Education and Training

Education and Culture DG

Lifelong Learning Programme

Advanced level study programme in Electronics Design and Integration Technologies

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RF Signals and Systems

1. Introduction. Communications Systems

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1.Information, Messages, Signals

Information: general intuitive term.

Message: a physical manifestation of the information as produced by the source.

Various **sources of messages (**people, machines, measuring instruments, etc.).

Analog message: a physical time-variable quantity usually in smooth and continuous form.

Digital message: ordered sequence of symbols selected from finite set of elements.

Signal: physical embodiment of the information.

$$\text{Signal} \approx \text{Message}$$

Electrical signal: voltage or current representing the message.

2.Elements of a Communication System

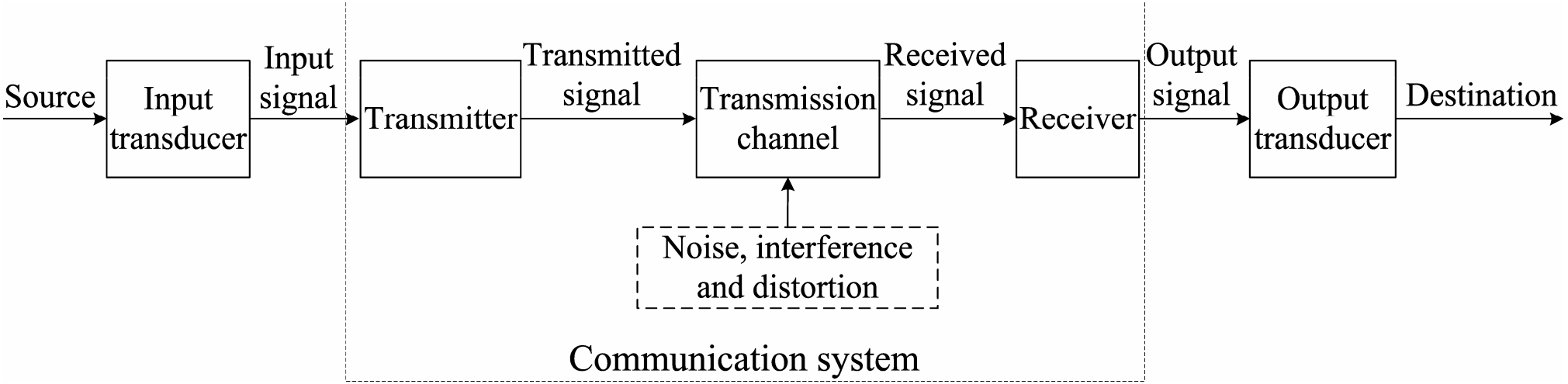

Figure 1. Block-diagram of a communication system with input and output transducers.

Input transducer converts the message to an electrical signal.

The **transmitter** converts the input signal to transmitted signal suited for the transmission channel.

Transmission cannel is the electric medium that bridges the distance from source to destination.

The **receiver** converts the received signal in a form appropriate for the output transducer.

Output transducer converts the output electrical signal the desired message form.

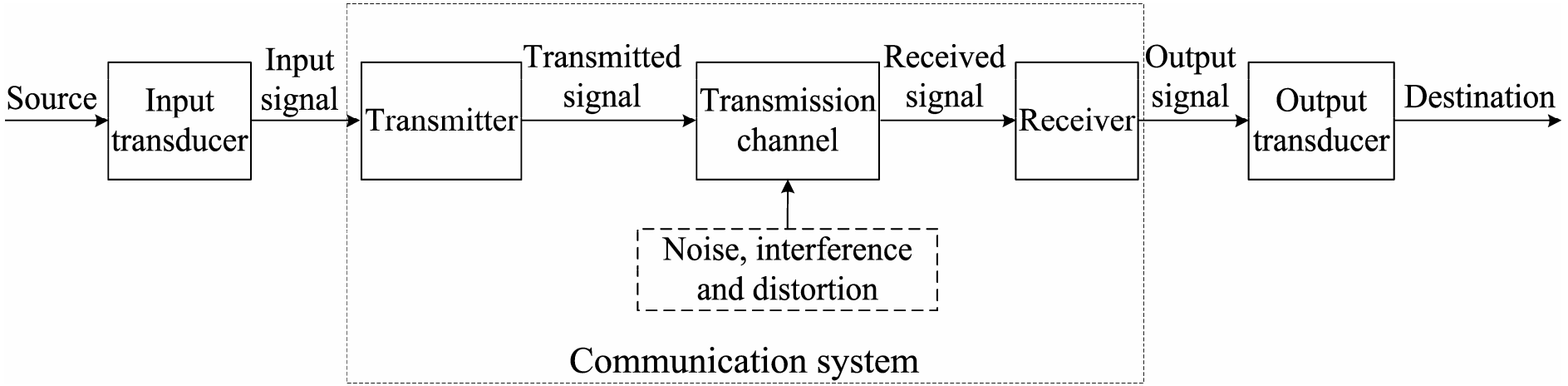

Figure 1 (repeated). Block-diagram of a communication system with input and output transducers.

