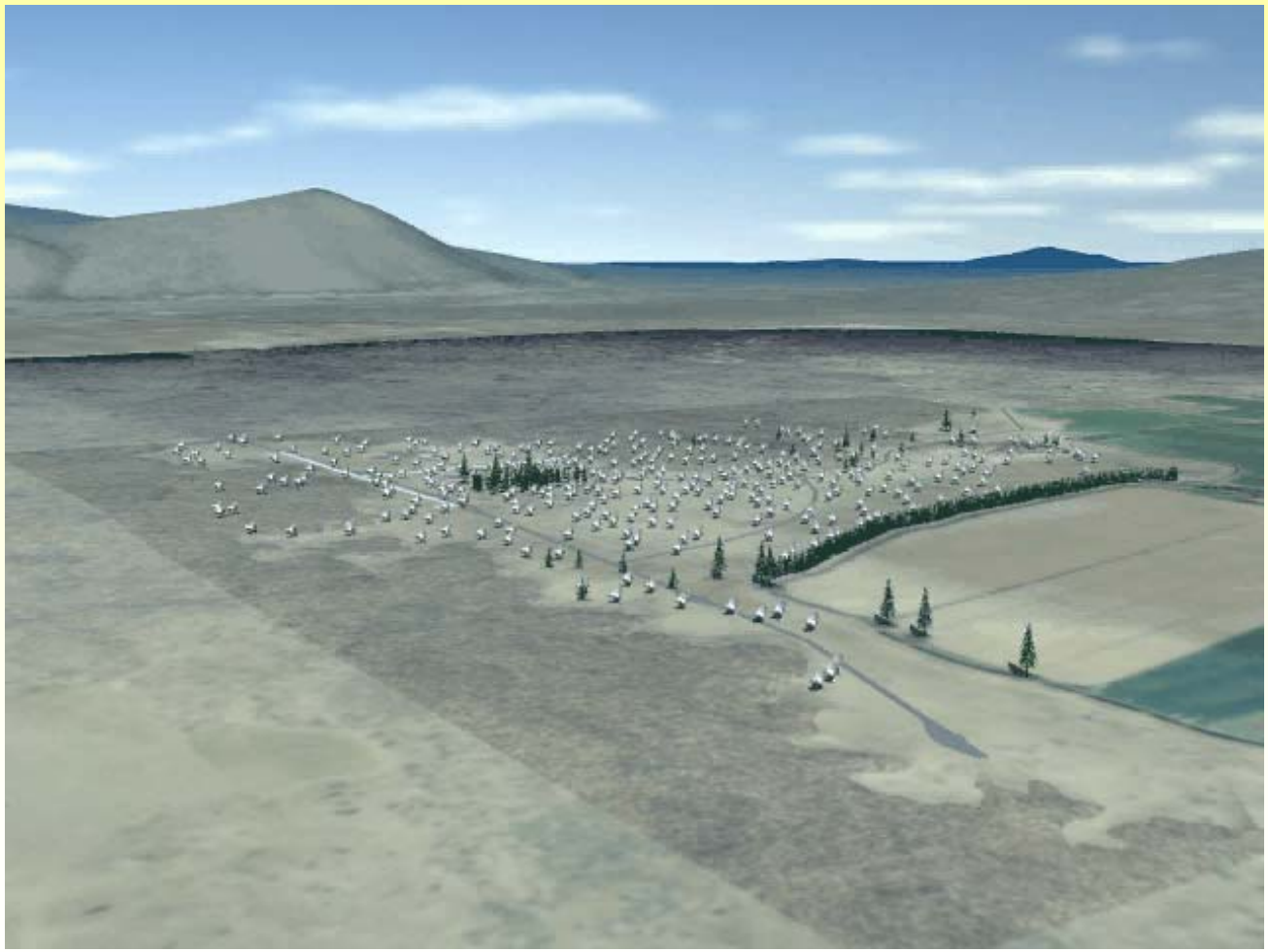
Signal Processing Requirements are Dominated by RFI Concerns at the ATA

Gerry Harp
Allen Telescope Array
SETI Institute

Acknowledgements: G. C. Bower, L. R. D'Addario, M. M. Davis, D. R. DeBoer, J. W. Dreher, G. Girmay-Kaleta, W. L. Urry, and M. C. H. Wright

