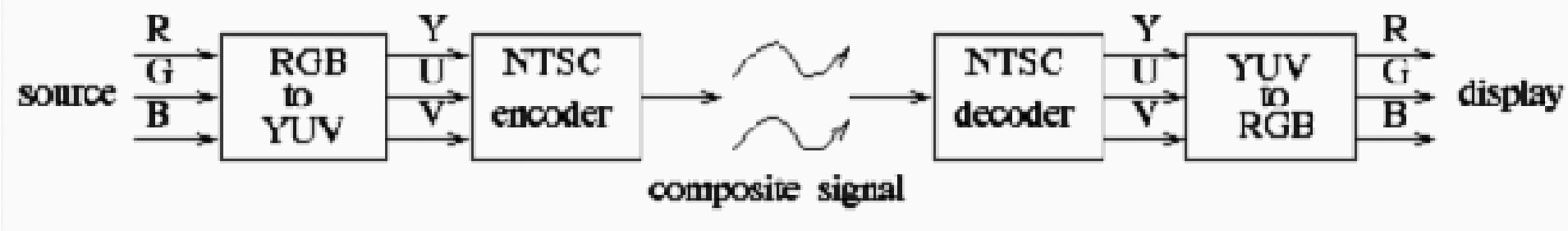
LECTURE 1 - Part 2
SPATIO - TEMPORAL SAMPLING

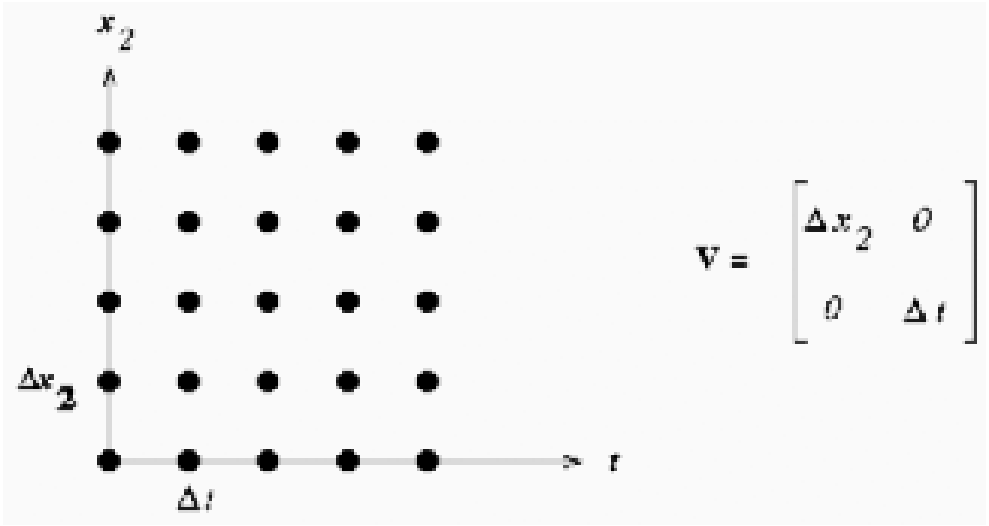
- Spatio-Temporal Sampling
  - 2-D Sampling Structures for Analog Video
  - 3-D Sampling Structures for Digital Video
  - Analog-to-Digital Conversion
- Spectral Characterization of Sampled Video
  - Sampling on a 2-D Rectangular Grid
  - Sampling on a Lattice
- Reconstruction of Continuous Video from Samples
  - Digital-to-Analog Conversion

Sampling in analog and digital video

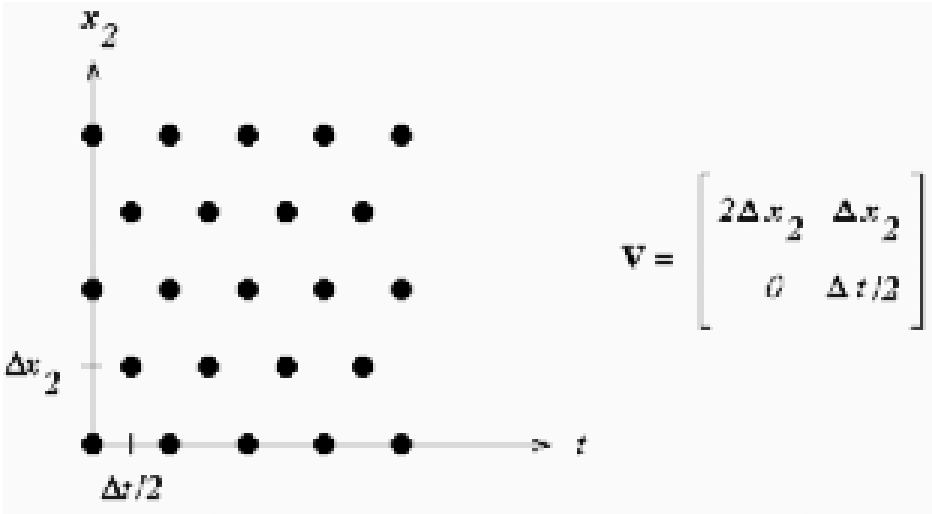


- Analog video is sampled in two dimensions (usually x_2 and t) by means of the scanning process, and
- Digital video is sampled in all three dimensions (x_1,x_2,t)

