打印一下Noise and Distortion slidesFile

DSC-SC = Double Sideband Suppressed Carrier.

$$\phi(t)cosw_ct = f(t)cos^2w_ct = \frac{1}{2}f(t)[1+cos2w_ct]$$

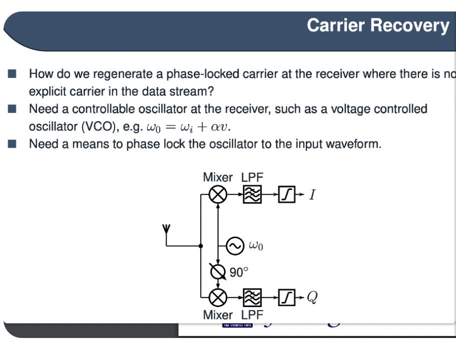
- Recovery of the original signal (demodulation) could be accomplished by another frequency shift, i.e. modulating with $\cos\omega_c t$ again.

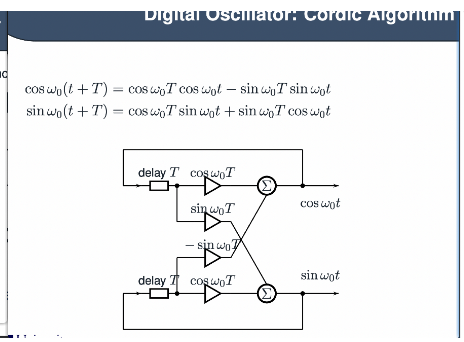
$$\phi(t)\cos\omega_c t = f(t)\cos^2\omega_c t = \frac{1}{2}f(t)[1+\cos 2\omega_c t]$$

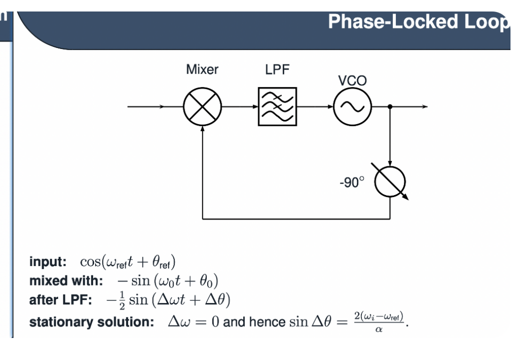
- Taking the Fourier transform,

$$\mathcal{F}\{\phi(t)\cos\omega_c t\} = \frac{1}{2}F(\omega) + \frac{1}{4}F(\omega+2\omega_c) + \frac{1}{4}F(\omega-2\omega_c)$$

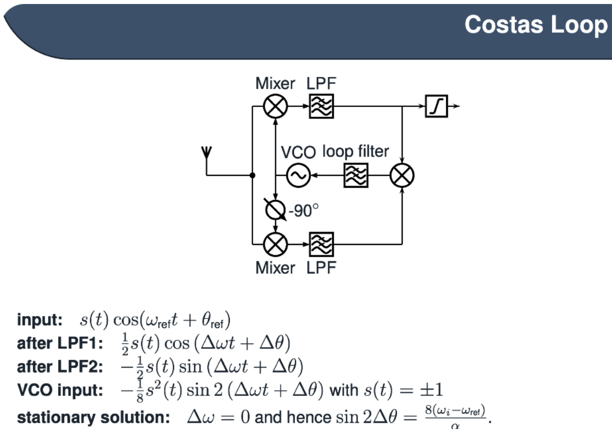
- We can reject the signals around $\pm 2\nu_c$ with a low-pass filter and obtain output $e_0(t) = \frac{1}{2}f(t)$.
- However, we'll see with demodulation of DSB-SC that phase and frequency must exactly match.

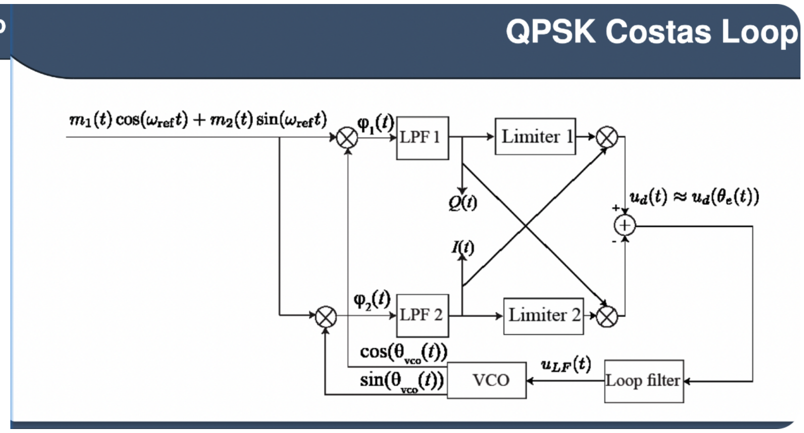






左边是BPSK,右边是QPSK





Costa Loop

$S(t) * cos(2\pi f_0)$

$S(t)$ -> symbols

$cos(2\pi f_0)$ -> carrier

Costas环是一种用于同步数字调制信号的电路。它通过对输入信号进行相位解调和相位比较，产生一个误差信号，并将该信号通过反馈回路调节本地振荡器的频率和相位，以实现对输入信号的同步。

