Multiply - Filter - Divide

$$\sin(\phi t) \xrightarrow{2} \sin^2(\phi t) = 1 - \cos(2\phi t)$$

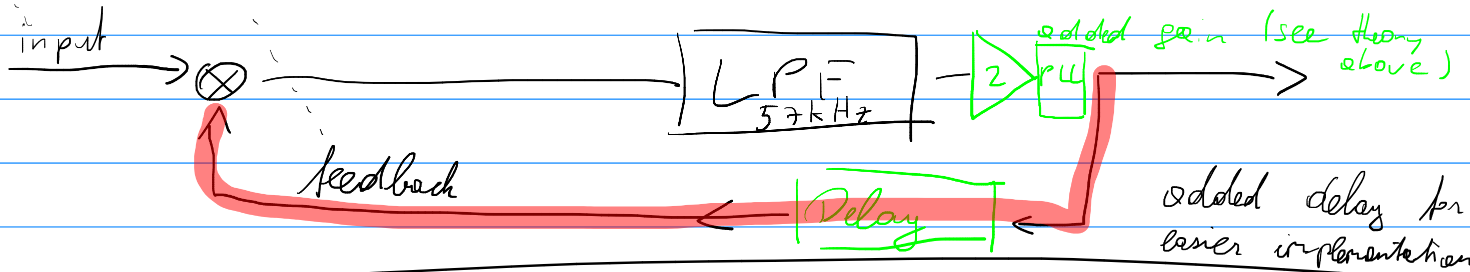
$$\sin(\varphi t) \cdot \sin(\phi t) = \frac{1}{2}\left(\cos((\phi - \varphi)t) - \cos((\phi + \varphi)t)\right)$$

$$\sin(\omega t) \cdot \sin\left(\frac{\omega}{2} t\right) = \frac{1}{2}\cos^3\left(\frac{\omega t}{2}\right) + \boxed{\frac{1}{2}\cos\left(\frac{\omega t}{2}\right)} - \frac{3}{2}\sin^2\left(\frac{\omega t}{2}\right) \cdot \cos\left(\frac{\omega t}{2}\right)$$

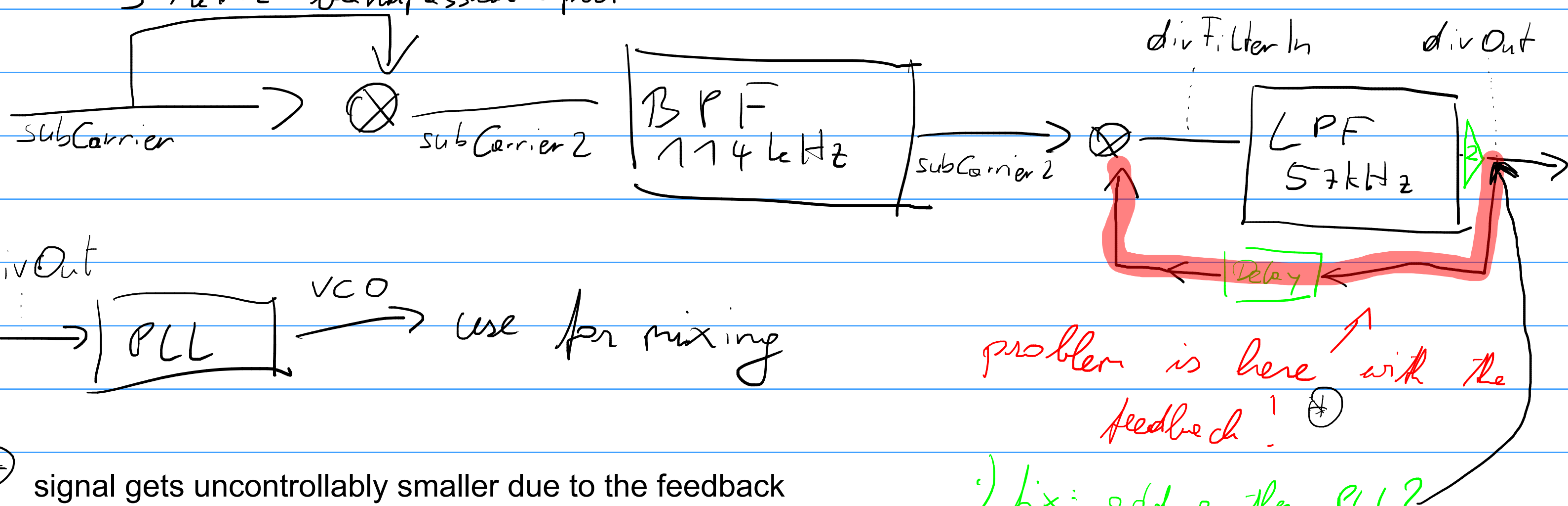
input feedback

beware!

filter this part in the frequency divider!



