FieldStrength

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Application tips: voxel size, bandwidth and water-fat shift

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PHILIPS

Voxel size, bandwidth and water-fat shift

Pixel size is a more convenient parameter than matrix for representing in-plane spatial resolution. Voxel size is used similarly for spatial resolution in three dimensions. This application tip also explains the relation between water-fat shift (in pixels) and bandwidth and shows how to use water-fat shift when optimizing image quality.

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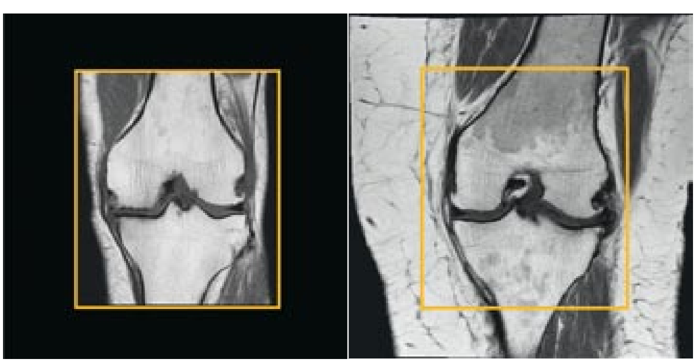
Pixel size better describes spatial resolution than matrix

In MR images pixel size depends on both the selected field of view (FOV) and matrix. In-plane pixel size is determined as :

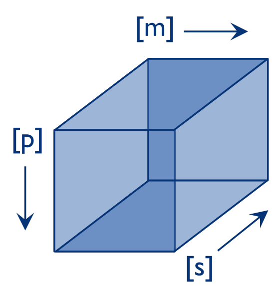
$$\frac{\text{FOV}}{\text{Matrix}} = \text{Pixel size}$$

The images below have different FOV and matrix, but the same **pixel size**, and thus the **same spatial resolution** in the area of interest within the orange square.



As this example demonstrates: pixel size, not matrix, determines spatial resolution.

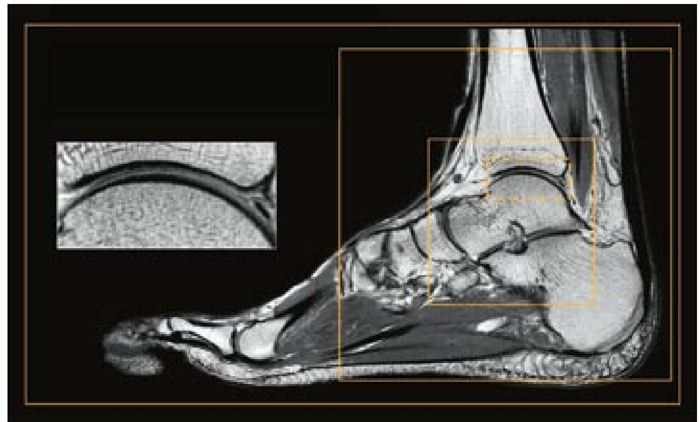
While pixel size reflects in-plane resolution, voxel size represents three-dimensional resolution by taking slice thickness into account as well. Voxel size is inversely proportional to spatial resolution. In other words: high spatial resolution is equivalent to small voxels.



A voxel is a small volume element that represents resolution in measurement, phase encoding and slice encoding directions.

Pixel size	Matrix	FOV
160 microns (0.16 mm)	512	85 mm
330 microns (0.33 mm)	512	170 mm
660 microns (0.66 mm)	512	340 mm

Combining a matrix size of 512 with different FOVs generates different pixel sizes.



Pixel size	Matrix	FOV
166 microns (0.166 mm)	512	85 mm
166 microns (0.166 mm)	1024	170 mm
166 microns (0.166 mm)	2048	340 mm

High spatial resolution (0.166 mm pixels) can be obtained with a range of different combinations of FOV and matrix.

