Estimating *CkL* from Space Based – Synthetic Aperture Radar Images

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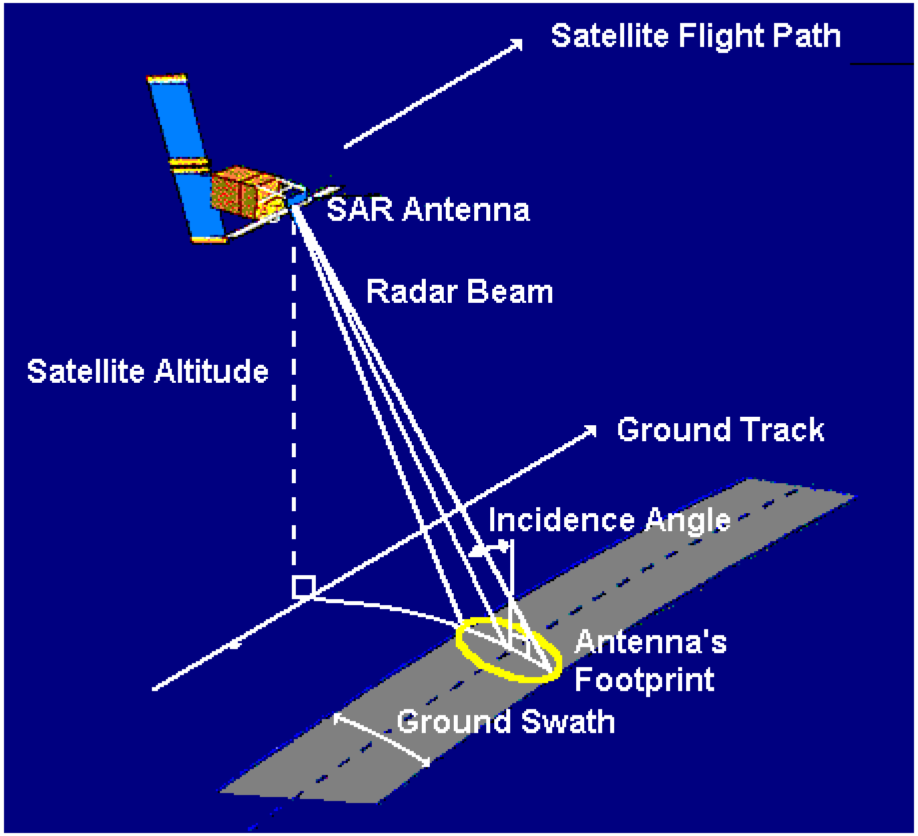
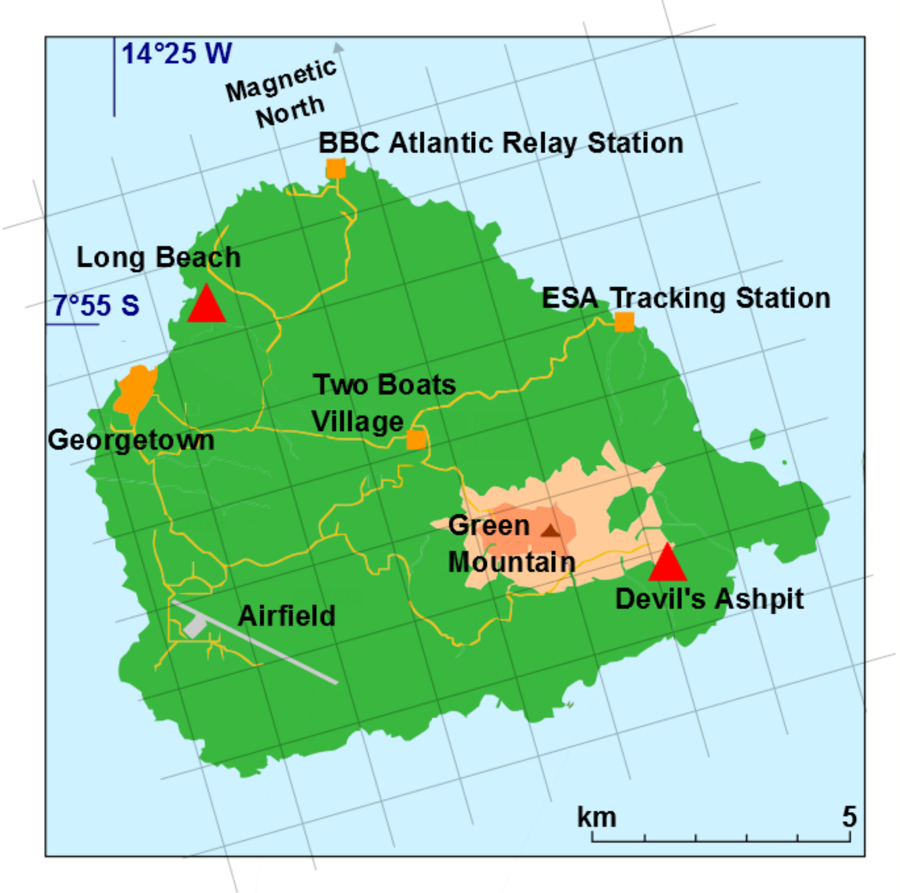
How synthetic radars work



