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Phase Control in the Digital Lens

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ABSTRUCT Phase and amplitude is controlled by manipulating the digitized radiation field. Application to the phase switching, and the calibration of phase and amplitude is discussed.

INTRODUCTION

2D FFT processor is an ideal digital lens. The present digital lens at Waseda university has 8bit dynamic range, and the phase error from quantization is within 1 degree. However the phase error in local and IF cable is much larger. In order to reduce these errors, the complex multiplication $R \cdot \exp(i\phi)$ is done between A/D converters and FFT processor. These complex amplitude equalisers have also 8 bit dynamic range, and the complex coefficients(or amplitude R and phase ϕ) are controled from computer. Some examples of the application of the complex equaliser are shown. 1)Phase switching in 8 element 1D array. Base line fluctuation is seen in non switchig data, while the effect of gain fluctuation in recivers is reduced in switchig data. Phase error is measured by observing a point source, and the correction is done by sending 8 complex coefficients from computer. Beam separation of any angular size corresponding to 0-180 deg in phase is possible. (Fig. 1) 2)phase adjustment in 2D small array($8\times8=64$).

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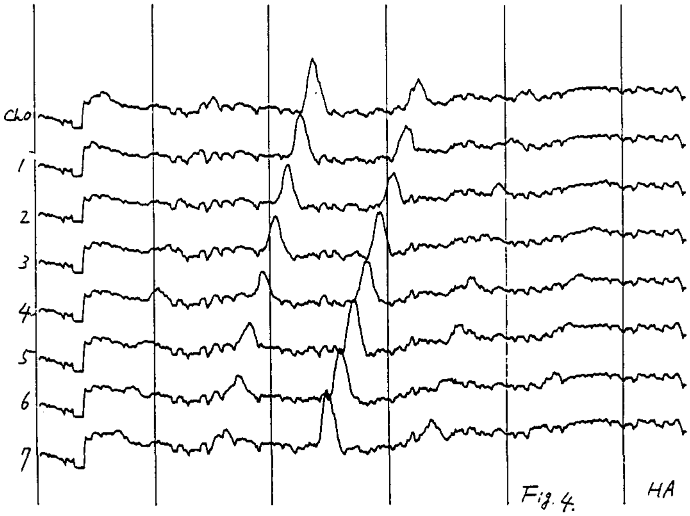
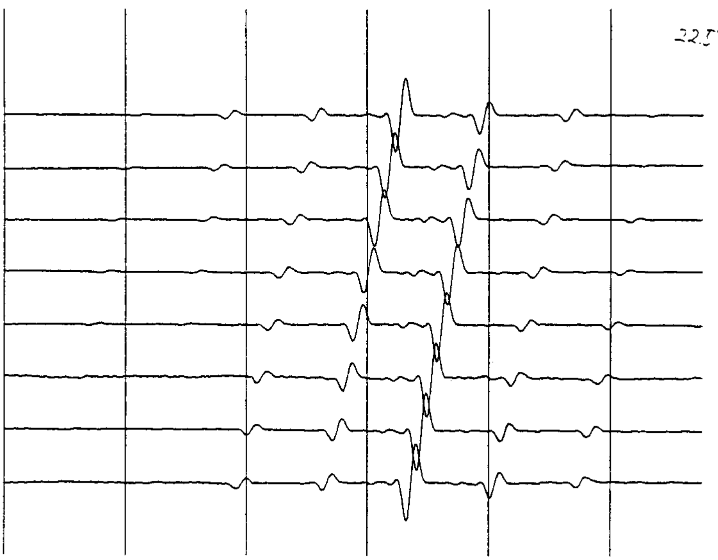


(Fig. 1-a) Direct image (non-switching)



(Fig. 1-b) Direct image (22.5 deg switching). The gain fluctuations are removed.

