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Ultrasound Diagnostics
_{5n} Rudolf Götz, Frank Schön
Rudolf Götz, Frank Schön **17. Ultrason 17.1.7 Second Harmon Coday, ultrasound diagnostics is an impor-**
Today, ultrasound diagnostics is an impor-
fields. The fact that it is quick, simple and in 17.2 Visualization of the
fields. The fact that it **17. Ultrascherry**
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Today, ultrasound diagnostics is an impor-

Tant imaging method in virtually all medical

Tanticular cost-efficient plays a major role in

Particular **17. Ultrasound 17.**

Idday, ultrasound diagnostics is an impor-

tant imaging method in virtually all medical

fields. The fact that it is quick, simple and in

particular cost-efficient plays a major role in

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tant imaging method in virtually all medical

particular cost-efficient plays a major role in

this. Further advantages are provided by the

mobility and the broad spectrum **Example 19 and Vascular Space 11.17** Second Harmonday, ultrasound diagnostics is an impor-

tant imaging method in virtually all medical

fields. The fact that it is quick, simple and in

particular cost-efficient plays a **COMPRET UP:** Trank Schön

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tant imaging method in virtually all medical

particular cost-efficient plays a major role in

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fields. The fact that it is quick, simple and in

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this. Further advantages are provided by the

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mobility and th 17.1.1 Principle South Martin 2014

17.1.2 Generation of Sound Waves

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Intrasound diagnostic systems. Not least,

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market for new devices has a sales volume in Germany 17.1.5 Penetration Depth, Axial 17.4.3 New and A

Resolution and Frequency Ranges 346

17.5 **Operation of an U**

Pressure and Temperature........... 346 17.5.1 General Conservation

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200 million per year. Approximate Resolution and Frequency Ranges 346

17.1.6 Influencing Factors:

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Pressure and Temperature........... 346 17.5.1 General Condition

According to data from the German Electrical and Elec-

ture in private practices. The distribution of sales between According to data from the German Electrical and Elec-
tronic Manufacturers' Association (Zentralverband der 30% internal medicine and approx
Elektrotechnischen Industrie – ZVEI), the ultrasound ology.
The high density According to data from the German Electrical and Elec-
ture: approximately 30% gynaecology, approxim
tronic Manufacturers' Association (Zentralverband der 30% internal medicine and approximately 20% e
Elektrotechnischen I

ology.

technical and applicative methods (Table 17.1) and a number of different industrial suppliers. Ultrasound diagnostics has partly replaced or supplemented other

According to data from the German Electrical and Elec-				ture: approximately 30% gynaecology, approximately			
tronic Manufacturers' Association (Zentralverband der				30% internal medicine and approximately 20% cardi-			
Elektrotechnischen Industrie - ZVEI), the ultrasound				ology.			
market for new devices has a sales volume in Germany				The high density of devices used in everyday diag-			
of approximately ϵ 200 million per year. Approximate-				nostics is due to there being a large number of different			
ly 50% of this volume is from acquisitions in clinics and hospitals, and approximately 50% is from doctors				technical and applicative methods (Table 17.1) and a number of different industrial suppliers. Ultrasound			
the different specialist fields gives the following pic-				methods, such as conventional x-ray diagnostics but			
Table 17.1 Overview of the advantages and disadvantages of imaging methods							
	Ultrasound	CT	MRI	X-ray	Angio	Nuclear medicine	
Ionizing radiation	N ₀	Yes	N ₀	Yes	Yes	Yes	
Real-time	Yes	N _o	N ₀	N _o	Yes	(Yes)	
Type of image	Slice	Slice	Slice	Section	Section	Section	
Overall costs	Low	Very high	Very high	High	High	Very high	

Medical Imaging
also computer tomography (CT) and magnetic resorting
imaging (MRI).
In contrast to these methods, ultrasound is a
called real-time method. The organs being investig
are displayed on a monitor in real time i **Medical Imaging**
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are also computer tomography (CT) and magnetic resortingly (MRI).

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called real-time method. The organs being investition

are displayed on a monitor in real time in this section
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imaging (MRI).
In contrast to these methods, ultrasound is a so-
collect resolution in the contrast of the cross being inves **Example 16 and Tanaging CIT)** and magnetic resonace imaging technique. They therefore ging (MRI).

In contrast to these methods, ultrasound is a so-

In contrast to these methods, ultrasound is a so-

Experiment is a so-
 imaging technique. They therefore correspond to a to-
mographic sectional image familiar from CT and MRI.
Ultrasound imaging thus differs substantially from the
method of looking through the body in a conventional imaging technique. They therefore correspond to a to-
mographic sectional image familiar from CT and MRI.
Ultrasound imaging thus differs substantially from the
method of looking through the body in a conventional
x-ray ex imaging technique. They therefore correspond to a to-
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method of looking through the body in a conventional
x-ray ex imaging technique. They therefore correspond mographic sectional image familiar from CT an Ultrasound imaging thus differs substantially free thod of looking through the body in a convex-ray examination. imaging technique. They therefore correspond to a to-
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x-ray ex

imaging (MRI).

In contrast to these methods, ultrasound is a so-

called real-time method. The organs being investigated method of looking through the body

are displayed on a monitor in real time in this sectional x-ray In contrast to these methods, ultrasound is a so-

called real-time method. The organs being investigated method of looking through the bod

are displayed on a monitor in real time in this sectional
 17.1.1 Basic Physical called real-time method. The organs being investigated method of looking through the body
are displayed on a monitor in real time in this sectional x -ray examination.
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The following explanations regarding the generation of

units therefore basically work with

units avoid images follow theoretical considerations and

and other animals for orientation.

are presented **17.1.1 Principle**

units therefore basically work with w

pulse method. This principle is also

ultrasound images follow theoretical considerations and

and other animals for orientation.

Impergented in an idealized for pulse method. This principle is also v

ultrasound images follow theoretical considerations and

and other animals for orientation.

are presented in an idealized form. They are based on

physical principles which are inte The following explanations regarding the generation of natural ultrasound images follow theoretical considerations and and othe are presented in an idealized form. They are based on physical principles which are intended t asound images follow theoretical considerations and

presented in an idealized form. They are based on

sical principles which are intended to be presented

17.1.2 Generation of Sound W

he reader in a way which is simple are presented in an idealized form. They are based on
physical principles which are intended to be presented **17.1.2 Generation of Sound**
to the reader in a way which is simple and easy to un-
derstand. The actual generati physical principles which are intended to be presented **17.1.2 Generation of Sour**
to the reader in a way which is simple and easy to un-
derstand. The actual generation of ultrasound images Special, cut piezoelectric crys to the reader in a way which is simple and easy to un-
derstand. The actual generation of ultrasound images Special, cut piezoelectric crystals
is much more complex, however. An essential part of sound waves. These synthet derstand. The actual generation of ultrasound images Special, cut piezoelectric crysta
is much more complex, however. An essential part of sound waves. These synthetic
image generation is based on the phenomenon of scat-
t is much more complex, however. An essential part of sound
image generation is based on the phenomenon of scat-
tering, which makes the process which actually takes titanat
place much more complicated, and this will only be called reaction the surface between bigger between the surface of biologic part of the surface texture in the surface of the surface of the surface text texture in the surface of the surface text texture in the surface te

ge generation is based on the phenomenon of scat-
tured industrially, for example from
g, which makes the process which actually takes
titanate, lead zirconate, lithium
ce much more complicated, and this will only be
crami tering, which makes the process which actually takes

place much more complicated, and this will only be

referred to here in passing. It will not be discussed in

the piezoelectric effect, which

further detail in the tex place much more complicated, and this will only be ceramics. These are subject to
referred to here in passing. It will not be discussed in the piezoelectric effect, which v
further detail in the text below.
In ultrasound d

referred to here in passing. It will not be discussed in the piezoelectric effect, which
further detail in the text below. In ultrasound diagnostics, the transmitter and re-
maline. As soon as a voltage inciver are combine further detail in the text below.

In ultrasound diagnostics, the transmitter and re-

maline. As soon as a voltage is

ceiver are combined in the ultrasound probe. The probe

this nature, it changes its form c

is connect In ultrasound diagnostics, the transmitter and re-

eiver are combined in the ultrasound probe. The probe

this nature, it changes its form or ge

is connected to the ultrasound unit via a cable, thereby

on the polarity ceiver are combined in the ultrasound probe. The probe
is connected to the ultrasound unit via a cable, thereby
on the polarity of the voltage
enabling very free positioning of the ultrasound probe
of the piezoelectric cr is connected to the ultrasound unit via a cable, thereby

on the polarity of the v

enabling very free positioning of the ultrasound probe

of the piezoelectric crys

on the body and thus also virtually any desired exami-
 bling very free positioning of the ultrasound probe of the piezoelectric crystal occurs
the body and thus also virtually any desired exami-
on plane and slice orientation. applied, then it oscillates at pre-
In contrast t on the body and thus also virtually any desired exami-

If a high-frequency alternating

mation plane and slice orientation.

In contrast to the x-ray method, which is a trans-

mation method, ultrasound is a so-called re nation plane and slice orientation. applied, then it oscillates at precise

In contrast to the x-ray method, which is a trans-

mission method. The ultrasound probe transmits a short ultra-

frequency, this produces ultra In contrast to the x-ray method, which is a trans-
mission method, ultrasound is a so-called reflection ternating current applied is
method. The ultrasound probe transmits a short ultra-
frequency, this produces ult
sound The untasound probe transmiss a short unta-

live which penetrates the body and is partially a no longer audible

at interfaces, e.g. between liver and kidney. ceive mode, how

pulse has been emitted, the unit switches th

mographic sectional image familiar from CT and MRI.
Ultrasound imaging thus differs substantially from the
method of looking through the body in a conventional
x-ray examination.
units therefore basically work with what is Ultrasound imaging thus differs substantially from the
method of looking through the body in a conventional
x-ray examination.
units therefore basically work with what is known as the
pulse method. This principle is also w 17.1.2 Superinted a method of Sound Waves

17.1.2 Generation of Sound Waves Special, work with what is known as the

17.1.2 Generation of Sound Waves

17.1.2 Generation of Sound Waves

17.1.2 Generation of Sound Waves

17. units therefore basically work with what is known as the
pulse method. This principle is also wide-spread in the
natural world and is used, for example, by bats, dolphins
and other animals for orientation.
17.1.2 Generati

units therefore basically work with what is known as the
pulse method. This principle is also wide-spread in the
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and other animals for orientation.
17.1.2 Generati pulse method. This principle is also wide-spread in the
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and other animals for orientation.
17.1.2 Generation of Sound Waves
Special, cut piezoelectric crystals ar natural world and is used, for example, by bats, dolphins

and other animals for orientation.
 17.1.2 Generation of Sound Waves

Special, cut piezoelectric crystals are used to generate

sound waves. These synthetic crys and other animals for orientation.
 17.1.2 Generation of Sound Waves

Special, cut piezoelectric crystals are used to generate

sound waves. These synthetic crystals are manufac-

tured industrially, for example from fra **17.1.2 Generation of Sound Waves**
Special, cut piezoelectric crystals are used to generate
sound waves. These synthetic crystals are manufac-
tured industrially, for example from fractions of barium
titanate, lead zircona **17.1.2 Generation of Sound Waves**
Special, cut piezoelectric crystals are used to generate
sound waves. These synthetic crystals are manufac-
tured industrially, for example from fractions of barium
titanate, lead zircona Special, cut piezoelectric crystals are used to generate
sound waves. These synthetic crystals are manufac-
tured industrially, for example from fractions of barium
titanate, lead zirconate, lithium compounds or other
cera cial, cut piezoelectric crystals are used to generate
nd waves. These synthetic crystals are manufac-
d industrially, for example from fractions of barium
nate, lead zirconate, lithium compounds or other
minics. These are sound waves. These synthetic crystals are manufactured industrially, for example from fractions of barium
titanate, lead zirconate, lithium compounds or other
ceramics. These are subject to what is known as
the piezoelectr tured industrially, for example from fractions of barium
titanate, lead zirconate, lithium compounds or other
ceramics. These are subject to what is known as
the piezoelectric effect, which was described by the
brothers Ja titanate, lead zirconate, lithium compounds or other
ceramics. These are subject to what is known as
the piezoelectric effect, which was described by the
brothers Jacques and Pierre Curie using crystals of tour-
maline. As

ceramics. These are subject to what is known as
the piezoelectric effect, which was described by the
brothers Jacques and Pierre Curie using crystals of tour-
maline. As soon as a voltage is applied to a crystal of
this na the piezoelectric effect, which was described by the
brothers Jacques and Pierre Curie using crystals of tour-
maline. As soon as a voltage is applied to a crystal of
this nature, it changes its form or geometry. Depending brothers Jacques and Pierre Curie using crystals of tour-
maline. As soon as a voltage is applied to a crystal of
this nature, it changes its form or geometry. Depending
on the polarity of the voltage, dilatation or contra maline. As soon as a voltage is applied to a crystal of
this nature, it changes its form or geometry. Depending
on the polarity of the voltage, dilatation or contraction
of the piezoelectric crystal occurs.
If a high-frequ this nature, it changes its form or geometry. Depending
on the polarity of the voltage, dilatation or contraction
of the piezoelectric crystal occurs.
If a high-frequency alternating current is therefore
applied, then it o (Sect. 17.3). If a high-frequency alternating current is then
applied, then it oscillates at precisely that frequent
and generates high-frequency sound waves. If the
ternating current applied is at a correspondingly
frequency, this pro and generates high-frequency sound waves. If the al-
ternating current applied is at a correspondingly high
frequency, this produces ultrasound waves which are
no longer audible to humans (Fig. 17.1). In the re-
ceive mode ternating current applied is at a correspondingly high
frequency, this produces ultrasound waves which are
no longer audible to humans (Fig. 17.1). In the re-
ceive mode, however, sound waves impinging on the
crystal are frequency, this produces ultrasound waves which are
no longer audible to humans (Fig. 17.1). In the re-
ceive mode, however, sound waves impinging on the
crystal are converted into an electrical alternating
current which

 10^5 10⁶ pending on the 1 the movement and the mass (Fig. 17.1). In the receive mode, however, sound waves impinging on the crystal are converted into an electrical alternating current which is then processed further by the unit (Sect. 17.3).
 17 ceive mode, however, sound waves impinging on the
crystal are converted into an electrical alternating
current which is then processed further by the unit
(Sect. 17.3).
17.1.3 Reflection
On the way through the tissue, c crystal are converted into an electrical alternating
current which is then processed further by the unit
(Sect. 17.3).
17.1.3 Reflection
On the way through the tissue, components of the trans-
mitted sound wave are refl current which is then processed further by the unit

(Sect. 17.3).
 17.1.3 Reflection

On the way through the tissue, components of the trans-

mitted sound wave are reflected at interfaces between

different organs and **17.1.3 Reflection**
 17.1.3 Reflection
 On the way through the tissue, components of the trans-

mitted sound wave are reflected at interfaces between

different organs and sections of organs. The energy of

the waves **17.1.3 Reflection**
On the way through the tissue, components of the transmitted sound wave are reflected at interfaces between different organs and sections of organs. The energy of the waves which are reflected is deter

Ultrasound Diagnostics |

In order to contribute towards the generation of an

ge, the reflected wave must have sufficient energy as

No reflection $R=0$

In reflected component is an
 $\frac{1}{2}$ also loss on the component Ultrasound Diagnostics 1

In order to contribute towards the generation of an

image, the reflected wave must have sufficient energy as

neergy is also lost on the return path to the crystal. The

corresponds to a reflect In order to contribute towards the generation of an
image, the reflected wave must have sufficient energy as
energy is also lost on the return path to the crystal. The
ideal reflected component is approximately 1% , whi Ultrasound Diagnostics

In order to contribute towards the generation of an

image, the reflected wave must have sufficient energy as

energy is also lost on the return path to the crystal. The

deal reflection coefficien Ultrasound Dia

In order to contribute towards the generation of an

image, the reflected wave must have sufficient energy as

energy is also lost on the return path to the crystal. The

ideal reflection coefficient is ap Ultrasound Diagnostics | T

In order to contribute towards the generation of an

image, the reflected wave must have sufficient energy as

energy is also lost on the return path to the crystal. The

ideal reflection coeff **Example 18 and the propagated wave sufficient energy as**
 Example, the reflected wave must have sufficient energy as

energy is also lost on the return path to the crystal. The

ideal reflected component is approximate In order to contribute towards the generation of an

image, the reflected wave must have sufficient energy as

energy is also lost on the return path to the crystal. The

ideal reflected component is approximately 1%, whi In order to contribute towards the generation
image, the reflected wave must have sufficient ene
energy is also lost on the return path to the crysta
ideal reflected component is approximately 1% ,
corresponds to a refl In order to contribute towards the generation of an

image, the reflected wave must have sufficient energy as

energy is also lost on the return path to the crystal. The

corresponds to a reflection coefficient of $R = 0.0$ In order to contribute towards the generation of an

image, the reflected wave must have sufficient energy as

energy is also lost on the return path to the crystal. The

ideal reflection coefficient is approximately 1%,

corresponds to a reflection coefficient of $R = 0.01$.

Higher reflection coefficients result in a greater loss of

energy of the propagated wave overall, thus resulting

in insufficient penetration of the ultrasonic beam in insufficient penetration of the ultrasonic beam into

deeper tissue.

The reflection coefficient is by definition between 0

and 1, where $R = 0$ means that there is no reflection

The reflection coefficient R is calc deeper tissue.

The reflection coefficient is by definition between 0

and 1, where $R = 0$ means that there is no reflection

The reflection coefficient R is calculated from the wave

impedances of the two media which f

The reflection coefficient is by definition between 0

and 1, where $R = 0$ means that there is no reflection

The reflection coefficient R is calculated from the wave

impedances of the two media which form the inter-
 and 1, where $R = 0$ means that there is no reflection

The reflection coefficient R is calculated from the wave

impedances of the two media which form the inter-

face (Fig. 17.2). The difference between the two wave
 taking place and $R = 1$ corresponds to total reflection.

The reflection coefficient R is calculated from the wave

impedances of the two media which form the inter-

face (Fig. 17.2). The difference between the two wav The reflection coefficient *R* is calculated from the wave

impedances of the two media which form the inter-

face (Fig. 17.2). The difference between the two wave

impedances is crucial here.

As can be seen from (Fig. impedances of the two media which form the inter-
face (Fig. 17.2). The difference between the two wave
impedances is crucial here.
As can be seen from (Fig. 17.3), the wave impe-
dance of air is vastly different from tha face (Fig. 17.2). The difference between the two wave

impedances is crucial here.

As can be seen from (Fig. 17.3), the wave impe-

dance of air is vastly different from that of human tissue,

with the result that there impedances is crucial here.

As can be seen from (Fig. 17.3), the wave impe-

dance of air is vastly different from that of human tissue,

with the result that there is a high reflection coefficient

of nearly $R = 1$ and As can be seen from (Fig. 17.3), the wave impe-

ce of air is vastly different from that of human tissue,

the result that there is a high reflection coefficient

early $R = 1$ and total reflection occurs. An interface

ea dance of air is vastly different from that of human tissue,

with the result that there is a high reflection coefficient

of nearly $R = 1$ and total reflection occurs. An interface

with air is therefore an obstacle to ul with the result that there is a high reflection coefficient
of nearly $R = 1$ and total reflection occurs. An interface
with air is therefore an obstacle to ultrasound which
cannot be overcome. In order to achieve the best of nearly $R = 1$ and total reflection occurs. An interface
with air is therefore an obstacle to ultrasound which
cannot be overcome. In order to achieve the best pos-
sible transmission from the probe to the body without
 with air is therefore an obstacle to ultrasou
cannot be overcome. In order to achieve the
sible transmission from the probe to the bod
any loss of energy, ultrasound gel is used as a
medium. On account of its very high wat

contact with a reflection coefficient of roughly $R = 0$.

However, it is not only air but also metal parts, bones

and calcium particles which can present problems that

produce virtually total reflection. This explains a However, it is not only air but also metal parts, bones

and calcium particles which can present problems that

produce virtually total reflection. This explains acoustic

shadows behind bones, gall stones or endoprosthes and calcium particles which can present problems that
produce virtually total reflection. This explains acoustic
shadows behind bones, gall stones or endoprostheses,
for example.
17.1.4 Spatial Mapping – Transit Time
Fig produce virtually total reflection. This explains acoustic
shadows behind bones, gall stones or endoprostheses,
for example.
17.1.4 Spatial Mapping – Transit Time
Fig. 17.3 Various reflection coefficie
The spatial mappin shadows behind bones, gall stones or endoprostheses,
for example.
17.1.4 Spatial Mapping – Transit Time
Fig. 17.3 Various reflection coefficient
The spatial mapping of the scanned tissue and reflect-
fig. 17.3 Various **17.1.4 Spatial Mapping – Transit Time**
 17.1.4 Spatial Mapping of the scanned tissue and reflect-

Fig. 17.3 Various reflection components interespentive transit time

from transmission of the pulse to receipt of the r **17.1.4 Spatial Mapping – Transit Time**

Fig. 17.3 Various reflection coefficient

ing interfaces is done by measuring the transit time

from transmission of the pulse to receipt of the respec-

tive reflected components. **17.1.4 Spatial Mapping – Transit Time**

The spatial mapping of the scanned tissue and reflect-

ing interfaces is done by measuring the transit time

from transmission of the pulse to receipt of the respec-

tive reflect The spatial mapping of the scanned tissue and reflect-
ing interfaces is done by measuring the transit time
from transmission of the pulse to receipt of the respec-
waves have been reflected or inferences means that the wa The spatial mapping of the scanned tissue and reflect-
ing interfaces is done by measuring the transit time
from transmission of the pulse to receipt of the respec-
tive reflected components. Early echoes means that the
t ing interfaces is done by measuring the transit time

from transmission of the pulse to receipt of the respec-

tive reflected components. Early echoes means that the

waves have been reflected by interfaces close to the u from transmission of the pulse to receipt of the respective reflected components. Early echoes means that the waves have been reflected by interfaces close to the ultrasound probe. Late echoes means that the waves have be tive reflected components. Early echoes means that the
waves have been reflected by interfaces close to the ul-
trasound probe. Late echoes means that the waves have
been reflected by interfaces a long way from the ul-
tra waves have been reflected by interfaces close to the ultrasound probe. Late echoes means that the waves have
been reflected by interfaces a long way from the ultrasound probe. This difference in time is represented
on the

COMPATE SET ASSEM SET ASSEM SET ASSEM
 Only very modern ultrasound units take into ac-
 EXECUTE:
 EXECUTE:
 EXECUTE:
 COMPATE ASSEM SET ASSEM SET ASSEMBLY A SET ASSEMBLY AND A decordinate of comparate for the di Medical Imaging
 Could Universe differences in the speed of travel of the terms of the axial resolution on account these differences in the speed of travel of the terms of the axial resolution on accound waves when ca **Solution**
 Solution C Conducts when calculating the ultrasound units take into accurate the ultrasound these differences in the speed of travel of the ultrasound images wavelength (λ). In a theoretical and compens Medical Imaging

Only very modern ultrasound units take into ac-

count these differences in the speed of travel of the terms of the axial resolution on ac

sound waves when calculating the ultrasound images wavelength $(\$ Medical Imaging

