# Introduction: The FFT emission measurement method

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## Outline

- The classical method of emissions measurements
  - Disadvantages
- The FFT method
  - Theory and implementation
  - Advantages
  - Disadvantages
- Summary of issues

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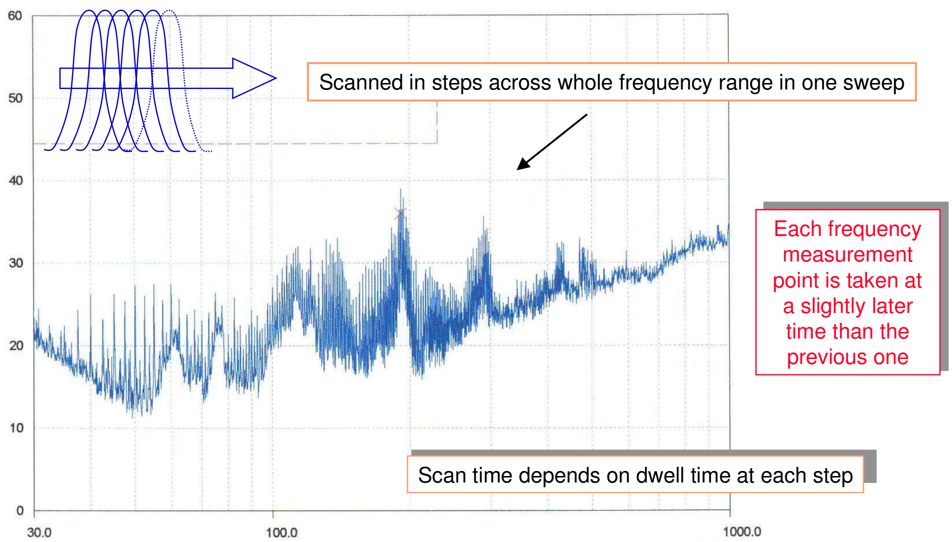
## Pre-scans in the frequency domain

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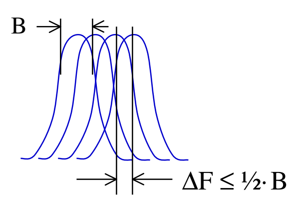
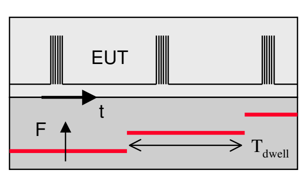
## The problem with frequency domain scans

- The scan step size ΔF must be ≤ ½ bandwidth to capture all possible emission frequencies adequately




- Each step must dwell for a time $T_{dwell}$ at least as long as the slowest EUT modulation period to capture all transient signals




- The span must be repeated for different geometries
- The method assumes that emissions will be present for the whole span duration $(F_{span}/\Delta F) \times T_{dwell}$

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## Probability of intercept

- At any frequency a transient emission will only be captured if it occurs at the same moment as the scan is on that frequency
- So, if the dwell time $T_{dwell}$ is less than the period $t_{EUT}$ of a repetitive emission, the probability of intercepting such an emission is

$$P = \frac{T_{dwell}}{t_{EUT}} < 1$$

- Too short a dwell time creates the risk of missing relevant emissions during the pre-scan, and so never measuring them
- Historically, pulsed emissions were broadband and so the risk was low; but pulsed or transient narrowband emissions are now more common

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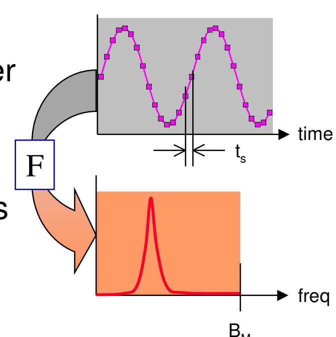
## The FFT time domain method

- The Fast Fourier Transform (FFT) is an algorithmic implementation of the Fourier Transform which acts on discrete samples of a time domain waveform
- The transformed time domain data gives a frequency domain representation of the captured signal spectrum
- The Nyquist-Shannon sampling theorem states that the signal can be completely reconstructed as long as the sampling frequency $1/t_S$ is greater than twice the maximum signal bandwidth