Costas环可以应用于多种数字调制方案，包括二进制相移键控（BPSK）、四进制相移键控（QPSK）和八进制相移键控（8PSK）等。Costas环通常采用两个正交振荡器的输出作为相位解调器的输入，通过低通滤波器和相位比较器来消除相位偏差，并通过反馈回路来调整本地振荡器的频率和相位，以实现同步。

使用Costas环可以有效地恢复数字调制信号中的载波信号，这对于正确解码数字信号非常重要。

Tutorial

2022

Q5. In the following question, you will provide additional specifications for a digital communications channel. The occupied bandwidth (OBW) is limited to 5 MHz. and the channel is required to achieve a communication data bit rate of at least $9\,\mathrm{Mbit\,s^{-1}}$.

(a) Using the Shannon-Hartley theorem, what is the minimum signal-to-noise ratio required to achieve error-free transmission in this communications channel? [4]

(b) Pulse modulation is considered for the communications format in this channel using a raised cosine pulse with a roll-off. Choose a value for the roll-off β that in your judgement provides a suitable compromise between limiting the occupied bandwidth and damping the wings of the pulse in the time domain and sketch the appropriate pulse spectrum. [5]

(c) Hence, what is the minimum value for the symbol period that allows the inter-symbol interference to be suppressed? [4]

(d) Hence, identify a form of modulation keying that allows the required communication bit rate to be met. [3]

(e) Sketch a constellation diagram corresponding to this modulation format. [3]

占用带宽（OBW）限制为5 MHz，且信道需要实现至少9 Mbit/s的通信数据比特率。

香农定理

香农定理

$$C_{max} = Blog_2(1+\frac{S}{N})$$

$\frac{S}{N}$ 表示的就是SNR,信噪比.不是简单的SIgnal 除以 Noise.
$\frac{S}{N}$的单位为dB. 与简单的S除以N的换算关系为 $SNR = \frac{S}{N} = 10lg(\frac{P_S}{P_N})$[以功率],注意是以10为底
用电压就是$SNR = \frac{S}{N} = 20lg(\frac{V_S}{V_N})$[以电压]

"信噪比" 概念：信号平均功率 与 噪声平均功率 比值；

① 比值形式：$\frac{\text{信号平均功率}}{\text{噪声平均功率}}$，记作 S/N，该信噪比没有单位，是一个纯数值；

② 分贝形式：单位是 分贝（dB），计算公式如下：

1

$$\text{信噪比(dB)} = 10\log_{10}(\frac{S}{N})$$

这里注意 信噪比 的两种表示方式：

2

- S/N 是纯数值，没有单位；
- $10\log_{10}(\frac{S}{N})$ 单位是分贝；

上述两种形式的信噪比是等价的，代表同一个含义，分贝单位的信噪比只是看起来数字比较好看；

信噪比越大，噪声大于码元的影响就越小；

四、 香农定理

3

香农定理：在 带宽受限，有噪声 的 信道 中，为了不产生误差，信息的 数据传输速率 有上限值；

① 前提条件：带宽受限，有噪声；注意 与 奈氏准则 的条件参照理解，奈氏定理 的条件是 带宽受限，没有噪声

② 误差原因：奈氏准则 是由于 码间串扰 产生失真，香农定理 是由于 噪声 产生 误差；

③ 限制内容：奈氏准则 设定 码元极限传输速率，香农定理 设定 数据极限传输速率；

香农定理公式：

4

$$\text{信道极限数据传输速率} = W\log_2(1+S/N)$$

单位是 比特/秒（b/s）

W 带宽，单位 是 赫兹（Hz）；

S/N 是信噪比

S 是信道内信号的平均功率

N 是信道内的高斯噪声功率；

信噪比计算：

- 数值 信噪比：如果给出的信噪比是 数值，没有单位可以直接代入，代替上述 S/N；
- 分贝 信噪比：如果给出的信噪比是 dB 值，那么需要 根据 $\text{信噪比(dB)} = 10\log_{10}(\frac{S}{N})$ 公式，计算出 S/N 的值；

(a)
使用香农-哈特利定理，这个通信信道中实现无误差传输所需的最小信噪比是多少？

根据香农-哈特利定理，$C = B * log_2(1 + SNR)$，其中C是通道容量（比特率），B是带宽，SNR是信噪比。在此问题中，$C = 9Mbit/s$，$B = 5MHz$。

(b)
在这个信道中，考虑使用带滚降的升余弦脉冲进行脉冲调制。请为滚降系数β选择一个值，以在限制占用带宽和抑制时域脉冲之间实现适当的折衷。 一个常见的折衷选择是β = 0.5，这会在带宽利用率和抑制脉冲之间达到适当的平衡。在频域中，信号的带宽将是(1+β)倍的符号速率。在本例中，滚降系数β = 0.5是一个合适的选择。关于脉冲谱的草图，您可以在网上查找“升余弦脉冲谱”找到相应的示例。