Only very modern ultrasound units take into ac-

count these differences in the speed of travel of the terms of the axial resolution on acc

sound waves when calculating the ultrasound images wavelength (automatically. **Medical Imaging**
 17.1.5 Penetration Depth, Axial Resolution
 17.1.5 Penetratio Imaging

very modern ultrasound units take into ac-

interestigate in the speed of travel of the

terms of the

vaves when calculating the ultrasound images

wavelength

ppensate for the differences in the transit time,

m Only very modern ultrasound units take into ac-

sount these differences in the speed of travel of the terms of the axial resolution on access

and compensate for the differences in the transit time, minimum wavelength (

COLORAT EXERCT CONFIDENT THE SOLUTION IN SOLUTION IN SOLUTION IN SOLUTION IN SOLUTION IN THE SOLUTION IN SOLUTION IN SUCHER STATES (THE MELT CONFIDENT AND THE SULTION INTO THE SULTION THE SULTION THE PERTENCE IS A SURVEN sound waves when calculating the ultrasound images
and compensate for the differences in the transit time, minimum wavelength for s
either manually with intervention by the user or else
transmission for example, gives a w and compensate for the differences in the transit time, minimum wavelength for separation either manually with intervention by the user or else terfaces is a single wavelength.
 17.1.5 Penetration Depth, Axial Resolution either manually with intervention by the user or else
attomatically.
to example, gives a waveleng
attomatically.
17.1.5 Penetration Depth, Axial Resolution of 0.15 mm. More individual in
the reflection over the parameter a frequency of 10 MH
 and Frequency Ranges a frequency of 10 MH
 and Frequency Ranges and the control of 0.15 mm. More in

the in the number of reflecting interfaces and merely not consist of their

their reflection co

Only very modern ultrasound units take into ac-

count these differences in the speed of travel of the terms of the axial resolution on acco

sound waves when calculating the ultrasound images wavelength (λ) . In a theor However, high frequencies have an advantage in
as of the axial resolution on account of their shorter
relength (λ) . In a theoretical best-case scenario, the
imum wavelength for senarate imaging of two in-However, high frequencies have an advantage in
terms of the axial resolution on account of their shorter
wavelength (λ) . In a theoretical best-case scenario, the
minimum wavelength for separate imaging of two in-
terfac However, high frequencies have an advantage in
terms of the axial resolution on account of their shorter
wavelength (λ). In a theoretical best-case scenario, the
minimum wavelength for separate imaging of two in-
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wavelength (λ) . In a theoretical best-case scenario, the
minimum wavelength for separate imaging of two in-
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so of the axial resolution on account of their shorter
relength (λ). In a theoretical best-case scenario, the
imum wavelength for separate imaging of two in-
aces is a sin However, high frequencies have an advantage in
terms of the axial resolution on account of their shorter
wavelength (λ). In a theoretical best-case scenario, the
minimum wavelength for separate imaging of two in-
terfa However, high frequencies have an advantage in
terms of the axial resolution on account of their shorter
wavelength (λ). In a theoretical best-case scenario, the
minimum wavelength for separate imaging of two in-
terfa terms of the axial resolution on account of their shorter
wavelength (λ). In a theoretical best-case scenario, the
minimum wavelength for separate imaging of two in-
terfaces is a single wavelength. A frequency of 5 MH

wavelength (λ). In a theoretical best-case scenario, the
minimum wavelength for separate imaging of two in-
terfaces is a single wavelength. A frequency of 5 MHz,
for example, gives a wavelength of 0.3 mm, whereas
a fr minimum wavelength for separate imaging of two in-
terfaces is a single wavelength. A frequency of 5 MHz,
for example, gives a wavelength of 0.3 mm, whereas
a frequency of 10 MHz corresponds to a wavelength
of 0.15 mm. Mor terfaces is a single wavelength. A frequency of 5 MHz,
for example, gives a wavelength of 0.3 mm, whereas
a frequency of 10 MHz corresponds to a wavelength
of 0.15 mm. More individual interfaces can therefore
theoretically for example, gives a wavelength of 0.3 mm, whereas
a frequency of 10 MHz corresponds to a wavelength
of 0.15 mm. More individual interfaces can therefore
theoretically be resolved at 10 than at 5 MHz (Fig. 17.5).
As can be a frequency of 10 MHz corresponds to a wavelength
of 0.15 mm. More individual interfaces can therefore
theoretically be resolved at 10 than at 5 MHz (Fig. 17.5).
As can be seen in the figure, a pulse packet does
merely not of 0.15 mm. More individual interfaces can therefore
theoretically be resolved at 10 than at 5 MHz (Fig. 17.5).
As can be seen in the figure, a pulse packet does
merely not consist of a single wave with a positive and
nega theoretically be resolved at 10 than at 5 MHz (Fig. 17.5).

As can be seen in the figure, a pulse packet does

merely not consist of a single wave with a positive and

negative amplitude but also includes attack and, in pa As can be seen in the figure, a pulse packet does
merely not consist of a single wave with a positive and
negative amplitude but also includes attack and, in par-
ticular, decay amplitudes. These lengthen the overall
pulse merely not consist of a single wave with a positive and
negative amplitude but also includes attack and, in par-
ticular, decay amplitudes. These lengthen the overall
pulse packet by several oscillations. In modern high-en negative amplitude but also includes attack and, in par-
ticular, decay amplitudes. These lengthen the overall
pulse packet by several oscillations. In modern high-end
units on the market, a considerable degree of technica ticular, decay amplitudes. These lengthen the overall
pulse packet by several oscillations. In modern high-end
units on the market, a considerable degree of technical
complexity is sought after in order to control the tran pulse packet by several oscillations. In modern high-end
units on the market, a considerable degree of technical
complexity is sought after in order to control the tran-
sient phenomena in the crystals. The aim is to gener units on the market, a considerable degree of technical
complexity is sought after in order to control the tran-
sient phenomena in the crystals. The aim is to generate
the shortest possible pulse packets, ideally with onl complexity is sought after in order to control the tran-
sient phenomena in the crystals. The aim is to generate
the shortest possible pulse packets, ideally with only
a single sine pulse. This can only be achieved through the phenomena in the crystals. The aim is to generate
shortest possible pulse packets, ideally with only
ngle sine pulse. This can only be achieved through
tise knowledge of the respective crystal characteris-
of the ultra the shortest possible pulse packets, ideally with only
a single sine pulse. This can only be achieved through
precise knowledge of the respective crystal characteris-
tics of the ultrasound probe and with appropriate contr a single sine pulse. This can only be achieved through
precise knowledge of the respective crystal characteris-
tics of the ultrasound probe and with appropriate control
using customized electrical pulse lengths and pulse precise knowledge of the respective crystal characteris-
tics of the ultrasound probe and with appropriate control
using customized electrical pulse lengths and pulse
forms. As a result of this *electrical behavior* of the tics of the ultrasound probe and with appropriate control
using customized electrical pulse lengths and pulse
forms. As a result of this *electrical behavior* of the crys-
tals, pulse packet lengths are achieved which are ign customized electrical pulse lengths and pulse
ms. As a result of this *electrical behavior* of the crys-
pulse packet lengths are achieved which are nearly
size of a single wavelength. The theoretical resolu-
of 0.15 m

forms. As a result of this *electrical behavior* of the crystals, pulse packet lengths are achieved which are nearly the size of a single wavelength. The theoretical resolution of 0.15 mm at 10 MHz can therefore approximat the size of a single wavelength. The theoretical resolution of 0.15 mm at 10 MHz can therefore approximately be achieved, as mentioned in the example above.
The axial resolution is thus proportional and the penetration dep .15 mm at 10 MHz can therefore approximately
ved, as mentioned in the example above.
axial resolution is thus proportional and the
ion depth is inversely proportional to the fre-
For practical applications of ultrasound, The axial resolution is thus proportional and the
penetration depth is inversely proportional to the fre-
quency. For practical applications of ultrasound, this
provides a necessary compromise between the desire for
high a

penetration depth is inversely proportional to the frequency. For practical applications of ultrasound, this
provides a necessary compromise between the desire for
high axial resolution and a good penetration depth.
Figure quency. For practical applications of ultrasound, this
provides a necessary compromise between the desire for
high axial resolution and a good penetration depth.
Figure 17.6 gives an overview of the different fre-
quencies provides a necessary compromise between the desire for
high axial resolution and a good penetration depth.
Figure 17.6 gives an overview of the different fre-
quencies used to produce images of different organs.
17.1.6 In high axial resolution and a good penetration depth.

Figure 17.6 gives an overview of the different fre-

quencies used to produce images of different organs.
 17.1.6 Influencing Factors:
 Pressure and Temperature

As Figure 17.6 gives an overview of the different frequencies used to produce images of different organs.
 17.1.6 Influencing Factors:
 Pressure and Temperature

As already mentioned, the speeds at which sound waves

pass **17.1.6 Influencing Factors:**
 17.1.6 Influencing Factors:
 Pressure and Temperature

As already mentioned, the speeds at which sound waves

pass through a medium are primarily dependent on

the material properties of **17.1.6 Influencing Factors:**
Pressure and Temperature
As already mentioned, the speeds at which sound
pass through a medium are primarily depende
the material properties of the medium. A cha
the atmospheric conditions o **I.6 Influencing Factors:**
Pressure and Temperature
already mentioned, the speeds at which sound waves
s through a medium are primarily dependent on
material properties of the medium. A change in
atmospheric conditions o **Pressure and Temperature**
As already mentioned, the speeds at which sound waves
pass through a medium are primarily dependent on
the material properties of the medium. A change in
the atmospheric conditions of temperature As already mentioned, the speeds at which sound waves
pass through a medium are primarily dependent on
the material properties of the medium. A change in
the atmospheric conditions of temperature and pressure
likewise infl As already mentioned, the speeds at which sound waves
pass through a medium are primarily dependent on
the material properties of the medium. A change in
the atmospheric conditions of temperature and pressure
likewise infl

 $\frac{15(MHz)}{15(MHz)}$ pulse itself exerts positive and negative pressure in periodic alternation on the transmission medium. This

Ultrasound Diagnostics |
pressure fluctuations. These effects on the medium and close to the crystal, as the distance
the resulting interactions continuously change the prop-
increases the shape of the wave is
through the Ultrasound Diagnostics
pressure fluctuations. These effects on the medium and
the resulting interactions continuously change the prop-
increases the shape of the wave
erties of the ultrasound pulse during the propagation
b Ultrasound Diag

pressure fluctuations. These effects on the medium and

the resulting interactions continuously change the prop-

increases the shape of the

erties of the ultrasound pulse during the propagation

the ultr Ultrasound Diagnostics

pressure fluctuations. These effects on the medium and

close to the crystal, as the distance

the resulting interactions continuously change the prop-

increases the shape of the wave in

erties of Ultrasound Dia

pressure fluctuations. These effects on the medium and

the resulting interactions continuously change the prop-

increases the shape of the

erties of the ultrasound pulse during the propagation

the same pressure fluctuations. These effects on the medium and
the resulting interactions continuously change the prop-
erties of the ultrasound pulse during the propagation
through the tissue. This change has an effect on the
esi Ultrasound Diague

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pressure fluctuations. These effects on the medium and

the resulting interactions continuously change the prop-

increases the shape of the

during the ultrasound pulse during the prop pressure fluctuations. These effects on the medium and
the resulting interactions continuously change the prop-
increases the shape of the wave interess of the ultrasound pulse during the propagation
through the tissue. Th

pressure fluctuations. These effects on the medium and close to the crystal, as the dist
the resulting interactions continuously change the prop-
increases the shape of the wave
retires of the ultrasound pulse during the p pressure fluctuations. These effects on the medium and close to the crystal, as the
the resulting interactions continuously change the prop-
encreases the shape of the verties of the ultrasound pulse during the propagation the resulting interactions continuously change the prop-

entries of the ultrasound pulse during the propagation

the earlier and mo

signal quality and can be put to technical use.
 17.1.7 Second Harmonic
 17.1.7 Seco erties of the ultrasound pulse during the propagation
through the tissue. This change has an effect on the emitted, the earlier and more pro
signal quality and can be put to technical use.
the emitted, the earlier and more through the tissue. This change has an effect on the emitted, the earlier and more proncing signal quality and can be put to technical use.
 17.1.7 Second Harmonic discussed the multiple sinusoidal oscillation. Every no signal quality and can be put to technical use. mation. Every nonsinuous
 17.1.7 Second Harmonic from the source of time of a sinusoidal wavelength, continue the periodic pressure fluctuation triggered by the ultime firs **1.7 Second Harmonic**
 Example 1.7 Second Harmonic (a sinusoidal wavelength, contains firstly a sinusoidal function

periodic pressure fluctuation triggered by the ul-

periodic pressure fluctuation triggered by the ul-**17.1.7 Second Harmonic** frequencies by means of Fourier anal

The saw-tooth-like shape of the

buring the course of time of a sinusoidal wavelength, contains firstly a sinusoidal fundat

the periodic pressure fluctuation The saw-tooth-like shape of the periodic pressure of time of a sinusoidal wavelength, contains firstly a sinusoidal fundat trasound pulse leads to a regularly changing sound by low amplitude and half wavelen propagation sp During the course of time of a sinusoidal wavelength, contains firstly a sinusoidal fund
the periodic pressure fluctuation triggered by the ul-
transmovent a sinusoidal oscillation
trasound pulse leads to a regularly chan

the periodic pressure fluctuation triggered by the ul-
trasound pulse leads to a regularly changing sound by low amplitude and half way
propagation speed. The positive half-wave (pressure) other sine oscillations with co
 trasound pulse leads to a regularly changing sound ly low amplitude and half wave
propagation speed. The positive half-wave (pressure) other sine oscillations with const
moves with greater speed than the negative half-wav propagation speed. The positive half-wave (pressure) other sine oscillations with constant moves with greater speed than the negative half-wave, plitudes which correspond to an invith the result that the negative-going edg moves with greater speed than the negative half-wave, plitudes which correspond t
with the result that the negative-going edge of the pos-
the fundamental wavelength
itive sound wave becomes increasingly steep as the compo The result that the negative-going edge of the pos-

the fundamental wavelength (c). The

the components are also known as har

ance from the sound source increases (Fig. 17.7). This harmony of sound is familiar

A simila itive sound wave becomes increasingly steep as the components are also known as hadistance from the sound source increases (Fig. 17.7). This *harmony of sound* is familiau A similar phenomenon can be observed in sea waves distance from the sound source increases (Fig. 17.7). This harmony of sound is familiar
A similar phenomenon can be observed in sea waves
sic, as the generation of sounds in r
on the beach. The lower section of the wave, w A similar phenomenon can be observed in sea waves sic, as the generation of sounds in mon the beach. The lower section of the wave, which is is subject to similar principles.

close to the sea bed, moves more slowly becaus

Ultrasound Diagnostics 17.1 Basic Physical Principles 347
close to the crystal, as the distance from the crystal
increases the shape of the wave increasingly resem-
bes a saw-tooth. The higher the intensity of the sound
em Ultrasound Diagnostics | 17.1 Basic Physical Principles 347

close to the crystal, as the distance from the crystal

increases the shape of the wave increasingly resem-

bles a saw-tooth. The higher the intensity of the so Ultrasound Diagnostics | 17.1 Basic Physical Principles 347

close to the crystal, as the distance from the crystal

increases the shape of the wave increasingly resem-

bles a saw-tooth. The higher the intensity of the so Ultrasound Diagnostics $\begin{bmatrix} 17.1 & Basic Physical Principles \\ 17.1 & Basic Physical Principles \\ 247 & 347 \end{bmatrix}$

close to the crystal, as the distance from the crystal

increases the shape of the wave increasingly resem-

bles a saw-tooth. The higher the inten Ultrasound Diagnostics 17.1 Basic Physical Principles 347

close to the crystal, as the distance from the crystal

increases the shape of the wave increasingly resem-

bles a saw-tooth. The higher the intensity of the soun Ultrasound Diagnostics $\begin{bmatrix} 17.1 & Basic$ Physical Principles 347

close to the crystal, as the distance from the crystal

increases the shape of the wave increasingly resem-

bles a saw-tooth. The higher the intensity of Ultrasound Diagnostics $\begin{bmatrix} 17.1 & Basic Physical Principles \\ 17.1 & Basic Physical Principles \\ 17.1 & Basic Principles \\ 27.1 & 17.1 \end{bmatrix}$

close to the crystal, as the distance from the crystal

increases the shape of the wave increasingly resem-

bles a saw-tooth. The hig Ultrasound Diagnostics $\begin{bmatrix} 17.1 & Basic Physical Principles \\ 17.1 & Basic Physical Principles \\ 247 & 347 \end{bmatrix}$

ee to the crystal, as the distance from the crystal

eases the shape of the wave increasingly resem-

i.a saw-tooth. The higher the intensity of th Ultrasound Diagnostics $\frac{17.1}{17.1}$ Basic Physical Principles 347

close to the crystal, as the distance from the crystal

increases the shape of the wave increasingly resem-

bles a saw-tooth. The higher the intensity Franceson to the crystal, as the distance from the crystal
increases the shape of the wave increasingly resem-
bles a saw-tooth. The higher the intensity of the sound
emitted, the earlier and more pronounced this defor-
ma close to the crystal, as the distance from the crystal
increases the shape of the wave increasingly resem-
bles a saw-tooth. The higher the intensity of the sound
emitted, the earlier and more pronounced this defor-
matio

close to the crystal, as the distance from the crystal
increases the shape of the wave increasingly resem-
bles a saw-tooth. The higher the intensity of the sound
emitted, the earlier and more pronounced this defor-
matio increases the shape of the wave increasingly resem-
bles a saw-tooth. The higher the intensity of the sound
emitted, the earlier and more pronounced this defor-
mation. Every nonsinusoidal oscillation can be broken
down i bles a saw-tooth. The higher the intensity of the sound
emitted, the earlier and more pronounced this defor-
mation. Every nonsinusoidal oscillation can be broken
down into multiple sinusoidal oscillations of different
fr emitted, the earlier and more pronounced this deformation. Every nonsinusoidal oscillation can be broken
down into multiple sinusoidal oscillations of different
frequencies by means of Fourier analysis (Fig. 17.8).
The saw mation. Every nonsinusoidal oscillation can be broken
down into multiple sinusoidal oscillations of different
frequencies by means of Fourier analysis (Fig. 17.8).
The saw-tooth-like shape of the changing pulse
contains f down into multiple sinusoidal oscillations of different
frequencies by means of Fourier analysis (Fig. 17.8).
The saw-tooth-like shape of the changing pulse
contains firstly a sinusoidal fundamental wave (a),
furthermore frequencies by means of Fourier analysis (Fig. 17.8).
The saw-tooth-like shape of the changing pulse
contains firstly a sinusoidal fundamental wave (a),
furthermore a sinusoidal oscillation with a relative-
ly low amplitud The saw-tooth-like shape of the changing pulse
tains firstly a sinusoidal fundamental wave (a),
hermore a sinusoidal oscillation with a relative-
ow amplitude and half wavelength (b), and also
per sine oscillations with c contains firstly a sinusoidal fundamental wave (a),
furthermore a sinusoidal oscillation with a relative-
ly low amplitude and half wavelength (b), and also
other sine oscillations with constantly decreasing am-
plitudes furthermore a sinusoidal oscillation with a relative-
ly low amplitude and half wavelength (b), and also
other sine oscillations with constantly decreasing am-
plitudes which correspond to an integral quotient of
the fund Iy low amplitude and half wavelength (b), and also
other sine oscillations with constantly decreasing am-
plitudes which correspond to an integral quotient of
the fundamental wavelength (c). These high-frequencies.
This emitted, the carlier and more pronounced this deformation. Every nonsinusoidal oscillation can be broken down into multiple sinusoidal oscillations of different frequencies by means of Fourier analysis (Fig. 17.8). The saw

other sine oscillations with constantly decreasing am-
plitudes which correspond to an integral quotient of
the fundamental wavelength (c). These high-frequency
components are also known as harmonic frequencies.
This *harm* plitudes which correspond to an integral quotient of
the fundamental wavelength (c). These high-frequencies.
This harmony of sound is familiar to us all from mu-
sic, as the generation of sounds in musical instruments
is s the fundamental wavelength (c). These high-frequency

components are also known as harmonic frequencies.

This *harmony of sound* is familiar to us all from mu-

sic, as the generation of sounds in musical instruments

is components are also known as harmonic frequencies.
This *harmony of sound* is familiar to us all from music, as the generation of sounds in musical instruments is subject to similar principles.
Conventional signal process Solution and is familiar to us all from mu-
as the generation of sounds in musical instruments
ubject to similar principles.
Conventional signal processing suppresses the
ener-frequency signal components, so that the dom-

Fig. 17.7 Change in the shape of a
sound wave as a result of nonlinear
sound velocity Fig. 17.7 Change in the shape of a
sound wave as a result of nonlinear
sound velocity Fig. 17.7 Change in the shape of a sound wave as a result of nonlinear sound velocity

and the lesser degree of deformation in liquid tissues.

Transformation of a nonsinusoidal oscillation into various sits also shows so-called half

al oscillations

and the harmonics already

tissues. The simultaneous use ¹⁶

¹⁶
 Example the Some modern high-end device
 Examplementary of a nonsinusoidal oscillation into various
 Examplementary described and solid tissues.

The reason for this is the more pronounced saw-tooth-
 Ex Some modern high-end device

possibility for using harmonic signal

dition to the harmonics already descention of a nonsinusoidal oscillation into various

with half the fundamental frequency

veluse.

Clearer differentiat possibility for using harmonic s

and the accellations

and socillations

and socillations

and socillations

clearer differentiation between liquid and solid tissues.

The simultaneous use of h

The reason for this is the dition to the harmonics already desc

Transformation of a nonsinusoidal oscillation into various

all oscillations

all oscillations

clearer differentiation between liquid and solid tissues.

The simultaneous use of half-Transformation of a nonsinusoidal oscillation into various
with half the fundamental frequency
with half the fundamental frequency
clearer differentiation between liquid and solid tissues. The simultaneous use of half-
The al oscillations

The reason for this is the more pronounced saw-tooth-

The simultaneous use of

The reason for this is the more pronounced saw-tooth-

harmonics to calculate an in

shaped signal deformation in solid struc pulse.

The simultaneous use of

reason for this is the more pronounced saw-tooth-

harmonics to calculate an in

reason for this is the more pronounced saw-tooth-

the lesser degree of deformation in iquid itssues, lower clearer differentiation between liquid and solid tissues. The simultaneous use of half-
The reason for this is the more pronounced saw-tooth-
harmonics to calculate an image c
shaped signal deformation in solid structures The reason for this is the more pronounced saw-tooth-

harmonics to calculate an imag

shaped signal deformation in solid structures (tissue) disadvantage of the short depth

and the lesser degree of deformation in liquid shaped signal deformation in solid structures (tissue) disadvantage of the short deptemble and the lesser degree of deformation in liquid tissues, lower frequency of the half--
in which virtually no reflected harmonic wave

Tissue harmonic imaging is therefore a tech
which reduces artifacts in the ultrasound image
makes it possible to more cleanly and clearly de
liquid-filled cavities in particular, such as the amr
cavity, the bladder, the ca makes it possible to more cleanly and clearly delimit reception of half-waves and harmo

liquid-filled cavities in particular, such as the anniotic to the quality of this reception. In

cavity, the bladder, the cardiac cav

17.1.8 Broadband Harmonics
One disadvantage of using the second harmonic is
that the reflected second harmonic has less penetra-**17.1.8 Broadband Harmonics**
One disadvantage of using the second harmonic is
that the reflected second harmonic has less penetra-
tive power as a result of the doubling in the frequency.
Recause these waves must cover the **17.1.8 Broadband Harmonics**
One disadvantage of using the second harmonic is
that the reflected second harmonic has less penetra-
tive power as a result of the doubling in the frequency.
Because these waves must cover the **17.1.8 Broadband Harmonics**
One disadvantage of using the second harmonic is
that the reflected second harmonic has less penetra-
tive power as a result of the doubling in the frequency.
Because these waves must cover, th **17.1.8 Broadband Harmonics**

One disadvantage of using the second harmonic is

that the reflected second harmonic has less penetra-

tive power as a result of the doubling in the frequency.