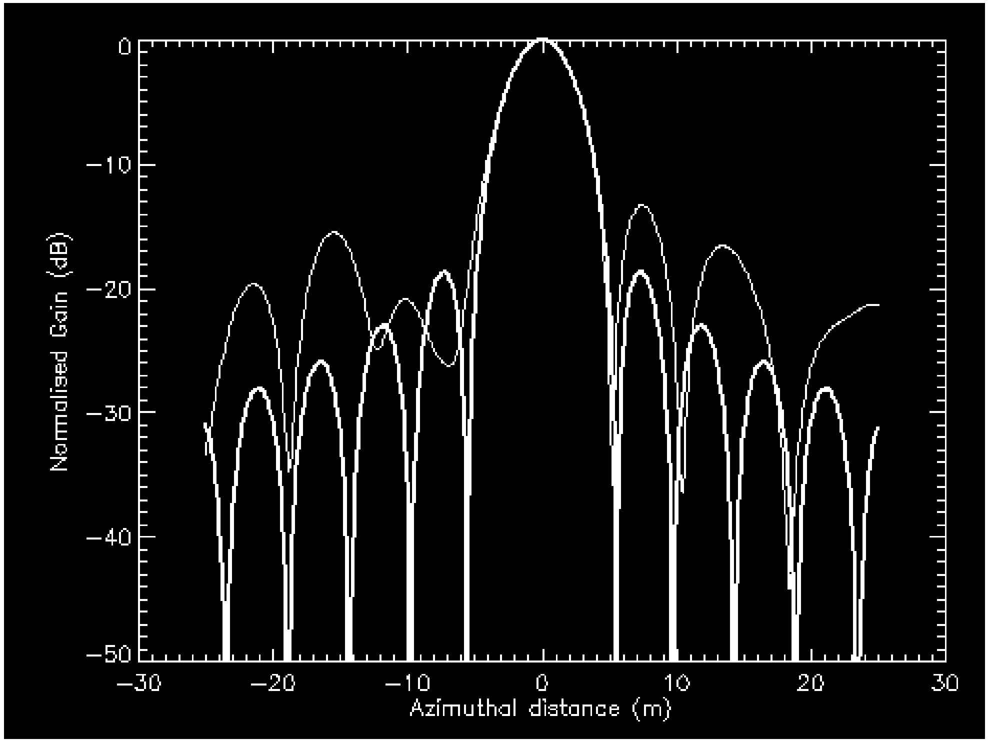
- Returns gathered along the satellite track are coherently added to synthesise a very large aperture antenna.
- The azimuthal resolution is a function of the synthetic aperture length
- The range resolution is dependent on the signal bandwidth

Using a Corner Reflector


14°25 W
Magnetic North
BBC Atlantic Relay Station
Long Beach
7°55 S
ESA Tracking Station
Two Boats Village
Georgetown
Green Mountain
Devil's Ashpit
Airfield
km
5

The Point Spread Function (PSF)

- Turbulence causes electron density irregularities, which in turn causes fluctuations in the phase (scintillation) of a radar signal passing through it.
- The phase scintillation raises the level of along track sidelobes, and if severe enough, causes defocusing.
- Generally its effect is to reduce the contrast.
- For an L-band SAR ionospheric effects are often observed, but complete defocusing is very rare.



