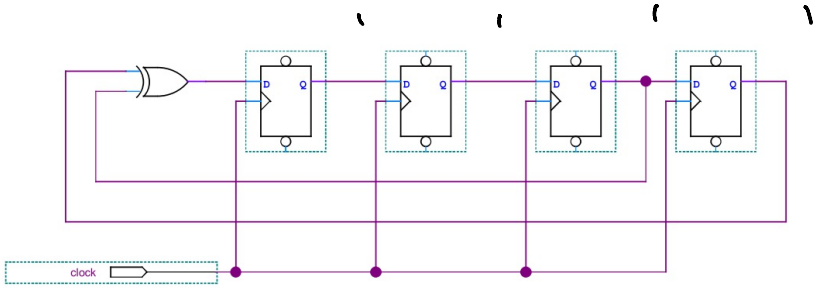
PN Sequences and Spread-Spectrum

Exercise 1: How many bits are there in an m-sequence for $m = 6$? How many are 1's? How many are 0's?

period = $2^m - 1 = 2^6 - 1 = 63$ bits

32 ones
31 zeros.

Exercise 2: If the initial value of each flip-flop is 1, what are the values of the next 4 bits output by the right-most flip-flop?



1 1 1 1

SR	input
1 1 1 1	1⊕1 = 0
0 1 1 1	1⊕1 = 0
0 0 1 1	1⊕1 = 0
0 0 0 1	0⊕1 = 1
1 0 0 0	0⊕0 = 0
0 1 0 0	= 0

Exercise 3: How many flip-flops would be required to generate a ML PRBS of period 8191? How many ones would the sequence have? What is the longest sequence of 0's?

$2^{m-1} = 8191$

$2^m = 8192$

$m = \log_2(8192) = 13$

1 0 0 ... 0 0 (12 zeros)

4096 ones = half of the bits a zeros. $\left(\frac{8192}{2}\right)$.

(4095 zeros)

longest sequence of zeros = $m-1$ (12)

Exercise 4: Derive H_2 and H_4. Show that the first two rows and last two columns of each matrix are orthogonal.

$H_1 = [1]$

$H_2 = \begin{bmatrix} H_1 & H_1 \\ H_1 & -H_1 \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$

$H_2 \cdot H_2$

$(1,1) \cdot (1,-1)$

$= 1 \times 1 + 1 \times -1$

$= 1 + -1 = 0$

$H_4 = \begin{bmatrix} H_2 & H_2 \\ H_2 & -H_2 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix}$

$H_{4_0} \cdot H_{4_1} = (1,1,1,1) \cdot (1,-1,1,-1)$

$= (1 \cdot 1) + (1 \cdot -1) + (1 \cdot 1) + (1 \cdot -1)$

$= 1 - 1 + 1 - 1 = 0$

Exercise 5: Spread the value a with H_{4_0} (equal to H_1) and the value b with H_{4_3}. Add the spread sequences and then de-spread them. Do you get back the original values?

$$= \left[\begin{array}{cc|cc} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ \hline 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{array}\right] \begin{array}{l} \rightarrow H_{4_0} \\ \\ \\ \rightarrow H_{4_3} \end{array}$$

$$a \quad a \quad a \quad a$$

$$b \quad -b \quad -b \quad b$$

$$a+b \quad a-b \quad a-b \quad a+b \leftarrow$$

$$\times \quad 1 \quad 1 \quad 1 \quad 1$$

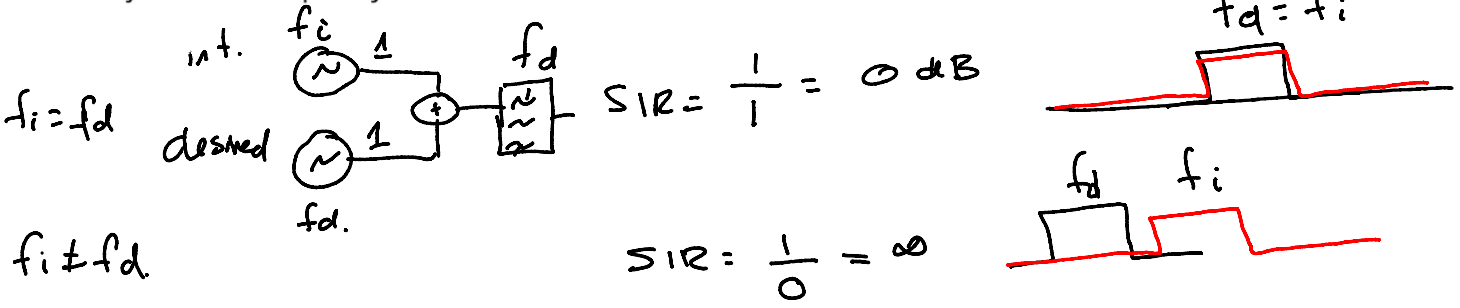
$$\frac{1}{4}\sum \; a+b \quad a-b \quad a-b \quad a+b = \frac{4a}{4} = a$$