(c)
因此，允许抑制符号间干扰的最小符号周期是多少？ 首先，我们需要计算符号速率Rs。由于滚降系数β = 0.5，信号带宽为(1+β) *Rs = 1.5* Rs，因此 Rs = OBW / (1+β) = 5 MHz / 1.5 ≈ 3.33 Msymbols/s。符号周期Ts为1/Rs，即： Ts = 1 / 3.33 Msymbols/s ≈ 0.3 μs 所以最小符号周期约为0.3 μs。

(d)
因此，确定一种调制键控形式，以满足所需的通信比特率。 要实现9 Mbit/s的通信速率，我们可以选择8PSK（四相相移键控），每个符号携带3比特信息。因此，比特速率Rb = 3 *Rs = 3* 3.33 Msymbols/s = 9.9 Mbit/s，满足所需的通信速率。所以选择8QAM, 一个symbol表示3个bit就是9.99M,这样才对. 9.99 > 9 M 所以满足题目所需要求.

(e)
8QAM
(e)

2021_Q4

Q4. A transmission channel of a digital communications system based on double sideband modulation has an available bandwidth of 12 MHz.

(a) If the signal to noise ratio corresponds to 8.45 dB, what does the Shannon-Hartley theorem give for the maximum rate at which information can be transmitted over this channel with an arbitrarily low error rate? [3]

(b) Pulse modulation is considered for the communications format in this channel. By using matched filtering, the pulse spectrum is a raised cosine pulse with a roll-off of $\beta = 0.5$. Explain what is meant by the term **matched filter**. [2]

(c) Sketch the pulse spectrum. [5]

(d) If the bandwidth of the pulse spectrum equals the available bandwidth, what is the minimum symbol separation time which suppresses inter-symbol interference? [3]

(e) For the quadrature phase shift keying (QPSK) modulation format, what is the corresponding data rate (bits per unit time) for this communication link? [2]

(a)?

根据香农-哈特利定理，信道容量C（即最大信息传输速率）可以通过以下公式计算：

$C = B * log_2(1 + SNR)$，其中B是信道带宽，SNR是信噪比。

(b)

匹配滤波器是一种线性滤波器，其目的是在接收端最大限度地提高信号与噪声的比值。匹配滤波器的脉冲响应是传输脉冲信号的时间反转和共轭，以便在滤波器的输出处实现最佳信噪比。

Matched filter is a type of linear filter, whose purpose is to maximize the signal-to-noise ratio at the receiver. The impulse response of the matched filter is the time-reversal and complex conjugate of the transmitted pulse signal, in order to achieve the best signal-to-noise ratio at the output of the filter.

匹配滤波是一种用于无线通信中提高信噪比和减少干扰的技术。它涉及在发射端和接收端同时使用特定类型的滤波器，称为匹配滤波器。

在传统通信系统中，脉冲整形滤波器只需要在接收前对齐即可进行采样。但在现代通信系统中，脉冲整形滤波器被平分在发射端和接收端。这样做是为了减少信号使用的频谱，以及尽可能消除噪声和干扰。

匹配滤波的概念涉及在发射端和接收端使用相同的滤波器，以在存在加性白噪声的情况下最大化信噪比。匹配滤波器的频率响应被设计为与信号脉冲形状相匹配。通过在两端使用相同的匹配滤波器，系统可以在降噪和信号恢复方面实现最佳性能。

需要注意的是，发射端和接收端使用的滤波器不必完全相同，但它们应该被设计为相互补充。匹配滤波器的使用已经成为现代无线通信系统的标准实践，例如Wi-Fi、移动通信和卫星通信。

在这里，相互补充的意思是指发射端和接收端的滤波器不必完全相同，但它们应该被设计为相互配合、协同工作的滤波器。在匹配滤波的概念中，发射端和接收端的滤波器应该具有相似的形状和频

率响应，以达到最佳的性能表现。因此，它们需要被设计为相互补充、相互匹配的滤波器，以实现最佳的信号传输和噪声消除效果。

Matched filtering is a technique used in wireless communication to improve signal-to-noise ratio and reduce interference. It involves using specific types of filters, called matched filters, at both the transmitting and receiving ends.