PSF (2)

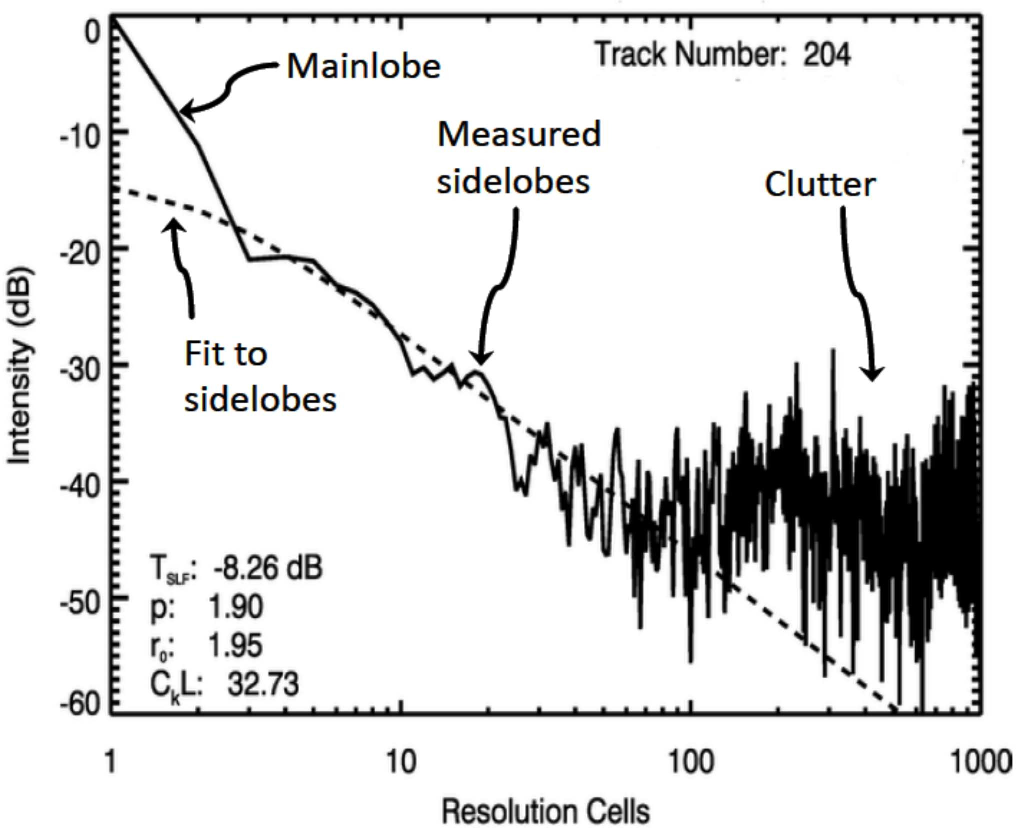
- We define the PSF to be equal to the mainlobe plus the sidelobes η, which are zero if there are no ionospheric effects.
- The ensemble average sidelobe function (SLF) is given by

$$\langle \left|\eta\left(\boldsymbol{r}^{/}\right)\right|^{2} \rangle = T_{SLF} \left(\sqrt{r_0^2 + (|r^{/}| + 1)^2}\right)^{-p}$$

T_{SLF} is the turbulence of the sidelobes
$\boldsymbol{r}^{/}$ is the along track resolution cell
p is the ionospheric phase screen spectral index.