2-D sampling structures

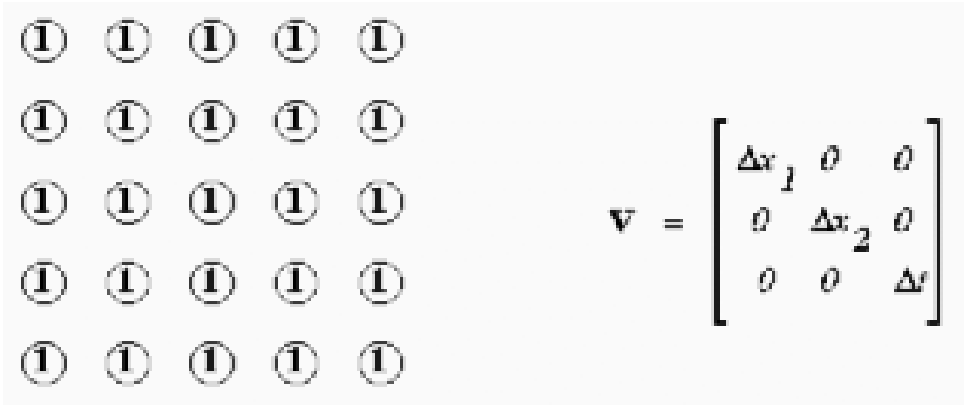


Analog progressive



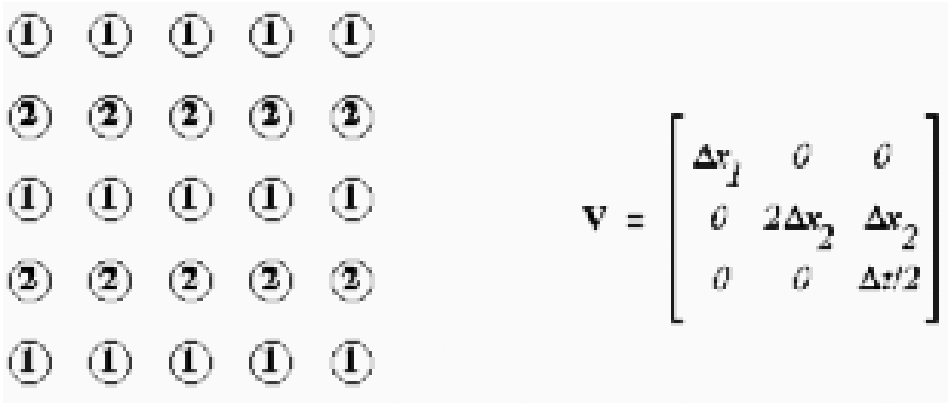
Analog 2:1 interlaced

3-D sampling structures



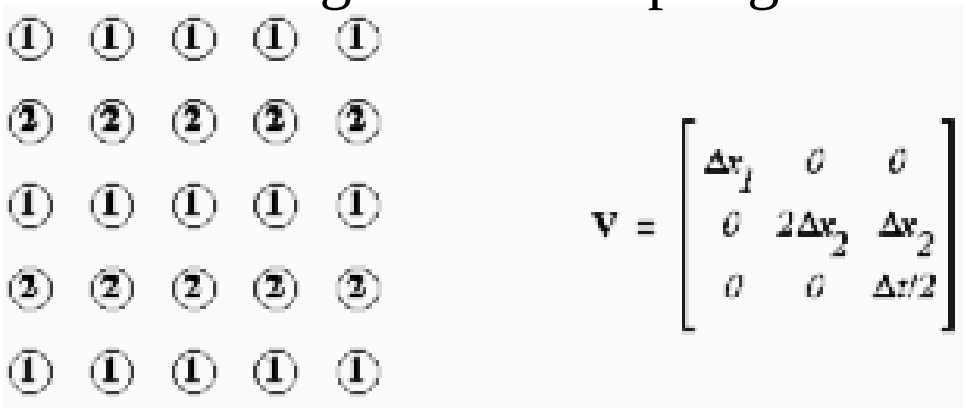
$$\mathbf{V} = \begin{bmatrix} \Delta x_1 & 0 & 0 \\ 0 & \Delta x_2 & 0 \\ 0 & 0 & \Delta t \end{bmatrix}$$