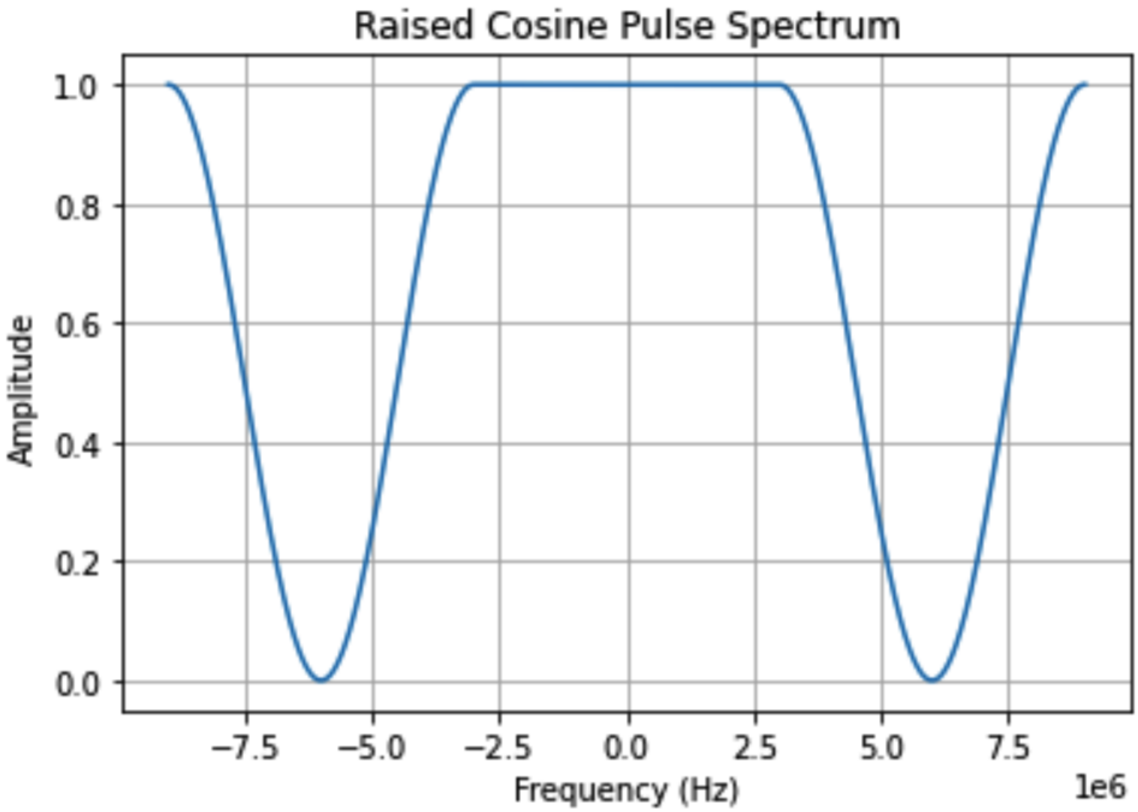
In traditional communication systems, pulse shaping filters only need to be aligned before sampling at the receiving end. However, in modern communication systems, pulse shaping filters are divided between the transmitting and receiving ends. This is done to reduce the spectrum used by the signal and to eliminate noise and interference as much as possible.

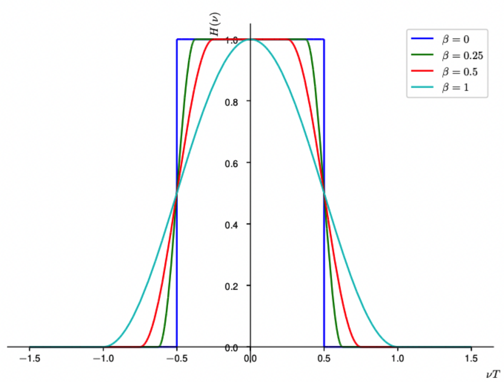
The concept of matched filtering involves using the same filter at both the transmitting and receiving ends to maximize signal-to-noise ratio in the presence of additive white noise. The frequency response of the matched filter is designed to match the signal pulse shape. By using the same matched filter at both ends, the system can achieve optimal performance in terms of noise reduction and signal recovery.

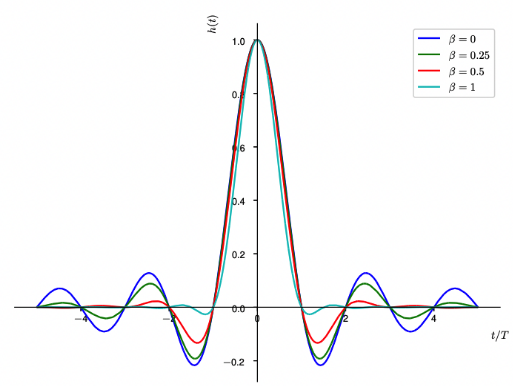
It should be noted that the filters used at the transmitting and receiving ends do not have to be identical, but they should be designed to complement each other. The use of matched filters has become a standard practice in modern wireless communication systems, such as Wi-Fi, mobile communication, and satellite communication.

In this context, complementary means that the filters used at the transmitting and receiving ends do not have to be identical, but they should be designed to work together in a complementary and coordinated manner. In the concept of matched filtering, the filters at the transmitting and receiving ends should have similar shapes and frequency responses to achieve optimal performance. Therefore, they need to be designed as complementary and matching filters to achieve the best signal transmission and noise reduction effects.

(c)?







$$H(\nu) = \begin{cases} 1 & |\nu| \leq \frac{1-\beta}{2T_{\text{sym}}} \\ \frac{1}{2}\left[1 + \cos\frac{\pi T_{\text{sym}}}{\beta}\left(|\nu| - \frac{1-\beta}{2T_{\text{sym}}}\right)\right] & \frac{1-\beta}{2T_{\text{sym}}} < |\nu| < \frac{1+\beta}{2T_{\text{sym}}} \\ 0 & \text{otherwise} \end{cases}$$

(d)

如果脉冲谱的带宽等于可用带宽，则脉冲谱的带宽为12 MHz。对于升余弦脉冲，符号间隔时间Ts可以通过以下公式计算： $\frac{1}{T_{sym}} = \frac{B_{DSB}}{1+\beta}$，其中B是信道带宽，β是滚降因子。

(e) 对于QPSK调制格式，每个符号表示2比特的数据。因此，数据速率（比特率）可以通过以下公式计算： 数据速率 = (1 / Ts) * 每个符号的比特数。

因此，这个通信链路的数据速率约为 x Mbps。

2020_Q6?