$r_0 = L_{SA}/\gamma l_0$ is the ratio of the synthetic aperture length L_{SA} to the ionospheric outer scale size l_0 scaled by γ, the velocity ratio of the satellite to the effective velocity of the ray-path in the phase screen

An ionospherically disturbed PSF



$$\langle |\eta(\boldsymbol{r}')|^2 \rangle = T_{SLF} \left(\sqrt{r_0^2 + (|r'| + 1)^2} \right)^{-p}$$

$$T_{SLF} = \frac{4\gamma\kappa_C^{1-p} G \sec\theta \, (r_e \lambda_0)^2 \sqrt{\pi}\, \Gamma(p/2)}{(2\pi)^2 \Gamma\big((p+1)/2\big) \kappa_{1km}^{-1-p}} C_k L$$

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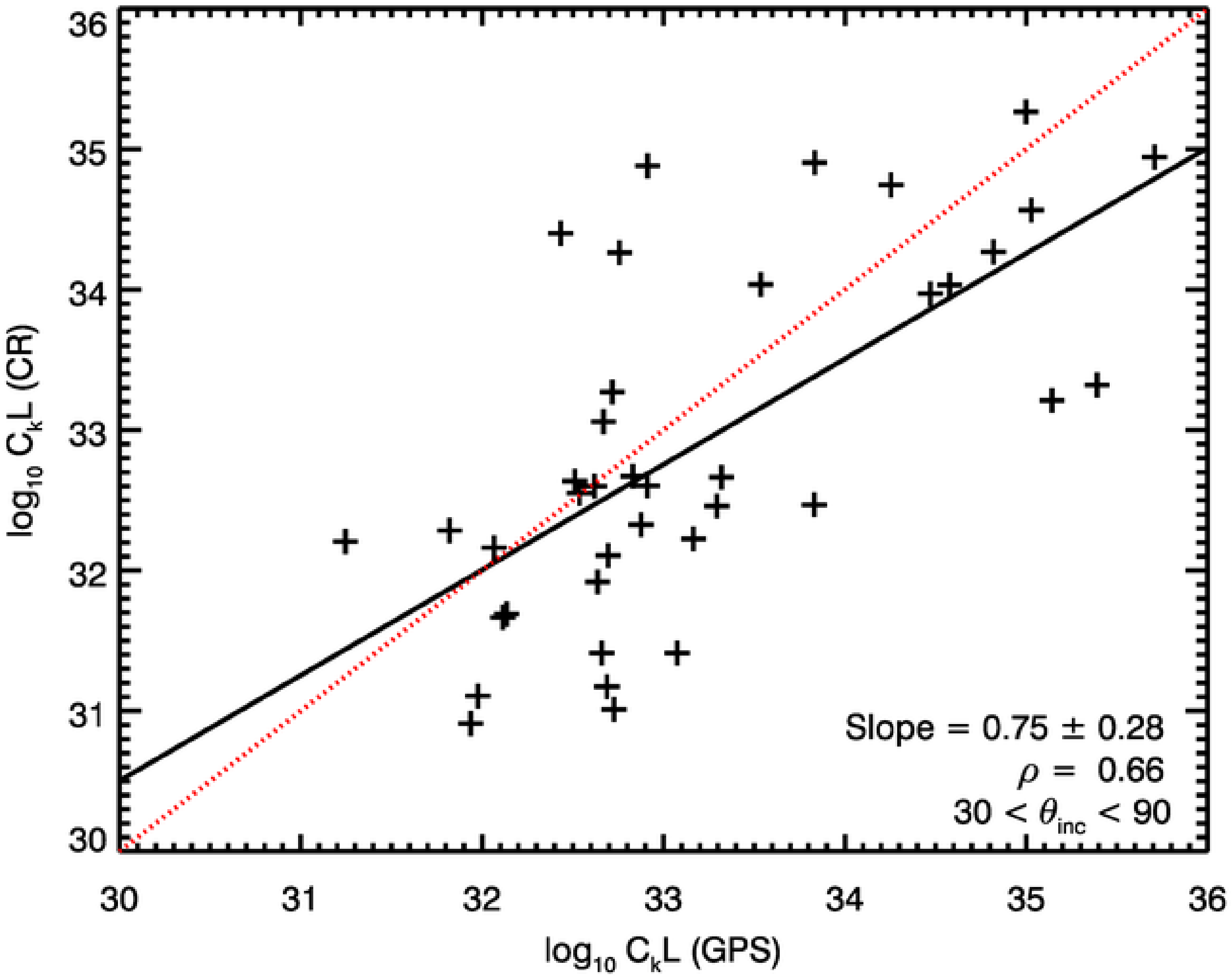
Comparison with GPS measurements