$$\frac{1}{t_S} > 2 \cdot B_M$$

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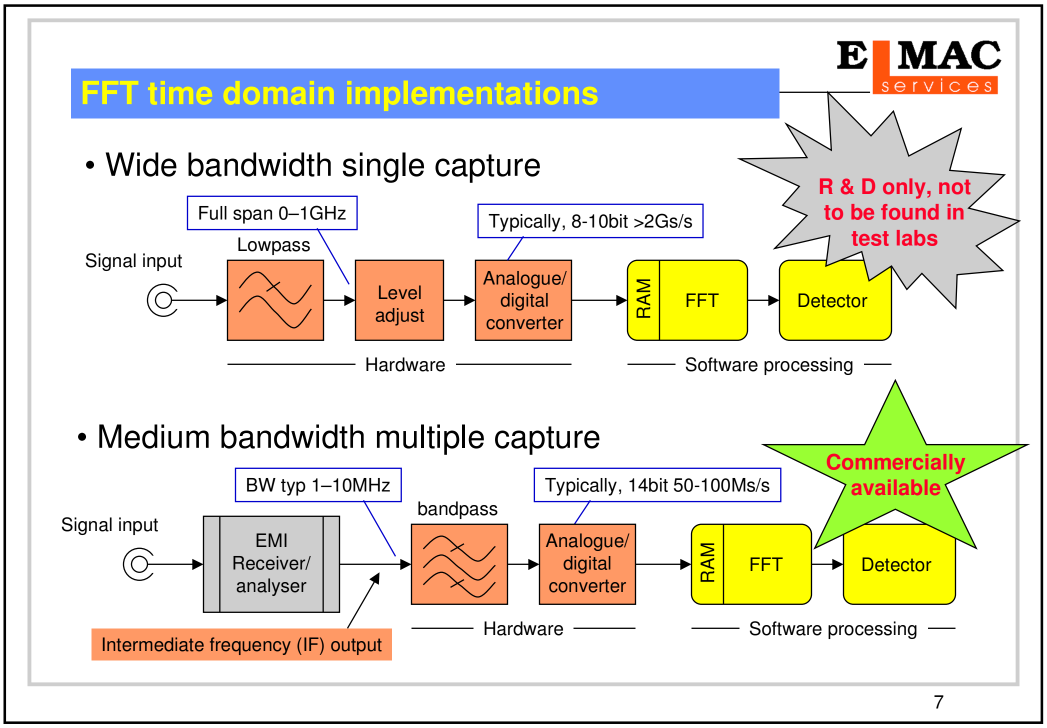
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FFT time domain implementations
• Wide bandwidth single capture
Full span 0–1GHz
Typically, 8-10bit >2Gs/s
R & D only, not to be found in test labs
Signal input
Lowpass
Level adjust
Analogue/ digital converter
RAM
FFT
Detector
Hardware
Software processing
• Medium bandwidth multiple capture
BW typ 1–10MHz
Typically, 14bit 50-100Ms/s
Commercially available
Signal input
EMI Receiver/ analyser
bandpass
Analogue/ digital converter
RAM
FFT
Detector
Intermediate frequency (IF) output
Hardware
Software processing
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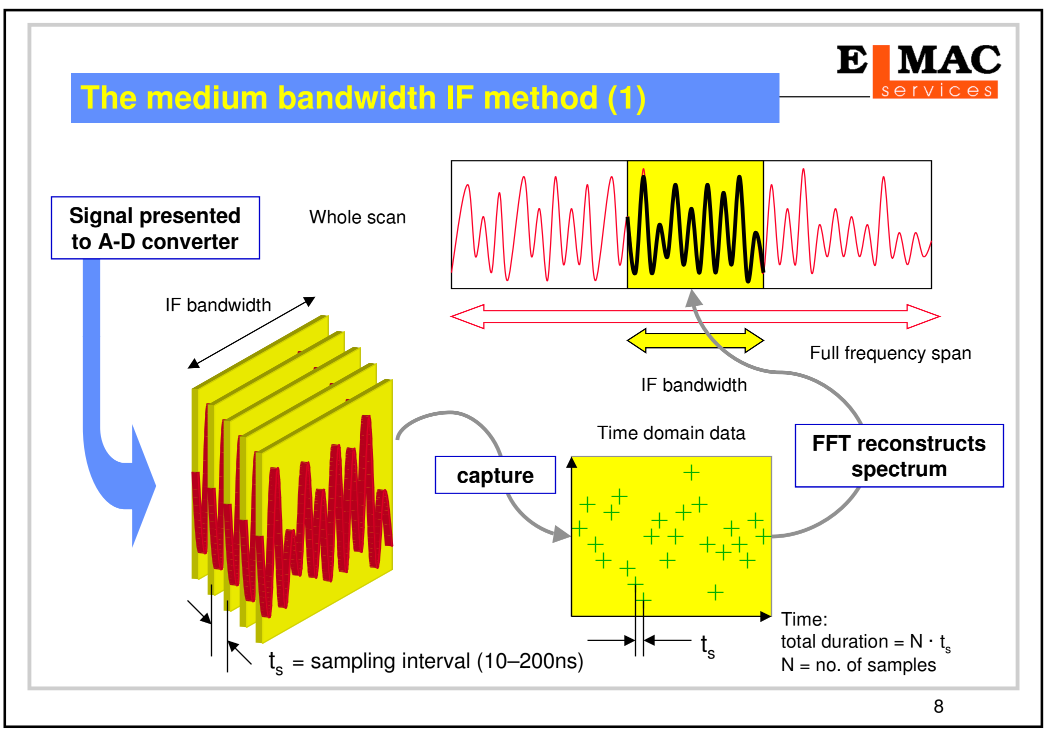
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The medium bandwidth IF method (1)
Signal presented to A-D converter
Whole scan
IF bandwidth
Full frequency span
IF bandwidth
Time domain data
capture
FFT reconstructs spectrum
$t_s$ = sampling interval (10–200ns)
$t_s$
Time:
total duration = N · $t_s$
N = no. of samples
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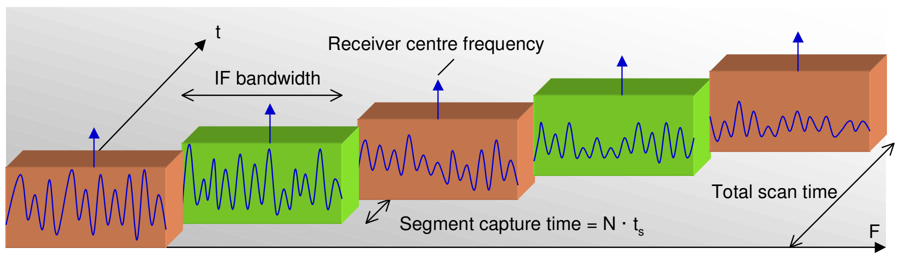
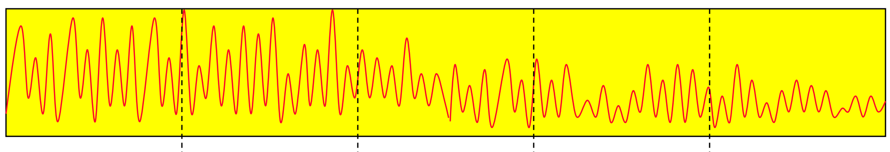
## The medium bandwidth IF method (2)