Q6 Figure Q6 shows the results of two BPSK transmission with carrier recovery using a 2nd generation Costas loop. Transmission shown in Figure Q6(a/b) indicates correct data decoding, whilst transmission shown in Figure Q6(c/d) indicate incorrect decoding. The upper sub-figures show the results of carrier demodulation, and the lower figures show associated VCO control voltages. In each of the questions below, give detailed reasoning for your answers.

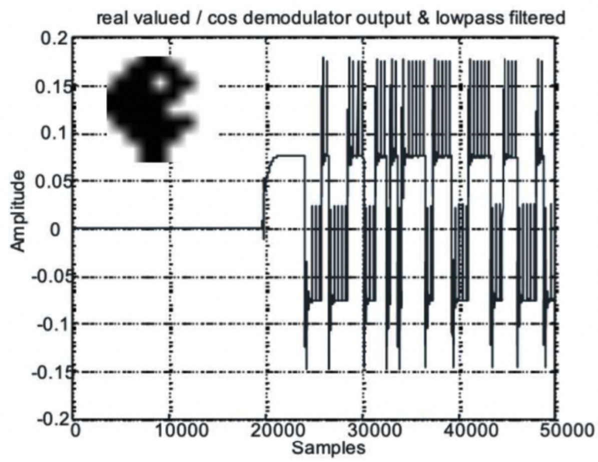


Figure Q6a

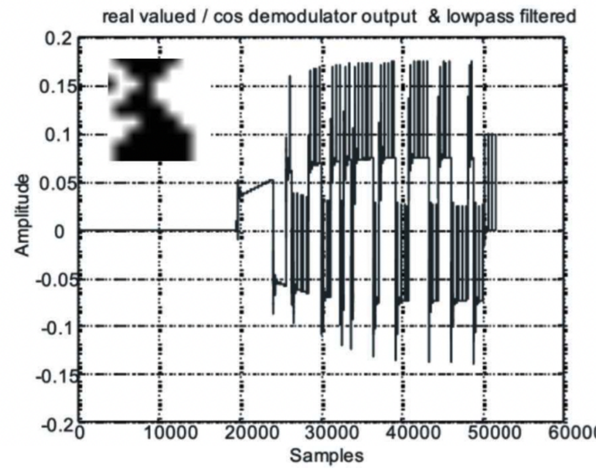


Figure Q6c

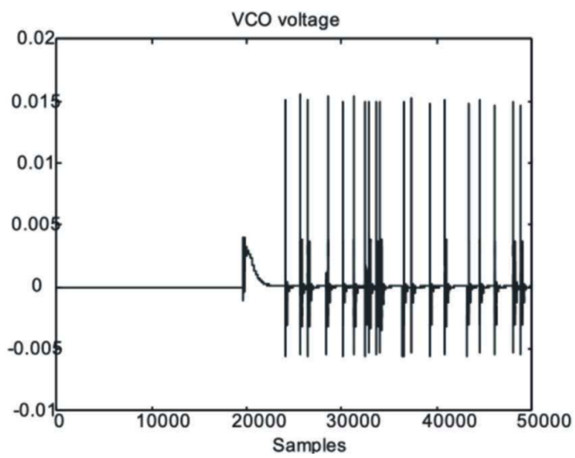


Figure Q6b

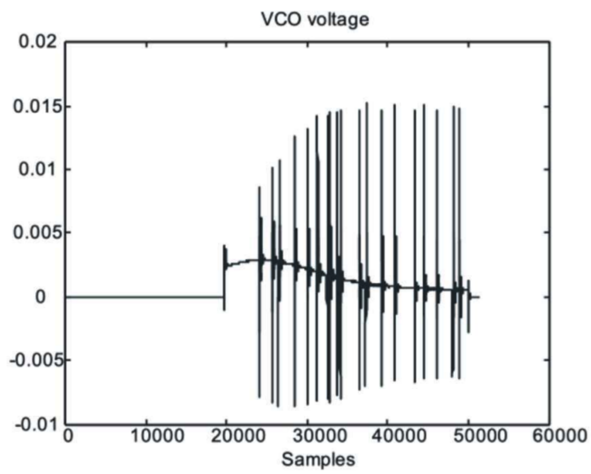


Figure Q6d

(a) Why does the trace, Figure Q6(c) lead to an incorrectly decoded Pacman? [6]

(b) Which parameter(s) is/are most likely to have been tuned incorrectly in the receiver to cause the problems associated with Figures Q6(c) and Q6(d), and how should this/these parameter(s) be altered to correct the problem? [10]

