



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

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

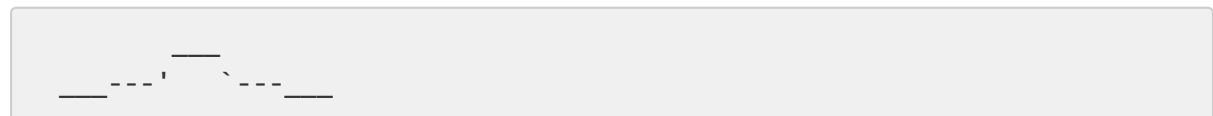
Recentered: -65 -33 0 32 64

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.