ATA 10^4 m^2

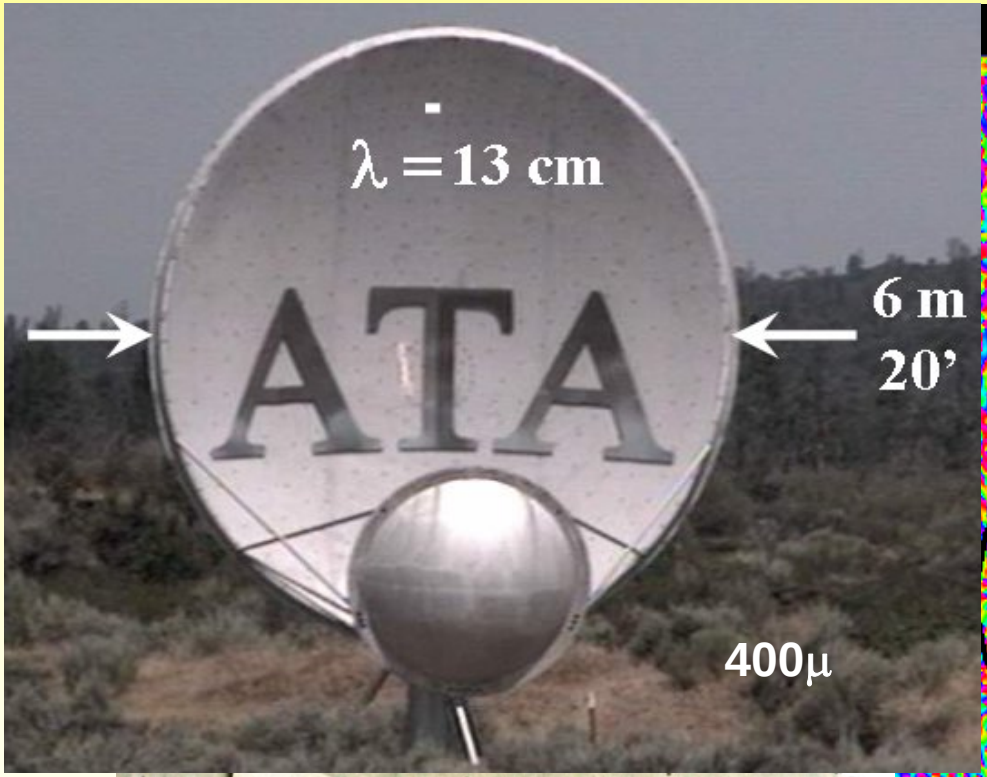


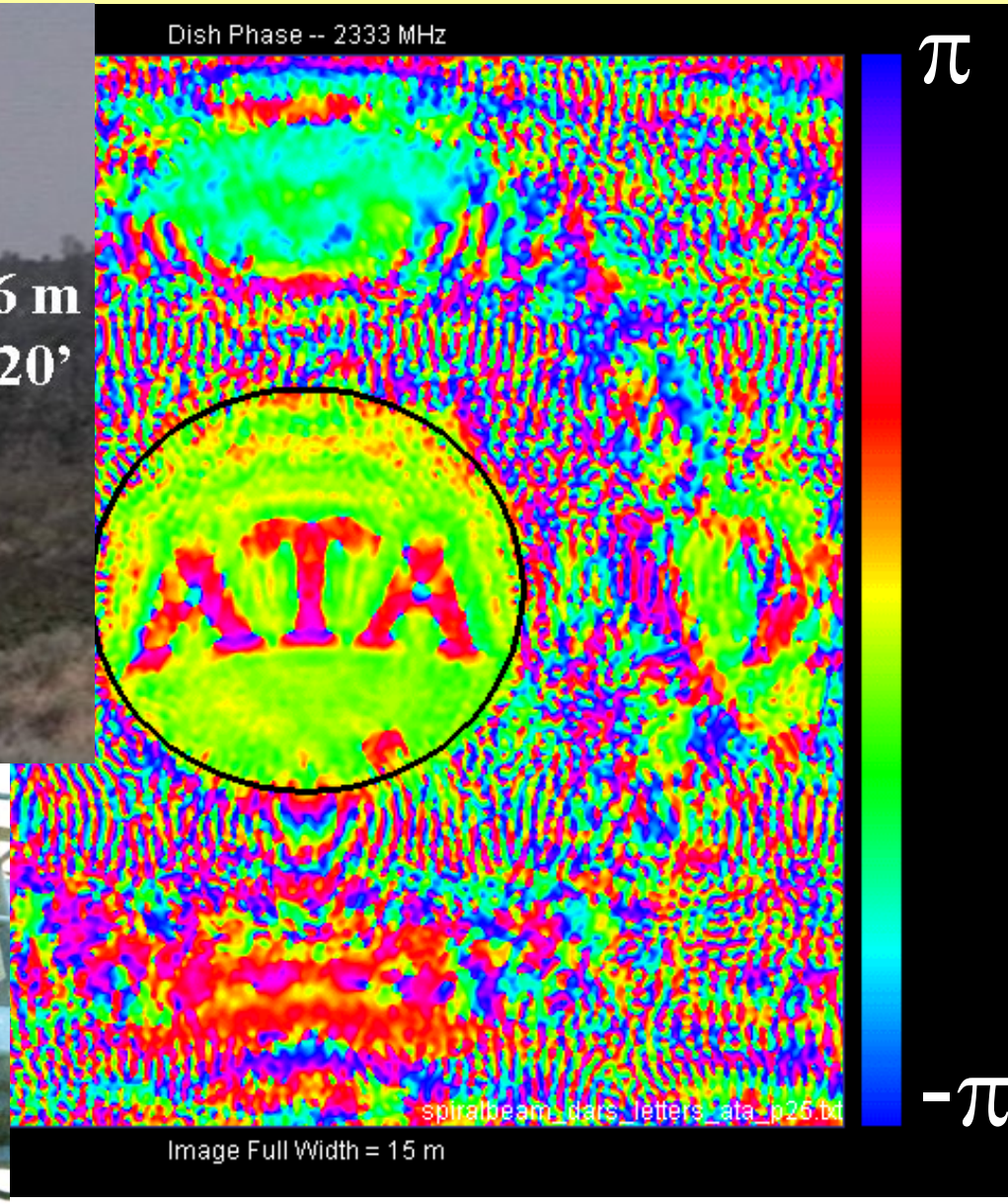
350 x 6m dishes
RF = 0.5 – 11.2 GHz
IF = 4 x 100 MHz