Progressive sampling



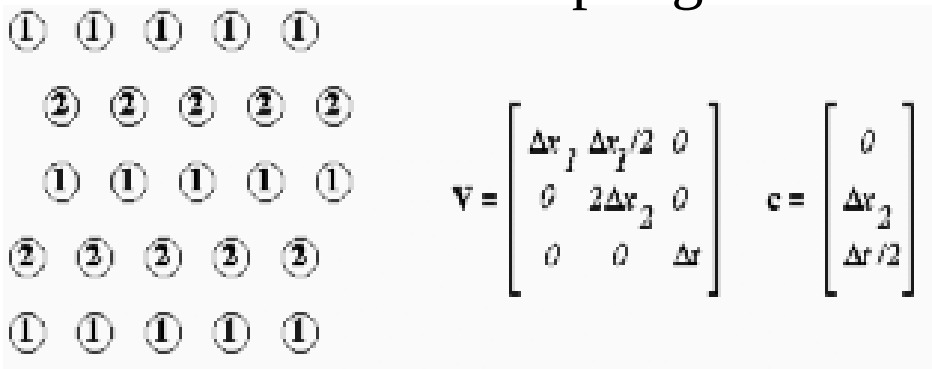
$$\mathbf{V} = \begin{bmatrix} \Delta x_1 & 0 & 0 \\ 0 & 2\Delta x_2 & \Delta x_2 \\ 0 & 0 & \Delta t/2 \end{bmatrix}$$

Interlaced sampling



$$\mathbf{V} = \begin{bmatrix} \Delta x_1 & 0 & 0 \\ 0 & 2\Delta x_2 & \Delta x_2 \\ 0 & 0 & \Delta t/2 \end{bmatrix}$$

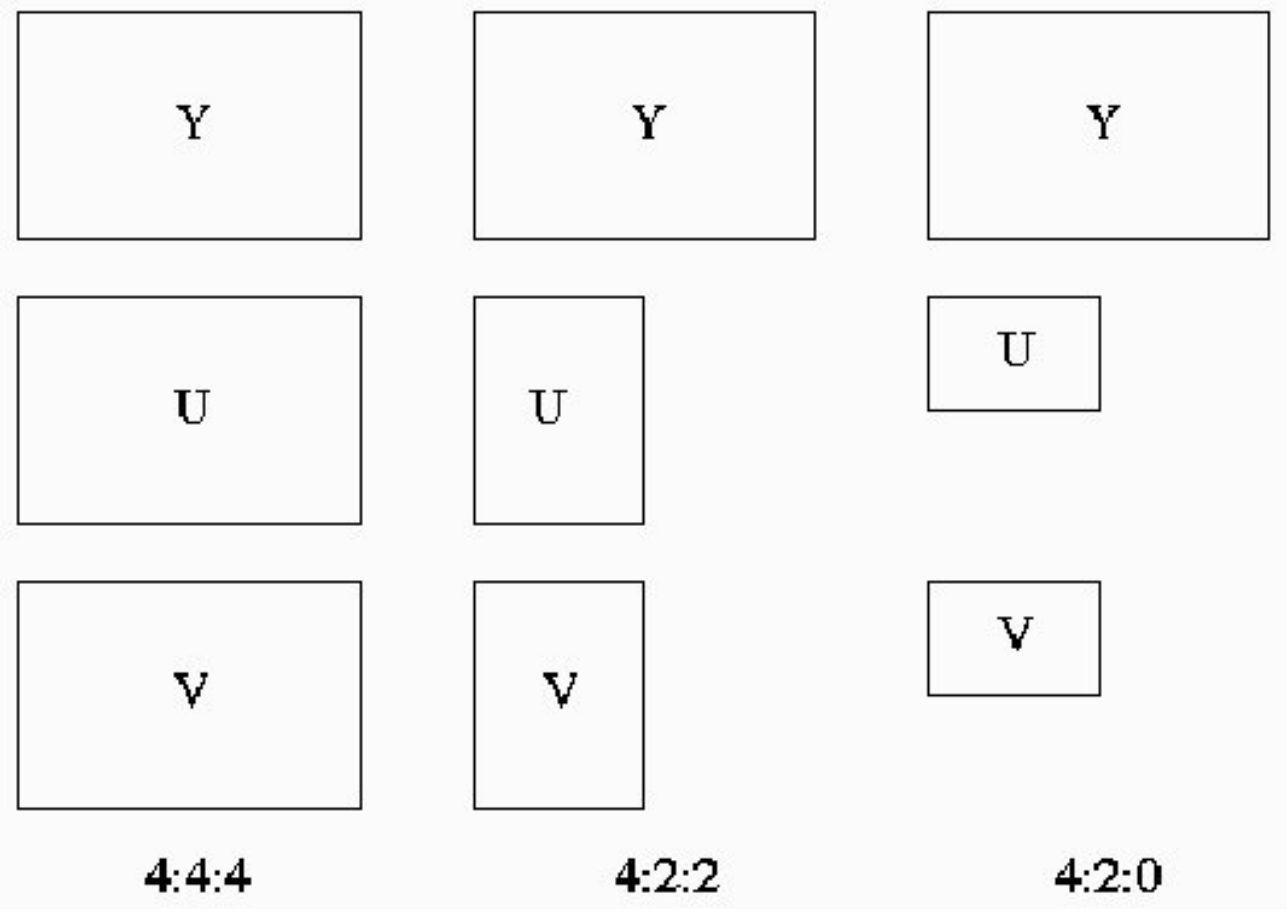
Field-Quincunx sampling



$$\mathbf{V} = \begin{bmatrix} \Delta x_1 & \Delta x_1/2 & 0 \\ 0 & 2\Delta x_2 & 0 \\ 0 & 0 & \Delta t \end{bmatrix} \quad \mathbf{c} = \begin{bmatrix} 0 \\ \Delta x_2 \\ \Delta t/2 \end{bmatrix}$$

