Name:

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COM-303 - Signal Processing for Communications
Midterm Exam

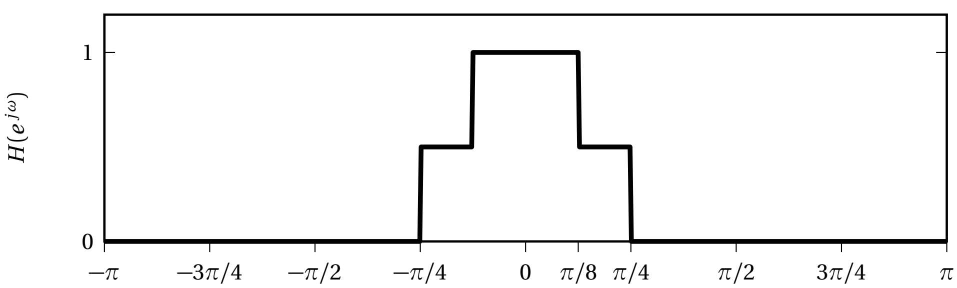
Monday, April 11 2016, 14:15 to 16:00

- **Room assignment**: if your last name begins with a letter from 'A' to 'L' inclusive, you should be in room INJ218, otherwise you should be in room INM200.
- **Write your name** on the top left corner of **ALL sheets you turn in**, including this one. When you are done, **staple** all your sheets together **with this sheet on top**!
- You can have two A4 sheet of *handwritten* notes (front and back). Please **no photocopies, no books and no electronic devices**. Turn off your phone if you have it with you.
- There are 5 problems with different scores for a total of 100 points.

Exercise 1. (15 points)
Compute the real and imaginary parts of the DFT coefficients of the length-N signal

$$x[n] = \alpha^n \qquad n = 0, 1, \ldots, N-1$$

Exercise 2. (15 points)
Compute the impulse response of an ideal filter whose real-valued frequency response $H(e^{j\omega})$ is shown in the following figure:



Exercise 3. (10 points)
Give an example of a **non**linear system and show why it's nonlinear

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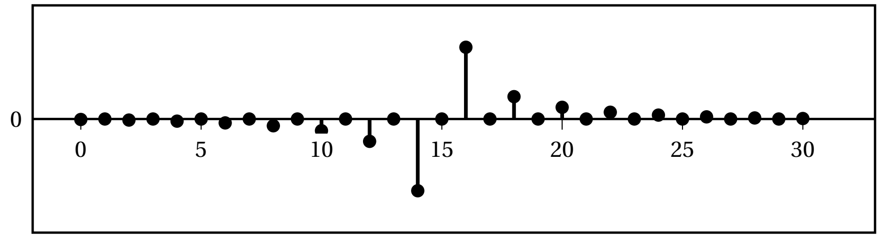
Exercise 4. (20 points)
The Parks-McClellan algorithm is often used to design optimal approximations of the Hilbert filter. Here is a plot of the coefficients returned by the algorithm when the requested filter length is 31:



(a) what type FIR has been used in the approximation? (I, II, III, or IV)

(b) sketch the magnitude of the frequency response of the approximation

(c) how would a longer filter be better?

Exercise 5. Echo cancellation (40 points)
In data communication systems one of the common problems is represented by *echos*, in which delayed and attenuated replicas of the transmitted signal are superimposed on the received signal. These echos are usually produced where the physical characteristics of the communication channel change, a bit in the same way that light is partially reflected by transparent surfaces.

Consider for instance a situation where the transmission channel creates two equally-spaced echos; if the transmitted signal is $x[n]$, the received signal will be

$$y[n] = x[n] + \alpha x[n-D] + \beta x[n-2D]$$

where α and β are the attenuation factors (with $0 < \alpha, \beta < 1$) and D is the reflection delay (assume D is an integer). We can model the channel as an LTI system $C(z)$ so that $y[n] = x[n] * c[n]$.

(a) derive the transfer function $C(z)$

(b) plot the poles and zeros of $C(z)$ assuming $D = 4$, $\alpha = 1/2$, $\beta = 1/4$ (hint: remember the multiplicity of complex roots; also, you may find these values useful: $2e^{j\frac{2\pi}{3}} = -1 + j\sqrt{3}$ and $2^{-1/4} \approx 0.84$).

(c) sketch the magnitude response $|C(e^{j\omega})|$.

If we have a good estimate of $C(z)$ we can try to design a perfect echo cancellation filter, i.e. a filter $G(z)$ such that $y[n] * g[n] = x[n]$.

(d) find $G(z)$

(e) if the echo delay D grows (while α and β remain the same), what could be the practical difficulty in implementing a perfect echo cancellation filter?
