TSKS03 Wireless Systems

Solutions for the exam 2013-05-31

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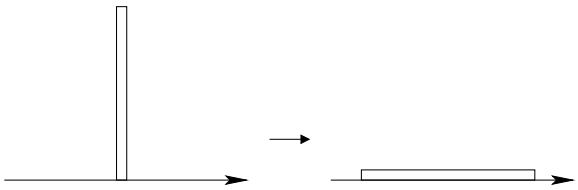
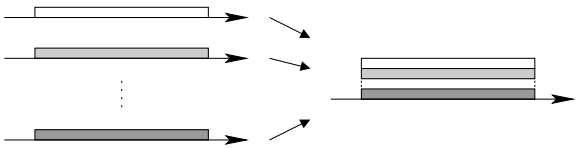
1

This answer is a bit more lengthy and detailed than what is needed to get full credit on this task.

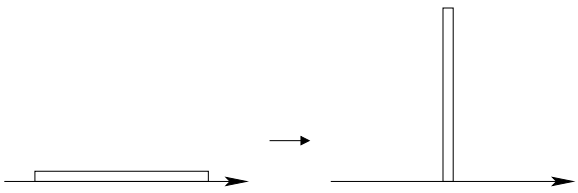
Each user represents his data with a narrow-band signal. That signal is multiplied by a so called spreading sequence that consists of ± 1 in a psedo-random fashion. The resulting signal is a broad-band signal.



Each user has his own spreading sequence, and each users signal then occupies the same frequency band. The broad-band signals are sent over a common channel that adds them together (possibly scaled), which gives us a received signal that is a linear combination of the different users broad-band signals.

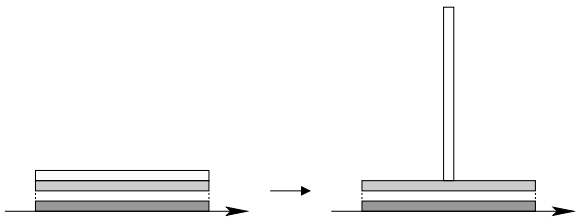


In the receiver, when we want to extract a certain users narrow-band signal from the received signal, we multiply the received signal by that users spreading sequence. The effect on the wanted part of the signal is obvious, since the original narrow-band signal of that user is then multiplied twice by 1 or by -1 (once in the sender and once in the receiver), which means that we get the original signal back. This is refered to as despreading of the signal.



The signal is disturbed by the other users signals. Each other users original narrow-band signal is first multiplied by his own spreading sequence (in the sender) and then by the wanted users spreading sequence (in the receiver). The result is that that signal is multiplied by the product of two different spreading sequences. The spreading sequences are chosen in such a way that the product of two different spreading sequences is a new spreading sequence with the same spreading properties as the original ones. Thus the other users signals are still spread after the despreading of our wanted signal.

The power of the broad-band signal of a user is the same as that of the narrow-band signal of that user, since we multiply by ± 1. But, since it is spread over a larger frequency band, the "height" (power spectral density in the interesting frequency band) of the broad-band signal is considerably smaller than that of the narrow-band signal. Thus the other users disturb the wanted signal as a fairly small noise.



When there are many users around, that noise can approximately be treated as white Gaussian noise.

2

Bonding and pairing has to do with Bluetooth units being aware of each other and being able to quickly connect to each other. There are also security reasons behind this mechanism, to make sure that only allowed devices can connect. When two Bluetooth devices first contact each other, typically when a user orders his or her device to

connect to a Bluetooth device, they exchange keys, each consisting of a personal identification number, a random number and the device address. This operation is called pairing and it creates a bond between the devices.

3
The three acronyms have the following meanings:

SISO Single Input – Single Output
MISO Multiple Input – Single Output
MIMO Multiple Input – Multiple Output

Single and multiple refer to the number of antennas at the sender (channel input) and at the receiver (channel output).

MISO gives us as benefit the possibility to direct sender power towards the receiver by using signal processing. That is done by sending the same signal over all antennas, but differently delayed, in order to create an almost plane wave in the general direction of the receiver. This also reduces interference for other users that are in other directions from the sender. This can also be used in MIMO, but in that case, the receiver can also achieve directionality by delaying the received signals from its antennas differently much before adding them, thereby increasing its gain for the signal from the intended sender, and also to reduce the interference from other senders in other directions.