Line-Quincunx sampling

Chrominance formats for digital video



Analog to Digital conversion

- The minimum sampling frequency is 4.2x2
- Sampling frequency should be an integral multiple of line rate
- To sample the composite signal, the sampling frequency should be an integral multiple of the subcarrier frequency. (This simplifies decoding (composite to RGB) of the sampled signal.)
- To sample *component signals*, there should be a single rate for 525/30 and 625/50 systems; i.e., the sampling rate should be an integral multiple of both
- 29.97 x 525 = 15,734 and 25 x 625 =15,625.

2D Fourier Transform

Continuous Signals

$$S_c(F_1, F_2) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} s_c(x_1, x_2) e^{-j(F_1 x_1 + F_2 x_2)} dx_1 dx_2$$

$$s_c(x_1, x_2) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} S_c(F_1, F_2) e^{j(F_1 x_1 + F_2 x_2)} dF_1 dF_2$$

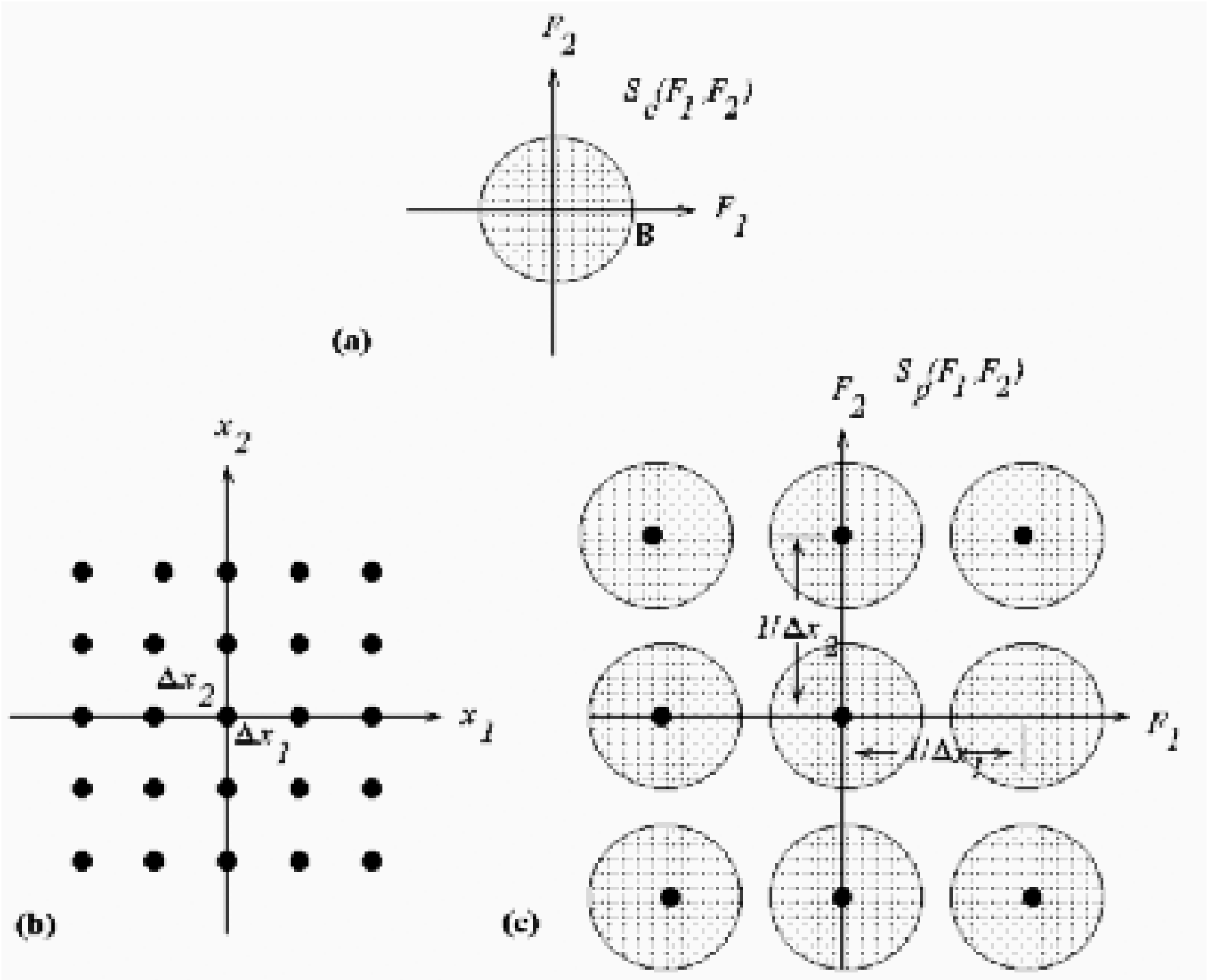
Discrete Signals

$$S(f_1, f_2) = \sum_{n_1=-\infty}^{\infty} \sum_{n_2=-\infty}^{\infty} s(n_1, n_2) e^{-j(f_1 n_1 + f_2 n_2)}$$

