

# Digital Communication Systems

## ECS 452

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## 6. Digital Modulation



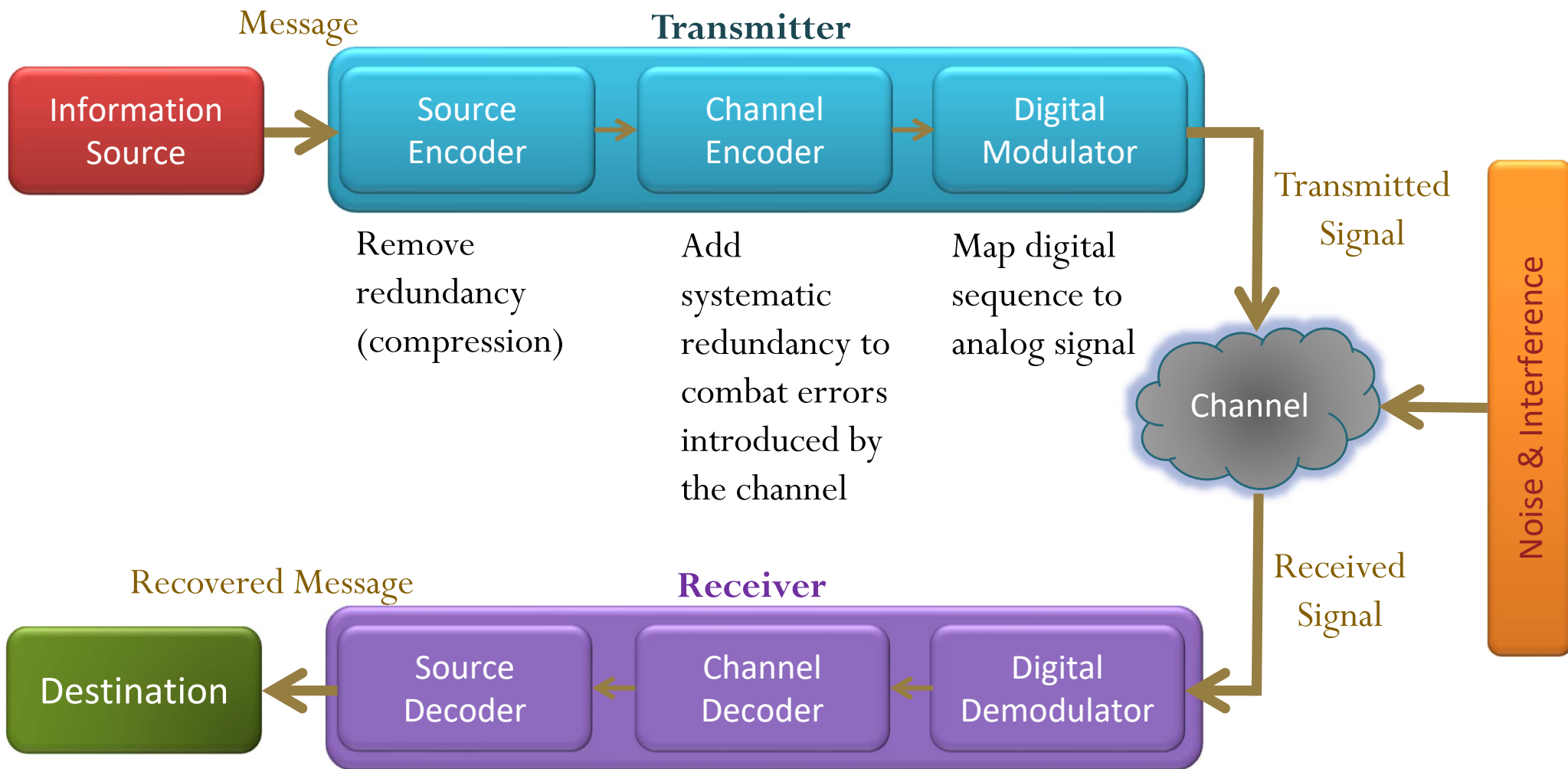
### Office Hours:

Check Google Calendar on the course website.