IF-wide segments captured in consecutive time slots...




… are "stitched together" to give the overall spectrum



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## The FFT method: advantages

- Once a segment is captured, any resolution bandwidth and any detector function can be applied retrospectively to the analysis
  - as long as there are enough time samples in the segment, approx. 2/RBW (narrow RBWs require longer time captures, i.e. more memory for given segment width), and enough time to ensure detector settling (e.g. 1 sec for QP)
- Measurement time for a complete span can be dramatically improved
- At the same time, probability of intercept for transient narrowband signals can also be improved

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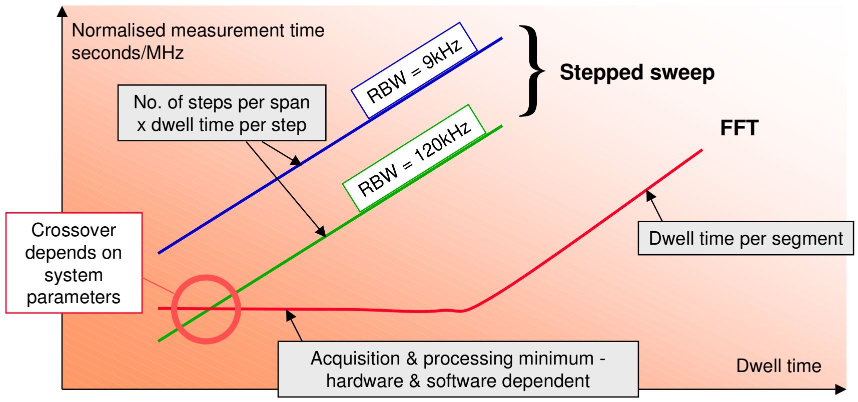
## Measurement time comparison

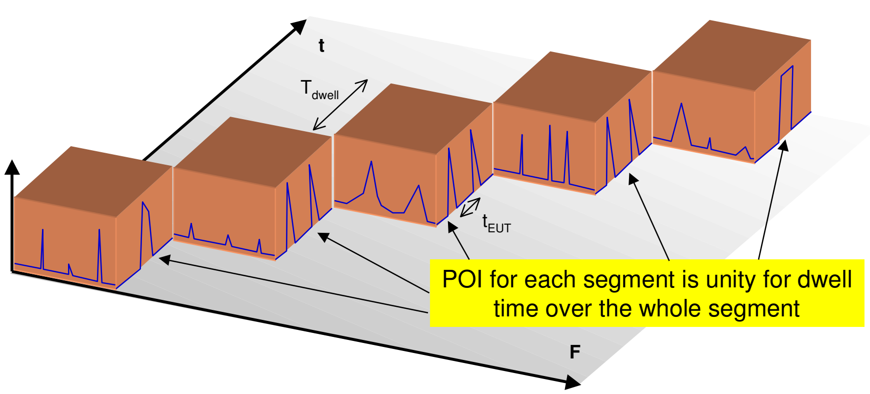



Because of the required processing time, wider RBWs and shorter dwells gain less from the FFT method than do narrow RBWs and longer dwells