Because these waves must cover **17.1.8 Broadband Harmonics**
One disadvantage of using the second harmonic is
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tive power as a result of the doubling in the frequency.
Because these waves must cover the **17.1.8 Broadband Harmonics**
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tive power as a result of the doubling in the frequency.
Because these waves must cover the 17.1.8 Broadband Harmonics
One disadvantage of using the second harmonic is
that the reflected second harmonic has less penetra-
tive power as a result of the doubling in the frequency.
Because these waves must cover the d 17.1.8 Broadband Harmonics

One disadvantage of using the second harmonic is

that the reflected second harmonic has less penetra-

tive power as a result of the doubling in the frequency.

Because these waves must cover t **17.1.8 Broadband Harmonics**
One disadvantage of using the second harmonic is
that the reflected second harmonic has less penetra-
tive power as a result of the doubling in the frequency.
Because these waves must cover the **1.8 Broadband Harmonics**

e disadvantage of using the second harmonic is

the reflected second harmonic has less penetra-

power as a result of the doubling in the frequency.

ause these waves must cover the distance to t One disadvantage of using the second harmonic is
that the reflected second harmonic has less penetra-
tive power as a result of the doubling in the frequency.
Because these waves must cover the distance to the
ultrasound p One disadvantage of using the second harmonic is
that the reflected second harmonic has less penetra-
tive power as a result of the doubling in the frequency.
Because these waves must cover the distance to the
ultrasound p that the reflected second harmonic has less penetra-
tive power as a result of the doubling in the frequency.
Because these waves must cover the distance to the
ultrasound probe, however, the depth of field of the
ultrasou tive power as a result of the doubling in the frequency.
Because these waves must cover the distance to the
ultrasound probe, however, the depth of field of the
ultrasound image which can be displayed is overall re-
duced.

pulse. asound probe, however, the depth of field of the
asound image which can be displayed is overall re-
ed. Use of this technology should therefore be left
he user, who differentiates depending on the organ
ang investigated by ultrasound image which can be displayed is overall re-
duced. Use of this technology should therefore be left
to the user, who differentiates depending on the organ
being investigated by switching the unit on and off.
Some duced. Use of this technology should therefore be left
to the user, who differentiates depending on the organ
being investigated by switching the unit on and off.
Some modern high-end devices provide another
possibility fo

and the lesser degree of deformation in liquid tissues, lower frequency of the half-wavin which virtually no reflected harmonic waves are generative power. The reception and rated. Some companies therefore also refer to th in which virtually no reflected harmonic waves are gen-
erated. Some companies therefore also refer to this signals place high demands on technique as tissue harmonic imaging. Another advan-
technique as tissue harmonics i to the user, who differentiates depending on the organ
being investigated by switching the unit on and off.
Some modern high-end devices provide another
possibility for using harmonic signals, however. In ad-
dition to the being investigated by switching the unit on and off.

Some modern high-end devices provide another

possibility for using harmonic signals, however. In ad-

dition to the harmonics already described, Fourier anal-

ysis al Some modern high-end devices provide another
possibility for using harmonic signals, however. In ad-
dition to the harmonics already described, Fourier anal-
ysis also shows so-called half-waves (subharmonics)
with half th possibility for using harmonic signals, however. In addition to the harmonics already described, Fourier analysis also shows so-called half-waves (subharmonics) with half the fundamental frequency of the transmission pulse dition to the harmonics already described, Fourier anal-
ysis also shows so-called half-waves (subharmonics)
with half the fundamental frequency of the transmission
pulse.
The simultaneous use of half-waves and second
harm ysis also shows so-called half-waves (subharmonics)
with half the fundamental frequency of the transmission
pulse.
The simultaneous use of half-waves and second
harmonics to calculate an image compensates for the
disadvant with half the fundamental frequency of the transmission
pulse.
The simultaneous use of half-waves and second
harmonics to calculate an image compensates for the
disadvantage of the short depth of field because of the
lower pulse.
The simultaneous use of half-waves and second
harmonics to calculate an image compensates for the
disadvantage of the short depth of field because of the
lower frequency of the half-wave and its better pen-
etrative The simultaneous use of half-waves and second
harmonics to calculate an image compensates for the
disadvantage of the short depth of field because of the
lower frequency of the half-wave and its better pen-
etrative power. harmonics to calculate an image compensates for the
disadvantage of the short depth of field because of the
lower frequency of the half-wave and its better pen-
etrative power. The reception and processing of these
signals disadvantage of the short depth of field because of the
lower frequency of the half-wave and its better pen-
etrative power. The reception and processing of these
signals place high demands on the frequency spectrum
of the lower frequency of the half-wave and its better penetrative power. The reception and processing of these signals place high demands on the frequency spectrum of the ultrasound probe which can be effectively used and also o harmonics. interfering side lobes which occur automatically at the eral, the ultrasound probe and the piezoelectric crystals
fundamental frequency is too low to generate overtones. used in it have optimized frequency ranges due to th erial and design. The broadband capability of the
asound probe is indispensable for the simultaneous
ption of half-waves and harmonics and is crucial
he quality of this reception. In high-end devices,
technology is found u ultrasound probe is indispensable for the simultaneous
reception of half-waves and harmonics and is crucial
to the quality of this reception. In high-end devices,
this technology is found under the name broadband
harmonics (a) the speed of the speed

Example in the pulse reflection method generally soft the section. The published as the anti-
state of cysts. These this technology is found under the days it is also used in devices in virtually all price ranges. harmoni Exercise of detection of the Blood Flow and Vascular System

17.2 Visualization of the Blood Flow and Vascular System

17.2.1 Doppler

17.2.1 Doppler

17.2.1 Doppler

17.2.1 Doppler

17.2.1 Doppler

17.2.1 Doppler

17.2.1 days it is also used in devices in virtually all price ranges. harmonics.
 17.2. Visualization of the Blood Flow and Vascular System
 17.2.1 Doppler This method is named after the μ Christian Doppler and is based o **17.2 Visualization of the Blood Flow and Vascular System**
 17.2.1 Doppler This method is named after the Christian Doppler and is based of the calculating the depth of a reflecting in-

In addition to calculating the d **17.2 Visualization of the Blood Flow and Vascular System**
 17.2.1 Doppler
 17.2.1 Doppler
 In addition to calculating the depth of a reflecting in
 Christian Doppler and is based
 Exercice, the pulse reflection 17.2 Visualization of the Blood Flow and Vascular System
 17.2.1 Doppler This method is named aftermining the depth of a reflecting in-

In addition to calculating the depth of a reflecting in-

which we know from eve **17.2 Visualization of the Blood Flow and Vascular System**
 17.2.1 Doppler This method is named after the displaying the depth of a reflecting in-

In addition to calculating the depth of a reflecting in-

terface, the **17.2.1 Doppler**
 Christian Doppler and is based
 17.2.1 Doppler
In addition to calculating the depth of a reflecting in-
terface, the pulse reflection method generally used in
ultrasound also provides the possibility of detecting
a moving structure and measuring its sp

reception of half-waves and harmonics and is crucial
to the quality of this reception. In high-end devices,
this technology is found under the name broadband
harmonics.
In the frequency
This method is named after the Aus to the quality of this reception. In high-end devices,
this technology is found under the name broadband
harmonics.
In the moving of a moving of a moving of a moving to the phenomenon,
which we know from everyday life, t this technology is found under the name broadband
harmonics.
 Ind Vascular System

This method is named after the Austrian physicist

Christian Doppler and is based on the phenomenon,

which we know from everyday life, t **nomenon of Vandalus System**

This method is named after the Austrian physicist

Christian Doppler and is based on the phenomenon,

which we know from everyday life, that the frequency

of sound of a moving object changes **INTER SYSTEM**
This method is named after the Austrian physicist
Christian Doppler and is based on the phenomenon,
which we know from everyday life, that the frequency
of sound of a moving object changes according to its
s **INTER System**

This method is named after the Austrian physicist

Christian Doppler and is based on the phenomenon,

which we know from everyday life, that the frequency

of sound of a moving object changes according to i **This method is named after the Austrian physicist**
This method is named after the Austrian physicist
istian Doppler and is based on the phenomenon,
ch we know from everyday life, that the frequency
ound of a moving object **Ind Vascular System**
This method is named after the Austrian physicist
Christian Doppler and is based on the phenomenon,
which we know from everyday life, that the frequency
of sound of a moving object changes according This method is named after the Austrian physicist
Christian Doppler and is based on the phenomenon,
which we know from everyday life, that the frequency
of sound of a moving object changes according to its
speed and direc

Example 19 and 19

Fig. 17.9 Formula for describing the Doppler effect $(f_1$
transmission frequency, f_2 reception frequency, Δf meas-
ured Doppler shift, v speed of the target particle, φ angle of
incidence between the sound bea **Example 12** transmission frequency, f_2 reception frequency, Δf measured Doppler shift, v speed of the target particle, φ angle of incidence between the sound beam direction and the direction of movement of the

ture. The relationship between the Doppler shift and the is increasingly used in diagnospeed of the target particle is illustrated in Fig. 17.9. medium is applied intravenou. The speed of the movement can be calculated b speed of the target particle is illustrated in Fig. 17.9. medium is applied intravenously, p.
The speed of the movement can be calculated by de-
fected through the lungs and is the
termining f_D in the ultrasound unit an The speed of the movement can be calculated by de-
termining f_D in the ultrasound unit and with the aid muscle
of the known variables of sound velocity, transmission solutio
frequency and reception frequency. compo
A fu termining f_D in the ultrasound unit and with the aid muscles and organs by the left hof the known variables of sound velocity, transmission solution with the blood. Ultrasourch in the actual problem in the practical Dop of the known variables of sound velocity, transmission solution with the blood. Ultra
frequency and reception frequency. composed of countless tiny ga
measurement is its reliance on angles. As can be seen beamed in signif frequency and reception frequency. composed of countless tiny

A fundamental problem in the practical Doppler of between 2 and 4 μ m and

measurement is its reliance on angles. As can be seen beamed in significantly bet speed. Surement is its reliance on angles. As can be seen beamed in significantly better
ig. 17.9, there is a connection, dependent on the an-
cular constituents of the blood
 φ , between the moving structure and the position Fig. 17.9, there is a connection, dependent on the an-
 φ , between the moving structure and the position of effect

observer. Extreme cases are, firstly, direct measure-

bles a

in in or against the direction of move mection, dependent on the an-

g structure and the position of effect, which increases the vi

es are, firstly, direct measure-

bles and therefore of the b

ection of movement ($\varphi = 0^{\circ}$) considerably smaller than th
 gle φ , between the moving structure and the position of effect, which increases the observer. Extreme cases are, firstly, direct measure-
bles and therefore of t
ment in or against the direction of movement ($\varphi = 0^{\$ ment in or against the direction of movement (φ = and, secondly, measurement at right angles to the rection of movement (φ = 90°). In the first case corresponds to the actual speed, whereas in the se case the resu

0° and no more than 6

 $17.2.2$ B-Mode

Should be used when using the Doppler technique. However, the acoustic preceding the U.S. and the change in d
 $17.2.2$ B-Mode

In the B-mode, too, visualizations of the blood flow are to the same degree. should be used when using the Doppler technique. How
field
relat
relat
relat
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place, too, visualizations of the blood flow are to the
also possible to a limited extent, since the reflection co-
efficient of blood is a **EXECT: B-Mode**
 EXECT: EXECT: EXEC 17.2.2 B-Mode relationship with one another. I
bles, for example, the bubbles d
also possible to a limited extent, since the blood flow are to the same degree. As a result
also possible to a limited extent, since the re

currently much less widespread than the Doppler spositics | 17.2 Visualization of the Blood Flow and Vascular System 349
with one of the noncontrast lines, modern signal
processing technology provides the possibility of imag-
the novement of the reflecting structures wh prostics | 17.2 Visualization of the Blood Flow and Vascular System 349
with one of the noncontrast lines, modern signal
processing technology provides the possibility of imag-
ing the movement of the reflecting structures spositics 17.2 Visualization of the Blood Flow and Vascular System

intuition of the moncontrast lines, modern signal

processing technology provides the possibility of imag-

ing the movement of the reflecting structures spositions and the two recordings. The two recordings and the two recordings processing technology provides the possibility of imaging the movement of the reflecting structures which takes places between the two recordings mostics 17.2 Visualization of the Blood Flow and Vascular System
with one of the noncontrast lines, modern signal
processing technology provides the possibility of imag-
ing the movement of the reflecting structures which
 relation of the Blood Flow and Vascular System
with one of the noncontrast lines, modern signal
processing technology provides the possibility of imag-
ing the movement of the reflecting structures which
takes places betwe spositics 17.2 Visualization of the Blood Flow and Vascular System

with one of the noncontrast lines, modern signal

processing technology provides the possibility of imag-

ing the movement of the reflecting structures w prostics 17.2 Visualization of the Blood Flow and Vascular System 349
with one of the noncontrast lines, modern signal
processing technology provides the possibility of imag-
ing the movement of the reflecting structures w mostics 17.2 Visualization of the Blood Flow and Vascular System 349
with one of the noncontrast lines, modern signal
processing technology provides the possibility of imag-
ing the movement of the reflecting structures wh with one of the noncontrast lines, modern signal
processing technology provides the possibility of imag-
ing the movement of the reflecting structures which
takes places between the two recordings. The ad-
vantage of this method. processing technology provides the possibility of imag-
ing the movement of the reflecting structures which
takes places between the two recordings. The ad-
vantage of this method (B-flow) is that it does not
rely on angl takes places between the two recordings. The ad-
vantage of this method (B-flow) is that it does not
rely on angles. The spatial resolution of the illus-
tration of the flow is dependent on the resolution
of the B-image, vantage of this method (B-flow) is that it does not
rely on angles. The spatial resolution of the illus-
tration of the flow is dependent on the resolution
of the B-image, however, and this can have a nega-
tive effect on rely on angles. The spatial resolution of the illus-
tration of the flow is dependent on the resolution
of the B-image, however, and this can have a nega-
tive effect on the diagnosis. This method is therefore
currently m

Fig. 17.9 Formula for describing the Doppler effect (f_1 transmission frequency, f_2 reception frequency, Δf measured Doppler shift, *v* speed of the target particle, φ angle of incidence between the sound be **Fig. 17.9** Formula for describing the Doppler effect (f_1
transmission frequency, f_2 reception frequency, Δf measured Doppler shift, v speed of the target particle, φ angle of
incidence between the sound beam Simssion requency, 72 reception requency, Δf measons and Doppler shift, v speed of the target particle, φ angle of the directical dence between the sound beam direction and the direction of movement of the target incidence between the sound beam direction and the direction of movement of the target particle, c sound velocity) achieve an accurate representation of movement of the target particle, c sound velocity) and the perfusion in the target particle between the solid beam direction and the unec-

in the medical indication of movement of the target particle, c sound velocity)

ture. The relationship between the Doppler shift and the is increasin achieve an accurate representation of
and the perfusion dynamics, ultrasoun
speed of the target particle is illustrated in Fig. 17.9. medium is applied intravenously, pa
The speed of the movement can be calculated by de-
 ture. The relationship between the Doppler shift and the perfusion dynamics, ul
speed of the target particle is illustrated in Fig. 17.9. medium is applied intravenous
The speed of the movement can be calculated by de-
fe °) considerably sm In the calculated by de-

1 unit and with the aid muscles and organs by the left

d velocity, transmission solution with the blood. Ultras

ncy.

2 composed of countless tiny gas

the practical Doppler of between 2 and 4 tration of the flow is dependent on the resolution
of the B-image, however, and this can have a nega-
tive effect on the diagnosis. This method is therefore
currently much less widespread than the Doppler
method.
17.2.3 of the B-image, however, and this can have a nega-
tive effect on the diagnosis. This method is therefore
currently much less widespread than the Doppler
method.
17.2.3 Ultrasound Contrast Medium
Depending on the medica tive effect on the diagnosis. This method is therefore
currently much less widespread than the Doppler
method.
17.2.3 Ultrasound Contrast Medium
Depending on the medical indication and in order to
achieve an accurate re currently much less widespread than the Doppler
method.
 17.2.3 Ultrasound Contrast Medium

Depending on the medical indication and in order to

achieve an accurate representation of the organ perfusion

and the perfusi method.
 17.2.3 Ultrasound Contrast Medium

Depending on the medical indication and in order to

achieve an accurate representation of the organ perfusion

and the perfusion dynamics, ultrasound contrast medium

is incr 17.2.3 Ultrasound Contrast Medium

Depending on the medical indication and in order to

achieve an accurate representation of the organ perfusion

and the perfusion dynamics, ultrasound contrast medium

is increasingly us **17.2.3 Ultrasound Contrast Medium**

Depending on the medical indication and in order to

achieve an accurate representation of the organ perfusion

and the perfusion dynamics, ultrasound contrast medium

is increasingly Depending on the medical indication and in order to
achieve an accurate representation of the organ perfusion
and the perfusion dynamics, ultrasound contrast medium
is increasingly used in diagnosis. Ultrasound contrast
m Depending on the medical indication and in order to
achieve an accurate representation of the organ perfusion
and the perfusion dynamics, ultrasound contrast medium
is increasingly used in diagnosis. Ultrasound contrast
m achieve an accurate representation of the organ perfusion
and the perfusion dynamics, ultrasound contrast medium
is increasingly used in diagnosis. Ultrasound contrast
medium is applied intravenously, passes largely unaf-
 and the perfusion dynamics, ultrasound contrast medium
is increasingly used in diagnosis. Ultrasound contrast
medium is applied intravenously, passes largely unaf-
fected through the lungs and is then pumped into the
musc is increasingly used in diagnosis. Ultrasound contrast
medium is applied intravenously, passes largely unaf-
fected through the lungs and is then pumped into the
muscles and organs by the left heart in a highly diluted
so medium is applied intravenously, passes largely
fected through the lungs and is then pumped in
muscles and organs by the left heart in a highly α
solution with the blood. Ultrasound contrast med
composed of countless t ed through the lungs and is then pumped into the
ccles and organs by the left heart in a highly diluted
tion with the blood. Ultrasound contrast medium is
pposed of countless tiny gas bubbles with a diameter
etween 2 and 4 muscles and organs by the left heart in a highly diluted
solution with the blood. Ultrasound contrast medium is
composed of countless tiny gas bubbles with a diameter
of between 2 and 4 µm and reflects ultrasound which is
 solution with the blood. Ultrasound contrast medium is
composed of countless tiny gas bubbles with a diameter
of between 2 and 4 µm and reflects ultrasound which is
beamed in significantly better than the natural corpus-
c composed of countless tiny gas bubbles with a diameter
of between 2 and 4 μ m and reflects ultrasound which is
beamed in significantly better than the natural corpus-
cular constituents of the blood. There is also a sec

Fraction of movement ($\varphi = 90^\circ$). In the first case, f_D In the compression wave of ancorresponds to the actual speed, whereas in the second areas of elevated and reduced processue the result given by the correction fa corresponds to the actual speed, whereas in the second

care the result given by the correction factor ($\varphi = 90^\circ$, surround each bubble completely.

which gives cos $\varphi = 0$) does not give a measurable evated pressure, case the result given by the correction factor ($\varphi = 90^{\circ}$, surround each bubble completel
which gives cos $\varphi = 0$) does not give a measurable evated pressure, bubbles are con-
speed.
bubbles in the low-pressure are
o which gives $\cos \varphi = 0$) does not give a measurable evated pressure, bubbles are
speed.

For practical use, it holds that an angle of between of these rhythmic changes in

0° and no more than 60° to the direction of moveme speed.

For practical use, it holds that an angle of between of these rhythmic changes in

0° and no more than 60° to the direction of movement come a source of sound as

should be used when using the Doppler technique. H For practical use, it holds that an angle of between of these rhythmic changes in volume of the difference of solution of movement come a source of solution as the should be used when using the Doppler technique. However, of between 2 and 4 μ m and reflects ultrasound which is
beamed in significantly better than the natural corpus-
cular constituents of the blood. There is also a second
effect, which increases the visualization of the ga beamed in significantly better than the natural corpus-
cular constituents of the blood. There is also a second
effect, which increases the visualization of the gas bub-
bles and therefore of the blood: the gas bubbles are cular constituents of the blood. There is also a second
effect, which increases the visualization of the gas bub-
bles and therefore of the blood: the gas bub-
bles are
considerably smaller than the spatial dimension of th effect, which increases the visualization of the gas bub-
bles and therefore of the blood: the gas bubbles are
considerably smaller than the spatial dimension of the
sound waves.
In the compression wave of an ultrasound pu bles and therefore of the blood: the gas bubbles are
considerably smaller than the spatial dimension of the
sound waves.
In the compression wave of an ultrasound pulse,
areas of elevated and reduced pressure periodically
s considerably smaller than the spatial dimension of the
sound waves.
In the compression wave of an ultrasound pulse,
areas of elevated and reduced pressure periodically
surround each bubble completely. In the area of el-
ev sound waves.

In the compression wave of an ultrasound pulse,

areas of elevated and reduced pressure periodically

surround each bubble completely. In the area of el-

evated pressure, bubbles are compressed. Conversely,
 In the compression wave of an ultrasound pulse,
areas of elevated and reduced pressure periodically
surround each bubble completely. In the area of el-
evated pressure, bubbles are compressed. Conversely,
bubbles in the lo areas of elevated and reduced pressure periodically
surround each bubble completely. In the area of el-
evated pressure, bubbles are compressed. Conversely,
bubbles in the low-pressure area dilate. On account
of these rhyt surround each bubble completely. In the area of elevated pressure, bubbles are compressed. Conversely, bubbles in the low-pressure area dilate. On account of these rhythmic changes in volume, the bubbles become a source of evated pressure, bubbles are compressed. Conversely,
bubbles in the low-pressure area dilate. On account
of these rhythmic changes in volume, the bubbles be-
come a source of sound as they begin to oscillate.
However, the bubbles in the low-pressure area dilate. On account
of these rhythmic changes in volume, the bubbles be-
come a source of sound as they begin to oscillate.
However, the acoustic pressure of the initial sound
field and the of these rhythmic changes in volume, the bubbles be-
come a source of sound as they begin to oscillate.
However, the acoustic pressure of the initial sound
field and the change in diameter are not in a linear
relationship come a source of sound as they begin to oscillate.
However, the acoustic pressure of the initial sound
field and the change in diameter are not in a linear
relationship with one another. If the pressure dou-
bles, for exam However, the acoustic pressure of the initial sound
field and the change in diameter are not in a linear
relationship with one another. If the pressure dou-
bles, for example, the bubbles do not reduce in size
to the same field and the change in diameter are not in a linear
relationship with one another. If the pressure dou-
bles, for example, the bubbles do not reduce in size
to the same degree. As a result of this nonlinear os-
cillation inkes places between the two recordings. The ad-
twitting of this method (B-How) is that it does not
related to the B-Home strategy of this method (B-How) is what it does not
extraction of the B-inage, however, and this ca

Medical Imaging

imaging. This method is known by the term contrast Here, Mi is the mechanical in

times occalled mechanical index (Mi) measures the transmission frequency (MHZ).

In the so-called mechanical effects of harmonic.

Example 16.1
 Solution is known by the term contrast

The so-called mechanical index (Mi) measures the

time megative acoustic pressure (1

The so-called mechanical index (Mi) measures the

transmission frequency (MHz **Medical Imaging**

imaging. This method is known by the term contrast Here, Mi is the mechanical index (harmonic.

the so-called mechanical index (Mi) measures the transmission frequency (MHz).

mechanical effects of the Medical Imaging

imaging. This method is known by the term contrast

harmonic.

The so-called mechanical index (Mi) measures the

the mechanical effects of the sound waves on tissue and

contrast medium bubbles
 $Mi = \frac{p^{-}}$ imaging. This method is known by the term contrast Here, Mi

harmonic.