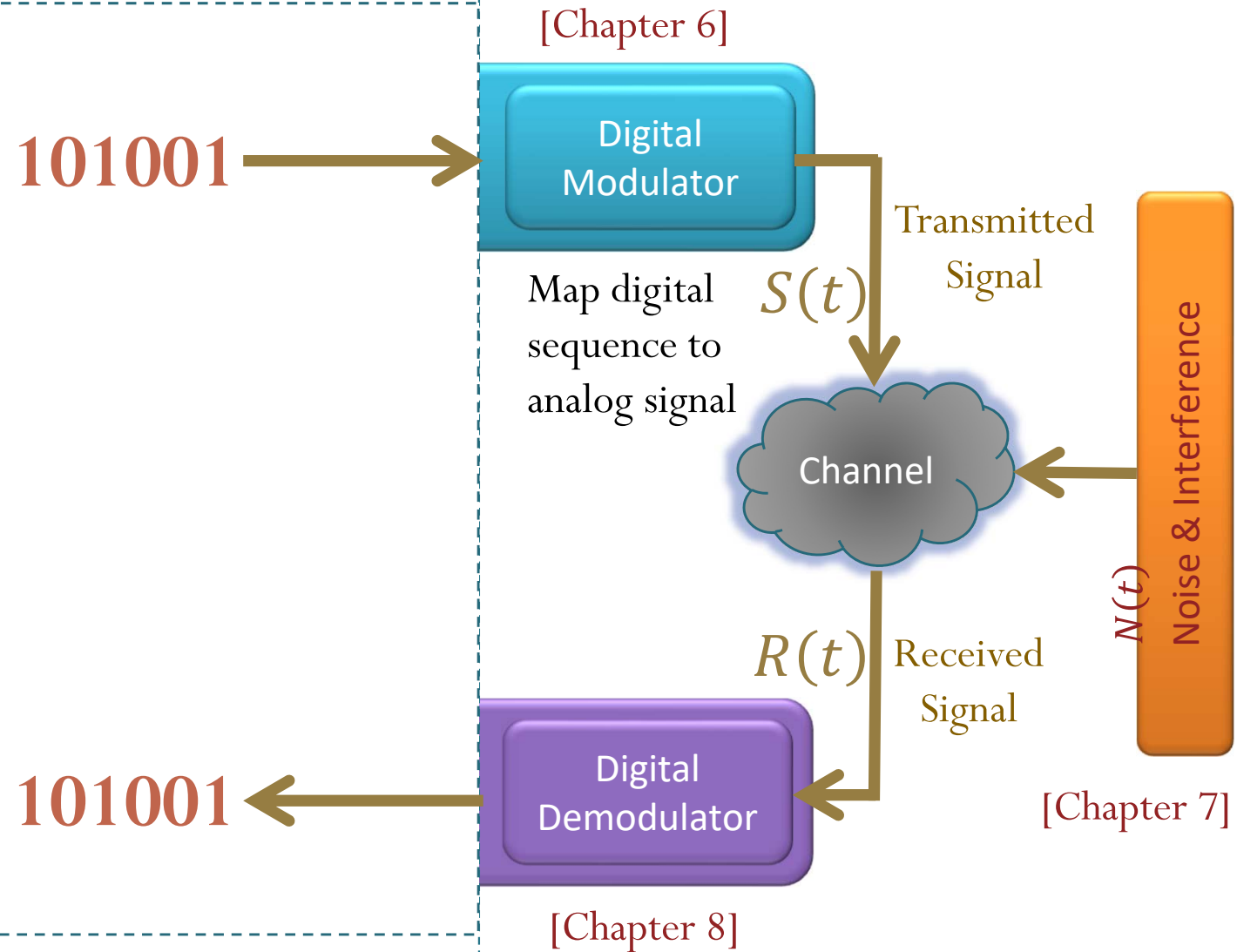
Dr.Prapun's Office:

