Significant advances have been recently introduced into various fields of technology, taking advantage of the use of new piezoelectric materials and the large diffusion of broadband transducers. Various types of modulation may be applied to the pulse characteristics, using single pulse, multipulse or multiline techniques, and resulting in improved spatial resolution and better penetration. Non-linear imaging uses the harmonics component, which is generated by tissues or by contrast agents. Different modalities can be used to separate harmonics from fundamental bands from the received signal. New Doppler modes have been developed, whereas grey-scale flow imaging allows the simultaneous imaging of blood flow and tissues. Compounding techniques improve the contrast resolution of tissues and reduce artefacts. If 3D techniques are now currently available, real-time 4D imaging has been recently introduced. Elastographic imaging is still under evaluation, but promising clinical results have been shown. Recent release of the DICOM specification has made the full integration of ultrasound to the PACS systems easier. All these advances indicate that the contribution and potential of ultrasound in patient management is still growing.

**Keywords** US · Technology · Doppler modes
rate shaping of ultrasound pulses, in terms of the control of transmission frequency, amplitude, phase and pulse length.

These developments have also permitted the widespread introduction of broadband transducers onto the market. From a theoretical point of view, the shorter the pulse length, the broader the pulse bandwidth (Fig. 1); therefore, the principal benefit of using a broadband transducer is the improvement of the axial resolution, due to shorter pulse lengths [3]. With broadband transducers, higher transmission frequencies give a better spatial resolution in the near field, whereas lower frequencies allow better penetration in the far field. In addition, as detailed below, harmonic imaging requires large transducer bandwidths, which respond to frequencies at least twice those of the transmitted pulse.

Moving to higher-transmission frequencies

The improvement in piezoelectric materials, the design of transducers, early digitisation and better analysis of received echoes with a lower level of noise allow the use of higher-emission frequencies for imaging. This results in higher axial and lateral spatial resolution while preserving good penetration. For example, it is now possible to evaluate the liver in adults with probes working at approximately 7 MHz.

High-frequency ultrasound (≥20 MHz) is another growing field, with increasing applications in dermatology, stomatology, ophthalmology, and the musculoskeletal field (Fig. 2) [5]. Original developments include, for example, measurement of very low blood flow velocities (<0.5 mm/s) in 100- to 300-μm-diameter vessels [6]. Very high-frequency ultrasound (≥50 MHz), including three-dimensional imaging, is also usable for the evaluation of the cornea and the anterior segment of the eye, allowing for precise biometry and delineation of pathological processes [6]; however, although many different dedicated transducers have been used for research, most of them are not yet commercially available.

Modulating pulses and lines

As mentioned above, the response of piezoelectric materials can be readily tailored, which allows modulation of the pulse characteristics, including the transmission frequency bandwidth, amplitude, phase and length. As a relative variable, phase can only be determined by comparison with a reference waveform, or with another pulse. This can be achieved by using multiple-beam formers, allowing a comparison of the phases for pulses from adjacent lines (coherent image formation; Acuson).

A wide variety of pulse-characteristics modulation processes have been introduced by commercial companies, but detailed specifications are often not published. We describe below some new processes that have been recently introduced which illustrate the great potential for improvements in the ultrasound technique. These new modalities can be classified according to the number of pulses and scan lines used.

**Single-pulse techniques**

With single-pulse techniques, modulation has been applied in the following ways:

1. To limit the overlap between the fundamental frequency and harmonic response by narrowing the frequency...