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RESOLUTION CAPABILITIES OF FUTURE THZ CAMERAS.

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Introduction: THz technology for developing imaging systems has recently aroused great interest, mainly due to the large number of applications in which these frequencies can be used: security, vision in hard environments, etc.

In this paper we propose a method that reduces significantly the number of detectors needed for achieving certain resolution by means of diffraction that paradoxically is its main limiting factor in current imaging devices. The method uses diffraction as a way of achieving spatial diversity and as an anti-aliasing LPF. Decimation is used to reduce the number of detectors.

Background Info: The technological difficulties to manufacture a large number of detectors in the THZ band, result to be a hard constrain that limits the possibilities of the imaging systems that work in it. Many times, the camera should include some kind of moving mirrors in order to scan the entire vision field. These limitations boost research towards finding alternative systems and techniques that allow us to overcome the shortcomings current technology has.

Nature has found its way to get round some of these weaknesses, achieving a more robust and less complex systems. One of the most representative exponents of this success is human eye. Even though it is not fully understood how it works, it is certainly true, and so demonstrates the evidence, that its acuity is beyond the theoretical limit it is supposed to have. Classical approaches (usually based on ray theory) fail to explain this fact and further research has yet to be made. This work ascribes this feature to a combination of spatial diversity of the information and cooperative detection, and aims to explore its usage in imaging systems.

Diffraction: Diffraction is a phenomenon present in every single imaging system. It is the main constrain to the maximum resolution achievable. It arises from the finite nature of any real imaging system compared with the infinitude of the incoming plane wave. This finitude produces the spatial windowing of the latter. The main effect of diffractions is transforming point sources in the landscape into blobs on the image. The shape of these blobs (also known as diffraction patterns) depends on the shape of the system's smallest aperture.

The relation between the system's diffraction pattern and the maximum resolution achievable in a classical imaging sensor such as the CCD is simple. In a CCD the resolution is given by the size and number of sensors: the smaller (i.e. the more) the sensors are, the more resolution you get. But this cannot be applied endlessly. The maximum resolution achievable will be given by the smallest sensor size which still allows the diffraction pattern to fit most of its energy within a single detector, Fig. 1. If smaller sensors are used the result is a blurry image. This is why these systems are diffraction limited.

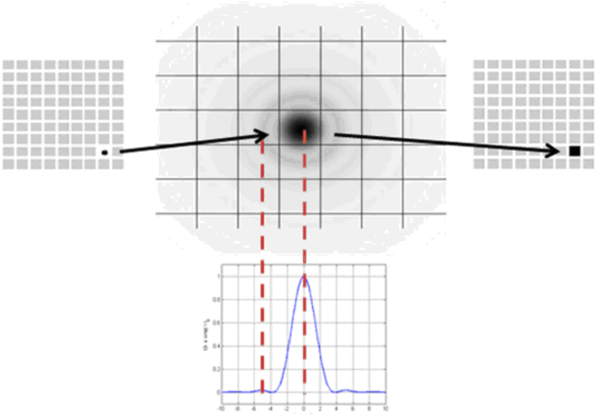

Fig. 1: Diffraction Vs Resolution in a CCD.

However, using average dimensions of a human eye in very well known imaging equations bring to light two facts: first, a single diffraction pattern produced by the eye covers several of its photo-detectors, but even though it should create a blurry image according to the diffraction limit it does not (we all see clear images); second, the minimum detectable detail size, given by the minimum angle of resolution, should be about 50 seconds of arc, but it is actually smaller. All this suggest that there are mechanisms, different from the CCD approach, which allow resolution beyond the diffraction limit.

Proposed Method and Results: The proposed method uses the diffraction pattern produced by the diaphragm (assumed known and constant for the entire image) to create a spatial diversity (phase plane) strategy to be able to perform the detection in optimal conditions. It assumes that the blur generated by the diaphragm is perfectly reversible by just applying the inverse function (Fig. 2). With the proposed technique: blur (diffraction) – detection – de-blur, detectors could be much simpler - the final SNR per final pixel may well be defined by the composition of many detectors (spatial diversity)- and the whole system becomes much more robust.

But it is possible to go a step forward. Taking advantage of the fact that the diffraction pattern is a slow variation function (LPF) over the image (many detectors will be "sampling" that function rather than integrating it) we can interpolate new points in it thus increasing, artificially, the number of sensors and therefore improving the resolution of the final image. In order to compare the results, we decrease intentionally the number of detectors (pixels) once the original image (Fig. 2a) has been blurred by the diaphragm. In Fig. 3, a point source (a), which originally would be missed by the array, is spread through the sensors by diffraction (b). Once detected, the missing values are calculated through interpolation (c) and then the whole image is de-blurred (d) and presented.