6th floor of Sirindhralai building,  
BKD

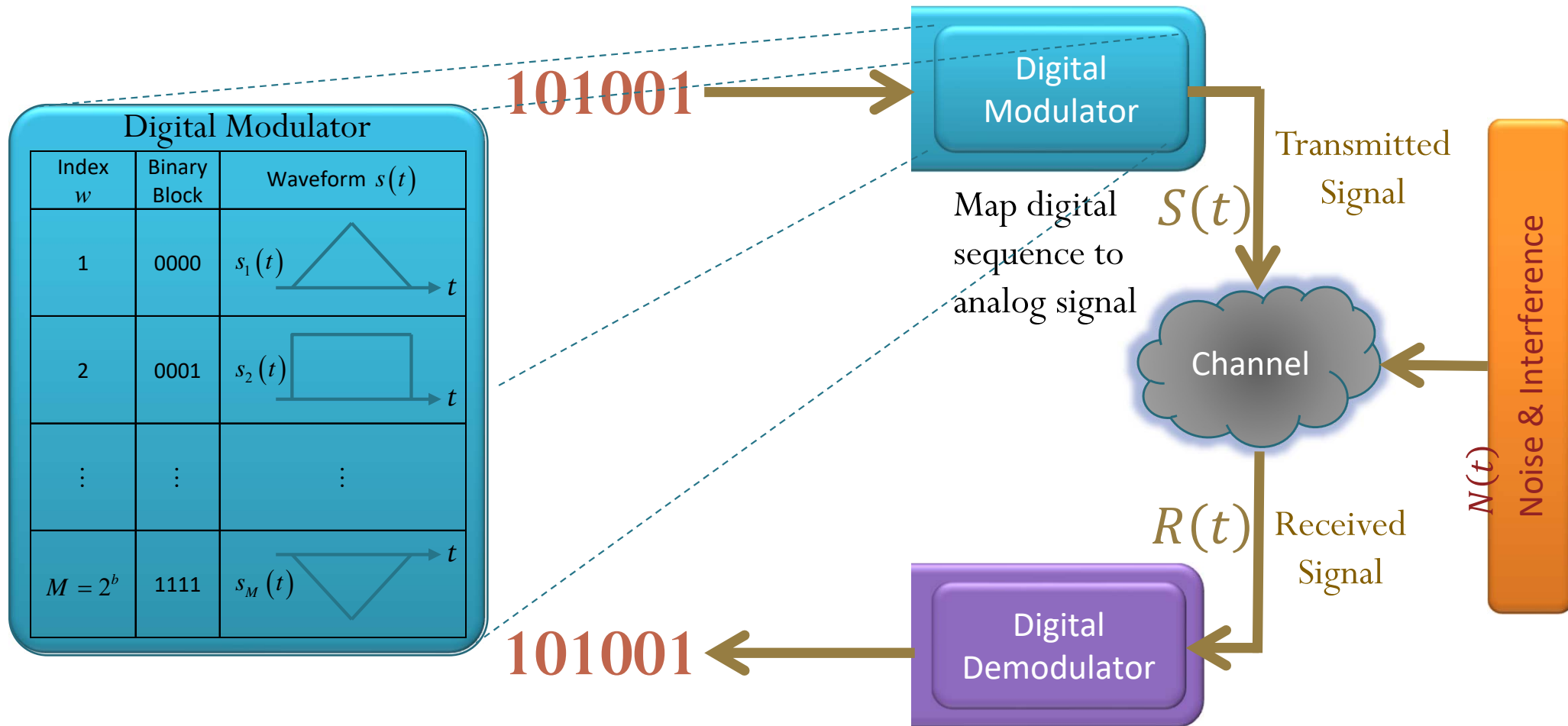
# Elements of digital commu. sys.



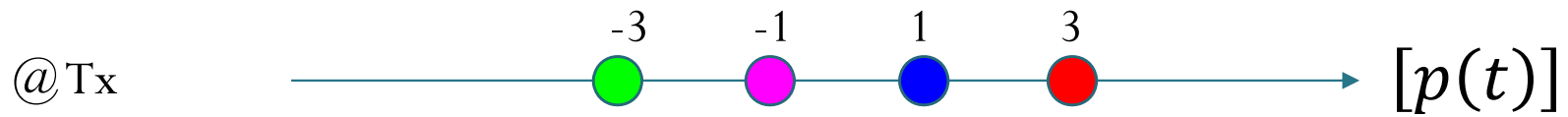
# Digital Modulation/Demodulation



# Digital Modulation/Demodulation



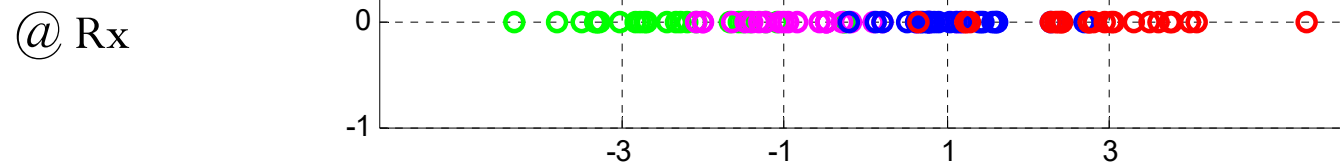
# Standard Quaternary PAM



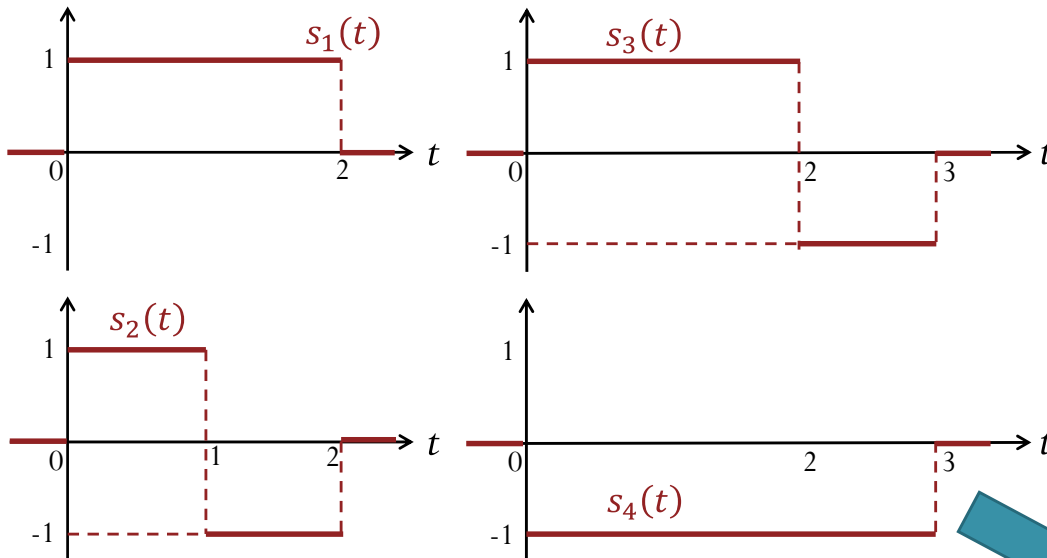
The points are chosen randomly  
(according to the bits that are fed into  
the digital modulator) 100 times.