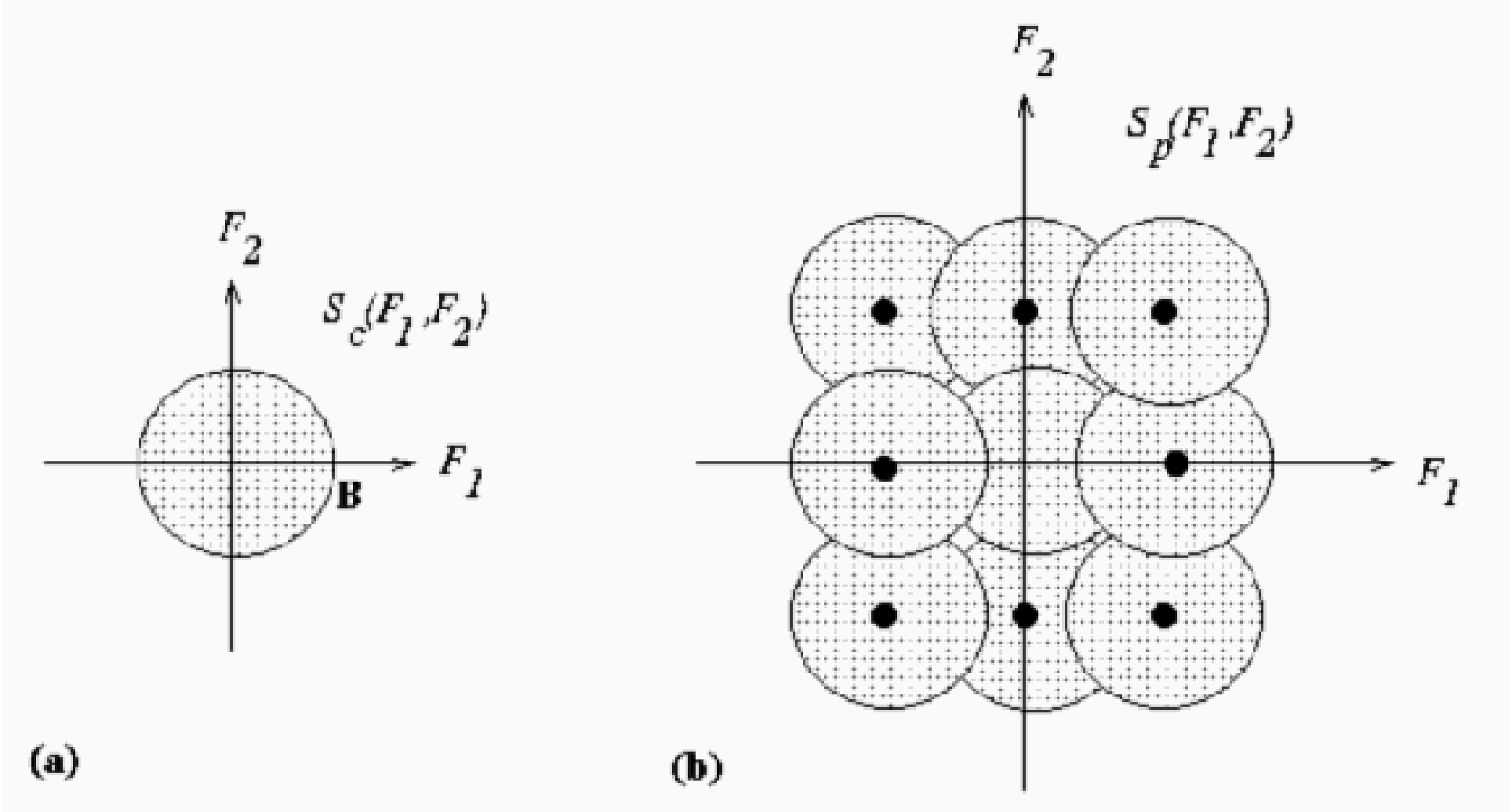
$$s(n_1, n_2) = \int_{-1/2}^{1/2} \int_{-1/2}^{1/2} S(f_1, f_2) e^{j(f_1 n_1 + f_2 n_2)} df_1 df_2$$