(c) What is the origin of the narrow spikes in the VCO control voltage traces? [8]

(d) If the system the sampling rate is fixed at 10 MHz, how long is required to transmit the complete Pacman when decoded correctly, and in your judgement, what is the shortest time possible for such a transmission? [6]

Continued overleaf

(a)

(b)

2019

Q2

Q2 (a) Figure Q2 shows a BPSK signal which is encoded with a cosine, and starts at phase zero with a binary '1'. The frequency of the signal is $f = 0.1$ and the symbol interval is $T = 20$ samples. Which bit values have been transmitted? [4]

(b) Sketch the block diagram of a Costas loop designed to recover the carrier from a BPSK system, and describe its operation [6]

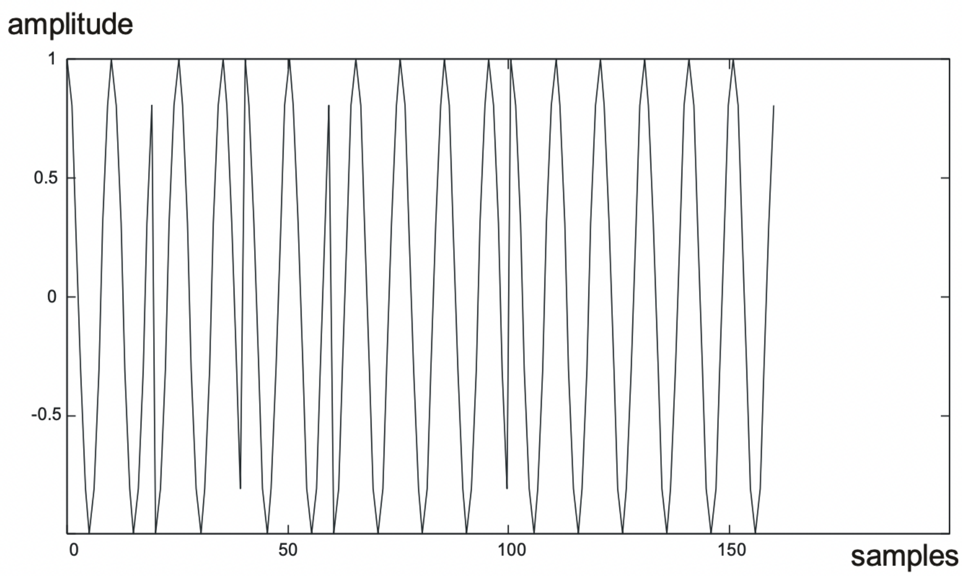


Figure Q2

(a)

10100111

cos

0 下面

180 上面的尖

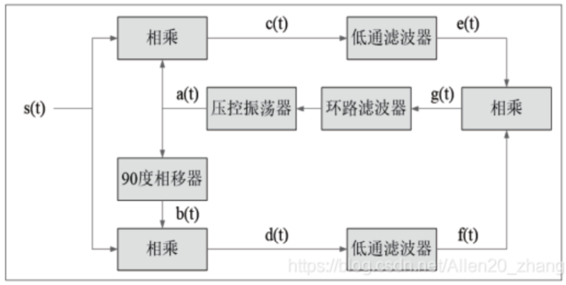
sin相反

看与开始相反的

(b)

一、Costas环基本概念

科斯塔斯 (COSTAS) 环又称同相正交环或边环，它的原理框图如图1所示。科斯塔斯 (COSTAS) 环主要由相位鉴别器 (PD)、压控振荡器 (VCO) 和环路滤波器 (LF) 三部分构成。相位鉴别器 (PD) 用来鉴别两个输入信号之间相位的差异，可以简单的是一个乘法器。环路滤波器 (LF) 的作用是滤波，降低环路中的噪声，使滤波结果既能真实地反映环路滤波器 (LF) 输入信号的相位变化情况，又能防止由于噪声的缘故而过激地调节压控振荡器 (VCO)，环路滤波器 (LF) 通常是一个低通滤波器。压控振荡器 (VCO) 的基本功能是产生一定频率的周期振荡信号，并且该信号的频率变化量与输入的控制信号的大小成正比。



二、公式推导

$$s(t)=m(t)\cos(\omega t+\theta) \tag{1}$$

式 (1) 中：$m(t)=\pm 1$

假定环路已经锁定，且不考虑噪声影响，则压控振荡器 (VCO) 输出的两路相互正交的载波分别为：

$$a(t)=\cos(\omega t+\varphi) \tag{2}$$

$$b(t)=\sin(\omega t+\varphi) \tag{3}$$

输入的二进制相移键控 (BPSK) 信号 s(t) 分别与 a(t)、b(t) 相乘，并经过低通滤波后分别为：

$$e(t)=\frac{1}{2}m(t)\cos(\varphi-\theta) \tag{4}$$

$$f(t)=\frac{1}{2}m(t)\sin(\varphi-\theta) \tag{5}$$

e(t)、f(t) 这两个信号相乘后，得到环路滤波器 (LF) 的输入信号为：

$$g(t)=\frac{1}{8}m^2(t)\sin 2(\varphi-\theta) \tag{6}$$

式 (6) 中：$(\varphi-\theta)$ 为压控振荡器 (VCO) 输出信号相位和输入的二进制相移键控 (BPSK) 信号相位之差。

将 $m(t)=\pm 1$ 代入式 (6)，并考虑到当 $(\varphi-\theta)$ 很小时，$\sin(\varphi-\theta)\approx(\varphi-\theta)$，则式 (6) 变为：