Funded by Paul Allen and Nathan Myhrvold

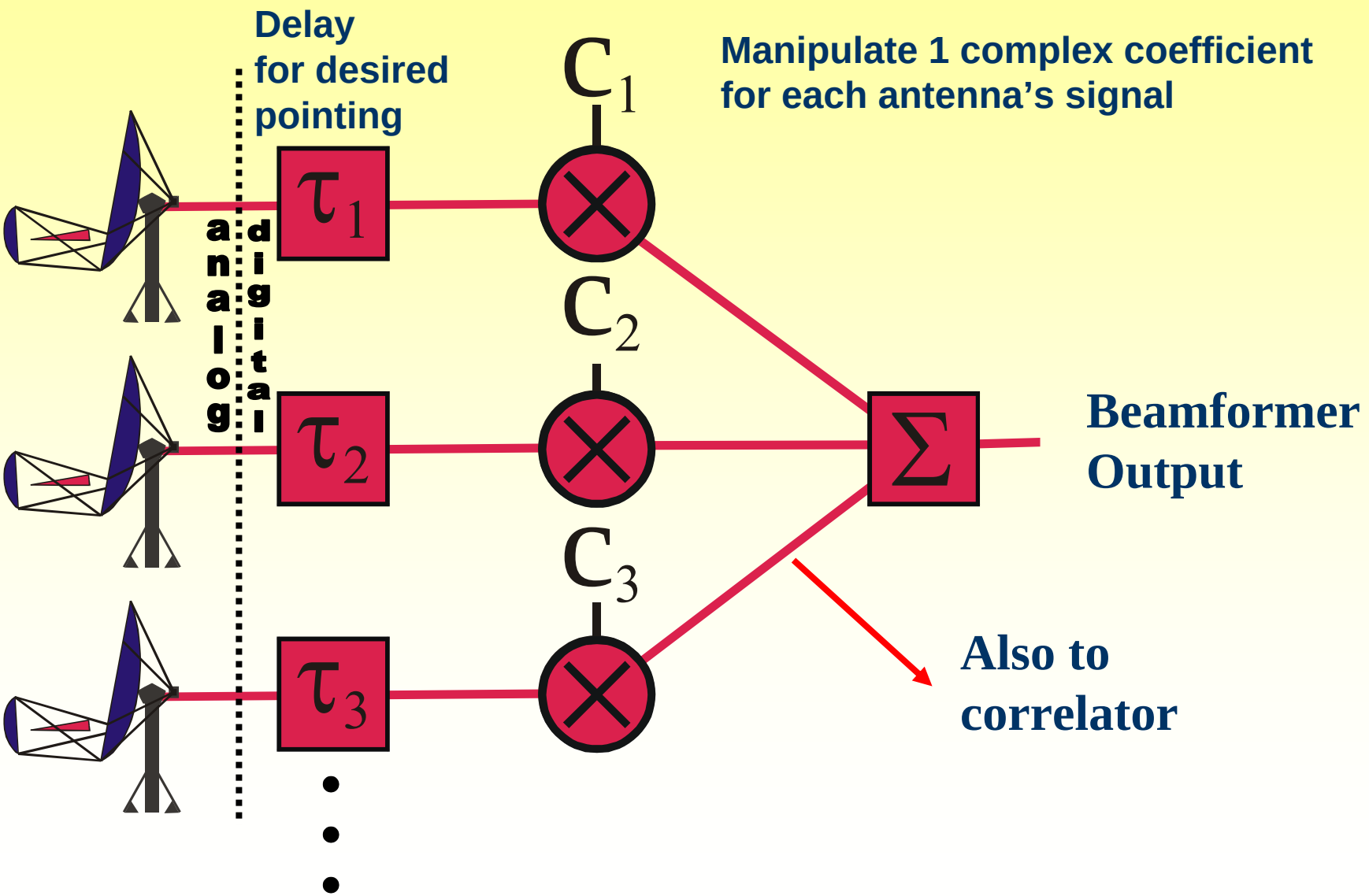
Developed jointly by SETI Institute and U. C. Berkeley RAL