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Using clutter measurements

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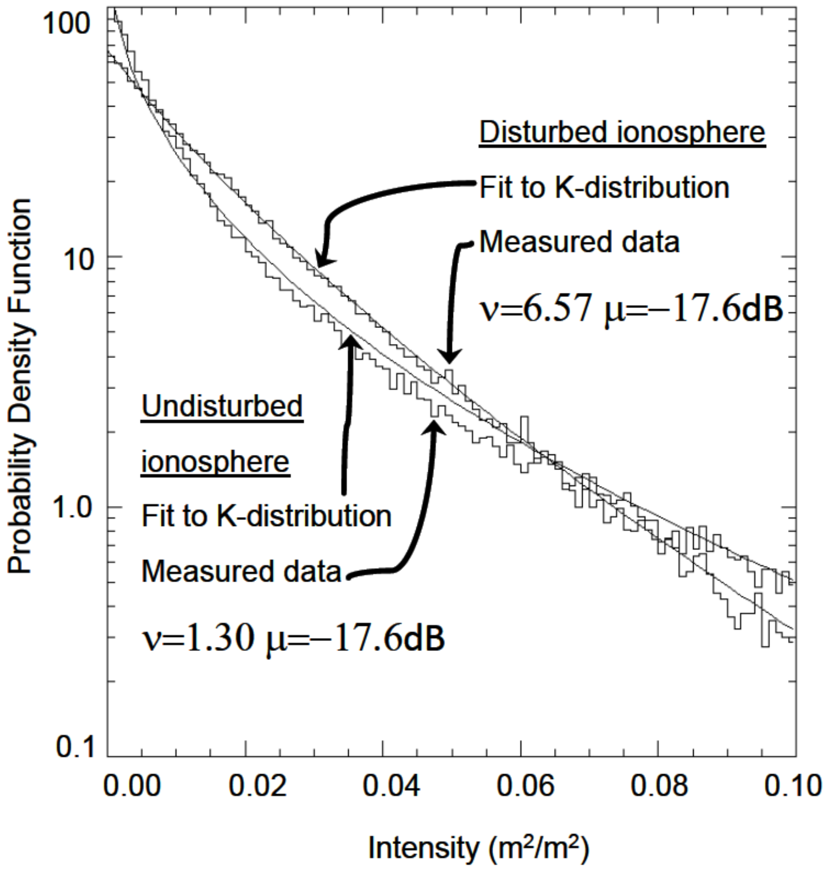
Correlated K-distributed clutter

- Radar clutter can often be described by:
  - the product of the underlying radar cross section (which is generally correlated over a few resolution cells)
  - with uncorrelated complex Gaussian speckle.
- Assume the underlying cross section is gamma-distributed in intensity then:
  - the combined image statistics are K-distributed in intensity.
- The K-distribution has just two parameters, the mean μ and order parameter ν



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Two competing effects

- The raised sidelobes add random complex Gaussian noise to the image. Thus the speckle increases.
- Recall that the ionospheric component of the sidelobe variance can be expressed as the integral of the sidelobe function.

$$\sigma_{SLF}^2 = \int_{-\infty}^{\infty} \left|\eta(\boldsymbol{r}^/)\right|^2 dr^/$$

- Then the disturbed ionopshere increases the speckle variance in the ratio 1 to $1 + \sigma_{SLF}^2$.

