



## Questioned Documents Section - 2014

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### **J21 Analysis of Paper Textures Using High-Resolution Digital Photography and the Two-Dimensional Discrete Fourier Transform**

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After attending this presentation, attendees will understand the application of the two-dimensional discrete Fourier transform to the discrimination of sheets of paper from different reams of paper.

This presentation will impact the forensic science community by demonstrating that two-dimensional discrete Fourier transform patterns can be obtained from sheets of paper using readily available digital camera equipment and ImageJ, an open source computer program.

Forensic document examiners may be asked to determine whether the paper on which a document was printed could have come from a particular source, such as a particular ream of paper. Such a problem can be approached using a variety of different measurements (e.g., thickness, color, fluorescence, Fourier transform infrared spectrometry, and X-Ray diffraction). Ideally, forensic methods of analysis for paper should be non-destructive and inexpensive. Paper manufacture can introduce repetitive patterns to the surface of the paper. These can be visualized using transmitted light, a procedure often used to visualize and photograph watermarks. The two-dimensional discrete Fourier transforms of transmitted light images of sheets of paper provide a way of visualizing repetitive patterns and of more objectively comparing them. The two-dimensional discrete Fourier transform produces images with patterns of spots which reflect the periodicity of repetitive patterns and their directionality. The research reported here explored whether forensically useful two-dimensional Fourier transform papers could be obtained using simple photographic equipment and open source computer software.

Sheets of white office paper were selected from each of 16 reams of paper. These reams of paper came from nine different vendors. Each sheet was placed on a white light transilluminator and three to five images of different areas on the sheets were captured with a 14-megapixel digital single lens reflex camera mounted on a tripod. It was found that exclusion of stray light and sharp focusing of the camera were critical to obtaining usable digital images. Two-dimensional discrete Fourier transforms were computed for each digital image using ImageJ, an open source computer program developed by the National Institute of Health for image analysis. Versions of this program are available for different computer operating systems. The images were converted to gray scale and cropped to provide a square image. This was done because the two-dimensional discrete Fourier transform algorithm employed by ImageJ requires square images. To allow the Fourier transform patterns to be more easily viewed, the image produced by the two-dimensional Fourier transform was converted to binary (black and white) and eroded twice to remove noise from the image.

The Fourier transform patterns obtained from each sheet proved to be highly reproducible. Each sheet of paper was found to produce a unique Fourier transform pattern. Moreover, these patterns were different from those reported by researchers at the Netherlands Forensic Institute. Further research must be done to determine whether the Fourier transform patterns are consistent within a ream of paper.

This presentation demonstrates that two-dimensional discrete Fourier transform patterns can be obtained from sheets of paper using readily available digital camera equipment and ImageJ, an open source computer program.

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### **Forensic Document Examination, Paper, Fourier Transform**