FLUKE®

MRI adjustments with a Fluke ScopeMeter® 190 Series

Application Note

In modern medicine, Magnetic Resonance Imaging or "MRI" is one of the techniques used to study the inner structure of a living body on a non-invasive basis. The technique is an application of Nuclear Magnetic Resonance or NMR which is also used beyond the medical field to study the structure of matter. The main advantage of MRI over X-ray based techniques is in the better imaging capability of soft tissue, where X-ray techniques are more useful for study of the bone structure, for instance in case of fractures.

Basics of MRI

NMR is based on the fact that the atoms of many chemical elements and their isotopes have some degree of magnetic orientation. Under normal conditions, the individual magnetic fields of individual atoms show a random orientation, and the net field is zero (Figure 1).

When placed in a very strong static magnetic field, the magnetic fields of the individual atoms line up, resulting in a net magnetization (Figure 2). The magnetic fields used to accomplish this are around 0.1 to 4 tesla (1 T = 10000 gauss) with a tendency to the ever stronger fields.

Once the nuclei are aligned by this static magnetic field, an alternating magnetic field in a direction perpendicular to the main field will make the protons precess around the axis of their static orientation.

When this occurs, the atoms turn out to have a resonance frequency in the RF-range. For instance the hydrogen atom (1H) has a resonance frequency of approximately 42.58 MHz when placed in a static magnetic field of 1 T.

Given this resonance, the nuclei can be thought of as resonators that absorb energy from the applied RF-field.

Nuclei of different elements and different isotopes all have different resonance frequencies.

For as long as the RF-field is applied, all nuclei will resonate in phase, but once this stimulus ends the individual nuclei will lose synchronism, or de-phase, and return to their original position aligned with the static magnetic field. This process of returning to the original orientation takes a length of time that is again characteristic of each different type of nucleus.

By measuring the resonance frequencies and the decay times, the individual elements present in the body can be determined.

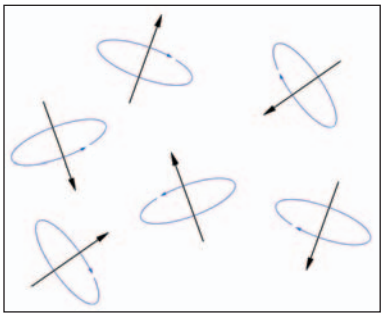

Figure 1: *Normal randomly arranged magnetic orientation of nuclei.*

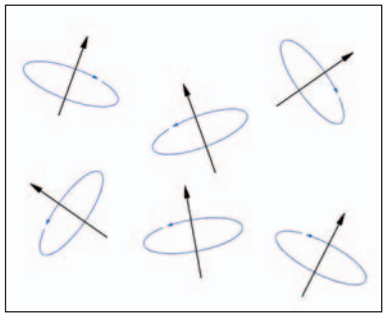

Figure 2: *When placed in a strong magnetic field, the magnetic orientation of nuclei align with the external field.*

Oscilloscopes used in MRI

For the proper functioning of the MRI-equipment, it is essential that the RF stimuli are switched on and off in a well controlled manner, and with good reproducibility. During development and adjustment of the equipment, a proper representation of these RF-bursts is most impor-

tant. For this purpose an oscilloscope is a most valuable piece of test equipment, if it can display the RF carrier frequency and is capable of showing the envelopes of the bursts properly. These envelopes show you everything that needs to be known about the process of activating and terminating the RF bursts.

Many oscilloscopes, however, have difficulty working properly in the vicinity of the MRI-equipment because of the extremely high static magnetic fields.

By nature, the CRT of the oscilloscope is sensitive to magnetic influences as it is based upon electrons travelling through the vacuum of the CRT.

The Fluke ScopeMeters are all able to operate as compact, high performance oscilloscope that are well equipped to acquire and display electrical signals of various frequencies and that are not influenced by magnetic fields (in contrast to a traditional CRT-based oscilloscope) since the display used is an LCD.

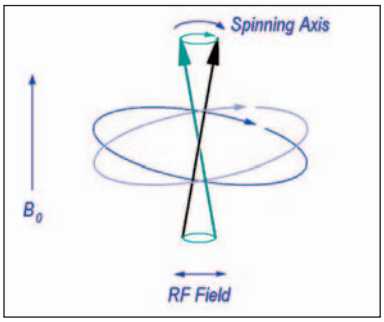

Figure 3: *When placed in a static magnetic field B_0 under the influence of an alternating field perpendicular to the static field, the nuclei start precessing.*

ScopeMeters used in MRI

The Fluke ScopeMeters are available in different bandwidth and with different sample rates (see table 1). Given the RF-frequencies commonly used in MRI of 42.58, 63.8 and 127 MHz, the Fluke 190 Series ScopeMeters are the most appropriate instruments for test and alignment purposes.

Fluke type number	Bandwidth	Max. sample rate (single shot)
Fluke 123	20 MHz	25 MS/s
Fluke 124	40 MHz	25 MS/s
Fluke 192B	60 MHz	500 MS/s
Fluke 196B, 196C, 196BM, 196CM	100 MHz	1 GS/s
Fluke 199B, 199C, 199BM, 199CM	200 MHz	2.5 GS/s

Table 1: *ScopeMeter models and their bandwidth.*

All Fluke ScopeMeters are equipped with a function called 'Glitch Detect'. This function activates a digital overscan mechanism to find high-frequency signal content even when working at low speed timebase settings. An example of this is given in Figure 4.