Basic operations in the transmitter

- *Modulation*
- *Coding*

Basic operations in the receiver

- *Amplification*
- *Filtering*
- *Demodulation*
- *Decoding*

Effects of the channel on the transmitted signal

- *Attenuation:* decreasing the signal strength;
- *Distortion of the signal waveform:* caused by channel characteristics (linearity, frequency response, etc.)
- *Noise:* contamination of random natural signals added to the transmitted signal
- *Interference:* contaminations of extraneous signal of human sources – machinery, power lines, digital switching circuits, etc.

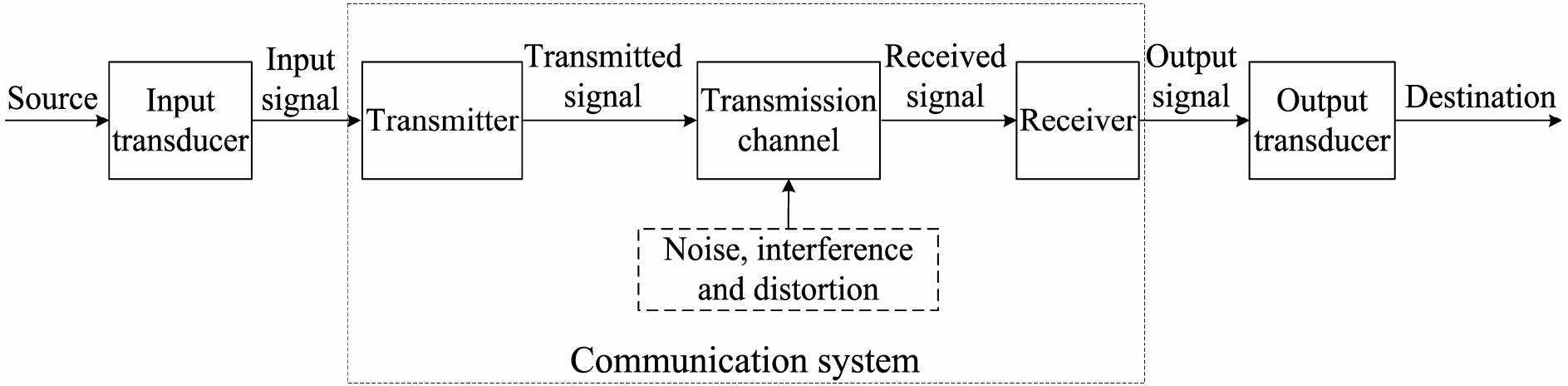

Figure 1 (repeated). Block-diagram of a communication system with input and output transducers.

One-way or **simplex** (**SX**) transmission. Transmission in one direction only. Example - Figure 1.

Full-duplex (**FDX**) system – a system, which channel allows transmission in both directions.

Full-duplex (**HDX**) system – a system, which channel allows transmission in both directions but not simultaneously.

3. Fundamental Limitations in Communications

3.1. Limitations Due to Technological Problems

- Hardware availability
- Economic factors
- International and national regulating norms

3.2. Fundamental Physical Limitations

3.2.1. Transmission Bandwidth B.

- Limits the spectrum of the transmitted signal, i.e. the maximum speed of variation of the transmitted signal.

- The time required for transmission of a given amount of information is inversely proportional to the transmission bandwidth *B*.

3.2.2. Noise

- Noise is generated in all conductors and in electronic devices as well.

- Thermal noise due to random motion of the charged particles like electrons.

- Noises generated in electronic devices: shot, flicker, popcorn, avalanche.

- The noise degrades the fidelity in analog communication systems and produces errors in digital communications.

- Noise generation limits the weakest transmitted signal. Significant in long-distance communications when the signal attenuation is large.

- Signal-to-noise ratio *S/N*

$$S/N = \frac{\text{power of the signal}}{\text{power of the noise}}$$

3.2.3. Hartley-Shannon low

The rate of information transmission cannot exceed the **channel capacity C**

$$C = B\log(1+S/N)$$

4. Modulation

4.1. Modulation Methods

- **Modulating signal** – represents the message.
- **Carrier wave** – suits the application.
- Usually the modulation signal is much slower than the carrier wave.
- **Modulation** – altering one or more of the parameters (amplitude, frequency, phase, pulse width) of the carrier in correspondence with the modulating signal.
- **Demodulation** – extraction of modulating signal from modulated signal; reverse operation to modulation.
- **Continuous wave modulation** – when the carrier is sinusoidal.
- **Pulse modulation** – the carrier is pulse train.