Add noise

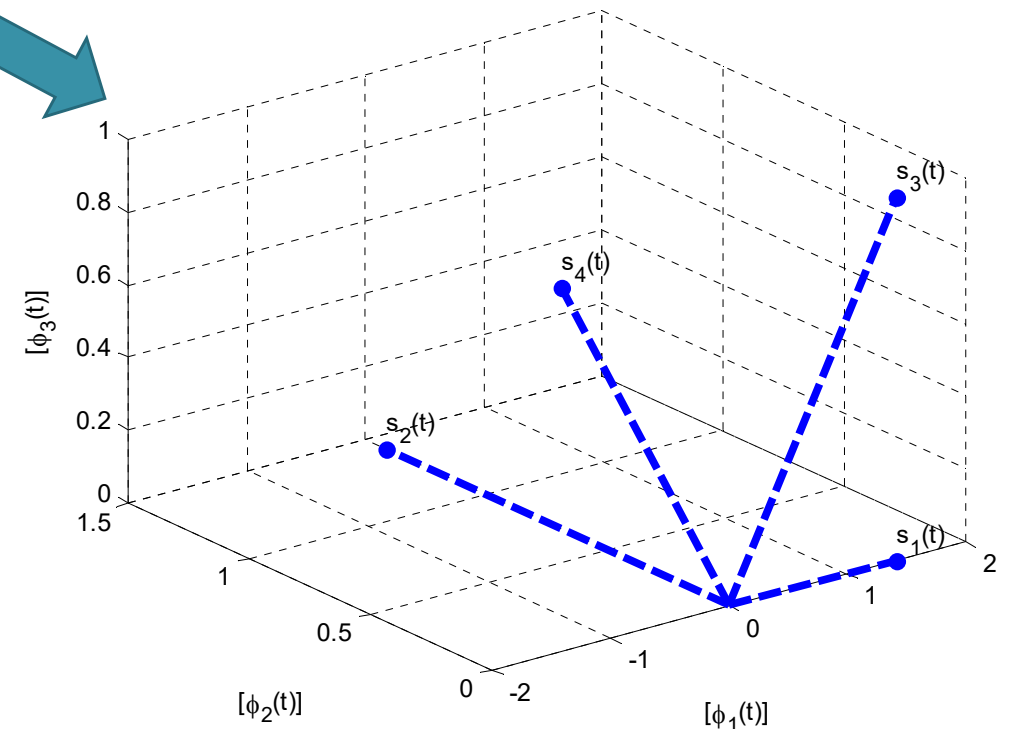


# Review: From Waveforms to Constellation



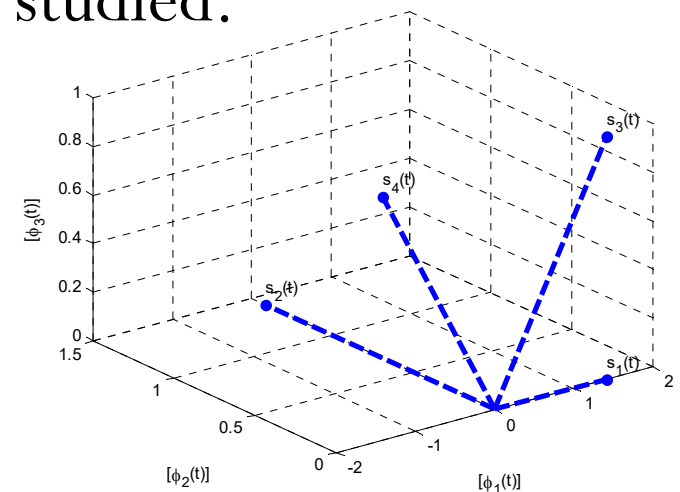
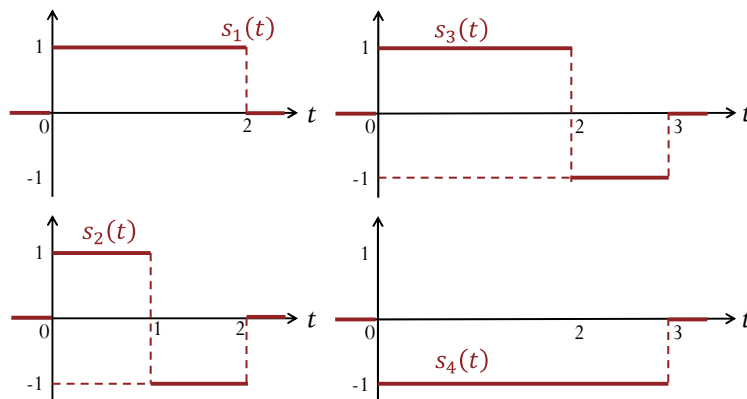
- What should be the axes?
  - 1 axis = 1 dimension
  - How many do we need?
- How to represent the waveform on these axes?