$$a+b \quad a-b \quad a-b \quad a+b \leftarrow$$

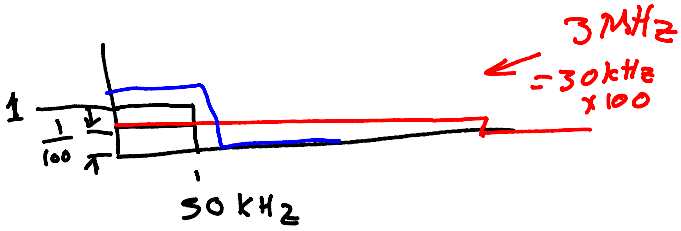
$$\times \quad 1 \quad -1 \quad -1 \quad 1$$

$$\frac{1}{4}\sum \; a+b \quad -a+b \quad -a+b \quad a+b = \frac{4b}{4} = b$$

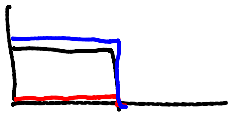
Exercise 6: Consider a 30 kHz signal. What is the SIR if a jammer is transmitting on the same frequency with equal received power? If the jammer is on a different frequency? What is the SIR if DSSS with a spreading factor of 100 is used? Does the SIR depend on the jammer's frequency?



baseband signal

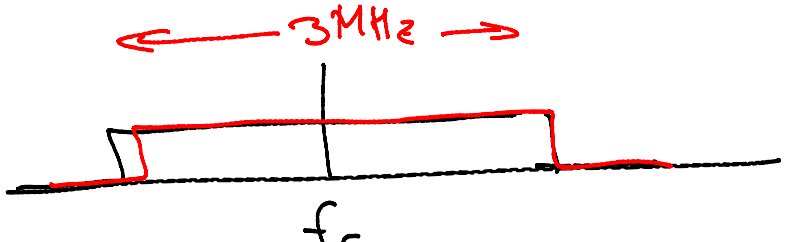


output of LPF



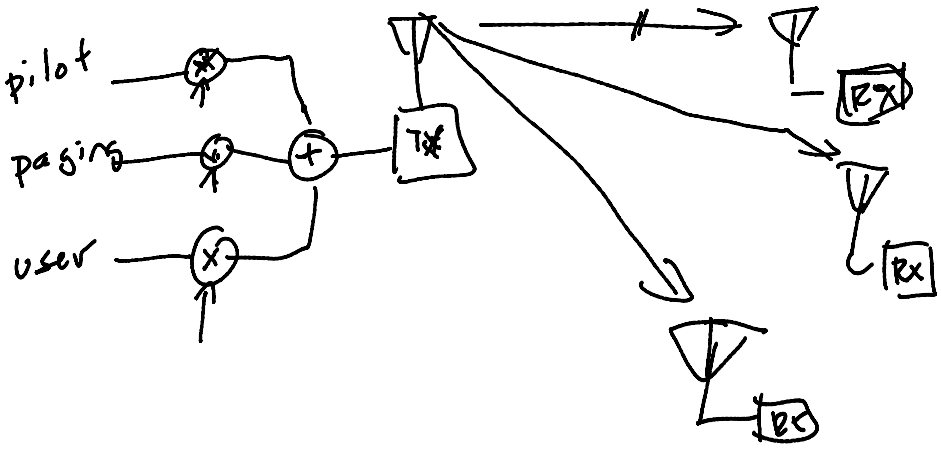
$SIR = \frac{1}{1/100} = 20\ dB.$

at RF:

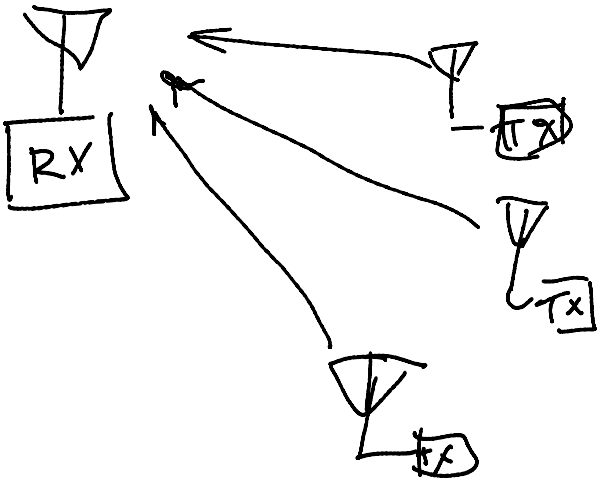


No. interference rejection is due to despreading not frequency selectivity.

Exercise 7: Why do all the downlink codes have the same delay? Why do different user's uplink signals have different delays?



all coming from same TX



all signals coming from different locations.

Exercise 8: Is BT FFH or SFH?

1 MHz channel → symbol rate ≈ 1 - 2 MHz

hop rate = 1600 Hz

SFH $\left(\frac{f_{symbol}}{f_{Hop}} \gtrsim 1000 \right)$