The so-called mechanical index (Mi) measures the transmiss

mechanical effects of the sound waves on tissue and At a

contrast medium bubbles

Mi = Frame is the mechanical effects of the sound waves on tissue and

the so-called mechanical index (Mi) measures the trans

contrast medium bubbles
 $Mi = \frac{p^{-}}{\sqrt{f}}$.

17.3 Equipment Technology

17.3.1 The Basic Design

of a of an Ultrasound Unit

$$
\mathrm{Mi} = \frac{p^-}{\sqrt{f}} \; .
$$

 $\text{Mi} = \frac{p^-}{\sqrt{f}}$.
 17.3 Equipment Technology
 17.3.1 The Basic Design
 18.11 Secondagram (Fig. 17.10).
 17.3.1 The Basic Design and Community of an Ultrasound Unit Specific ultrasound probe of an Ultrasound Unit Specific ultrasound probe derent fields of use. They different fields of use. They different fields of use and **17.3 Equipment Technology**
 17.3.1 The Basic Design
 **17.3.1 The Basic Design

of an Ultrasound Unit** Specific ultrasound probe designs a

ferent fields of use. They differ esse

the devices shown in the diagram (Fig. **17.3 Equipment Technology**
 17.3.1 The Basic Design
 17.3.1 The Basic Design
 17.3.1 The Basic Design
 18.6 The Specific ultrasound probe designed to Specific ultrasound probe designed the devices shown in the dia 17.3 Equipment Technology
 17.3.1 The Basic Design
 **17.3.1 The Basic Design

of an Ultrasound Unit** Specific ultrasound probe designs

The fundamental components of an ultrasound unit are of the crystal array. The st **17.3.1 The Basic Design**
 a of an Ultrasound Unit
 a Specific ultrasound probe deferent fields of use. They diff

The fundamental components of an ultrasound unit are of the crystal array. The stan

the devices show **17.3.1 The Basic Design

of an Ultrasound Unit** Specific ultrasound probe

frem fields of use. They differ essen

from the diagram (Fig. 17.10).

The combination of these components constitutes and radii of curvature, an scinded. The fundamental components of an ultrasound unit are of the crystal array
the devices shown in the diagram (Fig. 17.10). The section below components constitutes and radii of curvat
a medical device which is approved in ac ince where the diagram (Fig. 17.10).

The section below can be found in different sizes, widths

The combination of these components constitutes and radii of curvature, and in a wide variety of other

medical device which

Here, Mi is the mechanical index (dimensionless), p^{-}
is the negative acoustic pressure (MPa) and f is the
transmission frequency (MHz).
At a low Mi and thus a low acoustic pressure Here, Mi is the mechanical index (dimensionless), p^{-}
is the negative acoustic pressure (MPa) and f is the
transmission frequency (MHz).
At a low Mi and thus a low acoustic pressure,
bubbles still behave in a linear fas Here, Mi is the mechanical index (dimensionless), p^{-}
is the negative acoustic pressure (MPa) and f is the
transmission frequency (MHz).
At a low Mi and thus a low acoustic pressure,
bubbles still behave in a linear fas

e, Mi is the mechanical index (dimensionless), p -
he negative acoustic pressure (MPa) and f is the
smission frequency (MHz).
At a low Mi and thus a low acoustic pressure,
bles still behave in a linear fashion, and at Here, Mi is the mechanical index (dimensionless), p^{-}
is the negative acoustic pressure (MPa) and f is the
transmission frequency (MHz).
At a low Mi and thus a low acoustic pressure,
bubbles still behave in a linear fas Here, Mi is the mechanical index (dimensionless), p^{-}
is the negative acoustic pressure (MPa) and f is the
transmission frequency (MHz).
At a low Mi and thus a low acoustic pressure,
bubbles still behave in a linear fas Here, Mi is the mechanical index (dimensionless), p^{-}
is the negative acoustic pressure (MPa) and f is the
transmission frequency (MHz).
At a low Mi and thus a low acoustic pressure,
bubbles still behave in a linear fas the negative acoustic pressure (MPa) and f is the
smission frequency (MHz).
At a low Mi and thus a low acoustic pressure,
bles still behave in a linear fashion, and at higher
ustic pressures their behaviour becomes nonl transmission frequency (MHz).

At a low Mi and thus a low acoustic pressure,

bubbles still behave in a linear fashion, and at higher

acoustic pressures their behaviour becomes nonlinear

and they generate harmonics.

Spe

Contrast medium bubbles

Mi = $\frac{p^-}{\sqrt{f}}$.

The Basic Design

of an Ultrasound Unit

The fundamental components of an ultrasound unit are

the devices shown in the diagram (Fig. 17.10).

The fundamental components of an T_{NL} and they generate harmonics
 3.1 The Basic Design
 5.1 The Basic Design
 6.1 The Basic Design
 6.1 The Basic Design
 6.1 Of the Combination of these components constitutes
 6.1 Of the components const At a low Mi and thus a low acoustic pressure,
bubbles still behave in a linear fashion, and at higher
acoustic pressures their behaviour becomes nonlinear
and they generate harmonics.
They differ essentially in the design
 bubbles still behave in a linear fashion, and at higher
acoustic pressures their behaviour becomes nonlinear
and they generate harmonics.
Depecific ultrasound probe designs are available for dif-
ferent fields of use. They acoustic pressures their behaviour becomes nonlinear
and they generate harmonics.
Specific ultrasound probe designs are available for dif-
ferent fields of use. They differ essentially in the design
of the crystal array. T Ultrasound Probe

Ultrasound Probe

Specific ultrasound probe designs are available for dif-

ferent fields of use. They differ essentially in the design

of the crystal array. The standard designs described in

the sectio Ultrasound Probe
Specific ultrasound probe designs are available for dif-
ferent fields of use. They differ essentially in the design
of the crystal array. The standard designs described in
the section below can be found i Ultrasound Probe
Specific ultrasound probe designs are available for dif-
ferent fields of use. They differ essentially in the design
of the crystal array. The standard designs described in
the section below can be found **Ultrasound Probe**
Specific ultrasound probe designs are available for dif-
ferent fields of use. They differ essentially in the design
of the crystal array. The standard designs described in
the section below can be found **Ultrasound Probe**
Specific ultrasound probe designs are available for dif-
ferent fields of use. They differ essentially in the design
of the crystal array. The standard designs described in
the section below can be found mechanical effects of the sound waves on tissue and

contrast medium bubbles still behave in a linear fashion, and at higher

contrast medium bubbles
 $\overline{M1} = \frac{p^-}{\sqrt{f}}$.

The Basic Design

of an Ultrasound Unit

The f

und Diagnostics | 17.3 Equipment Technology | 351
|-
| Fig. 17.10 Components of an ultra-
| sound unit und Diagnostics 17.3 Equipment Technology
Fig. 17.10 Components of an ultra-
sound unit und Diagnostics 17.3 Equipment Technology

Fig. 17.10 Components of an ultra-

sound unit

Fig. 17.11 Diagram of A-mode,

B-mode, and M-mode

Fractional B-mode
the analogue-functioning ultrasound probe and the dig-
transmission, printer control and ital
processor is in the analogue/digital (A/D) converter. normally used today are also digita
The purpose of the A A-mode B-mode M-mode
the analogue-functioning ultrasound probe and the dig-
transmission, printer control and arc
ital processor is in the analogue/digital (A/D) converter. normally used today are also digital.
The purpose A-mode B-mode M-mode
the analogue-functioning ultrasound probe and the dig-
transmission, printe
ital processor is in the analogue/digital (A/D) converter. normally used today
The purpose of the A/D converter is firstly **EXECUTE A**
 EXECUTE A analogue-functioning ultrasound probe and the dig-

processor is in the analogue/digital (A/D) converter.

promally used today are also dig

purpose of the A/D converter is firstly to generate

o the analogue-functioning ultrasound probe and the dig-
tital processor is in the analogue/digital (A/D) converter. normally used today are also digital
The purpose of the A/D converter is firstly to generate
all of the ele the analogue-functioning ultrasound probe and the dig-
transmission, printer control and archital processor is in the analogue/digital (A/D) converter.
The purpose of the A/D converter is firstly to generate
for the elec the analogue-functioning ultrasound probe and the dig-
transmission, printer control
ital processor is in the analogue/digital (A/D) converter. normally used today are also c
The purpose of the A/D converter is firstly t

ital processor is in the analogue/digital (A/D) converter. normally used today are also
The purpose of the A/D converter is firstly to generate
all of the electrical pulses and pulse sequences required
for steering the s The purpose of the A/D converter is firstly to generate
all of the electrical pulses and pulse sequences required
for steering the sound beam and also to receive the re-
Historically, the A-mode meth
flected signals and c all of the electrical pulses and pulse sequences required
for steering the sound beam and also to receive the re-
Historically, the A-mode met
flected signals and convert them to digital form. It thus
the first ultrasound for steering the sound beam and also to receiver
flected signals and convert them to digital form
becomes clear that the image quality in part
heavily dependent on the quality of the A/D cc
The base unit also has the task omes clear that the image quality in particular is cludy dependent on the quality of the A/D converter.
The base unit also has the task of scan converting the same interfaces in (spatial mapping of the scan lines recorded) heavily dependent on the quality of the A/D converter.

The base unit also has the task of scan conver-

is very limited. Measure

sion (spatial mapping of the scan lines recorded) and

further processing the digitized sig The base unit also has the task of scan conver-

is very limited. Measurements of com

sion (spatial mapping of the scan lines recorded) and

can only be carried out at a single further processing. Other functions include sion (spatial mapping of the scan lines recorded) and can only be carried out at a single p
further processing the digitized signals by means of
image processing. Other functions include the operator-
through media boundar

A-Mode

M-Mode

Historically, the A-mode method (amplitude mode) was

the first ultrasound method (amplitude mode) was

the first ultrasound method used. It has been almost ex-

clusively replaced in the medical field by the meth The first unit

M-mode

transmission, printer control and archiving which are

normally used today are also digital.

A-Mode

Historically, the A-mode method (amplitude mode) was

the first ultrasound method used. It has b M-mode
transmission, printer control and archiving which are
normally used today are also digital.
A-Mode
Historically, the A-mode method (amplitude mode) was
the first ultrasound method used. It has been almost ex-
clusiv M-mode
transmission, printer control and archiving which are
normally used today are also digital.
 $A-Mode$
Historically, the A-mode method (amplitude mode) was
the first ultrasound method used. It has been almost ex-
clusiv **Example 15**
 Example 10
 Example 10 transmission, printer control and archiving which are
normally used today are also digital.
A-Mode
Historically, the A-mode method (amplitude mode) was
the first ultrasound method used. It has been almost ex-
clusively rep smission, printer control and archiving which are
mally used today are also digital.
A-Mode
torically, the A-mode method (amplitude mode) was
first ultrasound method used. It has been almost ex-
sively replaced in the med transmission, printer control and archiving which are
normally used today are also digital.
 $A-Mode$
Historically, the A-mode method (amplitude mode) was
the first ultrasound method used. It has been almost ex-
clusively rep normally used today are also digital.
 $A-Mode$

Historically, the A-mode method (amplitude mode) was

the first ultrasound method used. It has been almost ex-

clusively replaced in the medical field by the methods

describ

 $A-Mode$
Historically, the A-mode method (amplitude mode) was
the first ultrasound method used. It has been almost ex-
clusively replaced in the medical field by the methods
described below, as the diagnostic value of the A-A-Mode
Historically, the A-mode method (amplitude mode) was
the first ultrasound method used. It has been almost ex-
clusively replaced in the medical field by the methods
described below, as the diagnostic value of the A Historically, the A-mode method (amplitude mode) was
the first ultrasound method used. It has been almost ex-
clusively replaced in the medical field by the methods
described below, as the diagnostic value of the A-mode
i described below, as the diagnostic value of the A-mode
is very limited. Measurements of depths and distances
can only be carried out at a single point.
Along the sound propagation line, signals reflected
through media boun is very limited. Measurements of depths and distances
can only be carried out at a single point.
Along the sound propagation line, signals reflected
through media boundaries are displayed as individual
peaks on the depth

B-Mode

Medical Imaging
vidual, depth-dependent (transit time) pixel. The value of the transmission pulses emitted
of the amplitude is represented by the brightness of this identify its own pulses from a w
inco brightness. The s **Medical Imaging**
 Medical Imaging

vidual, depth-dependent (transit time) pixel. The value of the transmission pulses emitted

of the amplitude is represented by the brightness of this identify its own pulses from a wi **Medical Imaging**
 Medical Imaging
 Medical Imaging
 of the amplitude is represented by the brightness of this identify its own pulses from a with points of the interperated with points of vary- from other bats Medical Imaging
 Medical Imaging
 Medical Imaging
 **of the amplitude is represented by the brightness of this identify its own pulses from a wide

pixel, so that a line is generated with points of vary-

from other b** Medical Imaging

widual, depth-dependent (transit time) pixel. The value of the transmission pulses emitted b

of the amplitude is represented by the brightness of this identify its own pulses from a wide

pixel, so that a Medical Imaging

vidual, depth-dependent (transit time) pixel. The value of the transmission pulse

of the amplitude is represented by the brightness of this identify its own pulses fi

pixel, so that a line is generated **Medical Imaging**

Medical Imaging

oridual, depth-dependent (transit time) pixel. The value of the transmission pulses emi

oride amplitude is represented by the brightness of this identify its own pulses from a

pixel, vidual, depth-dependent (transit time) pixel. The value of the transmission pulses emitt
of the amplitude is represented by the brightness of this identify its own pulses from a
pixel, so that a line is generated with poi vidual, depth-dependent (transit time) pixel. The value of the transmission pulses emitted both the amplitude is represented by the brightness of this identify its own pulses from a wide pixel, so that a line is generated

vidual, depth-dependent (transit time) pixel. The value of the transmission pulses emitted of the amplitude is represented by the brightness of this identify its own pulses from a way pixel, so that a line is generated wi of the amplitude is represented by the brightness of this identify its own pulses from a w
pixel, so that a line is generated with points of vary-
from other bats. Every individua
ing brightness. The simple B-mode method c pixel, so that a line is generated with points of vary-

ing brightness. The simple B-mode method cannot be

despite a large number of other

used diagnostically. However, it was the basis for the safely in space with its ing brightness. The simple B-mode method cannot be despite a large number of or

used diagnostically. However, it was the basis for the safely in space with its own is

development of the M-mode and the 2-D B-mode.

In ad elopment of the M-mode and the 2-D B-mode.

M-Mode

M-Mode

M-mode (motion mode) is produced by the hori

deflection (time axis) of a B-mode line and std

display of the resulting images. The M-mode i

led to be used for t M-Mode

The *M-mode (motion mode)* is produced by the horizon-

The *M-mode (motion mode)* is produced by the horizon-

an then form a signal with a lower

and display of the resulting images. The M-mode is in-

and displ M-Mode

The *M-mode (motion mode)* is produced by the horizon-

transmission signal with a low

tal deflection (time axis) of a B-mode line and storage

again at a later point as a result and display of the resulting imag The *M-mode* (motion mode) is produced by the horizon-

an then form a signal with a higher than display of the resulting images. The *M*-mode is in-

individual digital pulses.

tended to be used for the diagnosis of mov

tal deflection (time axis) of a B-mode line and storage again at a later point as a rest
and display of the resulting images. The M-mode is in-
individual digital pulses.
tended to be used for the diagnosis of moving orga and display of the resulting images. The M-mode is in-

individual digital pulses.

tended to be used for the diagnosis of moving organ Two fundamental advan

parts, such as cardiac valves or cardiac muscle. It stands eme tended to be used for the diagnosis of moving organ Two fundamental advantages c
parts, such as cardiac valves or cardiac muscle. It stands emerge from this:
out in this area in particular due to its high time resolu-
tion parts, such as cardiac valves or cardiac muscle. It stands

out in this area in particular due to its high time resolu-

tion, as just one individual line is repeatedly scanned.

2. The useful signal is amp

2-D B-Mode

T out in this area in particular due to its high time resolution, as just one individual line is repeatedly scanned.

2. The useful signa

2-D B-Mode

1. Unwanted signa

2-D B-Mode

1. Unwanted signa

2-D B-Mode

1. Unwanted 1. Columbus is also dependent on the is repeatedly scanned.

2. The useful signal is amplified.

2. The useful signal is amplified.

2. The useful signal is amplified.

1. Columbus Integral of the context more important s 2-D B-Mode

The 2-D B-mode method (two-dimensional bright-

Unwanted signals such as nois

important sectional probably and at the same time the

meaning technique in ultrasound diagnostics and is gen-

same frequency and 2-D B-Mode

Unwanted signals such as nois

The 2-D B-mode method (two-dimensional bright-

maging technique in ultrasound diagnostics and is gen-

same frequency and thus also at the semely referred to as B-mode. The imag The 2-D B-mode method (two-dimensional bright-
ness mode) is these days the most important sectional
plified and raised above the ambien
imaging technique in ultrasound diagnostics and is gen-
same frequency and thus also ness mode) is these days the most important sectional plified and rai-
imaging technique in ultrasound diagnostics and is gen-
erally referred to as B-mode. The image is produced effects mentic
by quickly stringing togethe Iy referred to as B-mode. The image is produced effects
quickly stringing together a number of individual etration
ode lines (scanning lines) horizontally to give a flat of achi
image. Here, the image geometry is determine by quickly stringing together a number of individual etration depth. This significantly in B-mode lines (scanning lines) horizontally to give a flat of achieving a high resolution which 2-D image. Here, the image geometry B-mode lines (scanning lines) horizontally to give a flat of achieving a high resolution wh
2-D image. Here, the image geometry is determined obtaining a high penetration dept
by the relative arrangement of the individual 2-D image. Here, the image geometry is determined obtaining a high penetration depth.

by the relative arrangement of the individual B-mode not put us in a position to be able t

lines. It is also dependent on the design o by the relative arrangement of the individual B-mode

ines. It is also dependent on the design of the ultra-

compromise between frequen

sound probe. As in the traditional simple B-mode, the

tration depth. A significant mg Meyhmess. The simple limited method cannot be despite a large number
as diagnostically. However, it was the basis for the safely in space with
development of the M-mode and the 2-D B-mode.

Intersection takes place in

lines. It is also dependent on the design of the ultra-

sound probe. As in the traditional simple B-mode, the

tration depth. A significant imp

brightness of the individual pixels is determined by the

is possible, howev tion. threes of the individual pixels is determined by the is possible, however.

Digital of the reflected signals. Today, at least 256

des of grey are required as standard. **17.3.2 Doppler Ultrasonograpl**

Digitally Encoded U amplitude of the reflected signals. Today, at least 256

shades of grey are required as standard. **17.3.2 Doppler Ultrasor**

Digitally Encoded Ultrasound
 As outlined in the introduction

essay compromise between the des shades of grey are required as standard. **17.3.2 Doppler Ultrasonograp**

Digitally Encoded Ultrasound

The practical applications of ultrasound require a nec-

erses, Doppler ultrasonography is u

resolution and a good pen

Digitally Encoded Ultrasound

The practical applications of ultrasound require a nec-

expectation and a good penetration depth. Digital en-

ecolution and a good penetration depth. Digital en-

coding of ultrasound pulses Digitally Encoded Ultrasound

The practical applications of ultrasound require a nec-

respectives interfaces in The practical applications of ultrasound require a nec-

essary compromise between the desire for high axial flow. Different methods can be use

resolution and a good penetration depth. Digital en-

coding of ultrasound p essary compromise between the desire for high axial

resolution and a good penetration depth. Digital en-

coding of ultrasound pulses significantly improves

this compromise, with the benefit of better penetra-

Ligh-PRF resolution and a good penetration depth. Digital encyclosed wave (PW) Doppler

this compromise, with the benefit of better penetra-

this compromise, with the benefit of better penetra-

Unit encyclopter

Unit encyclopted coding of ultrasound pulses significantly improves
this compromise, with the benefit of better penetra-
tion.
During transmission, a typical digital encoding is
color Doppler.
Continuous-wave (CW) Do
neutrason the ultraso this compromise, with the benefit of better penetra-

tion.

During transmission, a typical digital encoding is

Color Dop

superimposed on the ultrasound pulse as an identifica-

With Dopple

tion pattern. This encoding c During transmission, a typical digital encoding is

Color Doppler.

Erimposed on the ultrasound pulse as an identifica-

With Doppler ultrasonography, a

pattern. This encoding can also be detected in the drawn on the bas During transmission, a typical digital encoding is
superimposed on the ultrasound pulse as an identifica-
With Doppler ultrasonograph
tion pattern. This encoding can also be detected in the drawn on the basis of whethee
ul

of the transmission pulses emitted by a bat allows it to
identify its own pulses from a wide number of pulses
from other bats. Every individual bat is therefore able,
desnite a large number of other nulses to move about of the transmission pulses emitted by a bat allows it to
identify its own pulses from a wide number of pulses
from other bats. Every individual bat is therefore able,
despite a large number of other pulses, to move about
s for the transmission pulses emitted by a bat allows it to
identify its own pulses from a wide number of pulses
from other bats. Every individual bat is therefore able,
despite a large number of other pulses, to move about
 of the transmission pulses emitted by a bat allows it to
identify its own pulses from a wide number of pulses
from other bats. Every individual bat is therefore able,
despite a large number of other pulses, to move about
s of the transmission pulses emitted by a bat allows it to
identify its own pulses from a wide number of pulses
from other bats. Every individual bat is therefore able,
despite a large number of other pulses, to move about
s In a the transmission pulses emitted by a bat allows it to
the entity its own pulses from a wide number of pulses
position to the bats. Every individual bat is therefore able,
bite a large number of other pulses, to move a of the transmission pulses emitted by a bat allows it to
identify its own pulses from a wide number of pulses
from other bats. Every individual bat is therefore able,
despite a large number of other pulses, to move about
s

of the transmission pulses emitted by a bat allows it to
identify its own pulses from a wide number of pulses
from other bats. Every individual bat is therefore able,
despite a large number of other pulses, to move about
s of the transmission pulses emitted by a bat allows it to
identify its own pulses from a wide number of pulses
from other bats. Every individual bat is therefore able,
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s of the transmission pulses emitted by a bat allows it to
identify its own pulses from a wide number of pulses
from other bats. Every individual bat is therefore able,
despite a large number of other pulses, to move about
s of the transmission pulses emitted by a bat allows it to
identify its own pulses from a wide number of pulses
from other bats. Every individual bat is therefore able,
despite a large number of other pulses, to move about
s he transmission pulses emitted by a bat allows it to
tiffy its own pulses from a wide number of pulses
in other bats. Every individual bat is therefore able,
pite a large number of other pulses, to move about
ly in space w identify its own pulses from a wide number of pulses
from other bats. Every individual bat is therefore able,
despite a large number of other pulses, to move about
safely in space with its own signals.
In addition to the e The moment of the pulses, to move about
despite a large number of other pulses, to move about
safely in space with its own signals.
In addition to the encoding, signal compression also
takes place, making it possible to pr Example a range number of outer parses, to move about
safely in space with its own signals.
In addition to the encoding, signal compression also
takes place, making it possible to produce an encoded
transmission signal wit In addition to the encoding, signal compression also

s place, making it possible to produce an encoded

smission signal with a lower level of energy, which

then form a signal with a higher level of energy

in at a later takes place, making it possible to produce an encoded
transmission signal with a lower level of energy, which
can then form a signal with a higher level of energy
again at a later point as a result of adding together the
i

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-

transmission signal with a lower level of energy, which
can then form a signal with a higher level of energy
again at a later point as a result of adding together the
individual digital pulses.
Two fundamental advantages o can then form a signal with a higher level of energy
again at a later point as a result of adding together the
individual digital pulses.
Two fundamental advantages of digital encoding
emerge from this:
1. Unwanted signals again at a later point as a result of adding together the
individual digital pulses.
Two fundamental advantages of digital encoding
emerge from this:
1. Unwanted signals are suppressed.
2. The useful signal is amplified.
U individual digital pulses.