At higher timebase speed, the number of cycles that is contained in an individual burst is quite limited, and it becomes more difficult to recognize the overall envelope of the signal (see Figure 5). Furthermore, at higher RF-carrier frequencies, the effects of aliasing may also influence the quality of the displayed bursts.

Here, some of the additional functions found in the ScopeMeters come in handy to enhance the quality of the displayed waveform.

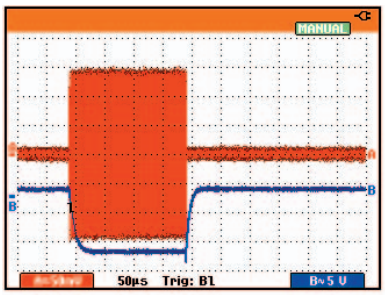

Figure 4: *At lower timebase setting, the 'glitch detect' function builds a solid envelope of a high frequency burst (Fluke 199C).*

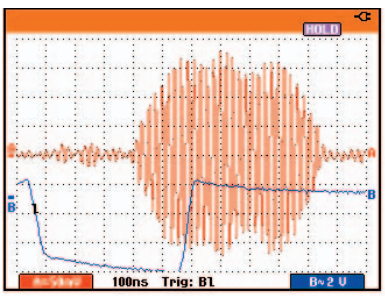

Figure 5: *A short duration burst is captured, but the envelope is more difficult to identify (Fluke 199C).*

Envelope function

The Fluke 190B Series ScopeMeters are equipped with a so-called "Envelope"- function that builds the envelope over successive waveform-acquisitions on the display. See Figure 6. For this, the extreme values (that is the most positive and the most negative value for each of the horizontal positions over successive traces) are stored, and these are overwritten only when newer values are found in a next trace that exceed the earlier ones at the same position.

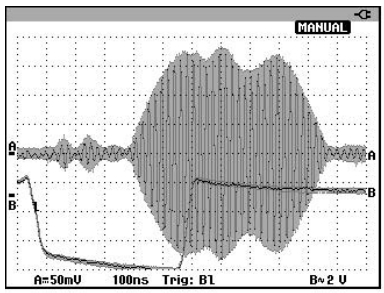

Figure 6: *The envelope function of the Fluke 199B is used here with the same signal as in Figure 5.*

After just a few acquired traces, the envelop function shows a good representation of the overall envelope of the burst. On top of the envelope pattern, the most recently acquired waveform is then also displayed.

Digital persistence

Next to the envelope function, the Fluke 190C Series of Color ScopeMeters also includes a so-called 'Digital Persistence' mode. In that mode, individual traces are stored in a dedicated display memory and each waveform fades away slowly. The decay time, or fade-out time, can be selected for short, medium or longer persistence, or it can be switched to have an 'infinite persistence'.

The resulting display shows a number of successive waveforms, superimposed and at different intensity levels in which the most recent ones stand out more clearly. See Figure 7.

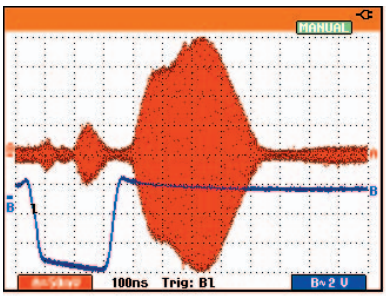

Figure 7: *The Fluke 199C is used here with 'Digital Persistence' to capture a natural envelope of a short duration burst of an RF-carrier.*

When used on burst signals, as encountered in MRI-equipment, this Digital Persistence gives the display quality one would expect from a traditional high-frequency oscilloscope with its phosphor ensuring the slow trace fade-out.

An additional benefit of the Digital Persistence mode is that it automatically adapts the waveform representation if the overall amplitude drops, e.g. as a result of an alignment made to the equipment under test.

The envelop mode, on the other hand, will continue to show the maximum amplitude that the envelope has ever attained since the functions was initiated. Should a new amplitude of the waveform be seen or expected, a simple key-press (e.g. of the attenuator, 1 step up and back) will delete the created envelope and start building a new one.

Conclusion

The Fluke 190 Series ScopeMeters are well equipped to capture and display the short-duration bursts of RF-energy as used in the MRI-medical imaging equipment. On top of the basic functionality of these high performance handheld oscilloscopes, some additional functions are built-in that help to optimally display the waveforms of such short duration bursts.

ScopeMeters for medical equipment applications

The Fluke ScopeMeter 190M Series offer additional capabilities targeting the service engineer dealing with Medical Imaging Equipment and Video Display Systems. These models have the following additional capabilities :

Current-over-time measurement giving mAs read-out
Using the cursors you can measure directly the amount of radiation produced by X-ray systems or the total amount of charge supplied to a system.

Extended video triggering
The 190M Series supports triggering on high-resolution non-interlaced video systems.

Smart averaging
Smart averaging shows the averaged curve of repeated signal parts, as well as incidental deviations.

Extended offset
Allows vertical zoom-in for study of small details of the larger amplitude signal or when a larger DC-component is included.

Medical models available are the Fluke 199CM, Fluke 199BM, Fluke 196CM and Fluke 196BM. See techical data sheet for full details.

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