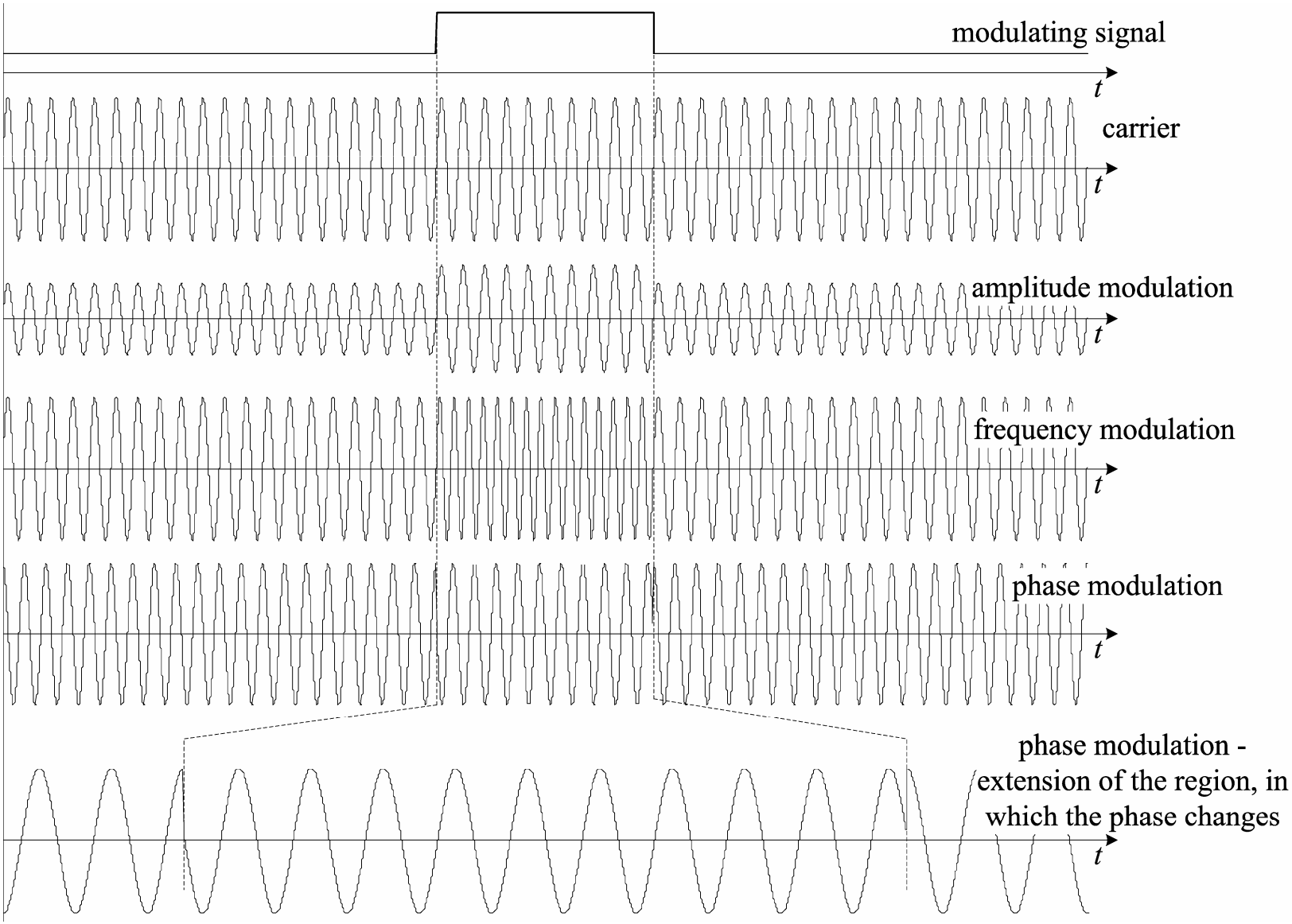

Figure 2. Examples of the basic continuous modulations.

