

✅ How Raw Time-Domain Waves Carry Information

🔄 "Time domain → frequency → signal → symbol → bits → information"

Let's walk through it step by step — like a zoom lens:

◆ 1. Time Domain = Waveform

- What you receive from an antenna is a continuous waveform $v(t)$ or a stream of digital samples $x[n]$.
- This signal **looks random**, but it's actually a **modulated wave** carrying meaningful patterns.

🕒 In this domain, you're just seeing **how the signal changes over time**.

◆ 2. Frequency = Tells You What Is Present

- Any waveform can be **broken into frequency components** using DFT/FFT.
- The result tells you: "Ah! There's strong energy at 433 MHz or 2.4 GHz."

This is like identifying **which instruments are playing in a noisy orchestra**.

◆ 3. Frequencies Carry Signals (Modulated Carriers)

- At that 2.4 GHz, you might find a **WiFi signal**, or **drone control signal**.
- These are not just sine waves — they are **modulated**: their amplitude, frequency, or phase is changing.

That change in carrier is what **encodes the signal**.

◆ 4. Signals Carry Symbols

- In digital communication, modulation schemes like **QPSK**, **16-QAM** use:
 - **Amplitude**
 - **Phase**
 - **Frequency**to form **symbols** — each a complex point in the I/Q plane.

E.g., QPSK = 4 points (00, 01, 10, 11), 16-QAM = 16 points.

◆ 5. Symbols Carry Bits



- Each symbol = a fixed number of **bits**.
 - QPSK → 2 bits per symbol
 - 16-QAM → 4 bits per symbol
- These bits are what you eventually **decode into data**.







◆ 6. Bits = Information

- The bits are grouped into:
 - Audio packets
 - Control signals
 - Commands
 - Telemetry (e.g., drone GPS position)

 This is the **actual payload** of the transmission.

Now Let's Put It All Together — SDR Chain

Layer	Description	Tool/Transform
 Antenna	Captures waveform (RF)	Hardware
 IQ Sampling	Converts wave to I/Q samples	RTL-SDR, ADC

Layer	Description	Tool/Transform
 Time Signal	Raw $x[n]$ samples	Python array
 Frequency View	Shows what frequency is present	FFT
 Signal Detection	Isolate modulated signal	Filtering
 Demodulation	Extract symbols (QPSK/QAM)	Python logic
 Bitstream	Recovered binary data	Decoder
 Information	Meaningful content	Application



Summary:

“Wave in time domain carry **frequency**,
 frequency carries **signal**,
 signal carries **symbols**,
 symbols carry **bits**,
 bits carry **information.**”



Perfectly captures the essence of SDR.