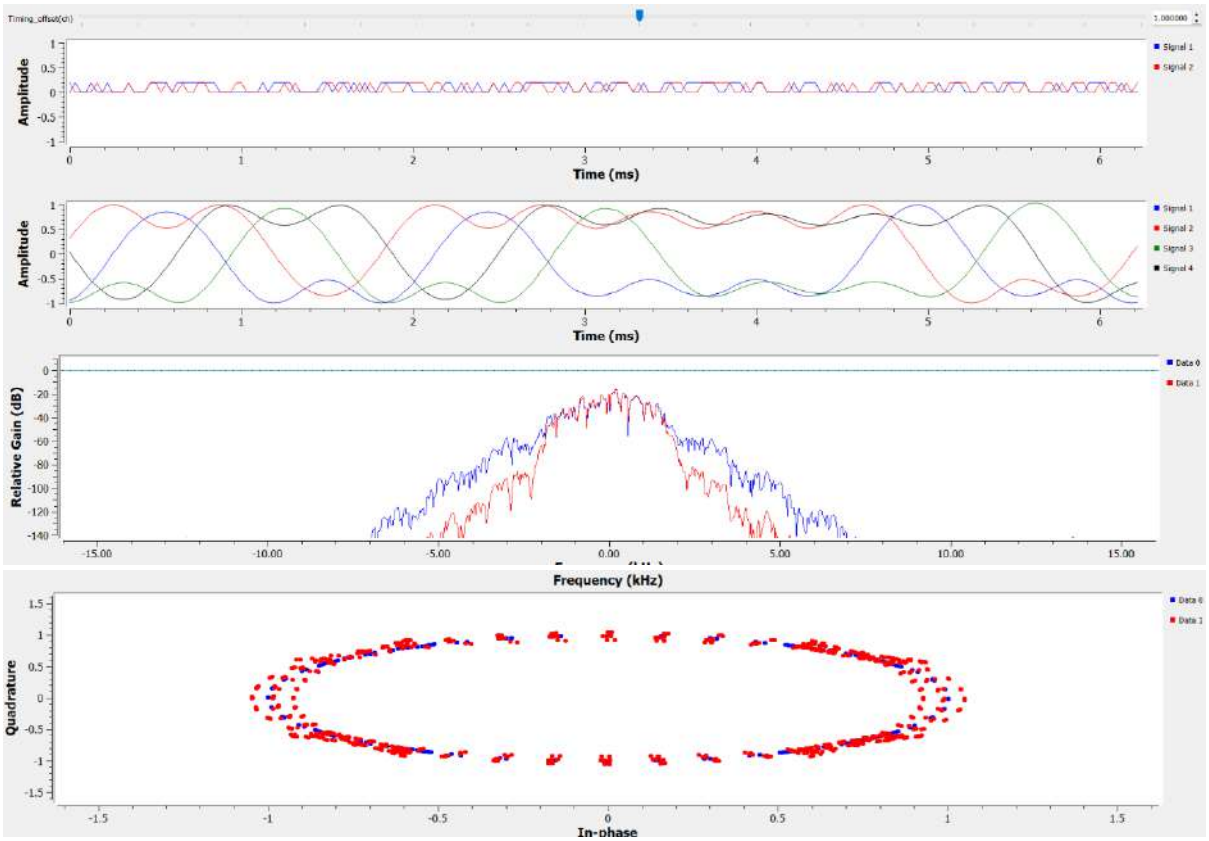
2. GMSK (With Channel)