ATA Dish at 13 cm

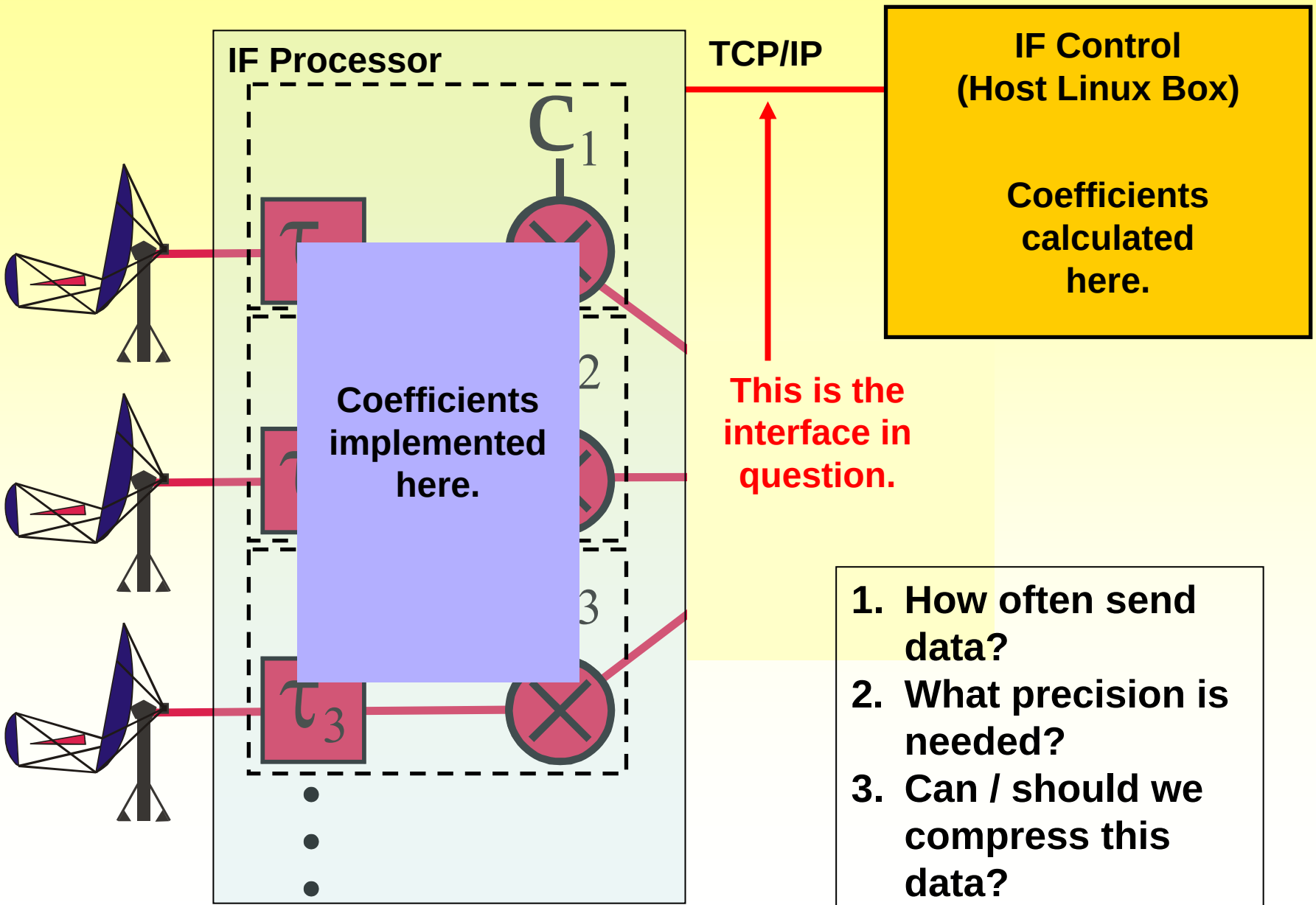




DSP: IF Processor



IF Processor Control Interface



Track a moving source.

$$B(t) = \sum_i c_i \, s_i(t - \tau_i), \text{ where}$$

$s_i = \text{signal at antenna } i$

$c_i = \text{beamformer coefficient} = e^{-i\vec{k}\cdot\vec{r}_i}$

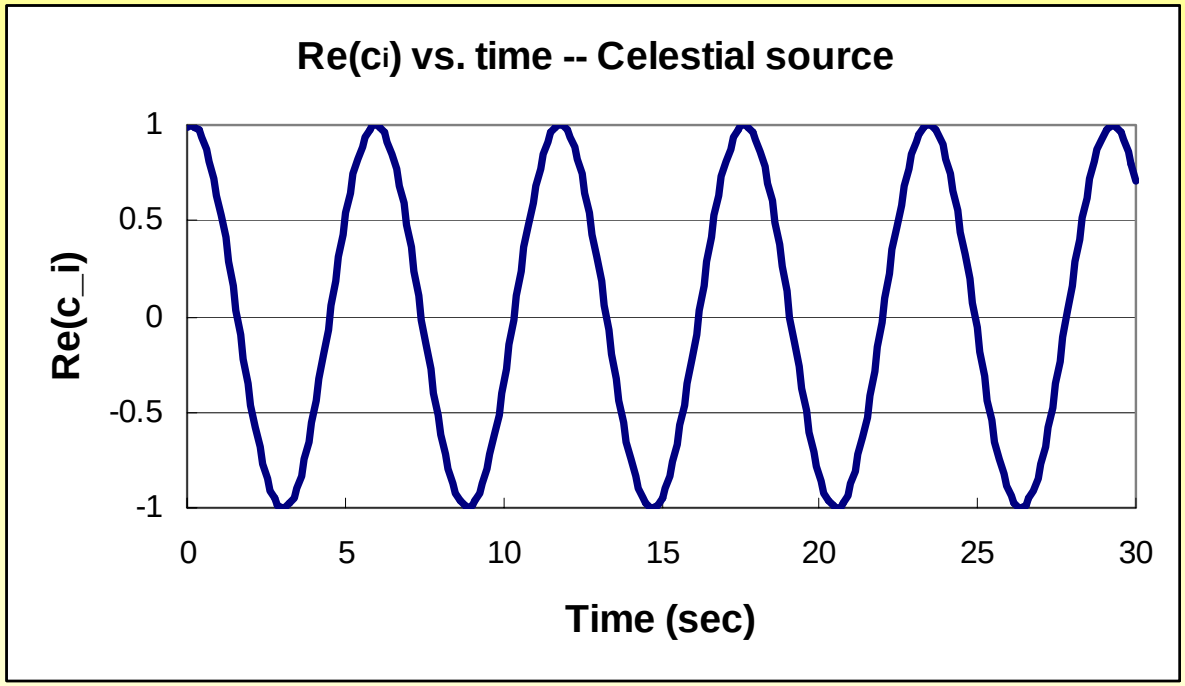
Suggested representation :