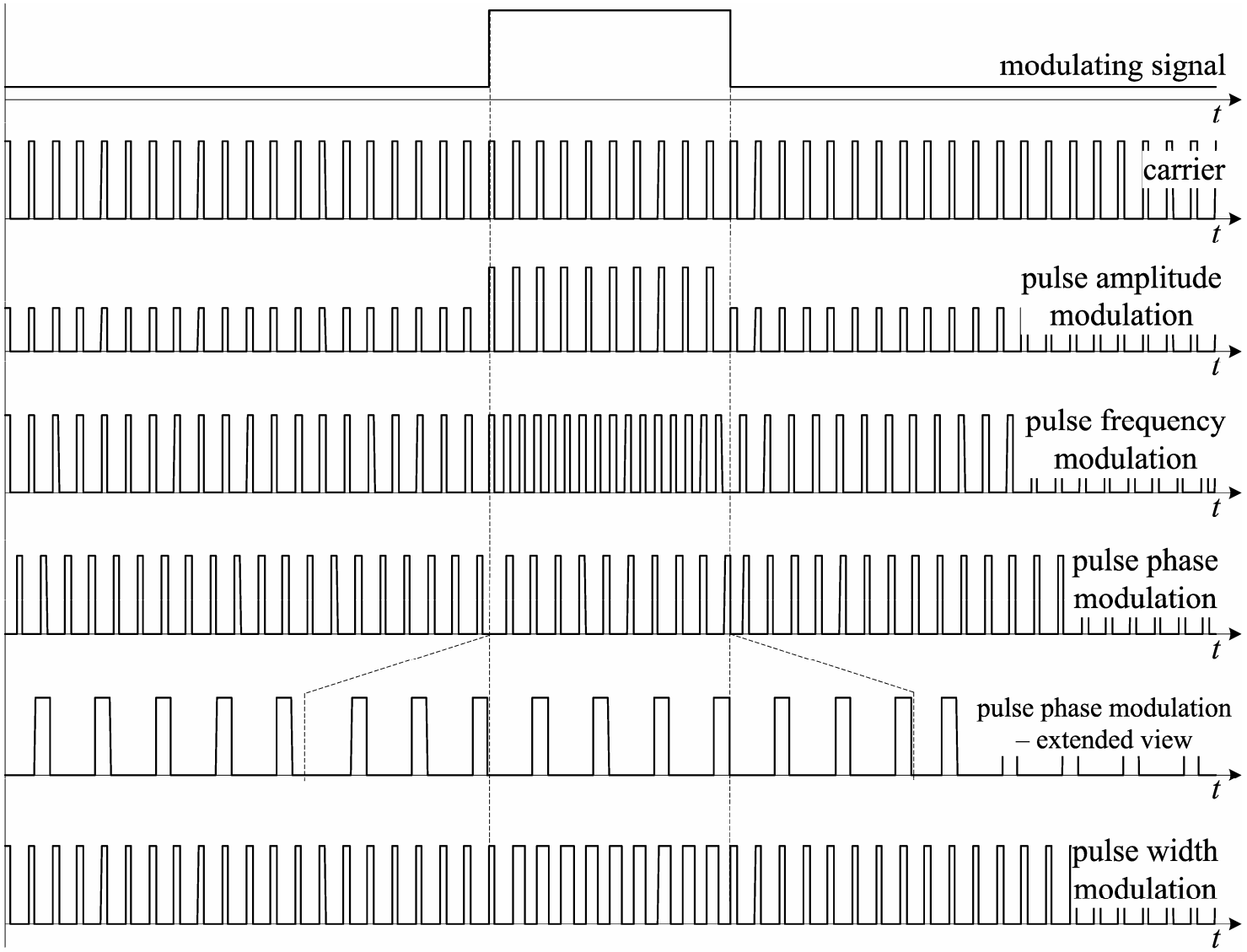

Figure 3. Examples of the basic pulse modulations.

4.2. Modulation Benefits and Applications

- Modulation for efficient transmission;
- Modulation to overcome hardware limitation;
- Modulation to overcome noise and interference;
- Modulation for frequency assignment
- Modulation for multiplexing: frequency division; time division, multiple access
- Coding methods and benefits

4.3. Analog and Digital Communications

- **Analog communication systems:** the informative signal is transmitted in continuous form.
- **Digital communication system:** the informative signal is represented as a sequence of limited set of symbols (digits) and these symbols are transmitted via the channel by applying of and appropriate modulation. The input signal must be **sampled** if it enters in analog form.
- Basic advantages of the digital communication systems:
  - better resistivity against the noise;
  - allows the use of effective coding methods;
  - more flexible signal handling suggested by digital signal processing methods
- However the front end of radiofrequency (RF) communication systems are always analog since signals are existing only in analog form.

References:

1. [1] A. Bruce Carlson, P. B. Crilly, J. C. Rutledge, Communication Systems, 4th ed., McGraw-Hill, 2002, ISBN 0-07-011127-8.