- A waveform contains infinitely many points. To represent *all* possible waveforms, we would need to work in infinite-dimensional space.
- However, we only have to consider four possible waveforms here.

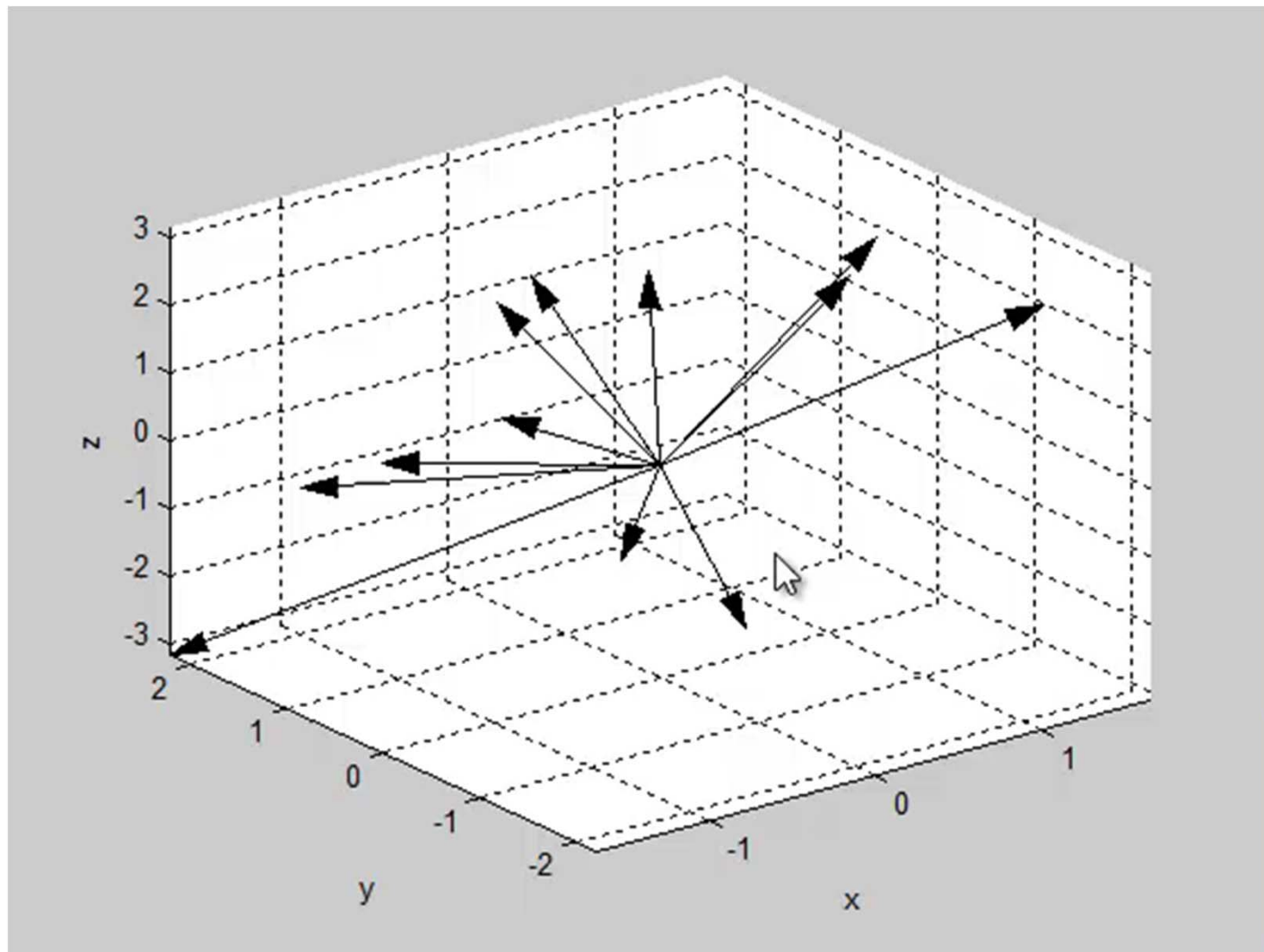


# Review: From Waveforms to Constellation

- In Section 6.2, we start with a collection of vectors instead of a collection of waveforms.
  - The calculation for vector case is easier.
  - It may seem redundant because some implicit axes are already there when we specify any vector.
    - Still useful because the calculation can remove the redundant axes.
  - The formula is exactly the same for the waveform case.
- In Section 6.3, the waveform case is studied.