Two fundamental advantages of digital encoding

emerge from this:

1. Unwanted signals are suppressed.

2. The useful signal is amplified.

Unwanted signals such as noise and artifacts are

supp Two fundamental advantages of digital encoding

emerge from this:

1. Unwanted signals are suppressed.

2. The useful signal is amplified.

Unwanted signals such as noise and artifacts are

suppressed, and at the same time emerge from this:

1. Unwanted signals are suppressed.

2. The useful signal is amplified.

Unwanted signals such as noise and artifacts are

suppressed, and at the same time the useful signal is am-

plified and raised ab 1. Unwanted signals are suppressed.

2. The useful signal is amplified.

Unwanted signals such as noise and artifacts are

suppressed, and at the same time the useful signal is am-

plified and raised above the ambient noi 2. The useful signals are suppressed.

2. The useful signal is amplified.

Unwanted signals such as noise and artifacts are

suppressed, and at the same time the useful signal is am-

plified and raised above the ambient n 2. The ascrit signal is amplined.

Unwanted signals such as noise and artifacts are

suppressed, and at the same time the useful signal is am-

plified and raised above the ambient noise level. At the

same frequency and t Unwanted signals such as noise and artifacts an suppressed, and at the same time the useful signal is an plified and raised above the ambient noise level. At the same frequency and thus also at the same resolution, the eff plified and raised above the ambient noise level. At the
same frequency and thus also at the same resolution, the
effects mentioned bring about an increase in the pen-
etration depth. This significantly reduces the problem effects mentioned bring about an increase in the pen-
etration depth. This significantly reduces the problem
of achieving a high resolution whilst at the same time
obtaining a high penetration depth. This method does
not p etration depth. This significantly reduces the problem
of achieving a high resolution whilst at the same time
obtaining a high penetration depth. This method does
not put us in a position to be able to do away with the
com of achieving a high resolution whilst at the same time
obtaining a high penetration depth. This method does
not put us in a position to be able to do away with the
compromise between frequency (resolution) and pene-
tratio • Pulsed-wave (CW) Doppler
• Pulsed-wave CMV Doppler
• Pulsed-wave members of the compromise between frequency (resolution) and pene-
• Fulsed-h. A significant improvement in the situation
• Spossible, however.
• Pulsed-w

• Continuous-wave (CW) Doppler
 Example 18 A significant improvement in the situation

is possible, however.
 17.3.2 Doppler Ultrasonography

As outlined in the introduction to the fundamental prin-

ciples, Doppler ul **17.3.2 Doppler Ultrasonography**
 17.3.2 Doppler Ultrasonography
 As outlined in the introduction to the fundamental proples, Doppler ultrasonography is used to detect ble
 flow. Different methods can be used technic

-
-
- High-PRF Doppler
-

17.3.2 Doppler Ultrasonography

As outlined in the introduction to the fundamental prin-

ciples, Doppler ultrasonography is used to detect blood

flow. Different methods can be used technically:

• Pulsed-wave (PW) Dop **17.3.2 Doppler Ultrasonography**
As outlined in the introduction to the fundamental prin-
ciples, Doppler ultrasonography is used to detect blood
flow. Different methods can be used technically:

• High-PRF Doppler
• Cont As outlined in the introduction to the fundamental principles, Doppler ultrasonography is used to detect blood
flow. Different methods can be used technically:

• Pulsed-wave (PW) Doppler

• High-PRF Doppler

• Color Dopp As outlined in the introduction to the fundamental principles, Doppler ultrasonography is used to detect blood
flow. Different methods can be used technically:

• Pulsed-wave (PW) Doppler

• High-PRF Doppler

• Color Doppl flow. Different methods can be used technically:

• Pulsed-wave (PW) Doppler

• High-PRF Doppler

• Color Doppler.

• Color Doppler intrasonography, a • Pulsed-wave (PW) Doppler
• High-PRF Doppler
• Continuous-wave (CW) Doppler
• Color Doppler.
With Doppler ultrasonography, a distinction is also
drawn on the basis of whether a device operates solely
in the Doppler mode **Point of the point of the velocity** of the velocity Doppler
 Point of the velocity Doppler
 Color Doppler.

With Doppler ultrasonography, a distinction is also

drawn on the basis of whether a device operates solely
 • Continuous-wave (CW) Doppler
• Color Doppler.
• Color Doppler.
With Doppler ultrasonography, a distinction is also
drawn on the basis of whether a device operates solely
in the Doppler mode or whether it operates in t Color Doppler.

Color Doppler.

With Doppler ultrasonography, a distinction is also

drawn on the basis of whether a device operates solely

in the Doppler mode or whether it operates in the

so-called duplex mode by supe

und Diagnostics 17.3 Equipment Technology
Fig. 17.12 Duplex Doppler, B-mode
with sample volume (*left*), and PW
spectrum (*right*) und Diagnostics 17.3 Equipment Technology

Fig. 17.12 Duplex Doppler, B-mode

with sample volume (*left*), and PW

spectrum (*right*) und Diagnostics 17.3 Equipment Technology
17.3 Equipment Technology
1953
Fig. 17.12 Duplex Doppler, B-mode
with sample volume (*left*), and PW
1978

Example 19 and 19 Example 19 and 19 EXECUTE 18 Frobe:5412

For the Similar of the M-model of the 1212 from BM pulsed-wave (PW) Doppler technique uses the frame frequency) is too low.

Expected the M-model and also the A-, M- and B-mode

From heigh-PRF Dop **EXECUTE:**
 EXECUTE: The pulsed-wave (PW) Doppler technique uses the frame frequency) is too low.

Imaging methods and also the A-, M- and B-mode

imaging methods are processing of the transit time in-

be mond in all mo **PW Doppler**
 PW Doppler
 PUM Doppler technique uses the frame frequency) is too low.
 PUM Doppler technique uses the transit time in-
 PUM DOPPLEM TOPPLEM CONTABER DOPPLEM EXECUTE TO EXECUT THE MIGHT PUPERT DOPPLER EXECT THE EVALUAT THE VERT THE VERT THE WE UNDER THE WARD SURVEY CONDID THE SURVEY CONDIMITY INTO THE READ THE THE READ THE INTERNET DOPEN THE INTERNET DOPEN THE INTERNET DOPEND INTO THE SURVEY CONDUCT THE SURVEY ON THE S pulsed-wave (PW) Doppler technique uses the frame frequency) is too low.

is ereflection method and also the A-, M- and B-mode

The high-PRF Doppler techni

ging methods. The processing of the transit time in-

be found in pulse reflection method and also the A-, M- and B-mode
imaging methods. The processing of the transit time in-
be found in all modern duplex s
formation is used here to determine the sample volume are the depth selectivity

imaging methods. The processing of the transit time in-
formation is used here to determine the sample volume are the depth selectivity. It all
not used to display an image but rather to measure the depth selectivity. It formation is used here to determine the sample volume oped to avoid this effect of aliasin
position. Reflected signals from the sample volume are the depth selectivity. It allows
not used to display an image but rather to position. Reflected signals from the sample volume are the depth selectivity. It allow
not used to display an image but rather to measure the frequency to be shifted upw
velocity according to the Doppler principle.
FRF. Th not used to display an image but rather to measure the frequency to be shifte
velocity according to the Doppler principle. PRF. The price paid for
Similar to the M-mode, the time profile of the ve-
umes, which results in
l Similar to the M-mode, the time profile of the ve-
ty of blood flow is displayed on the monitor. The
ition of the sample volume can be changed and posi-
ed accurately by sight in duplex mode (Fig. 17.12).
The maximum velo locity of blood flow is displayed on the monitor. The selectivity.

position of the sample volume can be changed and posi-

The use of duplex systems with

tioned accurately by sight in duplex mode (Fig. 17.12). If from PW position of the sample volume can be changed and posi-

The use of duplex systems with at

tioned accurately by sight in duplex mode (Fig. 17.12). from PW to high-PRF is a useful ad

De measured using PW is limited by the tioned accurately by sight in duplex mode (Fig. 17.12). from PW to high-PRF is a use

The maximum velocity of blood flow which can

DW mode.

be measured using PW is limited by the repetition fre-

sample volumes, this li The maximum velocity of blood flow which can PW mode.

be measured using PW is limited by the repetition fre-

quency of the pulses (PRF). By using other, additional analysis in order to make it possible

signally volumes be measured using PW is limited by the repetition fre-
quency of the pulses (PRF). By using other, additional analy
sample volumes, this limitation – which results from ical f
what is known as aliasing – is shifted into a

move of the pulses (PRF). By using other, additional analysis in order to make it possible
ple volumes, this limitation – which results from ical flows in the characteristics of the
t is known as aliasing – is shifted into sample volumes, this limitation – which results from ical flows in the characteristic
what is known as aliasing – is shifted into a velocity displayed. The Doppler sig
range which is no longer diagnostically relevant.
Four what is known as aliasing – is shifted into a velocity displayed. The Doppler signal
range which is no longer diagnostically relevant. The PW popler technique is imited by what is known components can be equated with
The P range which is no longer diagnostically relevant.

High-PRF Doppler

High-PRF Doppler

The PW Doppler technique is limited by what is known

components can be equated with

as *alicasing*. Above a certain frequency and vel **Figh-PRF Doppler**
 Example 10 Fourier transform or similar meth

The PW Doppler technique is limited by what is known

as *aliasing*. Above a certain frequency and velocity of Further information about the vel-

blood f

 5.4
 $\frac{5.4}{10}$
 $\frac{1}{10}$
 $\frac{1}{10$ be found in all modern duplex systems was devel- $\frac{1}{2}$

backwards because the scanning frequency (television

frame frequency) is too low.

The high-PRF Doppler technique which should

be found in all modern duplex systems was devel-

oped to avoid this effect of al Sevin: 2.5 and
backwards because the scanning frequency (television
frame frequency) is too low.
The high-PRF Doppler technique which should
be found in all modern duplex systems was devel-
oped to avoid this effect of al Sevent 2:25

backwards because the scanning frequency (television

frame frequency) is too low.

The high-PRF Doppler technique which should

be found in all modern duplex systems was devel-

oped to avoid this effect of **Example 1988**
 PRF. The price paid for this **EVALUATE:**
 selectivity. kwards because the scanning frequency (television
the frequency) is too low.
The high-PRF Doppler technique which should
found in all modern duplex systems was devel-
d to avoid this effect of aliasing while maintaining
de backwards because the scanning frequency (television
frame frequency) is too low.
The high-PRF Doppler technique which should
be found in all modern duplex systems was devel-
oped to avoid this effect of aliasing while mai The high-PRF Doppler technique which should
found in all modern duplex systems was devel-
d to avoid this effect of aliasing while maintaining
depth selectivity. It allows the aliasing cut-off
juency to be shifted upwards be found in all modern duplex systems was devel-
oped to avoid this effect of aliasing while maintaining
the depth selectivity. It allows the aliasing cut-off
frequency to be shifted upwards by increasing the
PRF. The pric oped to avoid this effect of aliasing while maintaining
the depth selectivity. It allows the aliasing cut-off
frequency to be shifted upwards by increasing the
PRF. The price paid for this is multiple sample vol-
umes, whi **Example 12.** The big separate crysses of the separate crystals, a transmission crys-
Two physically separate crys- Part C 18. The separate crys- Part C 18. The separate crys- Part C 18. The model of the set of the set of

PW mode.

the depth selectivity. It allows the aliasing cut-off
frequency to be shifted upwards by increasing the
PRF. The price paid for this is multiple sample vol-
umes, which results in a slight restriction in the depth
selectiv frequency to be shifted upwards by increasing the
PRF. The price paid for this is multiple sample vol-
umes, which results in a slight restriction in the depth
selectivity.
The use of duplex systems with automatic switchin PRF. The price paid for this is multiple sample volumes, which results in a slight restriction in the depth
selectivity.
The use of duplex systems with automatic switching
from PW to high-PRF is a useful addition to the pu is, which results in a slight restriction in the depth
ctivity.
The use of duplex systems with automatic switching
n PW to high-PRF is a useful addition to the pure
mode.
Today, duplex devices should include frequency
lysi selectivity.
The use of duplex systems with automatic switching
from PW to high-PRF is a useful addition to the pure
PW mode.
Today, duplex devices should include frequency
analysis in order to make it possible to detect p The use of duplex systems with automatic switching
from PW to high-PRF is a useful addition to the pure
PW mode.
Today, duplex devices should include frequency
analysis in order to make it possible to detect patholog-
ical

from PW to high-PRF is a useful addition to the pure
PW mode.
Today, duplex devices should include frequency
analysis in order to make it possible to detect patholog-
ical flows in the characteristics of the Doppler spectr PW mode.

Today, duplex devices should include frequency

analysis in order to make it possible to detect patholog-

ical flows in the characteristics of the Doppler spectrum

displayed. The Doppler signal is broken down a Today, duplex devices should include freq
analysis in order to make it possible to detect path
ical flows in the characteristics of the Doppler spe
displayed. The Doppler signal is broken down
displayed in its individual f flows in the characteristics of the Doppler speaking
played. The Doppler signal is broken down
played in its individual frequency component
rier transform or similar methods (Fig. 17.8).
When the angle of incidence is know displayed. The Doppler signal is broken down and
displayed in its individual frequency components by
Fourier transform or similar methods (Fig. 17.8).
When the angle of incidence is known, frequency
components can be equat displayed in its individual frequency components by
Fourier transform or similar methods (Fig. 17.8).
When the angle of incidence is known, frequency
components can be equated with velocity components.
Further information

Medical Imaging
tal and a reception crystal, are accommodated in In order to be able to disting
a probe and operate simultaneously. Whereas one crys-
tal constantly transmits, the second crystal continuously information (B **Medical Imaging**

a probe and operate simultaneously. Whereas one crys-

a probe and operate simultaneously. Whereas one crys-

information from the morpholog

information (B-mode), it is display

information (B-mode), i Medical Imaging

tal and a reception crystal, are accommodated in In order to be able

a probe and operate simultaneously. Whereas one crys-

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tal constantly transmits, the second crystal continuou **Medical Imaging**
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tal and a reception crystal, are accommodated

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tal constantly transmits, the second crystal continuous

receives the reflected signals. Alternatively, i **Solution**
 Solution and a reception crystal, are accommodated in In order to be able to obe and operate simultaneously. Whereas one crys-

information from the morphonstantly transmits, the second crystal continuously i **Medical Imaging**
 Is a and a reception crystal, are accommodated in

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tal constantly transmits, the second crystal continuously informa **Medical Imaging**

tal and a reception crystal, are accommodated in In order to be able to

a probe and operate simultaneously. Whereas one crys-

tal constantly transmits, the second crystal continuously information (B-m

tal and a reception crystal, are accommodated in In order to be able to distintion a probe and operate simultaneously. Whereas one crys-

are are information from the morphology

receives the reflected signals. Alternative tal and a reception crystal, are accommodated in In order to be able to distinguited and operate simultaneously. Whereas one crys-
information from the morphological constantly transmits, the second crystal continuously i tal and a reception crystal, are accommodated in In order to be able to dist
a probe and operate simultaneously. Whereas one crys-
information from the morpholog
tal constantly transmits, the second crystal continuously in a probe and operate simultaneously. Whereas one crys-

information from the morp

tal constantly transmits, the second crystal continuously

information (B-mode), it is deceives the reflected signals. Alternatively, it is tal constantly transmits, the second crystal continuously information (B-mode), it is differencieves the reflected signals. Alternatively, it is also (Fig. 17.13).

possible to use groups of crystals, e.g. in a phased arra receives the reflected signals. Alternatively, it is also (Fig. 17.13).

possible to use groups of crystals, e.g. in a phased array and probe of flow is given with the colors

Due to the continuous transmission, depth mapp selectivity. Due to the continuous transmission, depth mapp
o longer possible, however, as is it is not possi
neasure pulse transit times. The velocities measu
rather divided along the entire path of the m
ng beam. The resulting advant is no longer possible, however, as is it is not possible
to measure pulse transit times. The velocities measured
additional standardized color coding s
are rather divided along the entire path of the mea-
vidual color Dop to measure pulse transit times. The velocities measured
additional standardized color coding
are rather divided along the entire path of the mea-
vidual color Doppler systems, too,
suring beam. The resulting advantage is are rather divided along the entire path of the mea-
suring beam. The resulting advantage is the ease with
systems (color ch
which it is possible to measure high velocities of blood less follow subject
flow, such as those may beam. The resulting advantage is the ease with systems (color charts) can color it is possible to measure high velocities of blood less follow subjective pre v , such as those which are to be found in high-grade The receives the reflected signals. Alternatively, it is also (Fig. 17.13).

possible to use gronys of crystals, e.g. in a phased array α generally accepted illustration of the utxasound probe.

Dureto the continuous trans

flow, such as those which are to be found in high-grade

stenoses. The disadvantage of this method compared

with the PW Doppler technique is the lack of depth

with the PW Doppler technique is the lack of depth

the effe stenoses. The disadvantage of this method compared artifact in the color Distribution with the PW Doppler technique is the lack of depth the effect that, in the selectivity.

color Doppler technique is the lack of depth t with the PW Doppler technique is the lack of depth
selectivity.
Selectivity.
Color Doppler
Color Doppler
The industrial development of the first color Doppler in played is seen when the maximum velocity
The industrial dev selectivity. coded blue

correct correct correct correct correct correct position of the first color Doppler in played is expan (ALOKA, 1985, SSD-880) was an important step turns into in the development of ultrasound diagn Color Doppler

completely surrounded by blue (F

be seen when the maximum velocit

Dapan (ALOKA, 1985, SSD-880) was an important step

in the development of therasound diagnostics.

The color Doppler is in principle a PW Color Doppler

The industrial development of the first color Doppler in plays

Japan (ALOKA, 1985, SSD-880) was an important step turns

in the development of ultrasound diagnostics. A

The color Doppler is in principle a

In order to be able to distinguish the Doppler
primation from the morphological black-and-white
primation (B-mode), it is displayed with color-coding
 $y, 17.13$) In order to be able to distinguish the Doppler
information from the morphological black-and-white
information (B-mode), it is displayed with color-coding
(Fig. 17.13).
A generally accepted illustration of the direction In order to be able to distinguish the Doppler
information from the morphological black-and-white
information (B-mode), it is displayed with color-coding
(Fig. 17.13).
A generally accepted illustration of the direction
of (Fig. 17.13). In order to be able to distinguish the Doppler
transition from the morphological black-and-white
transition (B-mode), it is displayed with color-coding
 $\frac{1}{2}$, 17.13).
A generally accepted illustration of the direction

In order to be able to distinguish the Doppler
information from the morphological black-and-white
information (B-mode), it is displayed with color-coding
(Fig. 17.13).
A generally accepted illustration of the direction
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information from the morphological black-and-white
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A generally accepted illustration of the direction
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information from the morphological black-and-white
information (B-mode), it is displayed with color-coding
(Fig. 17.13).
A generally accepted illustration of the direction
of Francisco from the morphological black-and-white

formation (B-mode), it is displayed with color-coding

1.17.13).

A generally accepted illustration of the direction

flow is given with the colors red (towards the ul-

ou information (B-mode), it is displayed with color-coding
(Fig. 17.13).
A generally accepted illustration of the direction
of flow is given with the colors red (towards the ul-
trasound probe) and blue (away from the ultras (Fig. 17.13).

A generally accepted illustration of the direction

of flow is given with the colors red (towards the ul-

trasound probe) and blue (away from the ultrasound

probe). However, it must be mentioned that ther A generally accepted illustration of the direction
of flow is given with the colors red (towards the ul-
trasound probe) and blue (away from the ultrasound
probe). However, it must be mentioned that there is no
additional

which it is possible to measure high velocities of blood
flow subjective preferences.
flow, such as those which are to be found in high-grade
the effect of aliasing mentioned a
stenoses. The disadvantage of this method co of flow is given with the colors red (towards the ul-
trasound probe) and blue (away from the ultrasound
probe). However, it must be mentioned that there is no
additional standardized color coding system. In the indi-
vidu trasound probe) and blue (away from the ultrasound
probe). However, it must be mentioned that there is no
additional standardized color coding system. In the indi-
vidual color Doppler systems, too, various color coding
s probe). However, it must be mentioned that there is no
additional standardized color coding system. In the indi-
vidual color Doppler systems, too, various color coding
systems (color charts) can be accessed which more or
 additional standardized color coding system. In the indi-
vidual color Doppler systems, too, various color coding
systems (color charts) can be accessed which more or
less follow subjective preferences.
The effect of alias al color Doppler systems, too, various color coding
tems (color charts) can be accessed which more or
follow subjective preferences.
The effect of aliasing mentioned above occurs as an
fact in the color Doppler technique, systems (color charts) can be accessed which more or
less follow subjective preferences.
The effect of aliasing mentioned above occurs as an
artifact in the color Doppler technique, too. This has
the effect that, in the mi less follow subjective preferences.
The effect of aliasing mentioned above occurs as an artifact in the color Doppler technique, too. This has
the effect that, in the middle of a flow which is color-
coded blue, for exampl fact in the color Doppler technique, too. This has
effect that, in the middle of a flow which is color-
ed blue, for example, a red spot appears which is
ipletely surrounded by blue (Fig. 17.14). This can
eeen when the max the effect that, in the middle of a flow which is color-
coded blue, for example, a red spot appears which is
completely surrounded by blue (Fig. 17.14). This can
be seen when the maximum velocity which can be dis-
played

aliasing. Expressed at precisely surounded by onde (Fig. 17.14). This can
eeen when the maximum velocity which can be dis-
red is exceeded at precisely this point. The color then
the sinto the other color.
As it is obviously imposs

$$
y \text{quist limit} = f_{\text{Ny}} = \frac{\text{PRF}}{2} \, .
$$

Fig. 17.13 Color Doppler with alias-
ing ing

MESSICERT POSITOR THE POSITOR POSITOR THE POSITOR THE POSITOR CONTRACT THE POSITOR CONTRACT THE POSITOR CONTRACT THE POSITOR CONTRACT THE POSITOR OF THE SMALL STATE SMALL STATE SMALL STATE SMALL STATE OF THE SMALL STATE SM **EXECUTE:**

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ISBN CREATE THE CONDITIONS OF THE CONDITIONS OF THE CONDITIONS

ISBN CREATER THE CONDITIONS OF THE C 1196bH Routine C Probe:9130

Aliasing can even be useful here in that it shows us

Iar lumen better than the normal color

In order to measure the highest velocity, we position mation are not sufficient for further

In or Aliasing can even be useful here in that it shows us lar lumen better than the normal coltrar to the point in the blood flow with the highest velocity. to, as the low amplitudes of the availing the order to measure the hi Aliasing can even be useful here in that it shows us
the point in the blood flow with the highest velocity.
In order to measure the highest velocity, we position
the sample volume at this alias position. Using the color
Do point in the blood flow with the highest velocity
order to measure the highest velocity, we position
sample volume at this alias position. Using the col-
opler technique it is then possible to detect and pi
at the extent o

Doppler technique it is then possible to detect and pin-
point the extent of pathological flows such as jets and to
locate small vessels in real-time mode. Tech
If the color Doppler technique is also added to the At this
d From the extent of paintological flows such as jets and to
locate small vessels in real-time mode.
If the color Doppler technique is also added to the
duplex mode so that the B-mode, color Doppler and
Doppler spectrum are From the color Doppler technique is also added to
the color Doppler technique is also added to
duplex mode so that the B-mode, color Doppler a
Doppler spectrum are all displayed, this is referred
as the triplex mode.
Power • The color Doppler detailing is also added to the

Doppler spectrum are all displayed, this is referred to

as the triplex mode.