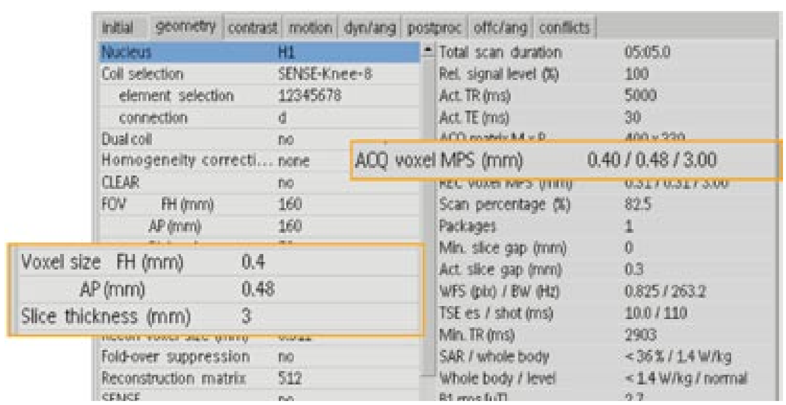
Use voxel size to directly control resolution

In MSK imaging, the most frequently changed parameters are number of slices and FOV. However, changing FOV also changes resolution, bandwidth and gradient waveform. So, changing FOV also changes image quality.

When optimizing spatial resolution, **first determine the FOV and pixel size needed, then derive the matrix size** needed to achieve this.

Philips scanners enable direct control of voxel size. This avoids changes in gradient waveform and thus helps with easier planning and maintaining consistent image quality.

The Info page displays ACQ voxel MPS which is the voxel sizes in measurement, phase and slice encoding directions respectively.



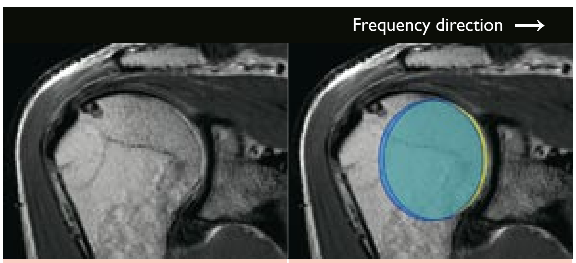
www.philips.com/netforum
Visit NetForum to view more Application Tips on this or other subjects.

Water-fat shift and bandwidth

Fat protons resonate at slightly lower frequencies than water. The frequency difference is called **chemical shift**. It depends on the magnetic field strength:

Field strength	Frequency difference between fat and water
1.0T	147 Hz
1.5T	220 Hz
3.0T	440 Hz

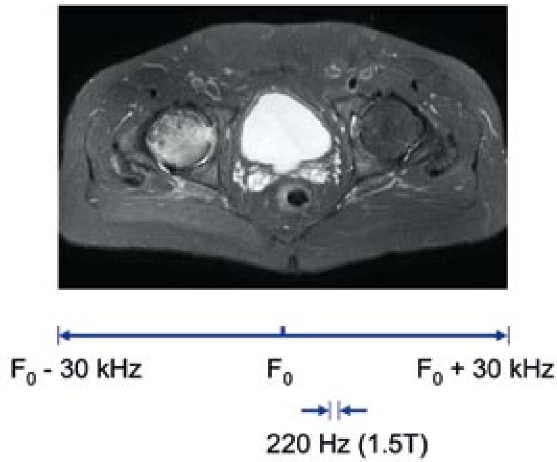
Because MRI also uses resonance frequencies for spatial encoding, this frequency difference causes a small shift between the fat and water position in the frequency direction in the MR image. **Water-fat shift (WFS)** is defined as the displacement of the water signal with respect to fat signal in the image. Water-fat shift is expressed in number of pixels (e.g. 3 pixels).



Shoulder image with clear water-fat shift.	Blue is position of water image, yellow is fat image.

The anatomy imaged determines how much water-fat shift is acceptable. The parameter water-fat shift can be used to optimize a scan. The table summarizes its effects and compares it to the bandwidth effect:

Bandwidth is the range of frequencies represented in an image. If bandwidth gets larger, the number of Hz per pixel gets larger. Water-fat shift (in pixels) is inversely proportional to bandwidth (if other parameters don't change).

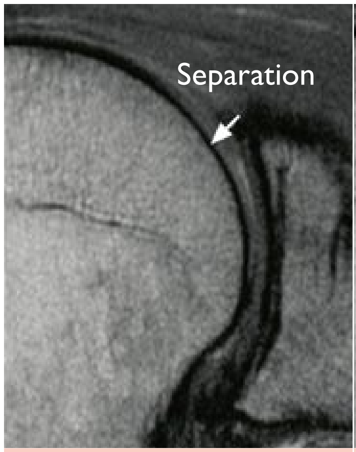


Example: if bandwidth is about 30 kHz for the full FOV, and matrix is 512, then a pixel's width is 30 kHz/512 = about 60 Hz. The water-fat frequency difference at 1.5T is 220 Hz, which then corresponds to 220/60 = 3.7 pixels.

