RF Processing

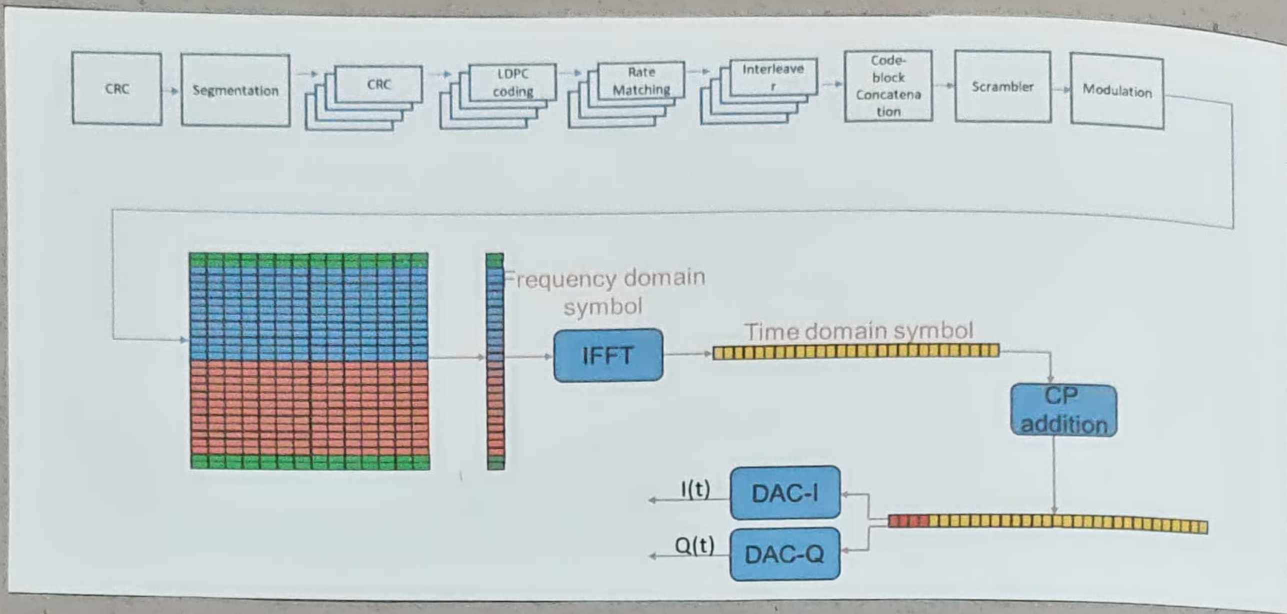


Fig: 5G Transmit chain.

