🕮 Chapter 5.2: Understanding IQ Data Values and the "Shifted Center"

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1. What is IQ Data?

When we capture IQ data from an SDR (like RTL-SDR), the receiver provides **I (In-phase)** and **Q (Quadrature-phase)** samples. These samples represent the signal in the **complex plane**:

- `I` → the x-axis projection
- `Q` → the y-axis projection

Normally, in mathematics or DSP theory, we expect these samples to range between **negative and positive values**, oscillating around **0**.
Example of an ideal sine wave (In-phase part):

-1 -0.5 0 0.5 1

This wave is centered at zero.

2. What RTL-SDR Actually Gives

RTL-SDR hardware doesn't store floats like `-1…+1`. Instead, for speed and efficiency, it stores samples as **unsigned 8-bit integers**:

- Values range from **0** → **255**
- `0` = minimum
- `255` = maximum
- The **middle point is 127 or 128**, not 0

So, if you captured the same sine wave, it might look like this in the raw file:

63 95 128 160 192

3. Why the Signal Looks “Shifted”

If you take these raw samples (`0…255`) and plot them directly:

- Instead of oscillating around 0, the signal floats around `128` .
- This is why it looks **shifted upward** in your plots.

🔍 The “center” we are referring to is **the mathematical zero line**, not the middle of your plot or file.

So what you’re really seeing is a wave that has been “lifted up” from zero.

4. Fixing the Shift (Recentering)

To make the data useful for DSP, we must **recenter** it:

- Subtract `127` (or `128`) from every sample.
- This converts `0…255` into `-128…+127` .

Example:

Raw data: 63 95 128 160 192

Recentered: -65 -33 0 32 64

Now, the signal is **properly centered around 0** again.

5. Visualization Example

Imagine two plots:

Raw Plot (0…255):

```
         ___
  ___---'   `---___
```

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(center at 128)

Recentered Plot (-128…+127):

___
___-' `  -___  -'` -

(center at 0)

The second one is what DSP algorithms expect.

6. Why This Matters

If you don’t recenter the data:

- Fourier transforms (FFT) will give wrong frequency content.
- IQ constellation diagrams will appear shifted.
- Demodulation won’t work correctly, because algorithms assume **zero-centered samples**.

Once you subtract the offset, everything lines up as it should.

7. Quick Python Example

python

import numpy as np

import matplotlib.pyplot as plt

Pretend we read from RTL-SDR file

raw_data = np.array([63, 95, 128, 160, 192], dtype=np.uint8)

Recenter

centered_data = raw_data.astype(np.int16) - 128

Plot comparison

plt.figure(figsize=(10,5))

plt.subplot(2,1,1)

plt.plot(raw_data, 'o-')

plt.title("Raw SDR Data (0-255, shifted up)")

plt.axhline(128, color='r', linestyle='--', label="Shifted center at 128")

plt.legend()

plt.subplot(2,1,2)

plt.plot(centered_data, 'o-')

plt.title("Recentered SDR Data (-128 to +127)")

plt.axhline(0, color='r', linestyle='--', label="True center at 0")

plt.legend()
plt.tight_layout()
plt.show()

This shows you exactly how the **raw data floats at 128**, and how **recentering brings it to zero**.

8. Takeaway

- The **“shifted center”** means the samples are centered at `128` instead of `0`.
- Always subtract `128` to get proper signed samples.
- Once recentered, you can safely do FFT, filtering, demodulation, or constellation plotting.