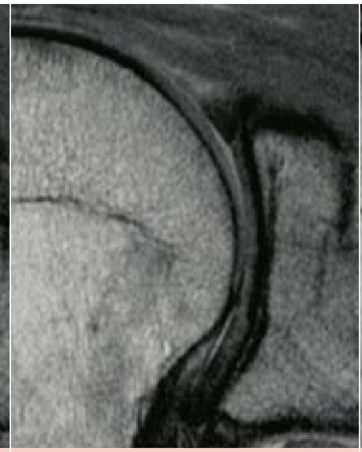
Water-fat shift	Bandwidth
Reduce water-fat shift to reduce chemical shift artifacts	**Increase bandwidth** to reduce chemical shift artifacts
Reduce water-fat shift to reduce metal artifacts	**Increase bandwidth** to reduce metal artifacts
Increased water-fat shift increases SNR	**Narrowing bandwidth** increases SNR
Reduce water-fat shift to reduce readout duration and echo spacing, and limit blurring	**Increase bandwidth** to reduce readout duration and echo spacing, and limit blurring

Adapting water-fat shift to improve image quality

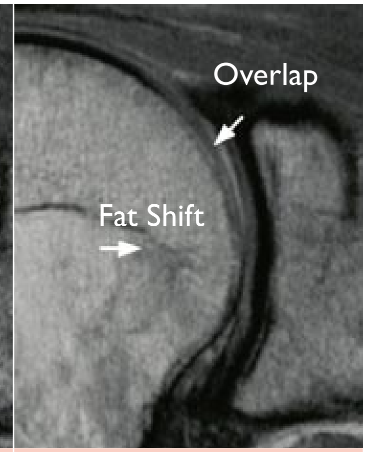
In the shoulder, fat shift (or chemical shift) may cause fat of the bone to overlap with the cartilage. **Decrease WFS while maintaining resolution to separate bone and cartilage** in the image, enabling good reviewing of the shoulder joint. These three images are acquired with the same 0.3 mm acquisition resolution. With the smallest WFS the separation is clearly visible.



Acq. resolution **0.3** mm
WFS = 1 pixel = 0.3 mm
BW = 95 kHz

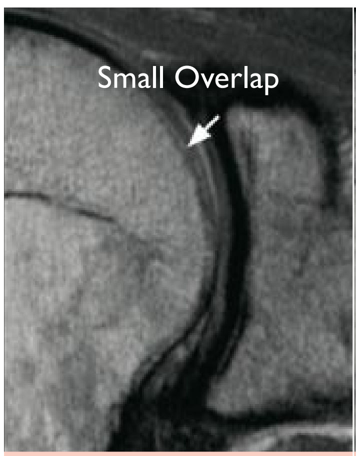


Acq. resolution **0.3** mm
WFS = 1.5 pixel = 0.45 mm
BW = 63 kHz

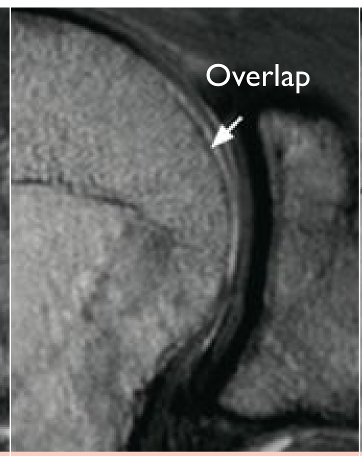


Acq. resolution **0.3** mm
WFS = 3 pixel = 0.9 mm
BW = 32 kHz

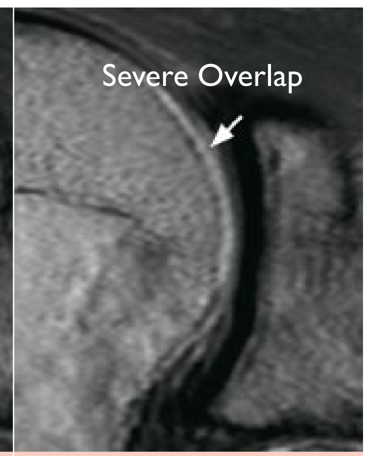
These images show that decreasing resolution (= larger pixels) leads to larger water-fat shift in millimeters (BW decreases), causing severe overlap in the image.