## Probability of intercept with FFT

- transient signals will be seen and can be analysed as long as they are present within the segment at any time during the capture period



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## The FFT method: disadvantages

- dynamic range is limited for each capture
  - no auto-ranging within a segment, wide noise bandwidth before ADC
  - but different segments can use auto-ranging
- absolute accuracy
  - slightly worse than conventional swept, because of imperfect correction for flatness of IF filter
- a true QP measurement still requires a long sample time (≥ 1 sec) to ensure settling of the QP detector
  - limited dynamic range at low PRFs due to wide IF BW
- not yet enough experience to be sure that some types of emissions may not defeat the FFT analysis

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## The FFT method: tradeoffs

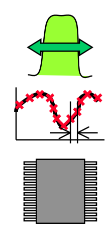
- Principal trade-offs in the instrument in FFT mode are between memory size, sampling interval, IF bandwidth and maximum capture duration

Wider IF bandwidth needs...

…a shorter sampling interval which requires...

…a faster ADC and more memory for a...

…longer capture duration



- Principal operator trade-off (choosing between conventional swept or FFT) is between dynamic range and measurement time

Wider dynamic range — Conventional

↕

Faster measurement time — FFT

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## FFT artefacts

- transient signals may give different results depending on the (unsynchronised) time relationship between the capture window and the transient duration
- finite capture periods result in “leakage” (frequencies in the output that are not present in the input spectrum)
- inadequate bandwidth filtering before the ADC can give rise to aliasing (input frequencies above the sampling frequency are folded into the output spectrum)

- All these artefacts can be controlled to an acceptable level by careful choice of the Fourier sampling window and parameters in firmware and by good hardware design

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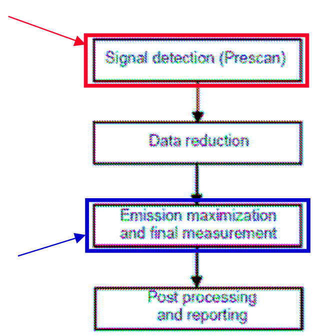
## Likely use of FFT in compliance tests

- Pre-scan: significant advantages
  - allows better coverage of maximization procedures – turntable and height scan
  - better probability of intercept
  - non-QP measurements not a problem

- Final measurement: probably better left to conventional technique
  - fixed frequency, no speed advantage
  - true QP compliance




(from CISPR 16-2-3)

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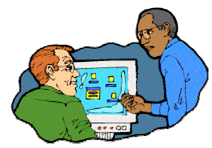
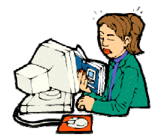
## Non-technical issues

- Training
  - does the advent of this method, with potentially complex EUT-dependent trade-offs, raise the need for more test engineer training?

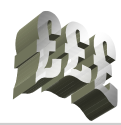


- Procedures and software
  - what are the implications for lab procedures (e.g., EUT setup, turntable/mast positioning) and control software?



- Accreditation and standards
  - should standards development explicitly cover the FFT method, and what does it imply for accreditation?

- Cost
  - if the test can be done very much faster, should third-party labs reassess their charging regime?



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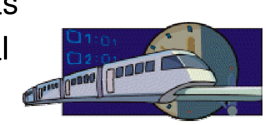
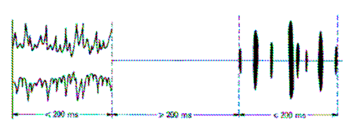
## New applications in EMC

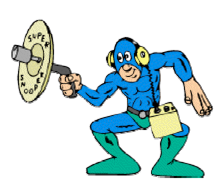
- Comprehensive emissions measurements of short-duration events are now practical
  - railway, automotive
  - time-limited EUTs



- Measurements of time-domain parameters are more easily available
  - possible improvement of the EN 55014-1 click measurement



- Greater variety of diagnostic and investigatory options



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The FFT emission measurement method

End

Thanks for your attention

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## Introduction: The FFT emission measurement method

Presented at EMCTLA workshop on

**The FFT time domain method: a sea change in RF emissions tests?**

Henley in Arden Golf & Country Club, UK

26th June 2008

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