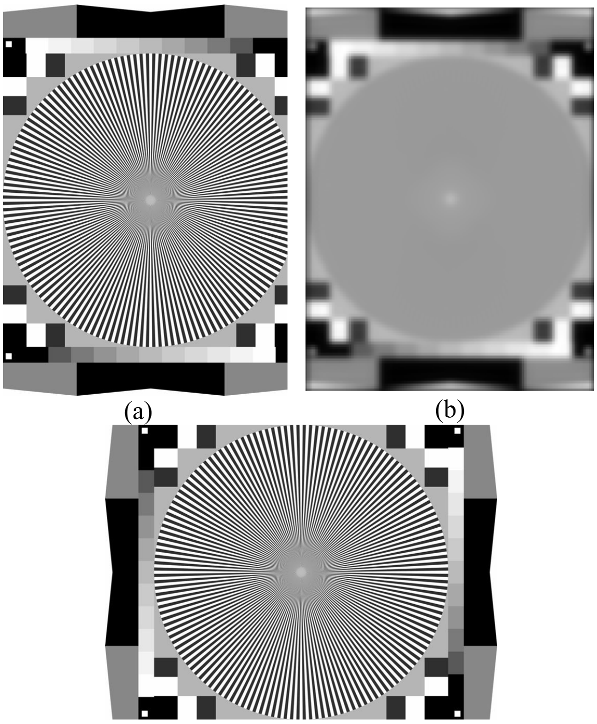
(a) (b)
(c)

Fig. 2. (a) Original Image. (b) Blurred Image. (c) Recovered image.

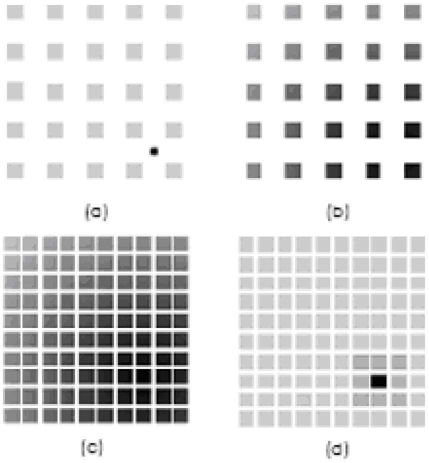

Fig. 3. The Method.

In figure 4, an inverse problem -maintaining the resolution (number of pixels) of the final image and reducing the required detectors- is presented. The obtained images using different number of detectors are shown, proving that the shapes (high frequencies) are properly restored despite the reduced number of sensors.

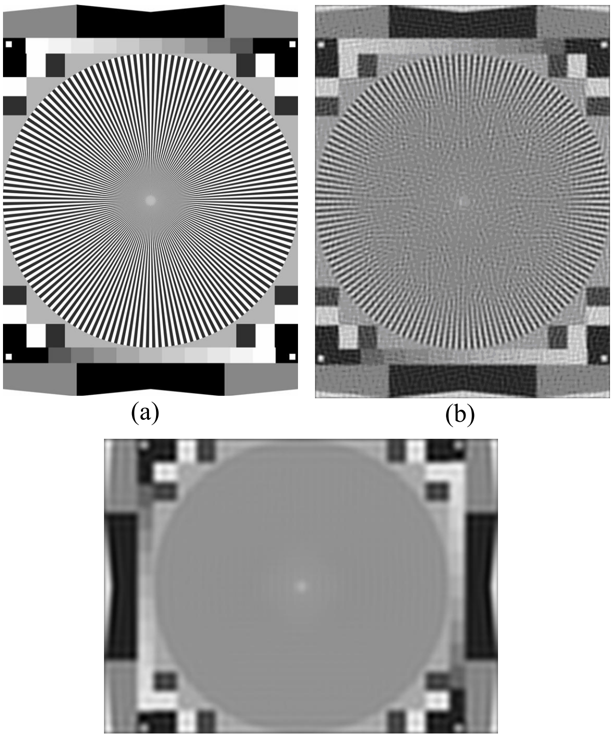
(a) (b)
(c)

Fig. 4. (a) Original image with NxN detectors, (b) the one obtained with NxN/16 and (c) with NxN/64.

Conclusions: Two main conclusions arise from this study: first, it is possible to get resolution beyond the diffraction limit (Fig. 2); second, the method proposed reduces significantly the number of sensors needed to achieve certain resolution. Note that a decimation factor M implies a M^2 reduction in the number of sensors.

Last but not least, our method produces a more robust system since the interpolation applied recovers not only the decimated pixels, but also the damaged ones. This is possible because diffraction spreads out the information that in a CCD would be received by a single pixel across several ones.

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