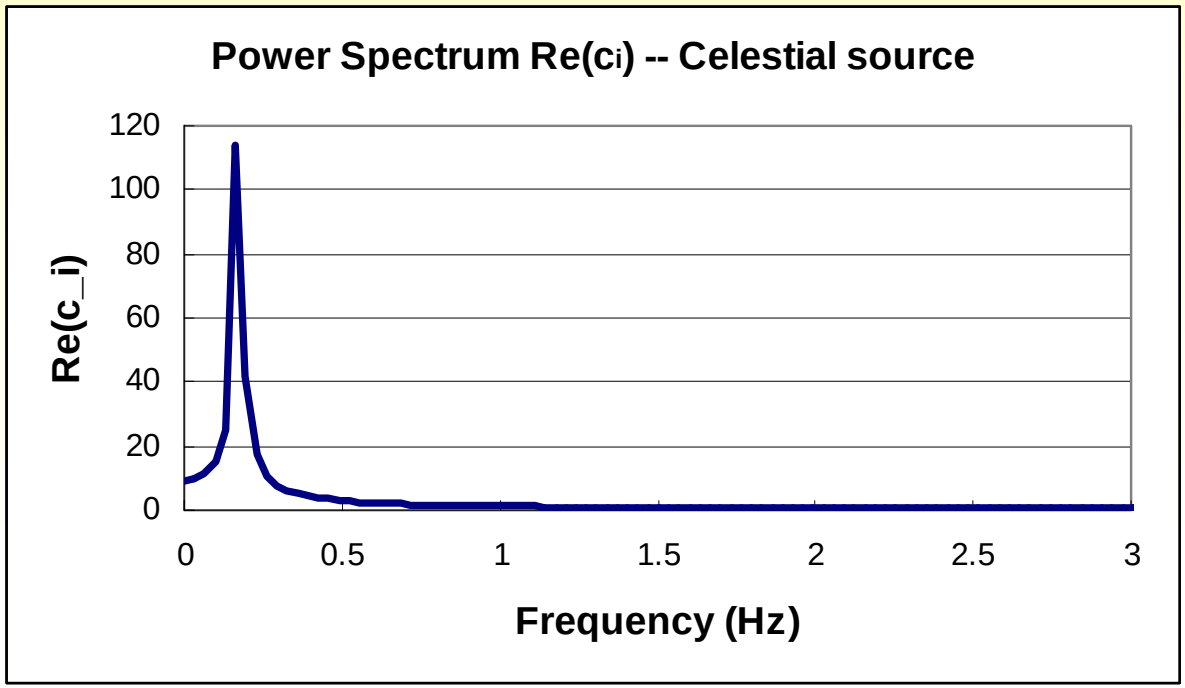
let $\vec{k}(t) \approx \vec{k}_0 + \vec{k}_1 t + \ldots$

$\rightarrow \text{Re}(c_i)$ is sine wave.

Tracking a celestial source at 10 GHz.