2-D sampling on a rectangular grid

$$S(F_1\Delta x_1, F_2\Delta x_2) = \frac{1}{\Delta x_1 \Delta x_2} \sum_{k_1} \sum_{k_2} S_c\left(F_1 - \frac{k_1}{\Delta x_1}, F_2 - \frac{k_1}{\Delta x_2}\right)$$

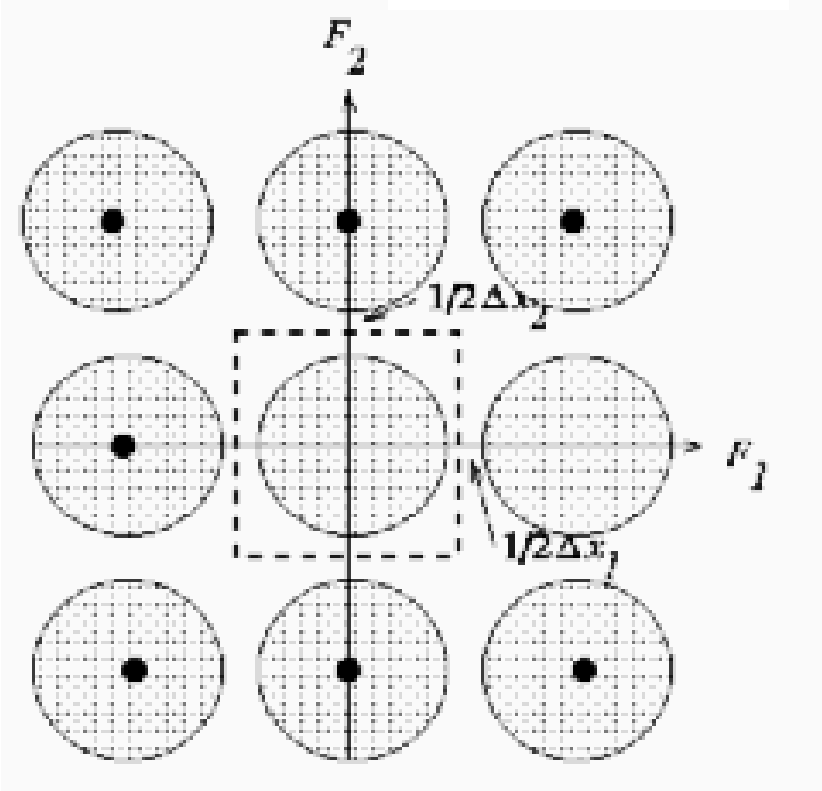

F_2
$S_g(F_1,F_2)$
F_1
B
(a)
x_2
Δx_2
Δx_1
x_1
(b)
F_2
$S_g(F_1,F_2)$
$1/\Delta x_2$
$1/\Delta x_1$
F_1
(c)

Aliasing



Reconstruction from samples on a rectangular grid

$$S_r(F_1,F_2)=\begin{cases}\Delta x_1\Delta x_2 S(F_1\Delta x_1,F_2\Delta x_2) & \text{for} \mid F_1 \mid < \dfrac{1}{2\Delta x_1} \text{ and } \mid F_2 \mid < \dfrac{1}{2\Delta x_2} \\ 0 & \text{otherwise}\end{cases}$$

