1. Assign the following modulation principle in the right-hand column to its name in the left-hand column.

|  |  |  |
| --- | --- | --- |
| AMI |  | phase of optical carrier is changed by π every bit regardless of the data traffic, no matter if it’s 0 or 1 |
|  |  |  |
| CSRZ |  | A binary 0 is encoded as absence of power during the bit interval (zero voltage), while a binary 1 is encoded alternately as a positive voltage or a negative voltage. A binary 1 is referred to as a mark |
|  |  |  |
| DPSK |  | A 180-degree carrier phase reversal preceding a chip shall characterize a binary 1. The absence of a preceding phase reversal shall denote a binary 0 |
|  |  |  |
| DB |  | Pairs of bits are assigned a specific phase, as for example: 00 → 45°, 01 → 135°, 10 → 315°, 11 → 225° |
|  |  |  |
| DQPSK |  | A binary zero is represented by the absence of a laser pulse; binary 1s can be represented by a laser pulse with altered phase, based on the previous symbols in the following manner. Phase of a binary symbol is shifted by π if there is an odd number of binary 0 between two binary 1 |
|  |  |  |
| QPSK |  | The pairs of bits correspond to a given phase shift from a reference (initial) phase, or, in other words, by 90° between the neighbouring symbols. The initial phase can be 0° or non-zero. 00 → shift by 0° from the initial phase; 01 → shift by 90° from the initial phase;  10 → shift by 180° from the initial phase; 11 → shift by 270° from the initial phase |

1. Tick all the boxes, which refer to the main benefits of (D)QPSK modulations.

**x** symbol rate is 2x slower than the bit rate

□ symbol rate is 2x faster than the bit rate

**x** robustness against polarization mode dispersion due to its longer symbol duration

**x** increased tolerance to chromatic dispersion

**x** narrow optical spectrum

□ broad optical spectrum

**x** promising even for terabit transmission

□ error detection

□ error correction

□ improved synchronization compared to DPSK and BPSK

□ elimination of Far End Crosstalk

1. Which modulation principle is illustrated in the following figure?



QPSK

□

OOK-RZ

**x**

OOK-NRZ

□

PM-QPSK

□

CSRZ

□

DPSK-RZ

□

1. Write “intensity modulation”, “phase modulation”, “multi-carrier modulation” or “frequency modulation” next to the following modulation formats listed in the right-hand column.

|  |  |
| --- | --- |
| **Type of modulation format** | **Name of modulation format** |
| **frequency modulation** | OFDM |
| **intensity modulation** | CSRZ |
| **phase modulation** | QPSK |
| **multi-carrier modulation** | DMT |
| **intensity modulation** | OOK |
| **frequency modulation** | VDMT |
| **phase modulation** | DPSK |
| **intensity modulation** | DB |

1. Modulate the following binary data using OOK, CSRZ and DB modulation.

The data is 01001110.

Example:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Bit value | 0 | | 1 | |
| Laser | ON/OFF | Phase/  phase shift | ON/OFF | Phase/  phase shift |
| OOK | OFF | - | ON | - |
| CSRZ | OFF | +90° | ON | +90° |
| DB | OFF | - | ON | +90° |

Solution:

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bit value | 0 | | 1 | | 0 | | 0 | |
| Laser | ON/OFF | Phase/  phase shift | ON/OFF | Phase/  phase shift | ON/OFF | Phase/  phase shift | ON/OFF | Phase/  phase shift |
| OOK | OFF | - | ON | - | OFF | - | OFF | - |
| CSRZ | OFF | +90° | ON | +90° | OFF | +90° | OFF | +90° |
| DB | OFF | - | ON | +90° | OFF | - | OFF | - |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bit value | 1 | | 1 | | 1 | | 0 | |
| Laser | ON/OFF | Phase/  phase shift | ON/OFF | Phase/  phase shift | ON/OFF | Phase/  phase shift | ON/OFF | Phase/  phase shift |
| OOK | ON | - | ON | - | ON | - | OFF | - |
| CSRZ | ON | +90° | ON | +90° | ON | +90° | OFF | +90° |
| DB | ON | - | ON | - | ON | - | OFF | - |