WN Sheet 2 Sol.

Modulation & Multiple Access

1) The bit rate of a digital communication system is 34 Mbps. The modulation scheme is QPSK. What is the baud rate (symbol rate) of the system?

Solution

$$Bit\ Rate = Symbol\ Rate \times \#Bits/Symbol$$

With $QPSK$ we have that $\#Bits/Symbol = 2$. Thus, to find the symbol rate

$$Symbol\ Rate = \frac{Bit\ Rate}{\#Bits/Symbol} = \frac{34 \times 10^6}{2} = 17\ baud/s \ = 17\ MBd/s$$

In the lecture, we covered $ASK, BFSK, BPSK$ (they are all binary as B stands for so 1 $bit/symbol$) and $QPSK$ (Q for quadrate; 2 $bits/symbol$) and QAM (3 $bits/symbol$ (default) but can be higher like 4 $bits/symbol$).

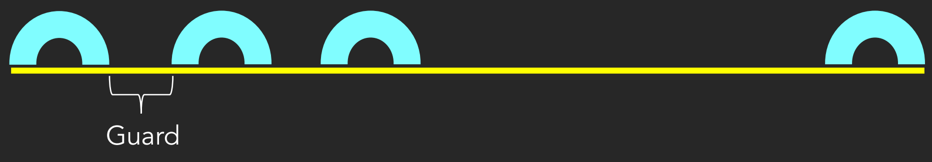
2) In an FDMA system, each user is allocated a duplex channel i.e., one for uplink and other for downlink voice communication. Also, these channels need to be guarded from each other for interference by providing sufficient separation in the spectrum through the use of guard bands.

A. If a US cellular operator is allocated $25\ MHz$ of spectrum, and guard band must be at least $10\ KHz$ and each voice channel is $30\ KHz$, then Find the number of channels in an FDMA system

B. Find the number of users FDMA can support at the same time. Now suppose the cellular operator decides to use TDMA system and the TDMA system can support maximum of 8 time slots per TDMA frame, then what is the total number of users supported per TDMA frame?

Solution

A. The cellular operator has $25\ MHz$ of spectrum. It needs to divide it into a number of channels each of bandwidth $30\ KHz$ separated from one another by $10\ KHz$ at least.



The following must clearly hold for the number of channels N and the bandwidths

$$25\ MHz = 30KHz \times N + 10KHz \times (N-1)$$

That is,

$$25000 = 30N + 10(N-1)$$

Which yields

$$N = 625.25$$

Thus, we can have at most 625 channels (less for wider guard bands).

For problems of exactly this form, we can write that in general

$$Full\ BW = Channel\ BW \times N + Guard\ BW \times (N-1)$$

B. Since each link is allocated as a duplex channel (frequency division duplex). Each user will get two channels and thus we can have at most

$$\#users = \lfloor N/2 \rfloor = 312$$

Now suppose that TDMA is used with 8 slots per frame. In this case, if the system also uses time division duplex (TDD) which require a time slot for uplink and a time slot for downlink then we would have at most

$$\#users = \left\lfloor \frac{\#slots/frame}{2} \right\rfloor = \lfloor 8/2 \rfloor = 4$$

Meanwhile, if it uses FDD (in each time slot there are separate uplink and downlink frequencies) then

$$\#users = \#slots/frame = 8$$

3) If TDMA uses a frame structure where each frame consists of 8 time slots, and each time slot contains 156.25 bits, and data is transmitted at 270.833 Kbps in the channel, Find:

A. The time duration of a bit
B. The time duration of slot
C. The time duration of a frame
D. How long a user must wait between two successive transmissions? Give the worst case and best case (assume each user is guaranteed transmission opportunity in each frame) solutions.

Solution

Clearly holds that:

$$t_{frame} = 8 \times t_{slot} \; and \; t_{slot} = 156.25 \times t_{bit}$$

Since $bitrate = 270.83\, Kb/s$ we have that

$$t_{bit} = \frac{1}{bitrate} = 0.0037ms$$

Thus,

$$t_{slot} = 156.25 \times 0.0037 = 0.578ms \; and \; t_{frame} = 8 \times 0.578 = 4.625ms$$

For the best-case and worst-case scenarios, assuming dynamic TDMA (the slot is not fixed) then

- Best case is being the last in the current frame and first in the next frame (no wait)

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- Worst case is being the first in the current frame and last in the next frame

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In this case, $14t_{slot} = 8.092ms$ has to be waited.

3) A CDMA receiver gets the following chips: $(+1 \;+1 \;+1 \;+1 \;+3 \;-1 \;-1 \;+3)$. Assuming the chip sequences for three stations as defined below, which stations transmitted, and which bit did each one send

A: $(-1 \;+1 \;+1 \;-1 \;-1 \;+1 \;+1 \;-1)$
B: $(-1 \;+1 \;-1 \;+1 \;+1 \;-1 \;+1 \;-1)$
C: $(-1 \;+1 \;+1 \;-1 \;+1 \;-1 \;-1 \;+1)$

Solution

The chip sequences for each station refer to the unique codes given for each station (that signifies that "1" was sent). The codes are of length 8 (chipping rate) and thus, what the $CDMA$ receiver got is a single vector equivalent to just $1\, bit$.

To know what bit A sent we dot product its code with the single vector we have in the stream:

$$(-1,1,1,-1,-1,1,1,-1) \cdot (1,1,1,1,3,-1,-1,3) = -8 \rightarrow \text{"0"}$$

We conclude "0" as the result is $-ve$.

To know what bit B sent we dot product its code with the single vector we have in the stream:

$$(-1, 1, -1, 1, 1, -1, 1, -1) \cdot (1, 1, 1, 1, 3, -1, -1, 3) = 0 \rightarrow Nothing$$

We conclude it sent nothing as the result is 0.

To know what bit C sent we dot product its code with the single vector we have in the stream:

$$(-1, 1, 1, -1, 1, -1, -1, 1) \cdot (1, 1, 1, 1, 3, -1, -1, 3) = 8 \rightarrow "1"$$

We conclude “1” as the result is $+ve$.