- At the same time, the variation in the underlying cross section is smoothed out by the PSF.
- These gamma distributed points are correlated over l_r resolution cells by an amount that depends on the sidelobe shape. The ionospherically disturbed order parameter ν_d is therefore given by

$$\nu_d = \nu(1 + \sigma_{SLF}^2 / l_r)$$

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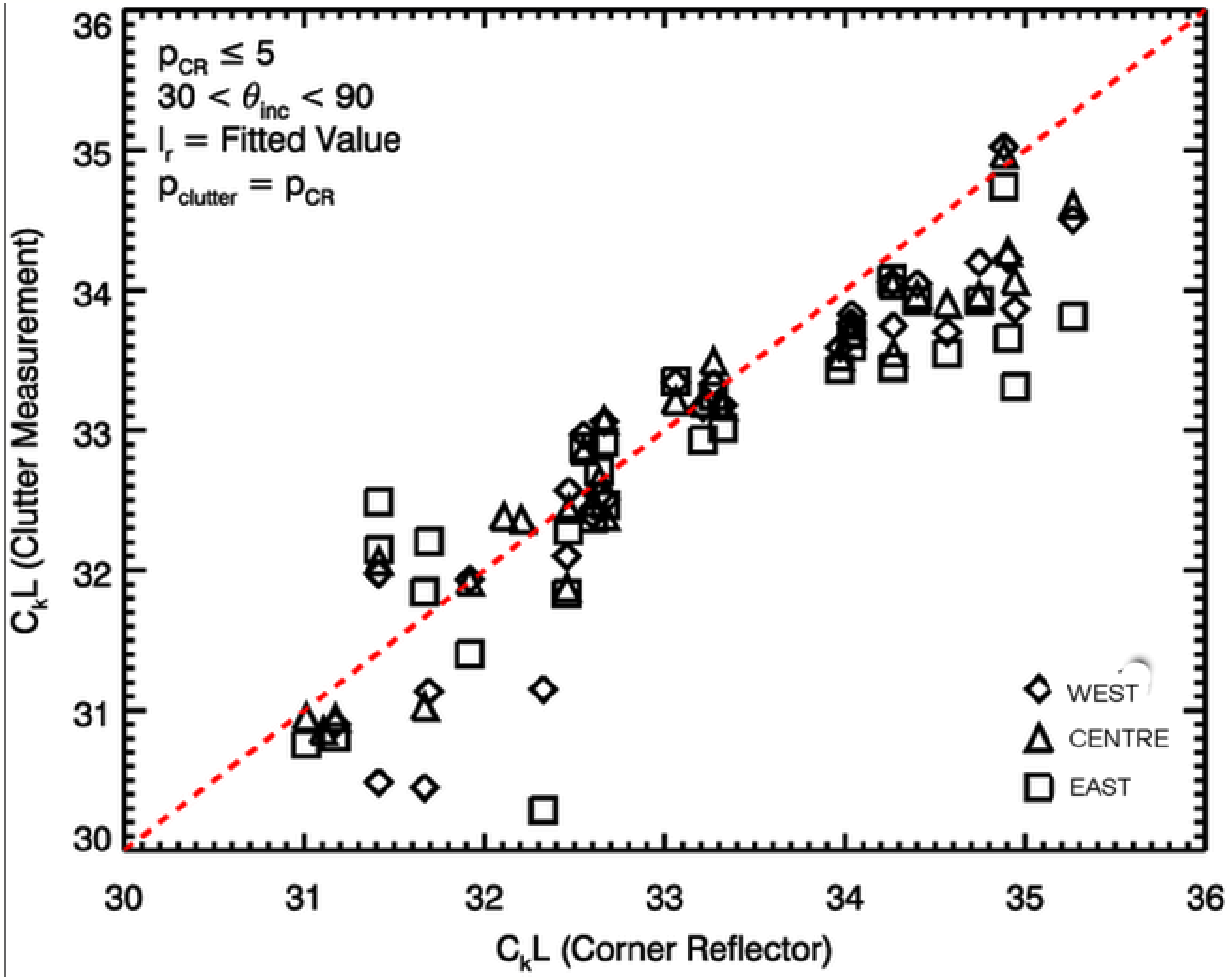
Comparison with CR technique



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Summary and Conclusions

- Believe that discrepancies between CR and GPS estimates are largely due to differences in geometry. A new experiment will hopefully test this.
- The agreement between the CR and clutter techniques is excellent.
- The clutter technique can be used to map turbulence within the swath and with a resolution along track of ~60km and across track of ~200m or better.

Section Header

- $\nu = \left[\frac{\langle I \log I \rangle}{\langle I \rangle} - \langle \log I \rangle - 1 \right]^{-1}$