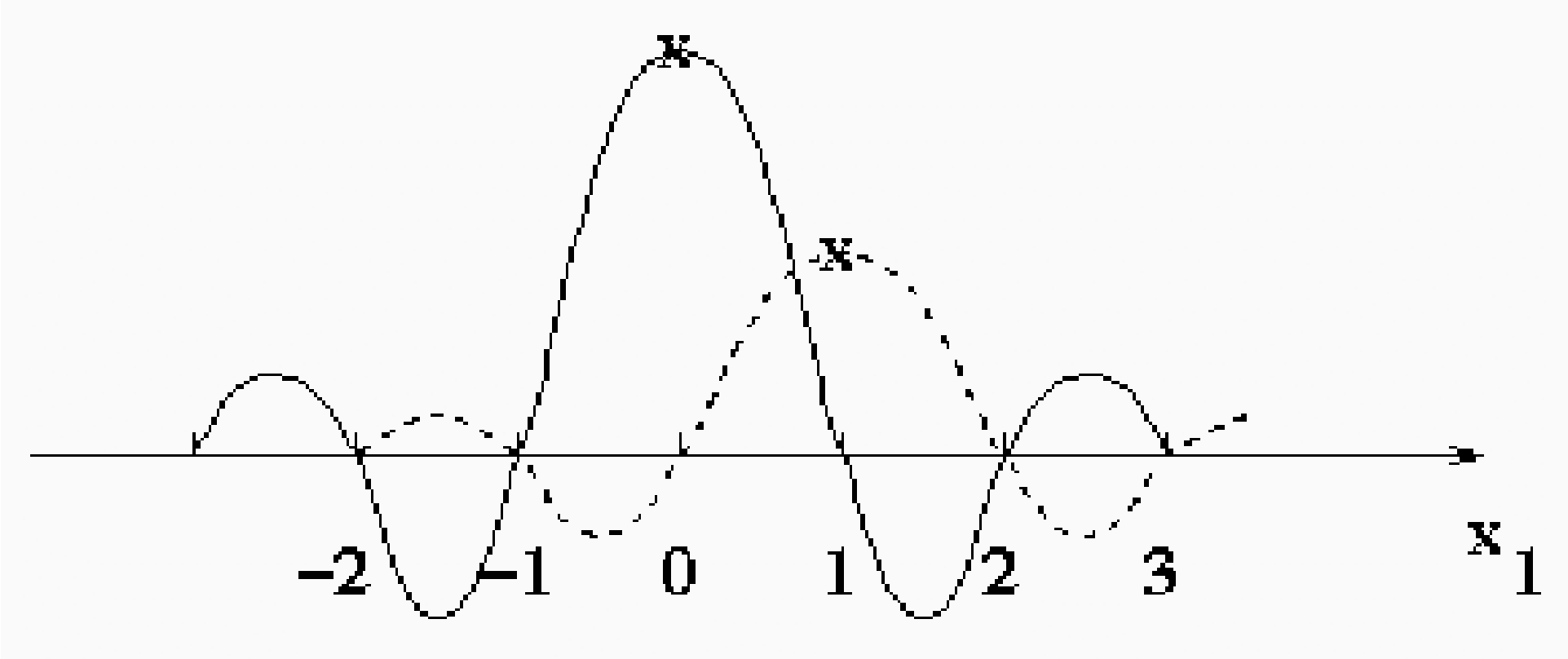


Space-domain filtering

$$s_r(x_1, x_2) = \Delta x_1 \Delta x_2 \sum_{n1} \sum_{n2} s(n_1, n_2) h(x_1 - n_1 \Delta x_1, x_2 - n_2 \Delta x_2)$$

$$h(x_1, x_2) = \frac{\sin(\frac{\Pi}{\Delta x_1} x_1) \sin(\frac{\Pi}{\Delta x_2} x_2)}{\frac{\Pi}{\Delta x_2} x_1 \frac{\Pi}{\Delta x_2} x_2}$$