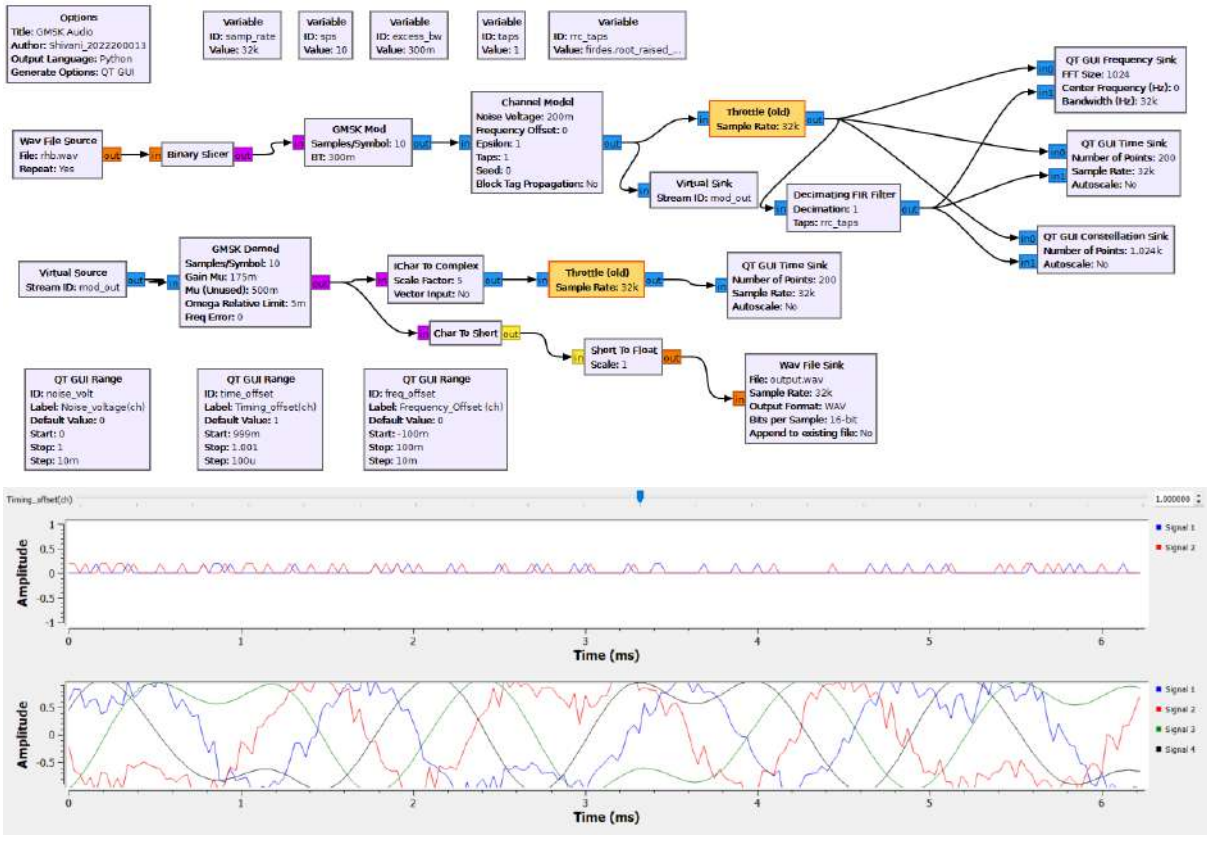


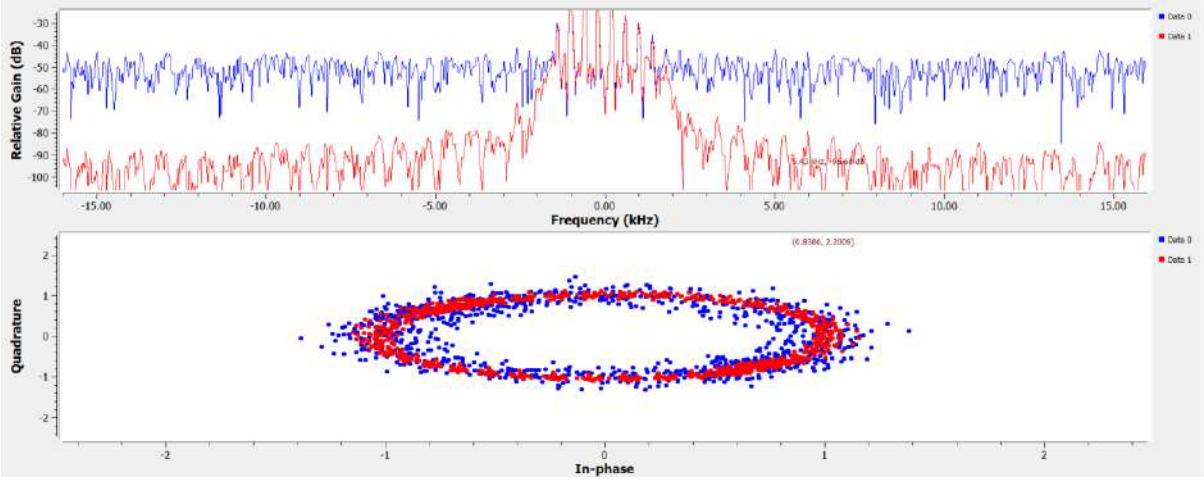
3. GMSK (Without channel)