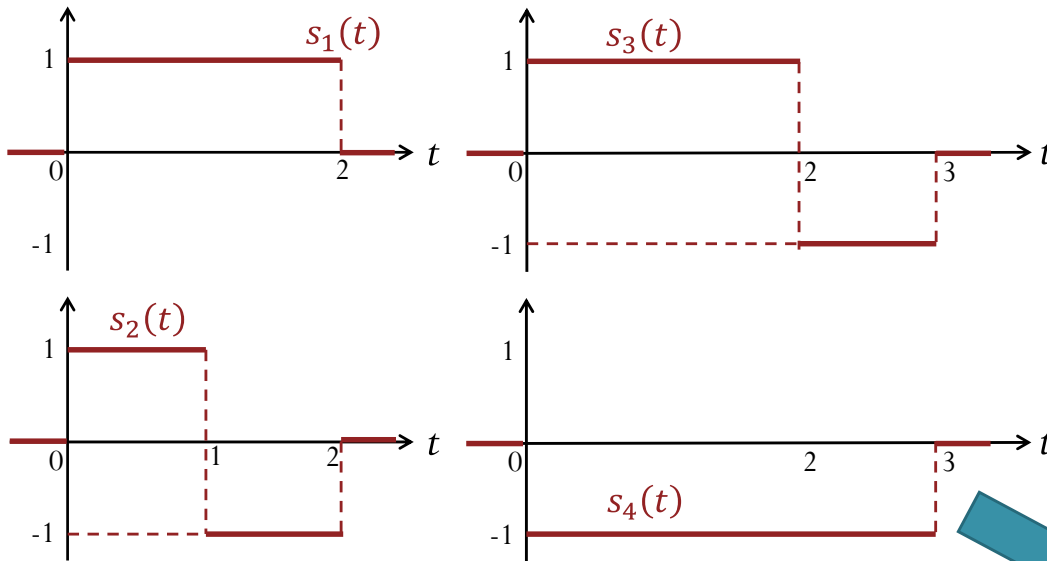


# Example 6.26





# From Waveforms to Constellation

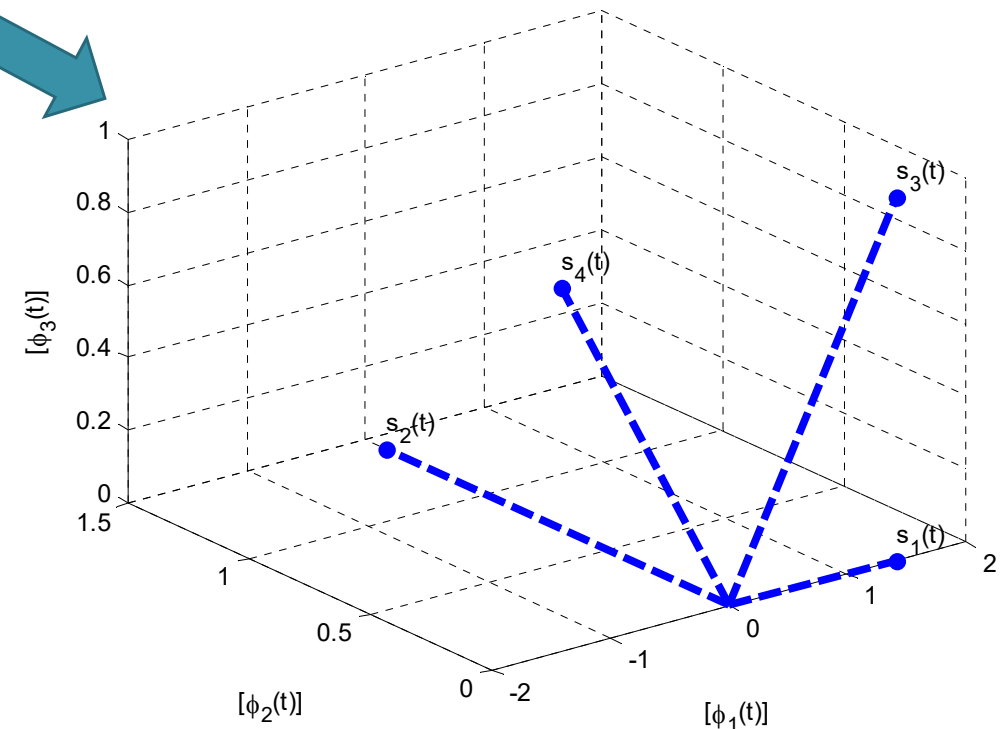


Find  $N$  orthonormal basis functions  $\{\phi_1(t), \phi_2(t), \dots, \phi_K(t)\}$  to use as axes for  $\{s_1(t), s_2(t), \dots, s_M(t)\}$ .