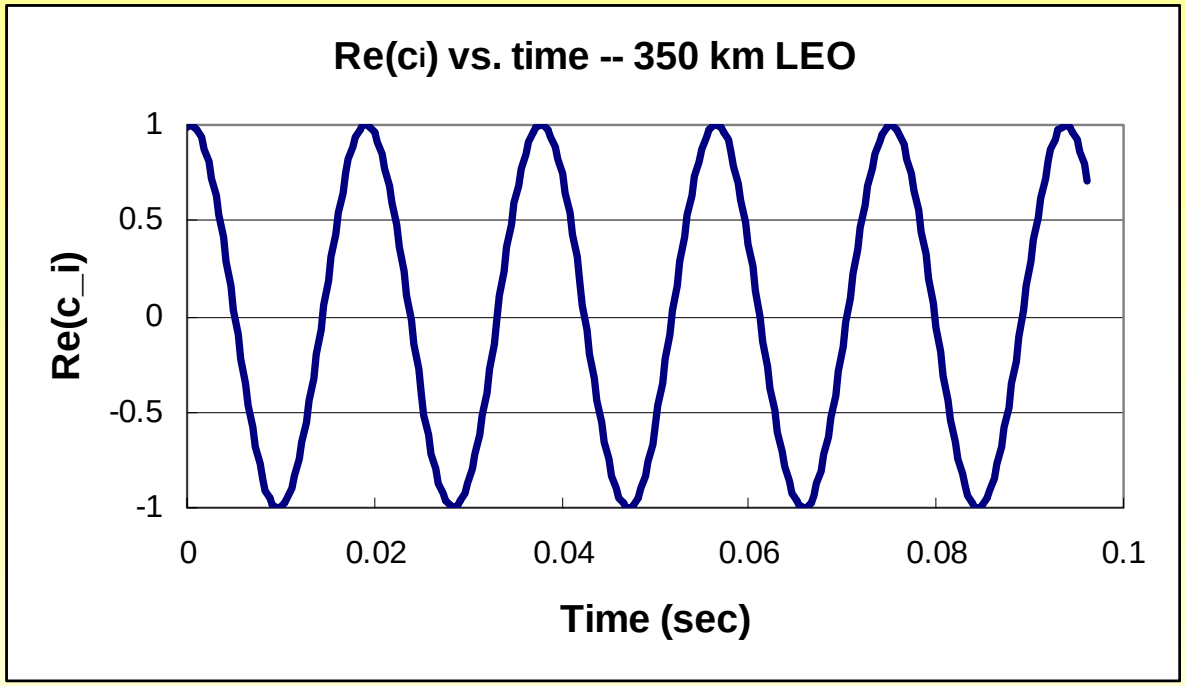
0.16 Hz typical

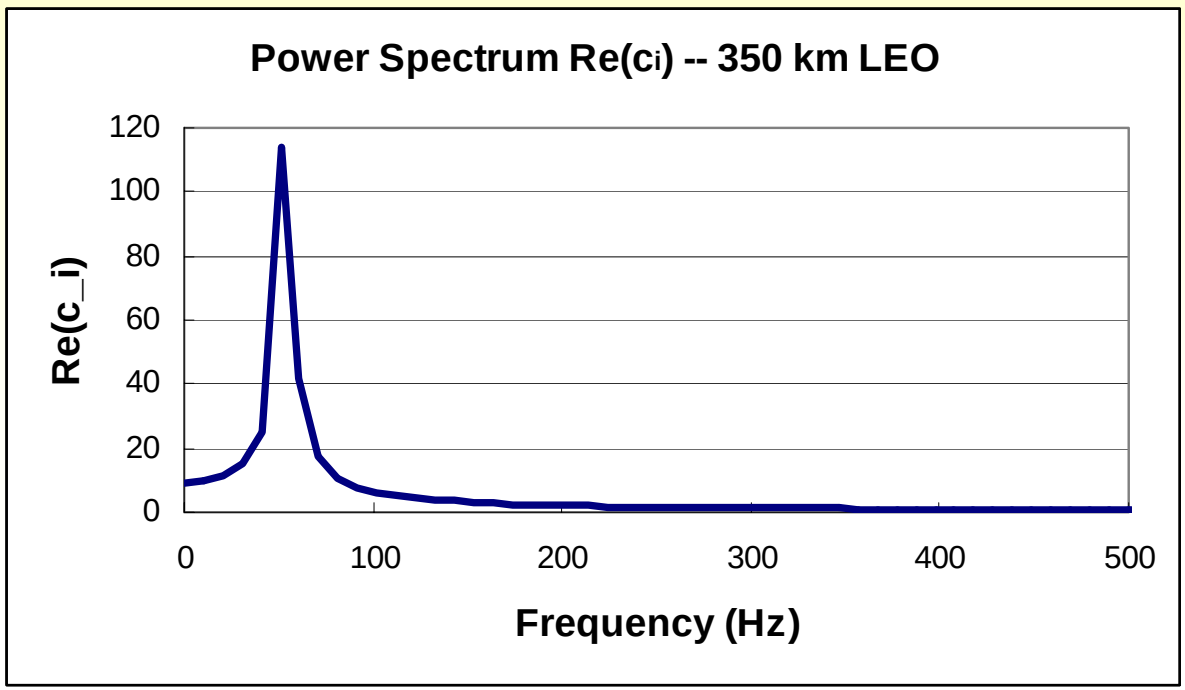




Tracking a 350 km LEO at 10 GHz.

50 Hz typical





Our first analysis.