• Power Doppler

• Power Doppler

• The term *power Doppler* is understood as meaning an-

-
-
-

Power Doppler
 Power Doppler

The term power Doppler is understood as meaning an-

rate, two-dimensional illustration of

other version of the color Doppler technique. It is also through which blood is actually flo

s **Power Doppler**

The term *power Doppler* is understood as meaning an-

The term *power Doppler* is understood as meaning an-

other version of the color Doppler technique. It is also through which blood is actual

known The term *power Doppler* is understood as meaning an-
other version of the color Doppler technique. It is also through which blood is actually fl
known by the following synonyms:
in the received by the following synonyms:
 other version of the color Doppler technique. It is also through which blood is actually

known by the following synonyms:

is of advantage particularly in the
 • Amplitude Doppler
 • Color angio
 • Power color, etc. **EXECUTE:**
 EXECU • Amplitude Doppler
• Color angio
• Color angio
• Color angio
• Power color, etc.
• The power Doppler technique also uses the Doppler phenomena in transmission p
that to image blood flow. However, it does not dis-
termely Frame Color angio

Color angio

Color angio

Color angio

Power color, etc.

The power Doppler technique also uses the Doppler phenomena in transmission pulls

play the velocity of the flow using color-coding, but spatial **EXECT MANUSE THE SLOW THE CONCRETE THE POWER CONTROLL THE POWER STAND AND SHEW the more of reflex and the velocity of the flow using color-coding**

Position

Position
 $\frac{1 \text{MA}}{1 \text{MA}}$
 $\frac{1}{1 \text{NA}}$
 Position

Fosition

TMA 14

Zoomfactor x0.99

lar lumen better than the normal color Doppler is able

to, as the low amplitudes of the available signal infor-

mation are not sufficient for further analysis with the

norma mation are not sufficient for further analysis with the
are not sufficient for further analysis with the
normation are not sufficient for further analysis with the
normal color Doppler.
High-Pesolution Modern Color Doppler Position

Think 14

Zoomfactor 30.99

lar lumen better than the normal color Doppler is able

to, as the low amplitudes of the available signal infor-

marion are not sufficient for further analysis with the

normal color Position

¹ IMA¹⁴

Comtacter 0.099

Ilumen better than the normal color Doppler is able

as the low amplitudes of the available signal infor-

ion are not sufficient for further analysis with the

mal color Doppler.
 FOSIDOR

TIMATA

TRIMMATA

TRIMMATA

At this point it is worth mention of the available signal information are not sufficient for further analysis with the

normal color Doppler.

High-Resolution Modern Color Doppler

Tech

Techniques

In order to measure the highest velocity, we position mation are not sufficient for furthe

the sample volume at this alias position. Using the color normal color Doppler.

Doppler technique it is then possible to detect the sample volume at this alias position. Using the color normal color Doppler.

Doppler technique it is then possible to detect and pin-

point the extent of pathological flows such as jets and to

locate small vessels i Doppler spectrum are all displayed, this is referred to known by various different nas the triplex mode.

The term power Doppler

The term power Doppler is understood as meaning an-

The term power Doppler is understood as as the triplex mode.
 Solution to the control of the co velopment of the power Doppler is able
to, as the low amplitudes of the available signal infor-
mation are not sufficient for further analysis with the
normal color Doppler.
High-Resolution Modern Color Doppler
Techniques
 lar lumen better than the normal color Doppler is able
to, as the low amplitudes of the available signal infor-
mation are not sufficient for further analysis with the
normal color Doppler.
High-Resolution Modern Color Dop lar lumen better than the normal color Doppler is able
to, as the low amplitudes of the available signal infor-
mation are not sufficient for further analysis with the
normal color Doppler.
High-Resolution Modern Color Do lar lumen better than the normal color Doppler is able
to, as the low amplitudes of the available signal infor-
mation are not sufficient for further analysis with the
normal color Doppler.
High-Resolution Modern Color Do to, as the low amplitudes of the available signal information are not sufficient for further analysis with the
normal color Doppler.

High-Resolution Modern Color Doppler

Techniques

At this point it is worth mentioning mation are not sufficient for further analysis with the
normal color Doppler.
 High-Resolution Modern Color Doppler
 Techniques

At this point it is worth mentioning a further de-

velopment of the power Doppler techni normal color Doppler.

High-Resolution Modern Color Doppler

Techniques

At this point it is worth mentioning a further de-

velopment of the power Doppler technique which is

known by various different names (e.g. eFLOW, High-Resolution Modern Color Doppler

Techniques

At this point it is worth mentioning a further de-

velopment of the power Doppler technique which is

known by various different names (e.g. eFLOW, dy-

namic flow, etc.) High-Resolution Modern Color Doppler

Techniques

At this point it is worth mentioning a further de-

velopment of the power Doppler technique which is

known by various different names (e.g. eFLOW, dy-

namic flow, etc.) Techniques
At this point it is worth mentioning a further de-
velopment of the power Doppler technique which is
known by various different names (e.g. eFLOW, dy-
namic flow, etc.). In some modern units, the method
can be f this point it is worth mentioning a further de-
opment of the power Doppler technique which is
wn by various different names (e.g. eFLOW, dy-
inc flow, etc.). In some modern units, the method
be found with markedly higher velopment of the power Doppler technique which is
known by various different names (e.g. eFLOW, dy-
namic flow, etc.). In some modern units, the method
can be found with markedly higher spatial resolution
values (<0.3 mm). known by various different names (e.g. eFLOW, dy-
namic flow, etc.). In some modern units, the method
can be found with markedly higher spatial resolution
values $(0.3 mm)$. It is extremely well suited for accu-
rate namic flow, etc.). In some modern units, the method
can be found with markedly higher spatial resolution
values $(<0.3 \text{ mm})$. It is extremely well suited for accu-
rate, two-dimensional illustration of the vascular lumina
 can be found with markedly higher spatial reso
values $(<0.3 \text{ mm})$. It is extremely well suited for
rate, two-dimensional illustration of the vascular h
through which blood is actually flowing. This m
is of advantage parti two-dimensional illustration of the vascular lumina

wugh which blood is actually flowing. This method

f advantage particularly in the case of slow veloci-

or small vessels and when imaging a complex organ

cularization, **Example 12**
 Example 12

through which blood is actually flowing. This method
is of advantage particularly in the case of slow veloci-
ties or small vessels and when imaging a complex organ
vascularization, but also in the case of stenoses.
It is is of advantage particularly in the case of slow veloci-
ties or small vessels and when imaging a complex organ
vascularization, but also in the case of stenoses.
It is made possible using modern pulse generators
(beamform ties or small vessels and when imaging a complex organ
vascularization, but also in the case of stenoses.
It is made possible using modern pulse generators
(beamformers) which shorten and optimize transient
phenomena in tr vascularization, but also in the case of stenoses.

It is made possible using modern pulse generators

(beamformers) which shorten and optimize transient

phenomena in transmission pulses. This makes ex-

tremely short pul

und Diagnostics 17.3 Equipment Technology
Fig. 17.14 Vascularization in the fetal
brain, imaged using eFlow technology und Diagnostics 17.3 Equipment Technology

Fig. 17.14 Vascularization in the fetal

brain, imaged using eFlow technology

Fig. 17.15 Tissue Doppler imaging
(TDI) (TDI)

Form and order of myocardium (Fig. 17.15) and thus allows

and the segments of the blood, low-pass filters are necessary here in-

segments of the blood, low-pass filters are necessary here in-

stead of the high-pass fil **Example 19**
 Example 19 The movement of the wall, e.g. as a result of a my-

and the move and the move is considerably slower than

that of the blood, low-pass filters are necessary here in-

stead of the high-pass filters which are customary in **Example 14:1Herz** Probe:5299 Probe:5299 Book Biograph Considerably slower than 17.3.3 Types of Probes that of the blood, low-pass filters are necessary here instead of the high-pass filters which are customary in the The ment in the myocardium is considerably slower than **17.3.3 Types of Pro**
that of the blood, low-pass filters are necessary here in-
stead of the high-pass filters which are customary in the The types of probes us
blood flo

 $\frac{5.60 \text{ m}}{17.3.3}$ Types of Probes
The types of probes used today are primarily divided
into two groups. Mechanical probes and electronic
probes, or combinations of the two, are almost exclu-
sively used **Extra i.6.2020**
 Extra i.6.2020
 IT.3.3 Types of Probes

The types of probes used today are primarily divided

into two groups. Mechanical probes and electronic

probes, or combinations of the two, are almost exclu-
 $\frac{1}{2}$
 Probes
 17.3.3 Types of Probes

The types of probes used today are primarily divided

into two groups. Mechanical probes and electronic

probes, or combinations of the two, are almost exclu-

sively used.
 $\frac{5.7.1}{6}$
 Signal Example 12.5 and Section
 Signal Express of Probes

The types of probes used today are primarily contours The types of probes used today are primarily contours and electrophos, or combinations of S. W. 1. 15.0mm

Bepthi 10.2cm

Mechanical Probes

Uypes of Probes

Uypes of Probes

Uypes and electronic

Deck, or combinations of the two, are almost exclu-

Uy used.

Mechanical Probes

Ay, these are still used for spe **17.3.3 Types of Probes**

The types of probes used today are primarily divided

into two groups. Mechanical probes and electronic

probes, or combinations of the two, are almost exclu-

sively used.

Mechanical Probes

Tod

Fig. 17.16a–c Sound field geometry
of various types of probes Fig. 17.16a-c Sound field geometry
of various types of probes

generating a two-dimensional image is carried out
a small electric motor in the ultrasound probe.
Electronic Probes
tronic probes are used far more frequently, and we
w these as linear, convex and sector scanners. They for generating a two-dimensional image is carried out
by a small electric motor in the ultrasound probe.

Electronic Probes

Electronic probes are used far more frequently, and we us the

know these as linear, convex and s

by a small electric motor in the ultrasound probe. The eral cryst
one another
expect to the interpretent of the set of their deflection geometry and
their d

their deflection method (Fig. 17.16).
The deflection of the ultrasonic beam is realized
electronically by time-shifted activation of a large num-
ber of crystals; no mechanical wearing parts are used
whatsoever. The maximu

Ultrasound Diagnostics

for generating a two-dimensional image is carried out

by a small electric motor in the ultrasound probe.

enal crystals, and in this case six crystals

one another are used, for example.

Flectroni Ultrasound Dia

for generating a two-dimensional image is carried out

by a small electric motor in the ultrasound probe.

Electronic Probes

Electronic probes

Electronic probes

Electronic probes

Electronic probes

Elec Ultrasound Diagnostics

for generating a two-dimensional image is carried out

by a small electric motor in the ultrasound probe.

Electronic Probes

Electronic Probes

Electronic Probes

Electronic probes

Electronic prob Ultrasound Diagnostics

for generating a two-dimensional image is carried out

by a small electric motor in the ultrasound probe.

eral crystals, and in this case six

one another are used, for example

Electronic probes
 Ultrasound Diagnostics

for generating a two-dimensional image is carried out

by a small electric motor in the ultrasound probe.

Electronic Probes

Electronic Probes

Electronic probes

Electronic probes

Electronic prob Ultrasound Diagnos

generating a two-dimensional image is carried out

A scanning line is always

eral crystals, and in this case

one another are used, for exar

tive crystals is also called an

tronic probes

tronic prob for generating a two-dimensional image is carried out
by a small electric motor in the ultrasound probe.

one another are used, for example

Electronic probes

Electronic probes

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Electronic probes

Elect for generating a two-dimensional image is carried out

by a small electric motor in the ultrasound probe.

Electronic Probes

Electronic probes

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E for generating a two-dimensional image is carried out
by a small electric motor in the ultrasound probe.

eral crystals, and in this case six crys

one another are used, for example.

Electronic probes

Electronic probes
 Electronic Probes

Electronic probes are used far more frequently, and we

use the frequently used term line

know these as linear, convex and sector scanners. They

tal is activated by an electronic

differ in principle Electronic probes are used far more frequently, and we us the frequently used term linear

know these as linear, convex and sector scanners. They tal is activated by an electronic pu

differ in principle due to their defl know these as linear, convex and sector scanners. They tal is activated by an electronic publifier in principle due to their deflection geometry and a sound wave which merges with their deflection method (Fig. 17.16).

Th differ in principle due to their deflection geometry and
their deflection method (Fig. 17.16). a wave front. As a resume the deflection of the ultrasonic beam is realized a sound field with a foce
electronically by time-sh Ultrasound Diagnostics | 17.3 Equipment Technology 357

A scanning line is always constructed using sev-

crystals, and in this case six crystals lying next to

another are used, for example. This group of ac-

crystals is Ultrasound Diagnostics 17.3 Equipment Technology

A scanning line is always constructed using sev-

eral crystals, and in this case six crystals lying next to

one another are used, for example. This group of ac-

tive cry Ultrasound Diagnostics 17.3 Equipment Technology

A scanning line is always constructed using sev-

eral crystals, and in this case six crystals lying next to

one another are used, for example. This group of ac-

tive cry Ultrasound Diagnostics 17.3 Equipment Technology

A scanning line is always constructed using sev-

eral crystals, and in this case six crystals lying next to

one another are used, for example. This group of ac-

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A scanning line is always constructed using sev-

eral crystals, and in this case six crystals lying next to

one another are used, for example. This group of ac-

tive cry Ultrasound Diagnostics 17.3 Equipment Technology

A scanning line is always constructed using sev-

eral crystals, and in this case six crystals lying next to

one another are used, for example. This group of ac-

tive cry Ultrasound Diagnostics 17.3 Equipment Technology

A scanning line is always constructed using sev-

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A scanning line is always constructed using sev-

eral crystals, and in this case six crystals lying next to

one another are used, for example. This group of ac-

tive cry Ultrasound Diagnostics 17.3 Equipment Technology

A scanning line is always constructed using sev-

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one another are used, for example. This group of ac-

tive cry A scanning line is always constructed using sev-
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tive crystals is also called an array, which has given
us the frequently used term linear array. Each crys-
ta one another are used, for example. This group of ac-
tive crystals is also called an array, which has given
us the frequently used term linear array. Each crys-
tal is activated by an electronic pulse and transmits
a soun tive crystals is also called an array, which has given
us the frequently used term linear array. Each crys-
tal is activated by an electronic pulse and transmits
a sound wave which merges with the others to form
a wave fr us the frequently used term linear array. Each crystal is activated by an electronic pulse and transmits
a sound wave which merges with the others to form
a wave front. As a result of various physical effects,
a sound fie tal is activated by an electronic pulse and transmits
a sound wave which merges with the others to form
a wave front. As a result of various physical effects,
a sound field with a focal constriction is generated in
the ty a sound wave which merges with the others to form
a wave front. As a result of various physical effects,
a sound field with a focal constriction is generated in
the typical sound field geometry illustrated (solid line).
A tive crystals is also called an array, which has given
us the frequently used term linear array. Each crys-
tal is activated by an electronic pulse and transmits
a sound wave which merges with the others to form
a wave fr

Fig. 17.17 Scanning principle of a lin-
ear probe Fig. 17.17 Scanning principle of a lin-
ear probe

Triffed

u pulse

If the dual pulse

Sumposed array principle

Sumposed array principle

Convex Probes. In the convex probe, also k

a curved array, the same method is used. The or

ence here is that the crystals are not a

Convex Probes. In the convex probe, also known as line). In addition, in electronic particle a curved array, the same method is used. The only differ-
ence multiple focal zones simulta
ence here is that the crystals are no Convex Probes. In the convex probe, also known as line). In addition, in electron a curved array, the same method is used. The only differ-
exerce multiple focal zones sime
ence here is that the crystals are not arranged a curved array, the same method is used. The only differ-

ence here is that the crystals are not arranged on a linear

it possible to produce a sharp in

contact surface but on a convex contact surface. Differ-

entire d ence here is that the crystals are not arranged on a linear it possible to produce a sharp image
contact surface but on a convex contact surface. Differ-
entire depth of field, although this c
ent radii of curvature are a contact surface but on a convex contact surface. Differ-
entire depth of field, although then tradii of curvature are available for different fields of
of the image frequency. This is c
use (Fig. 17.16b). (Fig. 17.20). Th ent radii of curvature are available for different fields of

use (Fig. 17.16b). (Fig. 17.20). The image regions of the

sector Probes. In the electronic sector, also called memory and are finally combined to

a phased arr use (Fig. 17.16b). (Fig. 17.20). The image regions of

zones are recorded one after the

a phased array, considerably fewer crystals are used image which is focused throughou

than in the linear or convex array. The elect **Sector Probes.** In the electronic sector, also called memory and are fit a phased array, considerably fewer crystals are used image which is focution in the linear or convex array. The electronic activa-

than in the lin for *Probes*. In the electronic sector, also called memory and are finally combined
hased array, considerably fewer crystals are used image which is focused throughout
in the linear or convex array. The electronic activa-
 a phased array, considerably fewer crystals are used image which is focused thr
than in the linear or convex array. The electronic activa-
tion is carried out with a time shift or phase shift, which four of these are usua than in the linear or convex array. The electronic activa-

the small control is carried out with a time shift or phase shift, which four of these are usually used

is where the term phased array comes from. However, namic tion is carried out with a time shift or phase shift, which four of these are us
is where the term phased array comes from. However, namic focusing bec:
this is no longer done from the outside in but contin-
of a buffer m there the term phased array comes from. However, namic focusing because, as already is no longer done from the outside in but contin-
of a buffer memory reduces the image sulf from one side to the other, with the result th this is no longer done from the outside in but contin-

of a buffer memory reduces the i

uously from one side to the other, with the result that

using conventional array technol

an oblique wave front is generated (Fig. uously from one side to the other, with the result that using conventional array techncan oblique wave front is generated (Fig. 17.18). Chang-
inque is only possible in the long
ing the activation at an appropriate speed a

ing the activation at an appropriate speed achieves an ultrasound p
oscillation in the beam, which in turn produces a two-
dimensional image in the form of a sector.
The advantage of sector probes can be clearly seen
from dimensional image in the form of a sector.
The advantage of sector probes can be clearly
from the example of avoiding rib shadows (Fig. 17
as the small contact surface of the sector probe ena
examination through the interc

examination through the intercostal spaces. The sound projection of the crystals. Both at close range the divergence of the ultrasonic beams at greater depths, the ultrasound can propagate relation windly poor in deeper ti A disadvantage of the sector technique is caused by
the cystals. Both at close range a
the divergence of the ultrasonic beams at greater depths,
the ultrasound can propagate relative
highly poor in deeper tissues. The gaps the divergence of the ultrasonic beams at greater depths, the ultrasound can propagation ingly poor in deeper tissues. The gaps which appear are extends in an unwanted fa filled in by the device using interpolations. The which results in the lateral resolution becoming increas-

in the actual two-dimensional sound

ingly poor in deeper tissues. The gaps which appear are

extends in an unwanted fashion at

filled in by the device using int ingly poor in deeper tissues. The gaps which appear are

filled in by the device using interpolations.
 17.3.4 Focusing
 17.3.4 Focusing
 17.3.4 Focusing
 17.3.4 Focusing
 18.4 Focusing
 18.4 Focusing
 18.4 F filled in by the device using interpolations.
 17.3.4 Focusing the production is a result, very small vessels,

As a result, very small vessels,

The focal constriction, mentioned above, is important in the middle, and e

manufacturers usually relate to the focal area. The focal
position is also crucial, however. Ideally, the focal posi-
tion should be precisely where the organ to be examined
is located. This is where the biggest advantage manufacturers usually relate to the focal area. The focal
position is also crucial, however. Ideally, the focal posi-
tion should be precisely where the organ to be examined
to cated. This is where the biggest advantage of manufacturers usually relate to the focal area. The focal
position is also crucial, however. Ideally, the focal posi-
tion should be precisely where the organ to be examined
is located. This is where the biggest advantage manufacturers usually relate to the focal area. The focal
position is also crucial, however. Ideally, the focal posi-
tion should be precisely where the organ to be examined
is located. This is where the biggest advantage manufacturers usually relate to the focal area. The focal
position is also crucial, however. Ideally, the focal posi-
tion should be precisely where the organ to be examined
is located. This is where the biggest advantage manufacturers usually relate to the focal area. The focal
position is also crucial, however. Ideally, the focal posi-
tion should be precisely where the organ to be examined
is located. This is where the biggest advantage nufacturers usually relate to the focal area. The focal
tition is also crucial, however. Ideally, the focal posi-
should be precisely where the organ to be examined
ocated. This is where the biggest advantage of elec-
ic p manufacturers usually relate to the focal area. The focal
position is also crucial, however. Ideally, the focal posi-
tion should be precisely where the organ to be examined
is located. This is where the biggest advantage manufacturers usually relate to the focal area. The focal
position is also crucial, however. Ideally, the focal posi-
tion should be precisely where the organ to be examined
is located. This is where the biggest advantage manufacturers usually relate to the focal area. The focal
position is also crucial, however. Ideally, the focal posi-
tion should be precisely where the organ to be examined
is located. This is where the biggest advantage

sound wave tivated simultaneously; instead, the outer crystals are For a compound the crystals are not arranged on a linear incompound in the crystal of shifting the focal propound and pulse of the crystal stativated first, followed by instead, incircusing the crystals incompound are act For a convex probe, also known as line). In dynamic focusing

By possibility of shifting the focal p

sound wave

a crivated simultaneously; instead,

sound wave

a crivated first, followed by the c

a crivation of the foc **Entired compound**
 Entrep 1980
 Extreme 2091
 Extreme 1991
 Extreme 2091
 Extreme 2091
 Extreme 2091
 Extreme 2 SECO EXECT PROPES. In the electronic sector, also called the image which is carried on is called the electronic sector Probes. In the convex probe, also known as line). In addition, in electronic parameters is that the c **B** Phased array principle

activated first, followed by the cen

sition of the focus is determined

activation between the outer and

activation between the outer and

activation between the outer and

activation simples stition of the focus is determine

activation between the outer an

activation between the outer an

activation state array, the same method is used. The only differ-

ence here is that the crystals are not arranged on a l manufacturers usually relate to the focal area. The focal
position is also crucial, however. Ideally, the focal posi-
tion should be precisely where the organ to be examined
is located. This is where the biggest advantage position is also crucial, however. Ideally, the focal posi-
tion should be precisely where the organ to be examined
is located. This is where the biggest advantage of elec-
tronic probes over mechanical probes is to be fou ion should be precisely where the organ to be examined
is located. This is where the biggest advantage of elec-
tronic probes over mechanical probes is to be found: the
possibility of shifting the focal position electronic is located. This is where the biggest advantage of electronic probes over mechanical probes is to be found: the possibility of shifting the focal position electronically.

Dynamic Focusing, the crystals are no longer all a tronic probes over mechanical probes is to be found: the
possibility of shifting the focal position electronically.
 Dynamic Focusing, the crystals are no longer all ac-

tivated simultaneously; instead, the outer cryst possibility of shifting the focal position electronically.