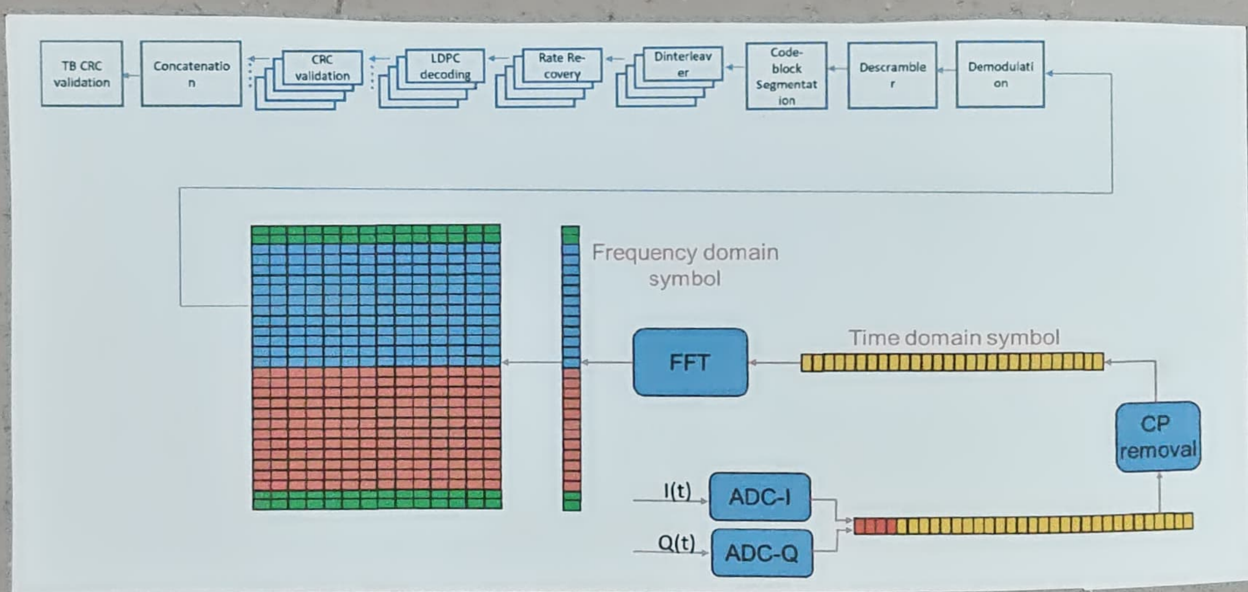


Fig: 5G Receive chain

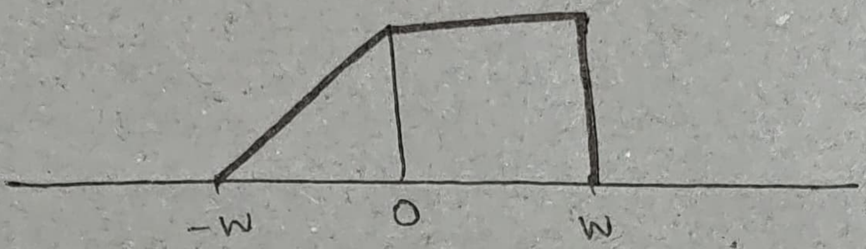
Base band - pass band System model

- Transmit complex waveform

$$s(t) = I(t) + j\,Q(t)$$

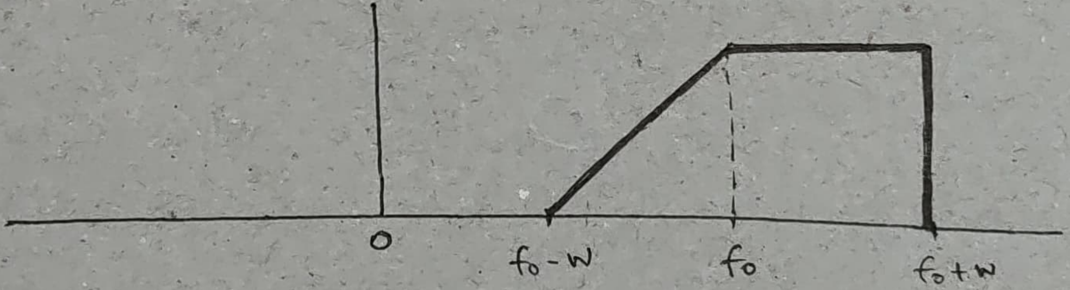
is called as baseband signal

- $s(t)$ will have asymmetric spectrum around Origin with bandwidth $-W$ to W.



- Upconvert the baseband signal to desired center frequency f_0 with $\omega_0 = 2\pi \cdot f_0$