- Nulling a LEO is about as hard as tracking a LEO
- Expand coefficients as Taylor's series

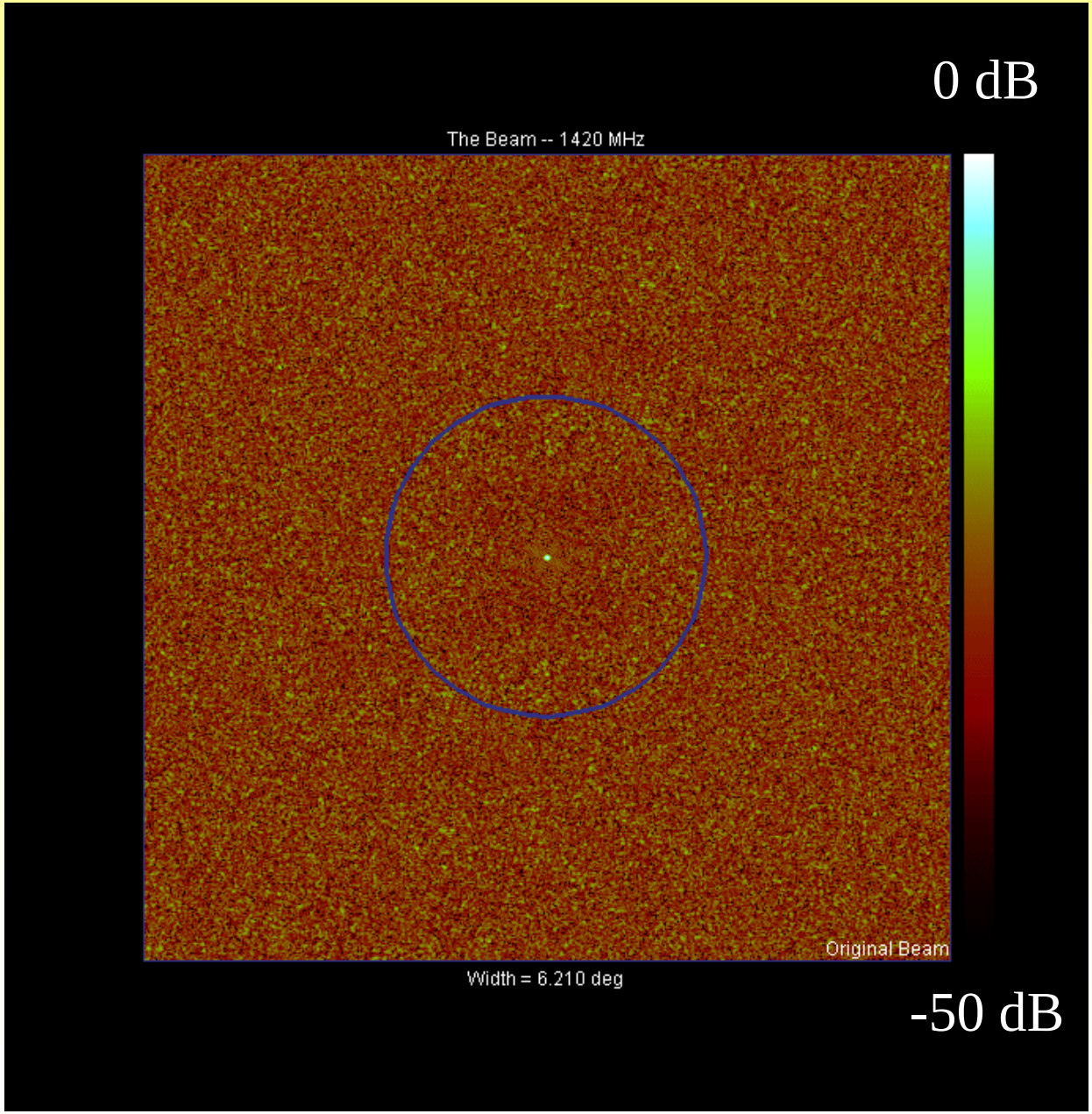
$$c_i = \alpha_i(t)\, e^{-i\vec{k}\cdot\vec{r}_i}$$

$$\alpha(t) = \alpha_0 + \alpha_1 t, \quad \vec{k} \approx \vec{k}_0 + \vec{k}_1 t + \vec{k}_2 t^2$$