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PRINCIPLE OF PHASE ADJUSTMENTS

In the 8×8 radio patrol camera(small Array), CW source(10.6 GHz) is used in order to correct the phase and amplitude errors in analogue system. The present calibration method is basically one dimensional and combination of them makes it possible to calibrate 2D array. Then, we describe how to correct the 1D phase and amplitude erros. Recieving the signal f(t) from the CW source, the output of A/D converted at k channel is

$$g(k) = a_k f(t)\exp(i\phi_k)$$

, where a_k is the gain in amplitude and ϕ_k is the phase before the A/D converter. 8 point DFT of g(k) is obtained by the digital lens as follows,

$$G(n) = 1/8\sum_{k=0}^{7} g(k)\exp(-i2\pi kn/8)$$

$$= 1/8\sum_{k=0}^{7} [a_k f(t)\exp\{i(\phi_k-2\pi kn/8)\}] \quad (1)$$

, where n is the pixel number in the image plane. To determine the relative phase $\phi_k-\phi_0$ and the relative gain in amplitude a_k/a_0, let the signal pairs be Fourier transformed(Young's experiment). We measure the value of the phase shift and the peak to peak value of the intensity in the image plane. If g(k) is given as following,

$$\begin{aligned} g(0) &= a_0 f(t)\exp(i\phi_0) \\ g(j) &= a_j f(t)\exp(i\phi_j) \\ g(k) &= 0 \text{ for } k\neq 0 \text{ and } k\neq j, \end{aligned} \quad (2)$$

substituting eq.(2) into eq.(1), we get the output power distribution P(n) in the image plane as,

$$\begin{aligned} P(n) &= \mathrm{Re}G(n)^2 \\ &= 1/64\ f(t)^2\{a_0^2+a_j^2+2a_0a_j\cos(-2\pi jn/8+\phi_j-\phi_0)\} \end{aligned} \quad (3)$$

From a set of equation (3), the relative phase is determind as,

$$\Delta\phi_j=(\phi_j-\phi_0).$$

The product of a_j and a_0 is also obtaind from equation (3). Thus, multiplying$(a_j/a_0)^{-1}\exp(-i\Delta\phi_j)$, we correct the phase and amplitude errors. The complex coefficients$((a_j/a_0)^{-1}, \Delta\phi_j)$ are sent from a computer.

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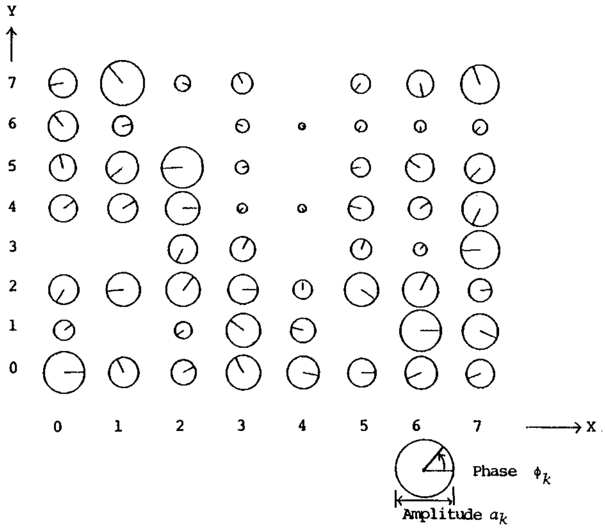
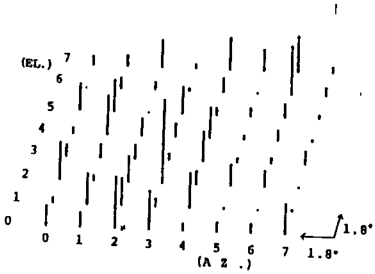
MEASURMENTS AND RESULTS

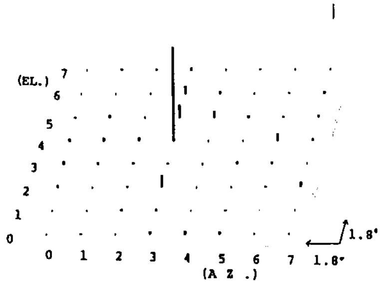
We mesured the amplitudes and phases along both x-axis and y-axis in the 2D Small Array. Fig.2 is the results of this measurements. Radius of circle and inclination of radius indicate the amplitude and phase respectively in our present system. Fig.3 shows the image of the CW source before correcting the phase errors. We see the clean image after reducing these errors (Fig.4).



(Fig.2) obtained amplitude and phase in 2D digital lens system



(Fig.3) The image before phase correction



(Fig.4) The phase error removed image

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