$$s_1(t) = s(t)\sqrt{2}\, e^{j\omega_0 t}$$

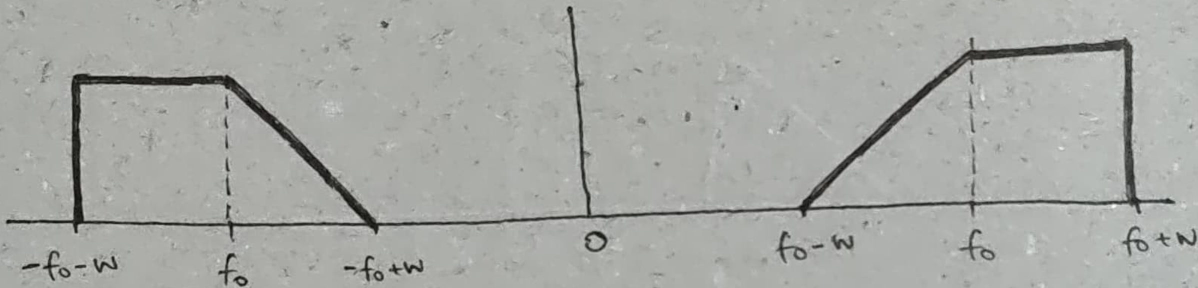


Transmit Passband system model

- We can transmit only real signals

$$s^{o}(t) = \Re(s_1(t))$$

$$= \sqrt{2}\,\Re\left(s(t)\,e^{j\omega_0 t}\right)$$



- $s_1(t)$ is called passband / RF / upconverted transmit signal

- Real transmit signal can equivalently be written as

$$s^{o}(t) = \Re(s_1(t)) = \sqrt{2}\,\Re\left(s(t)\,e^{j\omega_0 t}\right)$$

$$= \sqrt{2}\,\Re\left(\left[I(t) + j\,Q(t)\right]e^{j\omega_0 t}\right)$$

$$= \sqrt{2}\,I(t)\cos(\omega_0 t) - \sqrt{2}\,Q(t)\sin(\omega_0 t)$$

- Architecture is called <u>balanced homodyne transmitter</u>

- We assume that channel is not faded.

Receive Passband system model

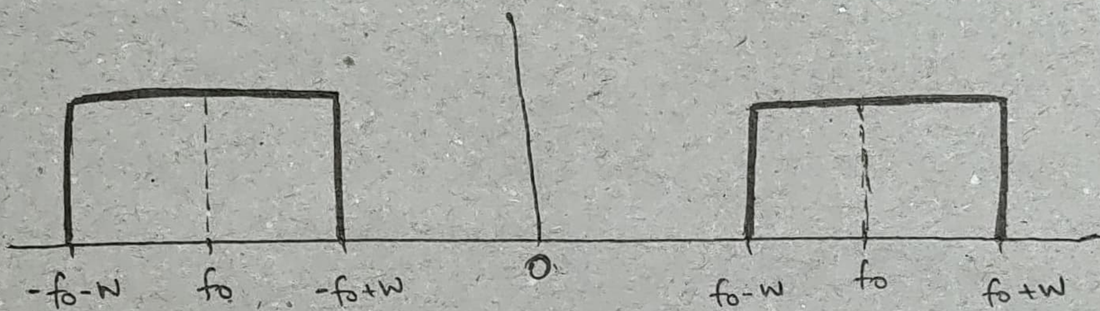
- Receive signal is :

$$r_1(t) = s^\circ(t) + n_\omega(t)$$

$$= \sqrt{2}\, I(t) \cos(\omega_0 t) - \sqrt{2}\, Q(t) \sin(\omega_0 t) + n_\omega(t).$$

- First step in recovering base band signal
  - Limit the band pass noise $n_\omega(t)$

- Filter the receive signal $r_1(t)$ using a band pass filter $W_0(f)$.



- Received equivalent signal is

$$r(t) = r_1(t) \circledast w_0(t)$$

$$= \left(s^\circ(t) + n_\omega(t)\right) \circledast w_0(t)$$

$$= s^\circ(t) + \left(n_\omega(t) \circledast w_0(t)\right)$$

$$= s^\circ(t) + n(t)$$

Receive baseband system model

⊙ Demodulate inphase signal $I(t)$

$$r_c(t) = \left[r(t)\sqrt{2}\cos(\omega_0 t) \right]_{lpf}$$

$$= \left[\left\{ \sqrt{2}\, I(t)\cos(\omega_0 t) - \sqrt{2}\, Q(t)\sin(\omega_0 t) + n(t) \right\} \sqrt{2}\cos(\omega_0 t) \right]_{lpf}$$

$$= \left[2 I(t)\cos^2(\omega_0 t) - Q(t)\sin(2\omega_0 t) + \sqrt{2}\, n(t)\cos(\omega_0 t) \right]_{lpf}$$

$$= \left[I(t) + I(t)\cos(2\omega_0 t) - Q(t)\sin(2\omega_0 t) + \sqrt{2}\, n(t)\cos(\omega_0 t) \right]_{lpf}$$

$$= I(t) + n_c(t)$$

⊙ Demodulate quadrature signal $Q(t)$.
(multiply $r(t)$ with $-\sqrt{2}\sin(\omega_0 t)$)

$$r_s(t) = -\left[r(t)\sqrt{2}\sin(\omega_0 t) \right]_{lpf}$$

$$= -\left[I(t)\cos(2\omega_0 t) - Q(t)\sin^2(\omega_0 t) + \sqrt{2}\, n(t)\sin(\omega_0 t) \right]_{lpf}$$