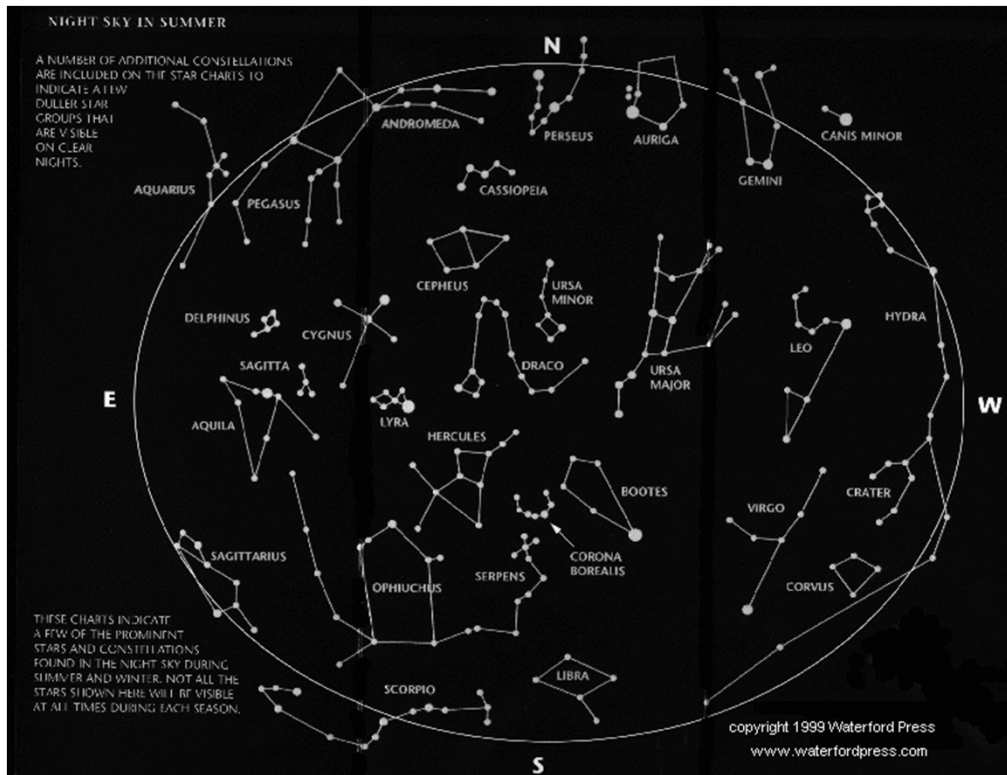
This gives vector representations for the waveforms  $s_1(t), s_2(t), \dots, s_M(t)$ :

$$\vec{\mathbf{s}}^{(1)}, \vec{\mathbf{s}}^{(2)}, \dots, \vec{\mathbf{s}}^{(M)}$$