Bandlimited interpolation



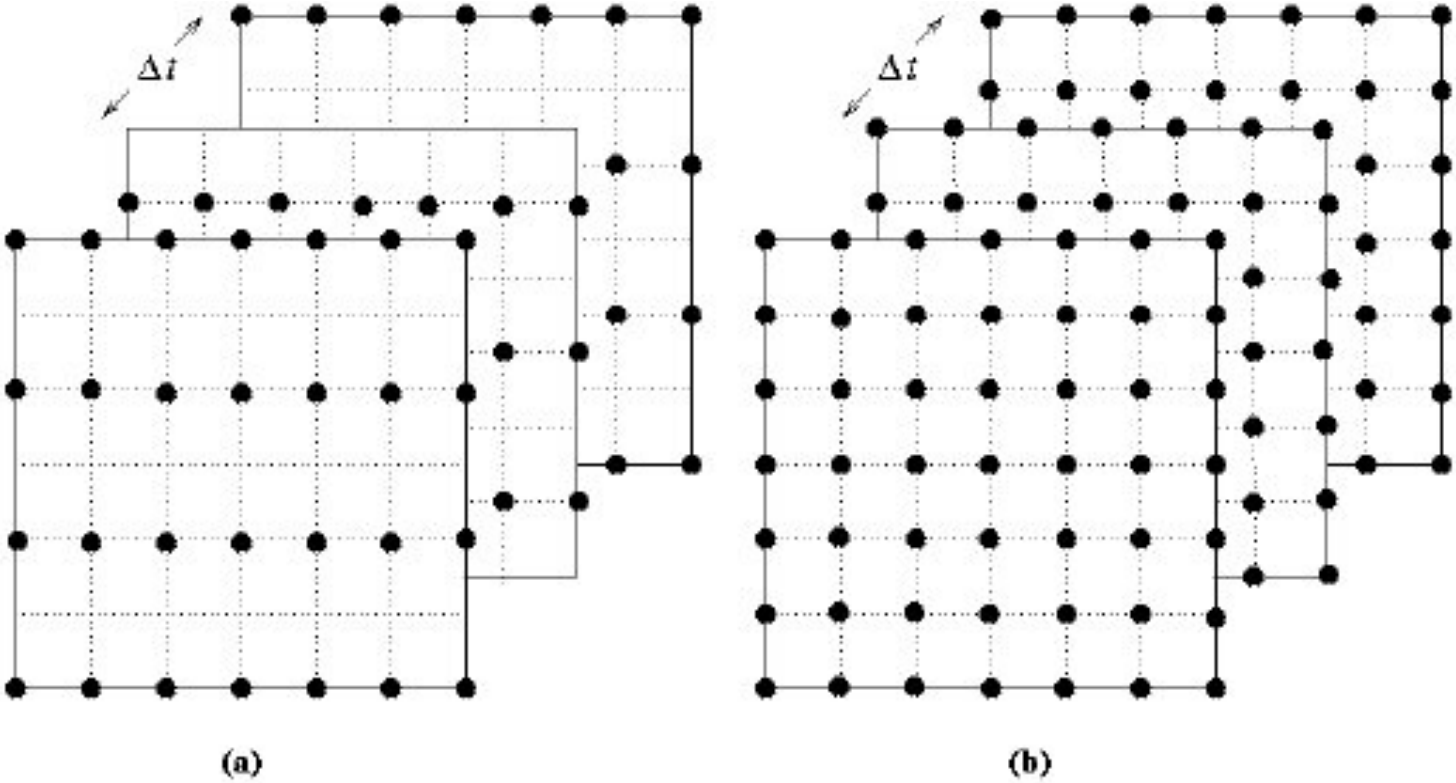
Sampling structure conversion

Spatio-temporal interpolation/decimation problem

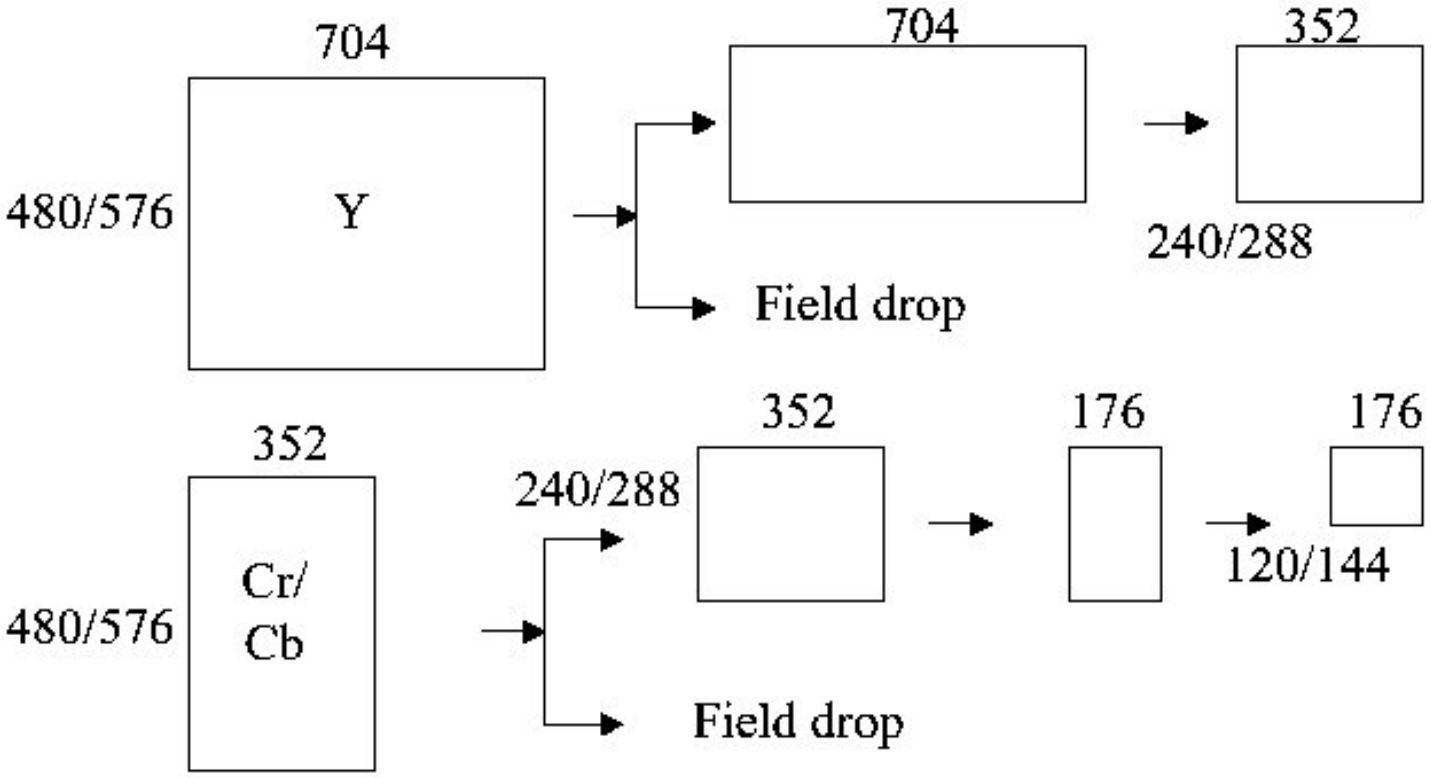
Applications

- Frame rate conversion
- Deinterlacing
- Interlacing
- NTSC-to-PAL conversion
- SIF/CIF conversion
- Data compression

Deinterlacing



ITU-R 601 4:2:2 to SIF Conversion



Motion picture -> NTSC