Dynamic Focusing

In dynamic focusing, the crystals are no longer all ac-

tivated simultaneously; instead, the outer crystals are

activated first, followed by t **Dynamic Focusing**
In dynamic focusing, the crystals are no longer all ac-
tivated simultaneously; instead, the outer crystals are
activated first, followed by the central crystals. The po-
sition of the focus is determine **Dynamic Focusing**
In dynamic focusing, the crystals are no longer all ac-
tivated simultaneously; instead, the outer crystals are
activated first, followed by the central crystals. The po-
sition of the focus is determin In dynamic focusing, the crystals are no longer all ac-
tivated simultaneously; instead, the outer crystals are
activated first, followed by the central crystals. The po-
sition of the focus is determined by the time-shift tivated simultaneously; instead, the outer crystals are
activated first, followed by the central crystals. The po-
sition of the focus is determined by the time-shifted
activation between the outer and inner crystals (dela activated first, followed by the central crystals. The position of the focus is determined by the time-shifted activation between the outer and inner crystals (delay line). In addition, in electronic probes it is possible on of the focus is determined by the time-shifted
vation between the outer and inner crystals (delay
). In addition, in electronic probes it is possible to
multiple focal zones simultaneously, which makes
ossible to produ activation between the outer and inner crystals (delay
line). In addition, in electronic probes it is possible to
use multiple focal zones simultaneously, which makes
it possible to produce a sharp image over virtually the line). In addition, in electronic probes it is possible to
use multiple focal zones simultaneously, which makes
it possible to produce a sharp image over virtually the
entire depth of field, although this comes at the expe use multiple focal zones simultaneously, which makes
it possible to produce a sharp image over virtually the
entire depth of field, although this comes at the expense
of the image frequency. This is called dynamic focusing The matrix of the small structure are after the small structure are aft

it possible to produce a sharp image over virtually the
entire depth of field, although this comes at the expense
of the image frequency. This is called dynamic focusing
(Fig. 17.20). The image regions of the individual fo entire depth of field, although this comes at the expense
of the image frequency. This is called dynamic focusing
(Fig. 17.20). The image regions of the individual focal
zones are recorded one after the other using a buffe of the image frequency. This is called dynamic focusing
(Fig. 17.20). The image regions of the individual focal
zones are recorded one after the other using a buffer
memory and are finally combined to form a complete
image resolution. mory and are finally combined to form a complete
ge which is focused throughout (Fig. 17.20b).
Modern devices have up to ten focal zones, but only
r of these are usually used simultaneously for dy-
inc focusing because, as image which is focused throughout (Fig. 17.20b).

Modern devices have up to ten focal zones, but only

four of these are usually used simultaneously for dy-

namic focusing because, as already mentioned, the use

of a buff Modern devices have up to ten focal zones, but only
four of these are usually used simultaneously for dy-
namic focusing because, as already mentioned, the use
of a buffer memory reduces the image frequency. When
using con four of these are usually used simultaneously for dy-
namic focusing because, as already mentioned, the use
of a buffer memory reduces the image frequency. When
using conventional array technology, this focusing tech-
niqu

an oblique wave front is generated (Fig. 17.18). Chang-

inque is only possible in the longitud

ing the activation at an appropriate speed achieves an

ultrasound probe, however, and only

oscillation in the beam, which from the example of avoiding rib shadows (Fig. 17.19), At right angles to the ultrasound protacle as the small contact surface of the sector probe enables right angles to the section plane, the examination through the inte as the small contact surface of the sector probe enables

examination through the intercostal spaces.

A disadvantage of the sector technique is caused by

only focused at a depth which is de

the divergence of the ultraso namic focusing because, as already mentioned, the use
of a buffer memory reduces the image frequency. When
using conventional array technology, this focusing tech-
nique is only possible in the longitudinal direction of th of a buffer memory reduces the image frequency. When
using conventional array technology, this focusing tech-
nique is only possible in the longitudinal direction of the
ultrasound probe, however, and only affects the late using conventional array technology, this focusing technology and
nique is only possible in the longitudinal direction of the
ultrasound probe, however, and only affects the lateral
resolution.
Slice-Thickness Focusing
At nique is only possible in the longitudinal direction of the
ultrasound probe, however, and only affects the lateral
resolution.
Slice-Thickness Focusing
At right angles to the ultrasound probe, and thus also at
right angle ultrasound probe, however, and only affects the lateral
resolution.
Slice-Thickness Focusing
At right angles to the ultrasound probe, and thus also at
right angles to the section plane, the scanning lines are
only focused thickness. Slice-Thickness Focusing

sight angles to the ultrasound probe, and thus also at

t angles to the section plane, the scanning lines are

y focused at a depth which is dependent on the shape

he crystals. Both at close rang Slice-Thickness Focusing
At right angles to the ultrasound probe, and thus also at
right angles to the section plane, the scanning lines are
only focused at a depth which is dependent on the shape
of the crystals. Both at At right angles to the ultrasound probe, and thus also at
right angles to the section plane, the scanning lines are
only focused at a depth which is dependent on the shape
of the crystals. Both at close range and at distan right angles to the section plane, the scanning lines are
only focused at a depth which is dependent on the shape
of the crystals. Both at close range and at distant range,
the ultrasound can propagate relatively uncontrol

only focused at a depth which is dependent on the shape
of the crystals. Both at close range and at distant range,
the ultrasound can propagate relatively uncontrollably.
The actual two-dimensional sound field therefore al of the crystals. Both at close range and at distant range,
the ultrasound can propagate relatively uncontrollably.
The actual two-dimensional sound field therefore also
extends in an unwanted fashion at right angles to the the ultrasound can propagate relatively uncontrollably.
The actual two-dimensional sound field therefore also
extends in an unwanted fashion at right angles to the
section plane. This unwanted extent is called the slice
th The actual two-dimensional sound field therefore also
extends in an unwanted fashion at right angles to the
section plane. This unwanted extent is called the slice
thickness.
As a result, very small vessels, cystic hollow extends in an unwanted fashion at right angles to the
section plane. This unwanted extent is called the slice
thickness.
As a result, very small vessels, cystic hollow bod-
ies or low-echo lesions are not intersected exact

only alteral plane. The matrix array ultrasound probe has a two-dimensional arrangement of up to approximately 1000 tiny square crystals which can be activated selectively. Electronic focusing as described by time-shifte (a)
Interal plane. The matrix array ultrasound probe has
a two-dimensional arrangement of up to approximately
1000 tiny square crystals which can be activated selec-
tively. Electronic focusing as described by time-shifte

17.4 Three-Dimensional ultrasound tech-

17.4 Three-dimensional ultrasound tech-

17.4 Three-Dimensional Ultrasound frequencies to be used while maintaining the

17.4 Three-Dimensional Ultrasound Tequency-dependent axial r ce and thus the increase in the energy density which
ompanies it at the same time. It allows higher ul-
ound frequencies to be used while maintaining the
e penetration depth, thus enabling an improvement
ne frequency-depen ce and thus the increase in the energy density which
ompanies it at the same time. It allows higher ul-
ound frequencies to be used while maintaining the
e penetration depth, thus enabling an improvement
ne frequency-depen accompanies it at the same time. It allows higher ul-
trasound frequencies to be used while maintaining the
same penetration depth, thus enabling an improvement
in the frequency-dependent axial resolution.
3-D, Real-Time

very small structures to be visualized without artifacts gence and thus the increase in the
and with a high resolution.
Another positive effect of the matrix array technique trasound frequencies to be used v
is the consid very small structures to be visualized without artifacts

are and thus the increase in the

and with a high resolution.

Another positive effect of the matrix array technique

is the considerable improvement in the penetra and with a high resolution.

Another positive effect of the matrix array technique trasound frequencies to be u

is the considerable improvement in the penetrative same penetration depth, thus

power on account of the redu Another positive effect of the matrix array technique

is the considerable improvement in the penetrative same penetration depth, thus enabli

power on account of the reduction in beam diver-

in the frequency-dependent a is the considerable improvement in the penetrative

power on account of the reduction in beam diver-

in the frequency-dependent axial r
 17.4 Three-Dimensional Ultrasound (3-D, Real-Time 3-D)

The development of threepower on account of the reduction in beam diver-
 17.4 Three-Dimensional Ultrasound (3-D, Real-
 17.4 Three-Dimensional Ultrasound tech

mology took into account the needs of many users

without Po

for three-dimension **17.4. Three-Dimensional Ultrasound** $(3-D)$
The development of three-dimensional ultrasound tech-
nology took into account the needs of many users $\frac{1}{100}$
for three-dimensional imaging of anatomical structures. This s

for three-dimensional imaging of anatomical structures. This simple techt

The objective was among other things to simplify and

improve the diagnosis of structures which can often

or around a fixed

or around a fixed
 1

17.4.1 Acquisition Techniques quence. The number of image will later be used to reconstruce ified before the procedure is play three-dimensional blocks of data. To this end, dimensional mapping, however a that dimension **17.4.1 Acquisition Techniques**

ified before the procedure is be

play three-dimensional blocks of data. To this end, dimensional mapping, however, a

a third dimension perpendicular to the 2-D plane is recorded is not k ified before the procedure is be
play three-dimensional blocks of data. To this end,
a third dimension perpendicular to the 2-D plane is recorded is not known and there is
added to the wo-dimensional (B-mode) ultrasound im Modern ultrasound diagnostics can also record and dis-

play three-dimensional blocks of data. To this end, dimensional mapping, however, as

a third dimension perpendicular to the 2-D plane is recorded is not known and th play three-dimensional blocks of data. To this end, dimensional n
a third dimension perpendicular to the 2-D plane is recorded is no
added to the two-dimensional (B-mode) ultrasound im-
cise and straig
ages and processed a

17.4. Three-Dimensional Ultrasound (3-D, Real-Time 3-D)
The development of three-dimensional ultrasound tech-
nology took into account the needs of many users without Position Sensors
for three-dimensional imaging of an The development of three-dimensional ultrasound tech-

The development of three-dimensional ultrasound tech-

The objective was among other things to simplify and trasound probe, which is moved or

The objective was among The development of three-dimensional ultrasound tech-

ands-Free Technology

for three-dimensional imaging of anatomical structures. This simple technology uses the com-

The objective was among other things to simplify a nology took into account the needs of many users

The objective was among other things to simplify and

The objective was among other things to simplify and

trasound probe, which is moved or p

improve the diagnosis of st Objective was among other things to simplify and trasound probe, which is moved or prove the diagnosis of structures which can often as possible by the examiner parall by the assessed with difficulty in 2-D images.
 4.1 improve the diagnosis of structures which can often

only be assessed with difficulty in 2-D images.
 17.4.1 Acquisition Techniques
 17.4.1 Acquisition Techniques
 17.4.1 Acquisition Techniques
 17.4.1 Acquisition only be assessed with difficulty in 2-D images.
 17.4.1 Acquisition Techniques will later be used to reconstruct the
 17.4.1 Acquisition Techniques will later be used to reconstruct the

ified before the procedure is b trasound frequencies to be used while maintaining the
same penetration depth, thus enabling an improvement
in the frequency-dependent axial resolution.
 $\mathbf{B}-\mathbf{D}$, $\mathbf{Real}\mathbf{S}-\mathbf{Pre}$ Ecchnology
Without Position Senso same penetration depth, thus enabling an improvement
in the frequency-dependent axial resolution.
 3-D, Real-Time 3-D)

Hands-Free Technology

Without Position Sensors

This simple technology uses the conventional 2-D u **3-D, Real-Time 3-D)**
 3-D, Real-Time 3-D)
 Hands-Free Technology

Without Position Sensors

This simple technology uses the conventional 2-D ul-

trasound probe, which is moved or panned as uniformly

as possible by **3-D, Real-Time 3-D)**

Hands-Free Technology

Without Position Sensors

This simple technology uses the conventional 2-D ul-

trasound probe, which is moved or panned as uniformly

as possible by the examiner parallel to **3-D, Real-Time 3-D)**

Hands-Free Technology

Without Position Sensors

This simple technology uses the conventional 2-D ul-

trasound probe, which is moved or panned as uniformly

as possible by the examiner parallel to **3-D, Real-Time 3-D)**

Hands-Free Technology

Without Position Sensors

This simple technology uses the conventional 2-D ul-

trasound probe, which is moved or panned as uniformly

as possible by the examiner parallel to **B-D, Real-Time 3-D)**

Hands-Free Technology

Without Position Sensors

This simple technology uses the conventional 2-D ul-

trasound probe, which is moved or panned as uniformly

as possible by the examiner parallel to Hands-Free Technology
This simple technology
This simple technology uses the conventional 2-D ul-
trasound probe, which is moved or panned as uniformly
as possible by the examiner parallel to the 2-D plane
or around a fixe Hands-Free Technology

Without Position Sensors

This simple technology uses the conventional 2-D ul-

trasound probe, which is moved or panned as uniformly

as possible by the examiner parallel to the 2-D plane

or around Without Position Sensors
This simple technology uses the conventional 2-D ul-
trasound probe, which is moved or panned as uniformly
as possible by the examiner parallel to the 2-D plane
or around a fixed point in order to This simple technology uses the conventional 2-D ultrasound probe, which is moved or panned as uniformly
as possible by the examiner parallel to the 2-D plane
or around a fixed point in order to record an image se-
quence. trasound probe, which is moved or panned as
as possible by the examiner parallel to the
or around a fixed point in order to record an
quence. The number of images to be record
will later be used to reconstruct the 3-D data round a fixed point in order to record an image se-
nce. The number of images to be recorded which
later be used to reconstruct the 3-D data set is spec-
l before the procedure is begun (Fig. 17.22). This
ds-free technolog nce. The number of images to be recorded which
later be used to reconstruct the 3-D data set is spec-
l before the procedure is begun (Fig. 17.22). This
ds-free technology does not allow accurate three-
ensional mapping, h will later be used to reconstruct the 3-D data set is spec-
ified before the procedure is begun (Fig. 17.22). This
hands-free technology does not allow accurate three-
dimensional mapping, however, as the distance actually ified before the procedure is begun (Fig. 17.22). This
hands-free technology does not allow accurate three-
dimensional mapping, however, as the distance actually
recorded is not known and there is no guarantee of a pre-
c hands-free technology does not allow accurate three-
dimensional mapping, however, as the distance actually
recorded is not known and there is no guarantee of a pre-
cise and straight recording movement. This also means
th

-Dimensional Ultrasound (3-D, Real-Time 3-D)
Fig. 17.22 Data block from multiple
parallel sectional images using 3-D
hands-free technology -Dimensional Ultrasound (3-D, Real-Time 3-D) 361

Fig. 17.22 Data block from multiple

parallel sectional images using 3-D

hands-free technology -Dimensional Ultrasound (3-D, Real-Time 3-D) 361

Fig. 17.22 Data block from multiple

parallel sectional images using 3-D

hands-free technology

mined.

The position detection can be achieved using dif-

the position detection can be achieved using dif-

the electromagnetic field, infrared, ultrasound

acceleration sensors (evro sensors) are also used Ferent techniques and position sensors. In addition to
the position sensors in the electromagnetic field, infrared, ultrasound
and acceleration sensors (gyro sensors) are also used.
These forms of sensor technology all hav The position detection can be achieved using dif-
ferent techniques and position sensors. In addition to
sensors in the electromagnetic field, infrared, ultrasound
and acceleration sensors (gyro sensors) are also used.
The The position detection can be achieved using dif-
ferent techniques and position sensors. In addition to
sensors in the electromagnetic field, infrared, ultrasound
and acceleration sensors (gyro sensors) are also used.
The

17.23 Integrated 3-D/4-D ultrasound probe with me-
incal deflection
incel deflection
hodological advantages and disadvantages. The dis-
manatages predominantly have an adverse effect on the
incel resolution.
Integrated 3-D

Fig. 17.23 Integrated 3-D/4-D ultrasound probe with me-

chanical deflection

a narrower or wider angle wit

three. By time-shifted activatic

methodological advantages and disadvantages. The dis-

anarrower or wider an chanical deflection

a narrower or wider angle with

face. By time-shifted activation

array ultrasound probe the din

advantages predominantly have an adverse effect on the determined in both horizontal

spatial resolutio face. By time-shifted activation of the rows and columns, unlike with the c
advantages predominantly have an adverse effect on the determined in both horizontal axes (
rais apatial resolution.
This type of ultrasound probe

Fig. 17.24 3-D frustum of a pyramid, generated with a ma-
trix phased array ultrasound probe
able reproducible recording of a 3-D data block. The
array oscillates in a special liquid-filled ultrasound
probe housing and s Fig. 17.24 3-D frustum of a pyramid, generated with a ma-
trix phased array ultrasound probe
able reproducible recording of a 3-D data block. The
array oscillates in a special liquid-filled ultrasound
probe housing and sca 17.24 3-D frustum of a pyramid, generated with a ma-
phased array ultrasound probe
e: reproducible recording of a 3-D data block. The
y oscillates in a special liquid-filled ultrasound
be housing and scans the anatomical s Fig. 17.24 3-D frustum of a pyramid, generated with a ma-
trix phased array ultrasound probe
able reproducible recording of a 3-D data block. The
array oscillates in a special liquid-filled ultrasound
probe housing and sc Fig. 17.24 3-D frustum of a pyramid, generated with a ma-
trix phased array ultrasound probe
able reproducible recording of a 3-D data block. The
array oscillates in a special liquid-filled ultrasound
probe housing and sc phased array ultrasound probe

2: reproducible recording of a 3-D data block. The

y oscillates in a special liquid-filled ultrasound

be housing and scans the anatomical structures re-

teedly at such a speed that a realexperiency and series of enousing and scans the anatomical structures re-
tedly at such a speed that a real-time representation
he volume can be calculated able reproducible recording of a 3-D data block. The
array oscillates in a special liquid-filled ultrasound
probe housing and scans the anatomical structures re-
peatedly at such a speed that a real-time representation
of

This smaller and lighter construction

mechanically moving components.

This smaller and lighter construction

mechanically moving components.

Solution in the distribution of the principle
 Fig. 17.23 Integrated 3advantages predominantly have an adverse effect on the theories and the principle of the state of the state of the state of the state of the principle of **Example 12**
 Example 17.23 Integrated 3-D/4-D ultrasound probe with me-

chanical deflection

chanical deflection

chanical deflection

chanical deflection

methodological advantages and disadvantages. The dis-

anarrow array oscillates in a special liquid-filled ultrasound
probe housing and scans the anatomical structures re-
peatedly at such a speed that a real-time representation
of the volume can be calculated (Fig. 17.23).
This type probe housing and scans the anatomical structures re-
peatedly at such a speed that a real-time representation
of the volume can be calculated (Fig. 17.23).
This type of ultrasound probe is currently primarily
used in gyna peatedly at such a speed that a real-time representation
of the volume can be calculated (Fig. 17.23).
This type of ultrasound probe is currently primarily
used in gynaecology to image the foetus, as it achieves
very good of the volume can be calculated (Fig. 17.23).
This type of ultrasound probe is currently primarily
used in gynaecology to image the foetus, as it achieves
very good resolution with integrated convex arrays.
Integrated 3-D This type of ultrasound probe is currently primarily
used in gynaecology to image the foetus, as it achieves
very good resolution with integrated convex arrays.
Integrated 3-D Ultrasound Probes
with Electronic Deflection
T used in gynaecology to image the foetus, as it achieves
very good resolution with integrated convex arrays.

Integrated 3-D Ultrasound Probes

with Electronic Deflection

This smaller and lighter construction manages witho very good resolution with integrated convex arrays.

Integrated 3-D Ultrasound Probes

with Electronic Deflection

This smaller and lighter construction manages without

mechanically moving components. As with the matrix
 Integrated 3-D Ultrasound Probes
with Electronic Deflection
This smaller and lighter construction manages without
mechanically moving components. As with the matrix
array ultrasound probe, the array of these probes con-
si Integrated 3-D Ultrasound Probes
with Electronic Deflection
This smaller and lighter construction manages without
mechanically moving components. As with the matrix
array ultrasound probe, the array of these probes con-
s with Electronic Deflection
This smaller and lighter construction manages without
mechanically moving components. As with the matrix
array ultrasound probe, the array of these probes con-
sists of a two-dimensional, usually This smaller and lighter construction manages without
mechanically moving components. As with the matrix
array ultrasound probe, the array of these probes con-
sists of a two-dimensional, usually square arrangement
of tiny mechanically moving components. As with the matrix
array ultrasound probe, the array of these probes con-
sists of a two-dimensional, usually square arrangement
of tiny piezoelectric crystals which can be activated se-
lec is ultrasound probe, the array of these probes consors of a two-dimensional, usually square arrangement
iny piezoelectric crystals which can be activated se-
ively. According to the principle of the sector phased
ay method sists of a two-dimensional, usually square arrangement
of tiny piezoelectric crystals which can be activated se-
lectively. According to the principle of the sector phased
array method, the crystals are electrically activ of tiny piezoelectric crystals which can be activated se-
lectively. According to the principle of the sector phased
array method, the crystals are electrically activated at
different points in time, so that the scanning b array method, the crystals are electrically activated at different points in time, so that the scanning beam forms a narrower or wider angle with respect to the array surface. By time-shifted activation of the respective c a narrower or wider angle with respect to the array sur-
face. By time-shifted activation of the respective crystal
rows and columns, unlike with the conventional phased
array ultrasound probe the direction of the beam can

4.6ebH 3D c

• Probe:1010

the scanning process such that their positions and angles

are correct, providing a three-dimensional data set.

This spatial data block represents the basis for all

further calculations. Differ scanning process such that their positions and angle
correct, providing a three-dimensional data set.
This spatial data block represents the basis for all
her calculations. Different display calculations are
different.
Sur

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are correct, providing a three-dimensional data set.

This spatial data block represents the basis for all

further calculations. Different display calculations are

ther. The examiner thus gain

used here:

Surface di This spatial data block represents the basis for all

further calculations. Different display calculations are

which are at any desired angles

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which impedance) of the state i **EXECUTE SOLUTE SOLUTE SOLUTE AND SOLUTE SOLUTE SOLUTE SOLUTE SOLUTE SOLUTE SOLUTE STRUCT SURFACE display

• Surface display

• Surface display

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• Transp** simulation of the tight of the fectus in ultrasound technology

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Found **ITALLE CONSUM CONTA THE SET ASSEMUST THE SET ASSEMUST A CONDUCT AND THE SURFACT USING THE SAME USING THE FOREXT** • Transparent display. By using filtering, it is po

flecting structures to the ampedances of the user impedances of the tissue structures be-

tween the wave impedances of the tissue structures searching for anomalies in **Surface Display**

Surface display

Surface display requires a considerable difference I

tween the wave impedance, of the tissue structu

(change in impedance), which generally exists betwe

liquid and solid structures. I Surface Display

face display rediet signals strongly. This alle

face display requires a considerable difference be-

of bones, for example, which is u

id an solid structures. In order to visualize the de-

id and suctur Surface display requires a considerable difference be-

tween the wave impedances of the tissue structures

(change in impedance), which generally exists between

liquid and solid structures. In order to visualize the detween the wave impedances of the tissue structures

(change in impedance), which generally exists between

liquid and solid structures. In order to visualize the de-

sired interfaces, it must be possible to clearly deline

(change in impedance), which generally exists between

liquid and solid structures. In order to visualize the de-

sired interfaces, it must be possible to clearly delineate

the object under examination from its surround liquid and solid structures. In order to visualize the de-
sired interfaces, it must be possible to clearly delineate
the object under examination from its surroundings.
These conditions can often be found when perform-
in object under examination from its surroundings. These conditions can often be found when perform-
diagnosis during pregnancy, as the skin of the foetus in
emarcated from the amniotic fluid by a considerable
nge in impedanc These conditions can often be found when perform-

ing diagnosis during pregnancy, as the skin of the foetus

in ultrasound technology:

is demarcated from the amniotic fluid by a considerable

change in impedance.
 Exten ing diagnosis during pregnancy, as the skin of the foetus

is demarcated from the amniotic fluid by a considerable

change in impedance.

Specific algorithms for representing surfaces in 3-D
 Extended field of view

data

the scanning process such that their positions and angles

are orrect, providing a three-dimensional data set.