Timing_offset(ch)
Amplitude
Time (ms)
Signal 1
Signal 2
Signal 3
Signal 4
Relative Gain (dB)
Frequency (kHz)
Data 0
Data 1
Quadrature
In-phase

4. Audio GMSK


Options
Title: GMSK Audio
Author: Shivani_2022260013
Output Language: Python
Generate Options: QT GUI
Variable
ID: samp_rate
Value: 32k
ID: sps
Value: 10
ID: excess_bw
Value: 300m
ID: taps
Value: 1
ID: rrc_taps
Value: firdes.root_raised_...
Wav File Source
File: rhb.wav
Repeat: Yes
Binary Slicer
GMSK Mod
Samples/Symbol: 10
BT: 300m
Channel Model
Noise Voltage: 200m
Frequency Offset: 0
Epsilon: 1
Taps: 1
Seed: 0
Block Tag Propagation: No
Throttle (old)
Sample Rate: 32k
Virtual Sink
Stream ID: mod_out
Decimating FIR Filter
Decimation: 1
Taps: rrc_taps
QT GUI Frequency Sink
FFT Size: 1024
Center Frequency (Hz): 0
Bandwidth (Hz): 32k
QT GUI Time Sink
Number of Points: 200
Sample Rate: 32k
Autoscale: No
QT GUI Constellation Sink
Number of Points: 1.024k
Autoscale: No
Virtual Source
Stream ID: mod_out
GMSK Demod
Samples/Symbol: 10
Gain Mu: 175m
Mu (Unused): 500m
Omega Relative Limit: 5m
Freq Error: 0
IChar To Complex
Scale Factor: 5
Vector Input: No
Throttle (old)
Sample Rate: 32k
QT GUI Time Sink
Number of Points: 200
Sample Rate: 32k
Autoscale: No
Char To Short
Short To Float
Scale: 1
Wav File Sink
File: output.wav
Sample Rate: 32k
Output Format: WAV
Bits per Sample: 16-bit
Append to existing file: No
QT GUI Range
ID: noise_volt
Label: Noise_voltage(ch)
Default Value: 0
Start: 0
Stop: 1
Step: 10m
QT GUI Range
ID: time_offset
Label: Timing_offset(ch)
Default Value: 1
Start: 999m
Stop: 1.001
Step: 100u
QT GUI Range
ID: freq_offset
Label: Frequency_Offset (ch)
Default Value: 0
Start: -100m
Stop: 100m
Step: 10m
Timing_offset(ch)
Amplitude
Time (ms)
Signal 1
Signal 2
Signal 3
Signal 4



Conclusion:

1. **BPSK Simulation (Baseline)**
    - Simple to implement, with clear symbol distinction.
    - Provides **robust error performance** but at the cost of **lower spectral efficiency** (1 bit/symbol).
    - Good as a reference modulation scheme for comparison.
2. **GMSK without Channel (Random Source)**
    - Output is smooth, constant-envelope, and spectrally efficient.
    - Shows how GMSK can transmit more compact signals compared to BPSK.
    - No distortion is observed since no channel impairments are applied.
3. **GMSK with Channel (Random Source)**
    - Channel effects (e.g., noise, fading, multipath) introduce **phase and amplitude distortions**.
    - Error performance depends on **SNR**: higher noise worsens bit recovery.
    - Demonstrates why **equalization and error correction** are crucial in real-world cellular systems.
4. **GMSK with Channel (Audio .wav Source)**
    - The recovered audio quality depends on **channel conditions** and **modulation robustness**.
    - In good channel conditions → audio is intelligible and close to original.
    - In poor channel conditions → audio suffers from distortion, delay, or dropouts.

- Highlights GMSK's **practical relevance in GSM**: efficient spectrum usage and resilience to mobile channel impairments while still maintaining acceptable voice quality.