MIMO provides another benefit. It is possible to create several independent channels between sender and receiver. Each sender antenna gives the sender one degree of freedom. Similarily, each receiver antenna gives the receiver one degree of freedom. The number of such independent channels is therefore upper bounded by the minimum of the number of sender antennas and the number of receiver antennas.

Those two methods can actually be combined. If we sacrifice a few independent channels, then the sacrificed degrees of freedom can be used for directionality. Therefore it may very well make sense to have differently many sender and receiver antennas. E.g. a base station can have several antennas, while a mobile reasonably has only a few.

4
In DS-CDMA (Direct Sequence Code Division Multiple Access), a narrow-band signal is spread to a broad-band signal using a spreading sequence consisting of ± 1. Let T denote the duration of one bit in this signal. This T is usually referred to as a chip.

We are supposed to consider a system that is based on M-sequences. In this case the spreading is based on an M-sequence, and all users use different shifts of this sequence as spreading sequence. If the spreading sequence in a receiver is delayed by nT, where n is a non-zero integer, then we will detect the signal of another user. If the delay is between 0 and T, then we will receive a linear combination of the intended users signal and another users signal. If the delay is close to 0 (much less than T), then this linear combination consists primarily of the intended users signal, somewhat disturbed by another users signal. Thus, a delay that is much less than T can be considered as a small delay, since the signal then is only slightly distorted. A delay that is more than T can be considered as a large delay, since we will not be able to detect the correct signal at all in that case.

5
A transmitted radio signal can reach a receiver via several different paths. This means that the receiver receives a weighted sum of different delayed versions of the transmitted signal. That also means that the impulse response of the channel is a weighted sum of different delayed versions of an impulse. The transfer function of the channel, which is the Fourier transform of this impulse response, is therefore not constant. In fact, it can vary heavily. Since objects in the surroundings may move, the transfer function may vary over time. In mobile radio transmission, the sender and/or the receiver may also move, which means that those variations over time can be even larger. This is called frequency selective (time-varying) fading.

6

a. A BCH code is a subfield subcode of an RS code. We have primarily dealt with binary BCH codes, and that is what is used in the DVB standards. Therefore, the following description assumes that we are dealing with binary BCH codes.
The RS code in this case is a linear code over an extension of the binary field. The coefficients of codewords in the RS code are therefore from that extension field. The corresponding binary BCH code consists of those codewords in the RS code that are binary, i.e. where all symbols are in the binary field.

b. Concatenation is a combination of (at least) two error control codes. The outer code is usually over a large alphabet. In practice, that alphabet size is always a power of 2. The inner code is usually over a smaller alphabet. In practice, that alphabat size is almost always 2.
The information is first encoded using the outer code. Then those codewords are mapped to bit sequences, which are then encoded using the inner code. This is in general an efficient way of producing powerful codes. The decoding of those codes, however, is somewhat complicated.

7

The near-far effect is a problem in mobile telephony. If mobiles that are on different distances from the base station send with the same power, the received power at the base station will differ for the two mobiles. The difference can be huge, which means that the stronger signal may cause cross-talk to the weaker signal if the corresponding parts of the channel are not enough separated. This problem is dealt with by power control. The base station measures the received power from the mobile, i.e. it estimates the channel attenuation, and orders the mobile to increase or decrease the power if needed. In this way, the received power is kept within designed limits.

Note: For those that are worried about medical risks with mobile telephony, this should be interpreted as follows. The nearer the base station is, the smaller the transmitted power is (from the mobile), and the smaller the health risks. So, based on the transmitted power from the mobile, the base stations should be placed as densely as possibly can be accepted.

8

Subchannels are reused in mobile telephone systems, i.e. two users may use the same subchannel simultaneously. If those users were too close to each other, they would interfere with each other. Therefore, the landscape is separated in cells around base stations. Subchannels are then allowed to be reused in cells that are on a large enough distance from each other. The cells are grouped together in clusters, in wich each subchannel is used only once.

The actual size of those clusters are determined by two competing demands:

- Capacity, i.e. the maximum number of simultaneously active users per cell. Tighter reuse (smaller clusters) means higher capacity.
- Interference. Tighter reuse means more interference.

The tradeoff between those two demands is not necessarily trivial.

It is possible to increase the subchannel reuse by so called sectoring. This is done by equipping the base station with directional antennas. Each cell is then divided into a number of sectors, and the same subchannel can be used by different users in different sectors.

9

You do not need to explain your answers in this task. All that is needed is a true or a false. However, a short explanation or comment is given here for each claim.

a. **False**.

b. **False**.

c. **True**.

d. **True**.

e. **False**.

f. **True**.