Acq. resolution **0.3** mm
WFS = 3 pixel = 0.9 mm
BW = 32 kHz

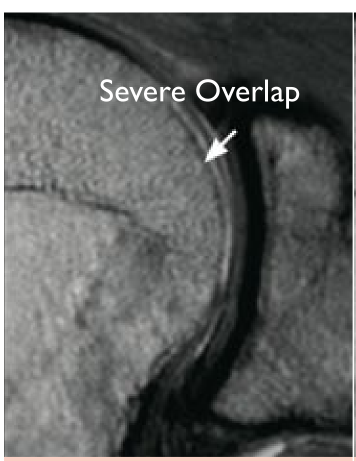


Acq. resolution **0.5** mm
WFS = 3 pixel = 1.5 mm
BW = 19.2 kHz

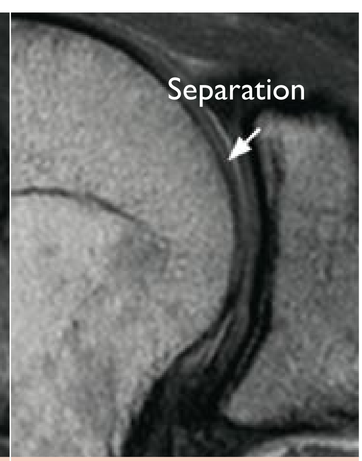


Acq. resolution **0.8** mm
WFS = 3 pixel = 2,4 mm
BW = 12 kHz

Decrease WFS to separate bone and cartilage:



Acq. resolution **0.5** mm
WFS = 3 pixel = 1.5 mm
BW = 19.2 kHz



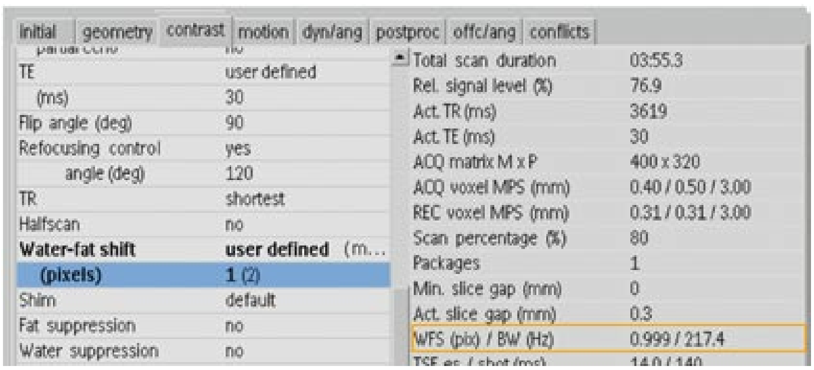
Acq. resolution **0.5** mm
WFS = 1 pixel = 0.5 mm
BW = 57 kHz

Setting the water-fat shift parameter

The Water-fat shift parameter appears on the Contrast page. Possible values are:

Minimum: smallest possible WFS
User defined: WFS will not exceed the user defined value
Maximum: largest possible WFS

Make sure to always check the actual WFS on the Info page.



Practical guidelines for setting WFS:

- For most MSK protocols a WFS of 1 to 2.5 pixels is recommended
- The anatomy determines how many millimeters of fat shift in can be tolerated
- With smaller pixels a slightly higher WFS may be acceptable

Calculating bandwidth from WFS or vice versa

To calculate bandwidth from WFS for 3.0T:
BW [kHz] = 0.22 x matrix_{freq} / WFS [pixels]

To calculate WFS from bandwidth for 3.0T:
WFS [pixels] = 0.22 x matrix_{freq} / BW [kHz]

For other field strengths the same formulas apply, but replace 0.22 by 0.11 for 1.5T, or by 0.074 for 1.0T.

Example: if WFS is 1.76 pixels for a 3.0T scan with matrix 512, then BW = 0.22 x 512 / 1.76 = 64 kHz

Example: if bandwidth is 62.5 kHz for a 3.0T scan with matrix 384, then: WFS = 0.22 x 384 / 62.5 = 1.35 pixels