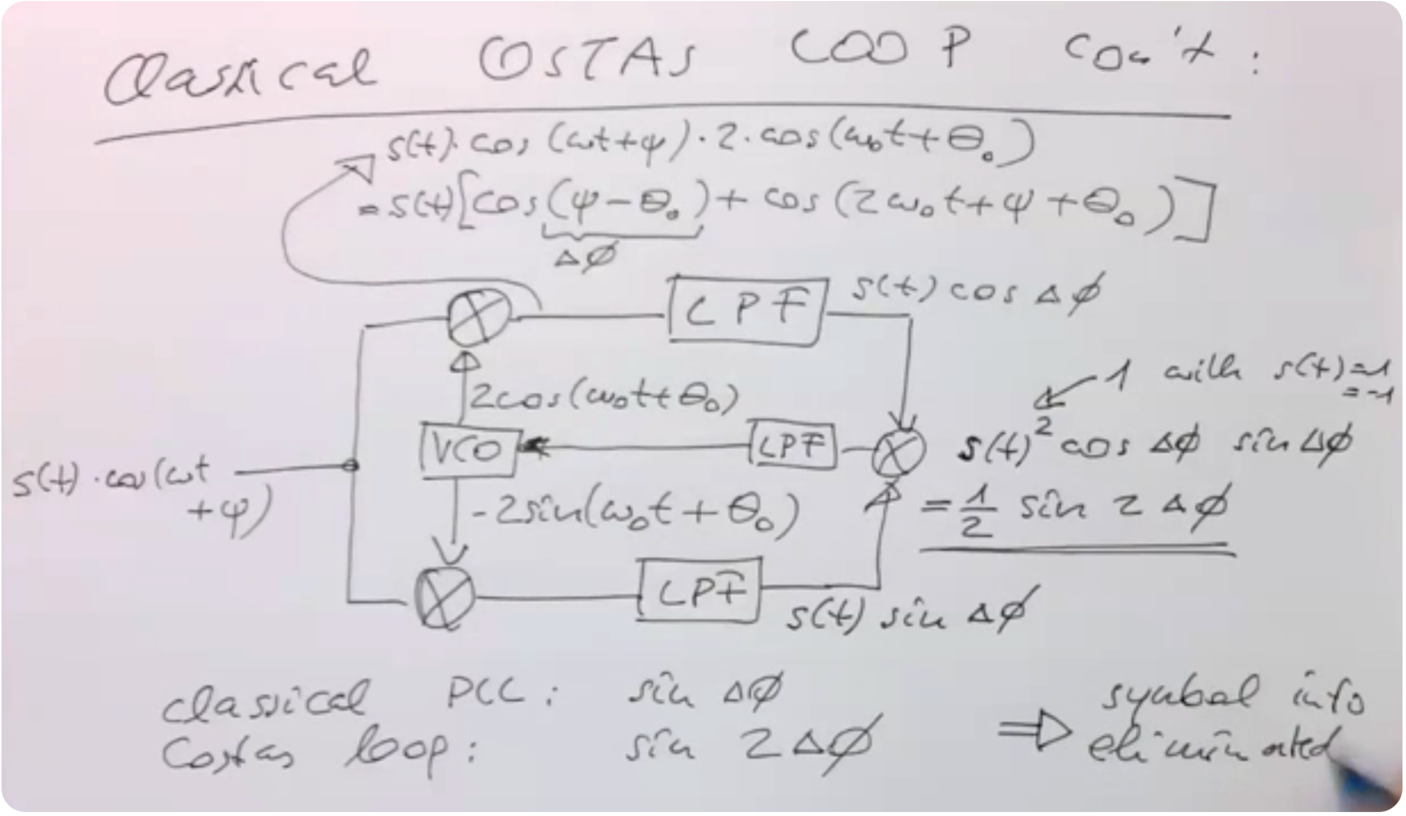
$$g(t)\approx\frac{1}{4}(\varphi-\theta) \tag{7}$$

信号 g(t) 通过环路窄带低通滤波器，控制压控振荡器 (VCO) 的振荡频率。此窄带低通滤波器的截止频率很低，只允许信号 g(t) 中近似直流的分量通过。这个信号控制压控振荡器 (VCO) 的输出信号相位，使 $(\varphi-\theta)$ 尽可能地小。当 $\varphi=\theta$ 时，g(t)=0。压控振荡器 (VCO) 的输出信号 a(t) 就是科斯塔斯 (COSTAS) 环提取出的载波。它可以用来作为相干解调的本地载波。

此外，由式 (4) 可见，当 $(\varphi-\theta)$ 很小时，除了差一个常数因子外，信号 e(t) 就近似等于解调输出信号 m(t)。所以科斯塔斯 (COSTAS) 环本身就同时兼有提取相干载波和相干解调的功能 [3]。

环路滤波器基本上决定这科斯塔斯 (COSTAS) 环的性能。

这是老师的图,但是这两张图都没错,都对.