which can be visualized in the form of signal constellation



# Star Constellations

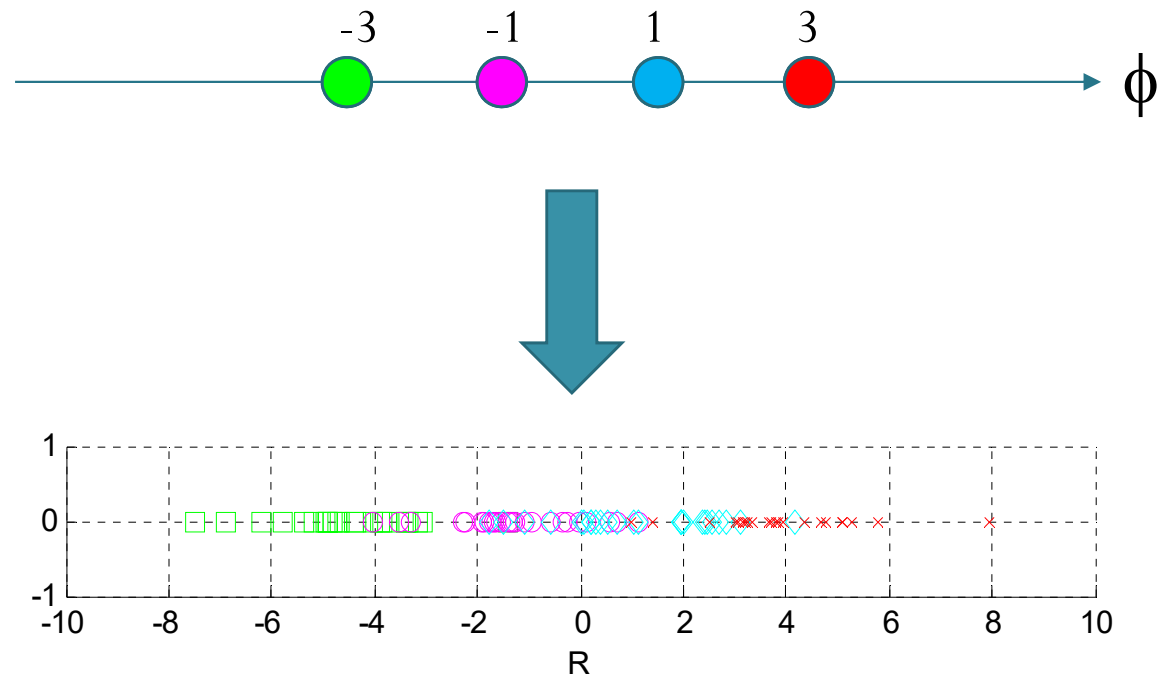


[<http://iamintellectuallypromiscuous.com/science/star-right-straight-morning/>]

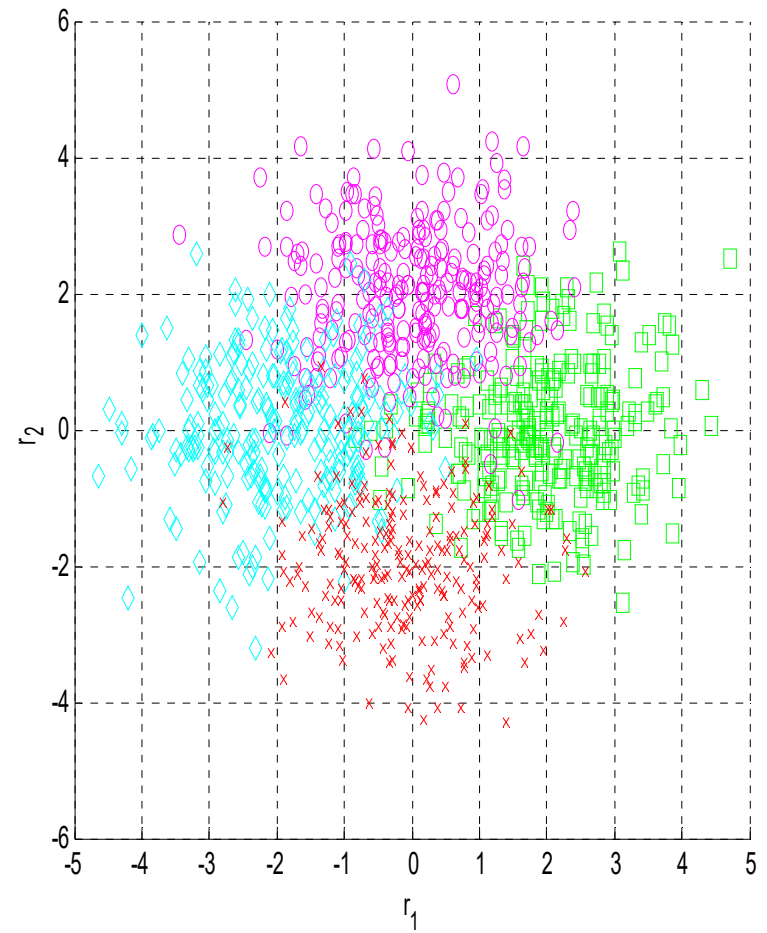
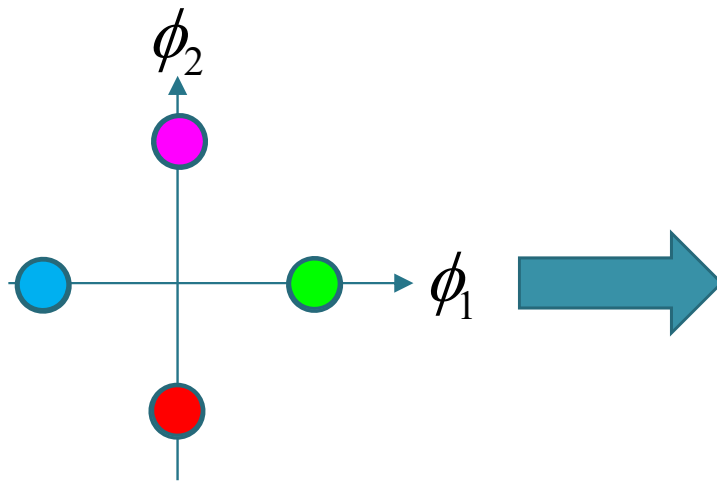


[[http://68.media.tumblr.com/89eed4669ec511bbb6413acb8da8b0e2/tumblr\\_mz3qmyQeLH1rhh9f5o1\\_r1\\_400.jpg](http://68.media.tumblr.com/89eed4669ec511bbb6413acb8da8b0e2/tumblr_mz3qmyQeLH1rhh9f5o1_r1_400.jpg)]

# Standard Quaternary PAM



# Standard Quaternary PSK



# Standard Quaternary QAM