This spatial data block represents the basis for all

the display multiple sections through an

further calcu **DENTIFIED AN ORDER CONSUMING A SUBSEURANT CONSUMING A SUBSEURANT CONSUMING A SUBSEURANT CONSUMING A SUBSEURANT CONSUMISTING AN ORGANIZED AN OR** Position

Position

Position

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plication point of view. It is possible to simultaneously

display multiple sections through an organ or structures

which are at any desired angles with respect other. The examiner thus gains the possibility of better Position

Position

Position

Position

plication point of view. It is possible to simultaneously

display multiple sections through an organ or structures

which are at any desired angles with respect to one an-

other. T **Example 1980**
Exampled and the main determining them and determining the setting point of view. It is possible to simultaneously
display multiple sections through an organ or structures
which are at any desired angles wit **FORMATE 1988**
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By using the positive vectors of view. It is possible to simultaneously

display multiple sections through an organ or structures

which are at any desired angles with respect to one an-

other. The examiner plication point of view. It is possible to simultaneously
display multiple sections through an organ or structures
which are at any desired angles with respect to one an-
other. The examiner thus gains the possibility of b plication point of view. It is possible to simultaneously display multiple sections through an organ or structures which are at any desired angles with respect to one another. The examiner thus gains the possibility of bet plication point of view. It is possible to simultaneously
display multiple sections through an organ or structures
which are at any desired angles with respect to one an-
other. The examiner thus gains the possibility of b display multiple sections through an organ or structures
which are at any desired angles with respect to one an-
other. The examiner thus gains the possibility of better
visualizing anatomical or pathological structures sp

other. The examiner thus gains the possibility of better
visualizing anatomical or pathological structures spa-
tially, measuring them and determining their volume.
Transparent Display
By using filtering, it is possible to tially, measuring them and determining their volume.

Transparent Display

By using filtering, it is possible to suppress faintly re-

flecting structures to the advantage of structures which

reflect signals strongly. Thi **Transparent Display**
By using filtering, it is possible to suppress faintly re-
flecting structures to the advantage of structures which
reflect signals strongly. This allows clear 3-D imaging
of bones, for example, which Transparent Display
By using filtering, it is possible to suppress faintly re-
flecting structures to the advantage of structures which
reflect signals strongly. This allows clear 3-D imaging
of bones, for example, which i flecting structures to the advantage of structures which

reflect signals strongly. This allows clear 3-D imaging

of bones, for example, which is usually necessary when

searching for anomalies in the foetal skeleton.

reflect signals strongly. This allows clear 3-D imaging
of bones, for example, which is usually necessary when
searching for anomalies in the foetal skeleton.
17.4.3 New and Additional Technologies
This section gives an of bones, for example, which is usually necessary when

searching for anomalies in the foetal skeleton.
 17.4.3 New and Additional Technologies

This section gives an overview of particular new tech-

nologies which have **17.4.3 New and Additional Technologies**

This section gives an overview of particular new tech

nologies which have started being used in recent year

in ultrasound technology:

• Extended field of view

• Trapezoidal tec Solition is a solid of view of particular new tech-
paies which have started being used in recent years
Itrasound technology:
Extended field of view
Trapezoidal technique
Steered compound imaging (real-time compound
imagin nologies which have started being used in recent years

in ultrasound technology:

• Extended field of view

• Trapezoidal technique

• Steered compound imaging (real-time compound

imaging)

• Speckle reduction

• Frackin

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- imaging)
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- eTracking.

Fig. 17.26 Scrotum imaged using
extended field of view Fig. 17.26 Scrotum imaged using
extended field of view

Example 19
 Example 19 Example 19 Probe:5411

imaging plane. By shifting the ultrasound probe in its ultrasonic beam either tangenti

longitudinal axis, an extended two-dimensional image angle. Under these conditions, the

is generated. This imaging plane. By shifting the ultrasound probe in its ultrasonic beam either tangentially
longitudinal axis, an extended two-dimensional image angle. Under these conditions, the p
is generated.
This does not involve exten imaging plane. By shifting the ultrasound probe in its ultrasonic l
longitudinal axis, an extended two-dimensional image angle. Und
is generated.
This does not involve extending the information in
the 3rd plane (perpendicu ging plane. By shifting the ultrasound probe in its ultrasonic beam either tangential
gitudinal axis, an extended two-dimensional image angle. Under these conditions, the
nerated.
This does not involve extending the inform is generated.
This does not involve extending the informat
the 3rd plane (perpendicular to the 2-D plane) as
case with 3-D, but rather extended the 2-D plane
Using image processing algorithms, matching se
of the respective

Trapezoidal

therefore produce a calculated, new and coherent p
ture of the organ structures (Fig. 17.26).
This technology is also known by other trade nam
SieScape, Freestyle, LOGIQ View, Panoramic Ult
sound, etc.
Trapezoidal
With the This technology is also known by other trade names:
SieScape, Freestyle, LOGIQ View, Panoramic Ultra-
sound, etc.
Trapezoidal
With the trapezoidal technique, the width of the sound
field of a linear probe is extended. By t

sonic beam reflected in the direction of the ultrasound
probe are very low. These structures therefore appear
only faintly or not at all. The scanning beam also barely
reaches the structures lying distal to these interface optimized zoom

sonic beam reflected in the direction of the ultrasound

probe are very low. These structures therefore appear

Because of their physical prop

only faintly or not at all. The scanning beam also barely are Optimized z

sonic beam reflected in the direction of the ultrasound

probe are very low. These structures therefore appear

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only faintly or not at all. The scanning beam also barely are alwa

sonic beam reflected in the direction of the ultrasound
probe are very low. These structures therefore appear
Because of their physical properties
only faintly or not at all. The scanning beam also barely are always accomp probe are very low. These structures therefore appear

because of their physical properties

only faintly or not at all. The scanning beam also barely

are always accompanied by noise.

reaches the structures lying distal only faintly or not at all. The scanning beam also barely are always accompanied by nois
reaches the structures lying distal to these interfaces, be-
ratio is in the region of approxim
cause the majority of the energy of t reaches the structures lying distal to these interfaces, be-

ratio is in the region of approxim

cause the majority of the energy of the ultrasonic beam

in g image processing. As a res

In addition to the known lateral e cause the majority of the energy of the ultrasonic beam
is deflected by reflection.
in a recorded by reflection.
In addition to the known lateral edge shadows artifi-
increasing computational power of
cial inhomogeneities $+30°$ (Fig. 17.28). Modern devices furthermore also allow angle steering, adapted according to requirements, ected by reflection.

ing image processing. As a result

addition to the known lateral edge shadows artifi-

increasing computational power of

homogeneities also appear in the distal structures

image-processing steps ca In addition to the known lateral edge shadows artifi-

cial inhomogeneities also appear in the distal structures image-processing steps c

and interfaces. The consequences of these phenomena acquisition of signal da

can cial inhomogeneities also appear in the distal structures image-processing steps can be and interfaces. The consequences of these phenomena acquisition of signal data. Specan be reduced if the structures being examined are and interfaces. The consequences of these phenomena acquisition of signal data. S

can be reduced if the structures being examined are image characteristics to be e

sounded not just from one direction but from differ-

T can be reduced if the structures being examined are image characteristics to be er
sounded not just from one direction but from differ-
This includes image homoger
ent directions using beam steering (phasing) and the pany directions. directions using beam steering (phasing) and the panying subjective noise suppl
thing sound reflections are superimposed using im-
example, edge enhancement of
processing to form a compound ultrasound image. tures.
ally, t resulting sound reflections are superimposed using im-

are processing to form a compound ultrasound image.

Usually, three consecutive images are generated, which These image-processing mo

have been recorded in a range b age processing to form a compound ultrasound i
Usually, three consecutive images are generated,
have been recorded in a range between -30,
+30° (Fig. 17.28). Modern devices furthermore a
low angle steering, adapted accordi

sonic beam reflected in the direction of the ultrasound
probe are very low. These structures therefore appear
only faintly or not at all. The scanning beam also barely are always accompanied by noise.
The reduced by the st sonic beam reflected in the direction of the ultrasound
probe are very low. These structures therefore appear
Because of their physical propert
only faintly or not at all. The scanning beam also barely are always accompani **Speckle Reduction**
 Speckle Reduction
 Because of their physical properties, ultrasound images

are always accompanied by noise. The signal-to-noise

ratio is in the region of approximately 1.9 and can only

be visual **Speckle Reduction**
 Speckle Reduction
 Because of their physical properties, ultrasound images

are always accompanied by noise. The signal-to-noise

ratio is in the region of approximately 1.9 and can only

be visual Speckle Reduction

Speckle Reduction

Because of their physical properties, ultrasound images

are always accompanied by noise. The signal-to-noise

ratio is in the region of approximately 1.9 and can only

be visually and **Speckle Reduction**
 Speckle Reduction
 Because of their physical properties, ultrasound images

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ratio is in the region of approximately 1.9 and can only

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 Speckle Reduction
 Because of their physical properties, ultrasound images

are always accompanied by noise. The signal-to-noise

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Speckle Reduction

Because of their physical properties, ultrasound images

are always accompanied by noise. The signal-to-noise

ratio is in the region of approximately 1.9 and can only

be visually and su Speckle Reduction
Because of their physical properties, ultrasound images
are always accompanied by noise. The signal-to-noise
ratio is in the region of approximately 1.9 and can only
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Because of their physical properties, ultrasound images
are always accompanied by noise. The signal-to-noise
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Because of their physical properties, ultrasound images
are always accompanied by noise. The signal-to-noise
ratio is in the region of approximately 1.9 and can only
be visually and subjectively improved Because of their physical properties, ultrasound images
are always accompanied by noise. The signal-to-noise
ratio is in the region of approximately 1.9 and can only
be visually and subjectively improved by correspond-
ing tures. is in the region of approximately 1.9 and can only
visually and subjectively improved by correspond-
image processing. As a result of the constantly
reasing computational power of computers, further
ge-processing steps can be visually and subjectively improved by correspond-
ing image processing. As a result of the constantly
increasing computational power of computers, further
image-processing steps can be added after the actual
acquisition ing image processing. As a result of the constantly
increasing computational power of computers, further
image-processing steps can be added after the actual
acquisition of signal data. Special algorithms allow
image chara increasing computational power of computers, further image-processing steps can be added after the actual acquisition of signal data. Special algorithms allow image characteristics to be emphasized and changed. This includ image-processing steps can be added after the actual
acquisition of signal data. Special algorithms allow
image characteristics to be emphasized and changed.
This includes image homogenization and the accom-
panying subjec acquisition of signal data. Special algorithms allow
image characteristics to be emphasized and changed.
This includes image homogenization and the accom-
panying subjective noise suppression, and also, for
example, edge e

is includes image homogenization and the accom-
ying subjective noise suppression, and also, for
mple, edge enhancement of adjacent organ struc-
s.
These image-processing measures can in many
es aid fast and easy diagnosis bying subjective noise suppression, and also, for
tying subjective noise suppression, and also, for
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S.
These image-processing measures can in many
es aid fast and easy diagnosis, but they are not al-
s and exclusively o example, edge enhancement of adjacent organ structures.
These image-processing measures can in many
cases aid fast and easy diagnosis, but they are not al-
ways and exclusively of use, as both false positive and
also false

Fig. 17.29a, b Vessel distension anal-
ysis using eTracking Fig. 17.29a, b Vessel distension anal-
ysis using eTracking

Example 1993. The distension is determined to the set of different is the solution of the real effects can be raised by means of a series of different ist software, the movement of movement of the distension in real explo

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Samme By analysing the raw data signal. Using special-

is followed by user-defined points along an ultrasonic

beam (tracking). This is done with a high level $\frac{\text{Al}}{\text{D}}$
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simulation of the same of the movement of moving organ structures
ollowed by user-defined points along an ultrasonic
m (tracking). This is done with a high level of
poral (**Example Shares and colocated detection**
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Ultrasound Diagnostics 17.5 Operation of an Ultrasound Unit 367 Ultrasound Diagnostics | 17.5 Operation of an Ultrasound Unit | 367

coupling between the heart and the vascular system

downstream (Fig. 17.29a,b). Ultrasound Diagnostics 17.5 Operation of an Ultrason

coupling between the heart and the vascular system

downstream (Fig. 17.29a,b).

17.5 Operation of an Ultrasound
 17.5.1 General Conditions

Operation of an ultrasound unit has today becomedard in most medical fields. Some important g

conditions should be observed and are detailed be
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Documentation

Consumeration of an ultrasound unit has today become standard. To this end, the ultrascondard in most medical fields. Some important general and retailers offer tailored manufor the conditions should be observed and are de Operation of an ultrasound unit has today become stan-

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conditions should be observed and are detailed below.

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for their customers. These cont

th dard in most medical fields. Some important general and retailers offer
conditions should be observed and are detailed below. The operator of an ultrasound unit is generally required the option of insu
The operator of an u conditions should be observed and are detailed below. agreements which conformation
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All suppliers of ultrasound equipment provide rel **Documentation**
 Socion Exercution The operator of an ultrasound unit is generally required probes. There are also offers for

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All suppliers of u The operator of an ultrasound unit is generally required probes. Then
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ument findings.
All suppliers of ultrasound equipment provide rel-
evant advice and he accounting body and by legal authorities to doc-

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In general, the operator should

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evant advice and solutions on request for the analogue In general, the operator sho

and digital storage of data and images for the findings. about possi All suppliers of ultrasound equipment provide rel-

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and digital storage of data and images for the findings. about possible legal hygiene regula
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In the simplest scenario this includes thermal printers of the p
or internal digital memory with CD/DVD/USB stor-
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age or export interfaces, such as nternal digital memory with CD/DVD/USB stor-
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ing of medical image data as well as other modalities to be used and approved cleanin

such as CT and MRI, but The DICOM standard not only governs the archiv-

intended image of medical image data as well as other modalities to be used and approved cleaning

such as CT and MRI, but also provides further functions ilization agents.
 ing of medical image data as well as other modalities
such as CT and MRI, but also provides further functions ilization agents.
and procedures which support work-flow (e.g. work list,
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Safe such as CT and MRI, but also provides further functions
and procedures which support work-flow (e.g. work list,
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Application-Specific Additions and Upgrades tic use of
Modern print, structured report, etc.).
 Safe Use of Ultrasound D

According to current scientific

Modern digital ultrasound units allow additional hard-

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Modern digital ultrasound units allow additional hard-

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ware or software to be installed to extend the scope of it is recommended that

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taneous ECG recording, memo ware or software to be installed to extend the scope of it is recommended that the Due of the unit. This includes, for example, units for si-

cautiously, particularly for the

multaneous ECG recording, memory upgrades, sp use of the unit. This includes, for example, units for si-

multaneous ECG recording, memory upgrades, specific aminations. Because ultrasoun

analysis programs (stress echo, contrast medium assess-

and converted into hea

multaneous ECG recording, memory upgrades, specific aminations. Because ultrasound analysis programs (stress echo, contrast medium assess-

and converted into heat at the tran

and pulse wave velocity, etc.).

In addition analysis programs (stress echo, contrast medium assessentiantly and converted into heat at the transmit ment, TDI evaluation, analysis of the vessel distension sues in bony structures, it is not and pulse wave velocity, e ment, TDI evaluation, analysis of the vessel distension
and pulse wave velocity, etc.).
In addition to these device-specific upgrades, there
is also always the possibility of extending the intended
use of a device with add pulse wave velocity, etc.).

In addition to these device-specific upgrades, there imperative that the recommendati

so always the possibility of extending the intended professional associations are observed a device with a In addition to these device-specific upgrades, there imperative that the is also always the possibility of extending the intended professional associations of a device with additional ultrasound probes.

Maintenance and Re

Ultrasound Diagnostics 17.5 0

allows further parameters to be calculated, e.g. pulse coupling between the heart and

wave propagation or wave intensity, which describe the downstream (Fig. 17.29a,b).
 17.5 0 Deration of allows further parameters to be calculated, e.g. pulse coupling between the heart are wave propagation or wave intensity, which describe the downstream (Fig. 17.29a,b).
 17.5 Operation of an Ultrasound Unit
 17.5.1 Gene allows further parameters to be calculated, e.g. pulse coupling between the heart as
wave propagation or wave intensity, which describe the downstream (Fig. 17.29a,b).
 17.5 Operation of an Ultrasound Unit
 17.5.1 Gener 17.5 Operation of an Ultrasound Unit
 17.5.1 General Conditions MedBetreibV), the operator of an ultrasound unit has today become stan-

operation of an ultrasound unit has today become stan-

used. To this end, the u **17.5 Operation of an Ultrasound Unit**
 17.5.1 General Conditions MedBetreibV), the operator of an
 Operation of an ultrasound unit has today become stan-

used. To this end, the ultrasound

dard in most medical field **Example 18**
 All Seneral Conditions
 **All suppliers of an actual of the set of this end, the ultrasound

in most medical fields. Some important general and retailed and redist 17.5.1 General Conditions** MedBetreibV), the operator comparison of an ultrasound unit has today become stan-

used. To this end, the ultras-

dard in most medical fields. Some important general and retailers offer tailo Ultrasound Diagnostics 17.5 Operation of an Ultrasound Unit

coupling between the heart and the vascular system

downstream (Fig. 17.29a,b).

MedBetreibV), the operator of an ultrasound unit has

certain duties to ensure t Ultrasound Diagnostics 17.5 Operation of an Ultrasound Unit

coupling between the heart and the vascular system

downstream (Fig. 17.29a,b).

MedBetreibV), the operator of an ultrasound unit has

certain duties to ensure t Ultrasound Diagnostics 17.5 Operation of an Ultrasound Unit 367

coupling between the heart and the vascular system

downstream (Fig. 17.29a,b).

MedBetreibV), the operator of an ultrasound unit has

certain duties to ensu coupling between the heart and the vascular system
downstream (Fig. 17.29a,b).
MedBetreibV), the operator of an ultrasound unit has
certain duties to ensure the safety of the systems
used. To this end, the ultrasound unit coupling between the heart and the vascular system
downstream (Fig. 17.29a,b).
MedBetreibV), the operator of an ultrasound unit has
certain duties to ensure the safety of the systems
used. To this end, the ultrasound unit coupling between the heart and the vascular system
downstream (Fig. 17.29a,b).
MedBetreibV), the operator of an ultrasound unit has
certain duties to ensure the safety of the systems
used. To this end, the ultrasound unit downstream (Fig. 17.29a,b).

MedBetreibV), the operator of an ultrasound unit has

certain duties to ensure the safety of the systems

used. To this end, the ultrasound unit manufacturers

and retailers offer tailored main MedBetreibV), the operator of an ultrasound unit has
certain duties to ensure the safety of the systems
used. To this end, the ultrasound unit manufacturers
and retailers offer tailored maintenance and inspection
agreemen MedBetreibV), the operator of an ultrasound un
certain duties to ensure the safety of the sy
used. To this end, the ultrasound unit manufac
and retailers offer tailored maintenance and insp
agreements which conform to the MedBetreibV), the operator of an ultrasound unit has
certain duties to ensure the safety of the systems
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agreemen certain duties to ensure the safety of the systems
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and retailers offer tailored maintenance and inspection
agreements which conform to the law support service
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and retailers offer tailored maintenance and inspection
agreements which conform to the law support service
for their customers. These contracts often also include
the o and retailers offer tailored maintenance and inspection
agreements which conform to the law support service
for their customers. These contracts often also include
the option of insuring against damage to the units and
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Hygiene

agreements which conform to the law support service
for their customers. These contracts often also include
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de their customers. These contracts often also include
option of insuring against damage to the units and
bes. There are also offers for regular updates of the
ice software.
Hygiene
general, the operator should inform him or the option of insuring against damage to the units and
probes. There are also offers for regular updates of the
device software.
In general, the operator should inform him or herself
about possible legal hygiene regulation

probes. There are also offers for regular updates of the
device software.
In general, the operator should inform him or herself
about possible legal hygiene regulations in the context
of the planned examinations. In additi device software.

In general, the operator should inform him or herself

about possible legal hygiene regulations in the context

of the planned examinations. In addition, the guidelines

of the professional associations i Hygiene
In general, the operator should inform him or herself
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of the professional associations include recomm Hygiene
In general, the operator should inform him or he
about possible legal hygiene regulations in the con
of the planned examinations. In addition, the guide
of the professional associations include recomme
tions regard in the context
the planned examinations. In addition, the guidelines
he professional associations include recommenda-
s regarding hygiene which should also be observed.
For the cleaning of units and also the cleaning,
infe of the planned examinations. In addition, the guidelines
of the professional associations include recommenda-
tions regarding hygiene which should also be observed.
For the cleaning of units and also the cleaning,
disinfec of the professional associations include recommenda-
tions regarding hygiene which should also be observed.
For the cleaning of units and also the cleaning,
disinfection and sterilization of ultrasound probes and
auxiliary tions regarding hygiene which should also be observed.

For the cleaning of units and also the cleaning,

disinfection and sterilization of ultrasound probes and

auxiliary equipment, such as puncture adapters, the

manufa

procedures which support work-flow (e.g. work list,
t, structured report, etc.).
Application -Specific Additions and Upgrades tic use of ultrasound which com
degral ultrasound units allow additional hard-
e or software t For the cleaning of units and also the cleaning,
disinfection and sterilization of ultrasound probes and
auxiliary equipment, such as puncture adapters, the
manufacturers provide information about the methods
to be used an disinfection and sterilization of ultrasound probes and
auxiliary equipment, such as puncture adapters, the
manufacturers provide information about the methods
to be used and approved cleaning, disinfection and ster-
iliza auxiliary equipment, such as puncture adapters, the
manufacturers provide information about the methods
to be used and approved cleaning, disinfection and ster-
ilization agents.
Safe Use of Ultrasound Diagnostics
Accordin manufacturers provide information about the methods
to be used and approved cleaning, disinfection and ster-
ilization agents.
Safe Use of Ultrasound Diagnostics
According to current scientific knowledge, the diagnos-
tic to be used and approved cleaning, disinfection and ster-
ilization agents.
Safe Use of Ultrasound Diagnostics
According to current scientific knowledge, the diagnos-
tic use of ultrasound which complies with standards
does ilization agents.

Safe Use of Ultrasound Diagnostics

According to current scientific knowledge, the diagnos-

tic use of ultrasound which complies with standards

does not have any unwanted side effects. However,

it is Safe Use of Ultrasound Diagnostics
According to current scientific knowledge, the diagnostic
tic use of ultrasound which complies with standards
does not have any unwanted side effects. However,
it is recommended that the Safe Use of Ultrasound Diagnostics
According to current scientific knowledge, the diagnos-
tic use of ultrasound which complies with standards
does not have any unwanted side effects. However,
it is recommended that the Do use of ultrasound which complies with standards
s not have any unwanted side effects. However
s recommended that the Doppler mode be used
tiously, particularly for the purpose of foetal ex-
nations. Because ultrasound ener does not have any unwanted side effects. However,
it is recommended that the Doppler mode be used
cautiously, particularly for the purpose of foetal ex-
aminations. Because ultrasound energy is absorbed
and converted into is recommended that the Doppler mode be used
tiously, particularly for the purpose of foetal ex-
nations. Because ultrasound energy is absorbed
converted into heat at the transition between tis-
is in bony structures, it i cautiously, particularly for the purpose of foetal ex-
aminations. Because ultrasound energy is absorbed
and converted into heat at the transition between tis-
sues in bony structures, it is not possible to rule out
cell-d nations. Because ultrasound energy is absorbed

converted into heat at the transition between tis-

is in bony structures, it is not possible to rule out

-damaging effects with certainty. It is therefore

erative that the and converted into heat at the transition between tis-

sues in bony structures, it is not possible to rule out

cell-damaging effects with certainty. It is therefore

imperative that the recommendations of the relevant

p is in bony structures, it is not possible to rule out
-damaging effects with certainty. It is therefore
erative that the recommendations of the relevant
fessional associations are observed.
Further Reading
V.M. Shami, M. cell-damaging effects with certainty. It is therefore
imperative that the recommendations of the relevant
professional associations are observed.
Further Reading
• V.M. Shami, M. Kahaleh (Eds.): *Endoscopic Ultra-*
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