To use both sine and cosine from the VCO and create the voltage by combining them.

Operation of the Costas Loop:

1. The incoming BPSK signal is first multiplied with the in-phase (I) and quadrature-phase (Q) components of the local carrier generated by the VCO.
2. The resulting I and Q components are then passed through low-pass filters to remove high-frequency components.
3. The filtered I and Q components are multiplied in the phase detector, which generates an error signal proportional to the phase difference between the input BPSK signal and the local carrier.
4. The error signal is passed through a loop filter to reduce noise and provide loop stability.
5. The filtered error signal is used to control the VCO frequency, adjusting it until the phase error converges to zero.
6. When the loop is locked, the local carrier is in phase with the input BPSK signal, and the original data can be recovered by comparing the incoming signal with the regenerated carrier.

The Costas loop efficiently recovers the carrier signal from a BPSK system by adjusting the VCO frequency to minimize the phase error between the input signal and the local carrier.

首先将输入的二进制相移键控(BPSK)信号与由VCO产生的同相位(I)和正交相位(Q)本地载波进行乘法运算。
然后将结果经过低通滤波器处理，以去除高频成分。
经过滤波的I和Q分量在相位检测器中进行乘法运算，生成与输入BPSK信号和本地载波之间的相位差成正比的误差信号。
误差信号通过环路滤波器处理，以降低噪声并提供环路稳定性。
经过滤波的误差信号用于控制VCO的频率，调节其直到相位误差收敛于零。
当环路锁定时，本地载波与输入BPSK信号处于同相位状态，可以通过比较输入信号和再生的载波来恢复原始数据。
Costas环通过调节VCO频率最小化输入信号和本地载波之间的相位误差，有效地从BPSK系统中恢复载波信号。

Q5

Q5 A Binary Phase Shift Keying (BPSK) phase demodulator with carrier recovery uses a Voltage Controlled Oscillator (VCO) to lock to a carrier signal. The VCO attempts to lock over a period of 2000 time steps before being fixed in frequency. Figure Q5 shows the VCO control voltage and demodulator output for two different demodulator configurations, where the traces A, result in correct image decoding, and the traces B, do not. Note that the time bases of the demodulator and VCO traces are not identical.

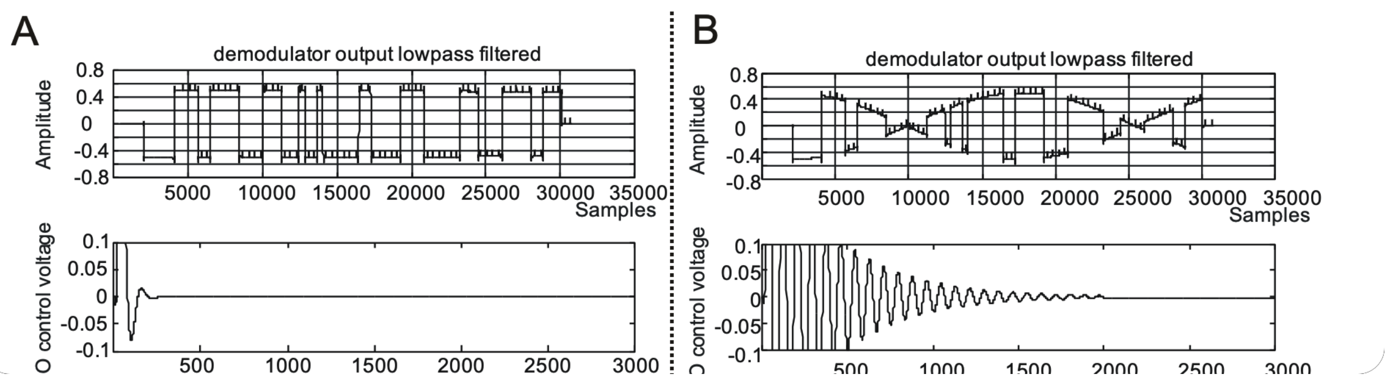
(a) Explain which system parameter or parameters are most likely to have been set incorrectly in the right hand trace B, giving reasons for your answer. [7]

(b) Discuss the best practical method of correcting this problem. [3]

(c) The demodulator output is labelled as 'lowpass filtered'. What is the purpose of this low pass filtering and what is the typical level of filtering required? [6]

(d) In the demodulator outputs, small spikes have been added to indicate when bits are recovered. Discuss the best time to sample and recover bits within a symbol period, sketching the signal to illustrate your discussion. [6]

(e) In many scenarios it might be useful to track the carrier at all times, rather than freezing the VCO. List the challenges in doing this, and provide a possible solution. [8]



Conclusion

符号间隔时间:

$$\frac{1}{T_{sym}} = \frac{B_{DSB}}{1+B}$$

数据速率 = $\frac{1}{T_s}$ * 每个符号的比特数