57kHz bandpassed input



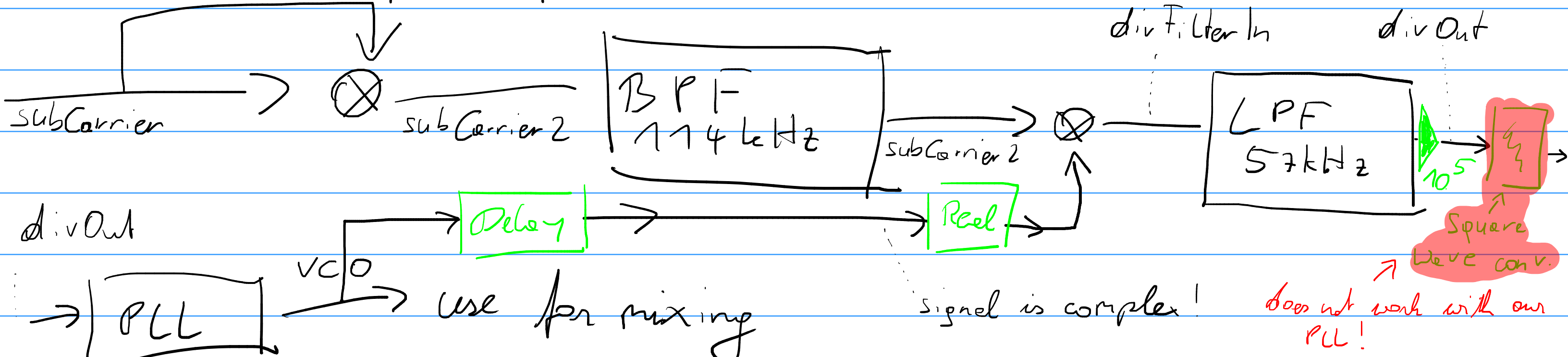
problem is here with the feedback! (*)

(*) signal gets uncontrollably smaller due to the feedback

:) fix: add another PLL?

FIX:

57kHz bandpassed input



.) new idea: use digital (divisor = 2) frequency divider instead of analog → tested and also does not work!

easy!

-) Costas Loop

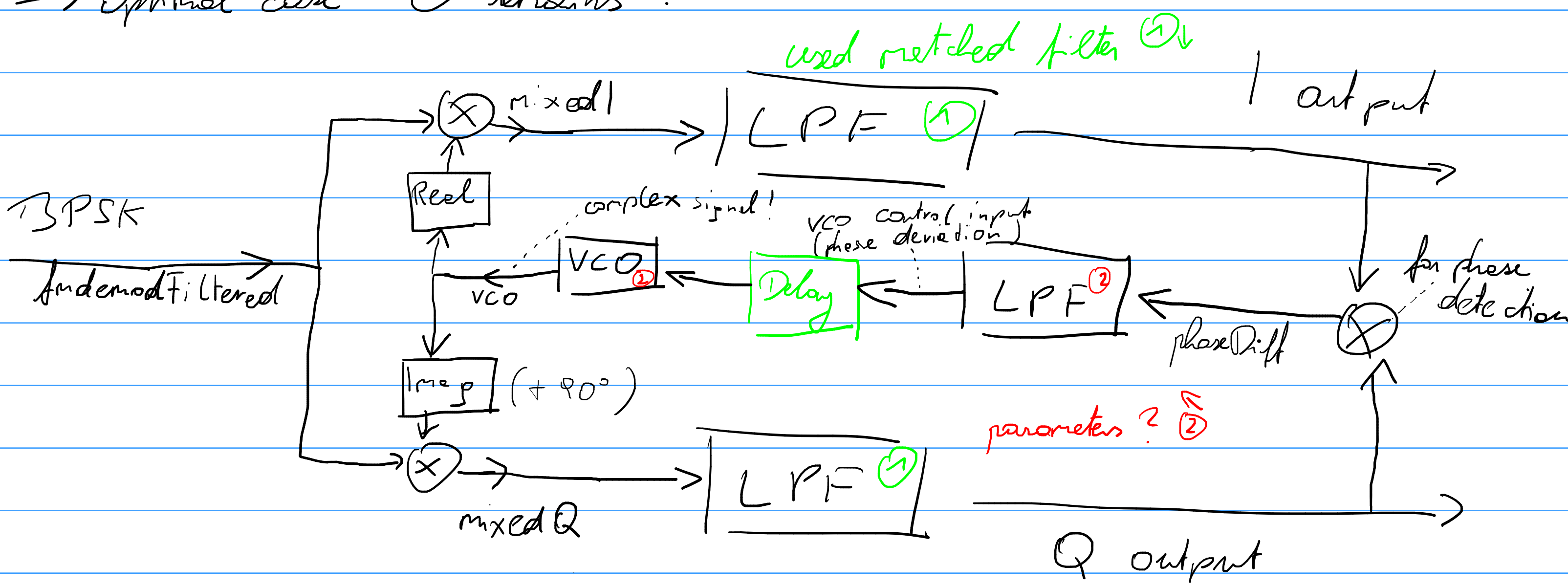
$$Q = Data \cdot \cos(2\pi f t) \cdot \cos(2\pi f_c' t) = \frac{1}{2}\Big(\underbrace{\cancel{\cos(4\pi f_c t)}}_{\text{filtered out}} + 1\Big) \cdot D$$

ensure $f_c = f_c'$

$\Rightarrow$ opt.: $\left(\frac{1}{2}\right)$ Data remains!

$$I = Data \cdot \underbrace{\cos(2\pi f_c t)}_{\text{subcarrier}} \cdot \underbrace{\sin(2\pi f_c' t)}_{90^\circ \text{ phase shifted carrier}} = \frac{1}{2}\Big(Data \cdot \sin(0) + \underbrace{\cancel{Data \cdot \sin(2\pi f_c t)}}_{\text{filtered out}}\Big)$$

$\Rightarrow$ optimal case Q remains!



$$\cos(2\pi f t + \varphi_1) \cdot \sin(2\pi f t + \varphi_2) = \frac{1}{4j}\left(e^{j2\pi f t + j\varphi_1} + e^{-j2\pi f t - j\varphi_1}\right)\left(e^{j2\pi f t + j\varphi_2} - e^{-j2\pi f t - j\varphi_2}\right)$$

$$= \frac{1}{2}\left[\sin(4\pi f t + \varphi_1 + \varphi_2) - \sin(\varphi_1 - \varphi_2)\right]$$