$$= Q(t) + n_s(t).$$

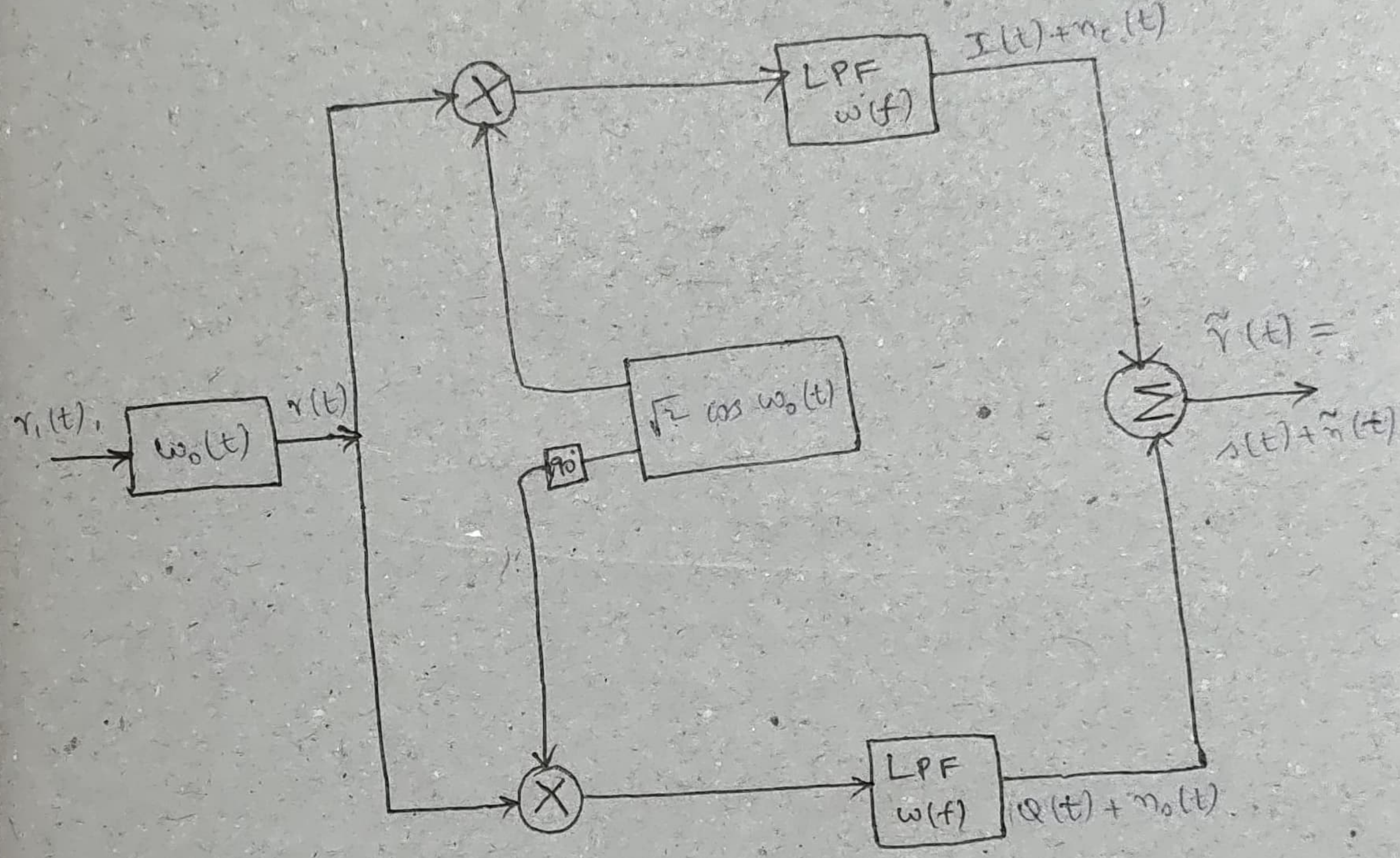
Demodulator block diagram:

- Demodulated complex baseband receive signal

$$\tilde{r}(t) = r_c(t) + j\, r_s(t) = I(t) + n_c(t) + j\,[Q(t) + n_s(t)]$$

$$= I(t) + jQ(t) + n_c(t) + j\,n_s(t)$$

$$= s(t) + \tilde{n}(t)$$



- Homodyne receiver architecture.