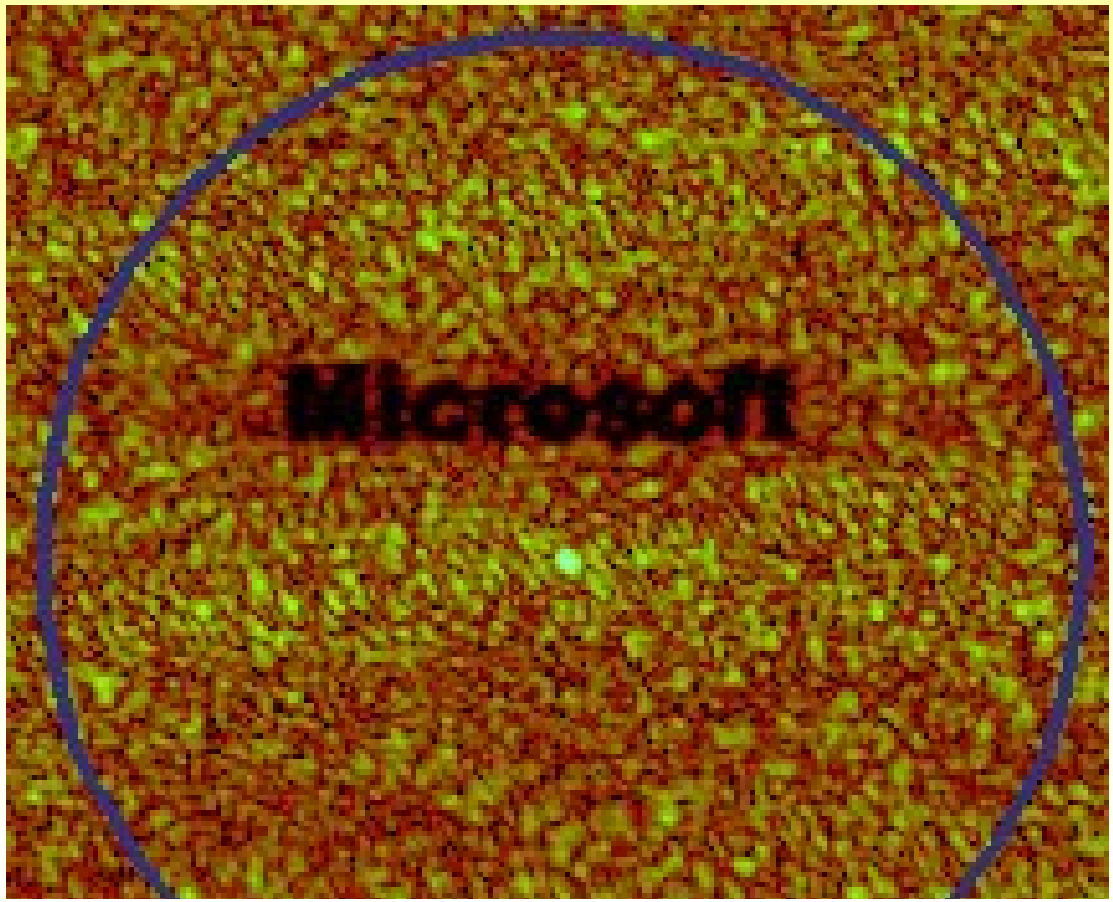
- This representation is good for about 0.2 seconds, even for LEO's
- Check this with simulations

Synthetic Beam Pattern

We've been working on methods to form (wide bandwidth) deterministic nulling in Single Tap Beamformer.

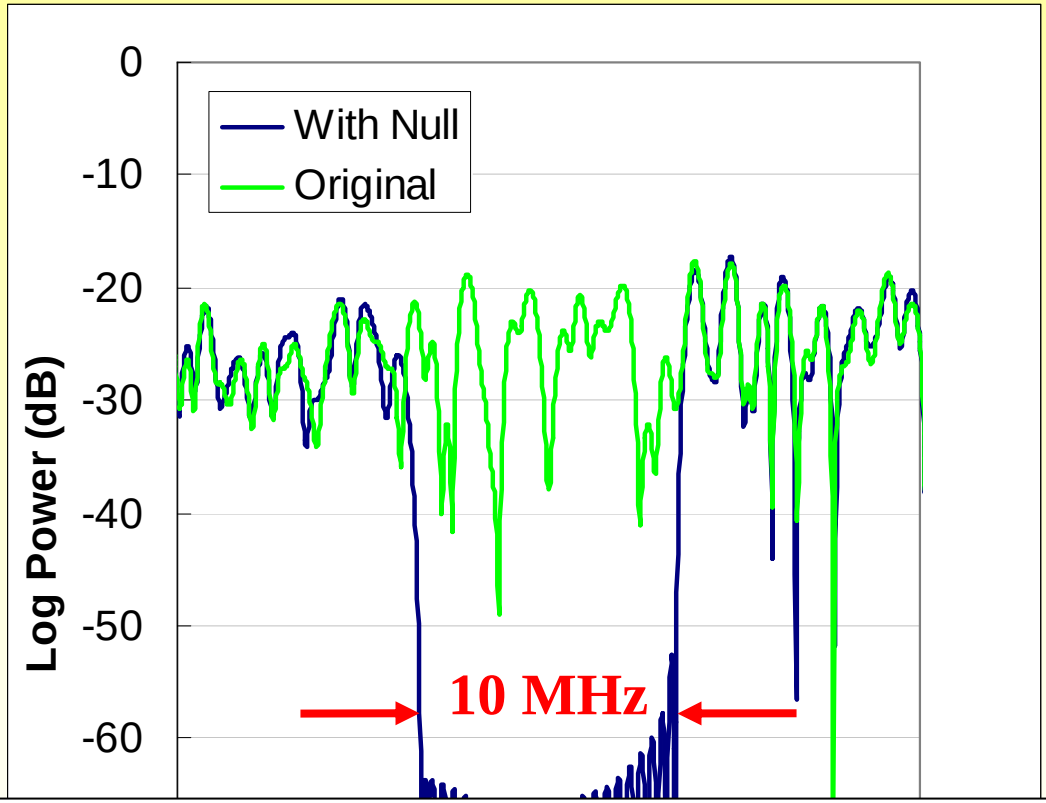


Place beamformer nulls on the sky where satellites appear.



With 350 Antennas, we have lots of flexibility.

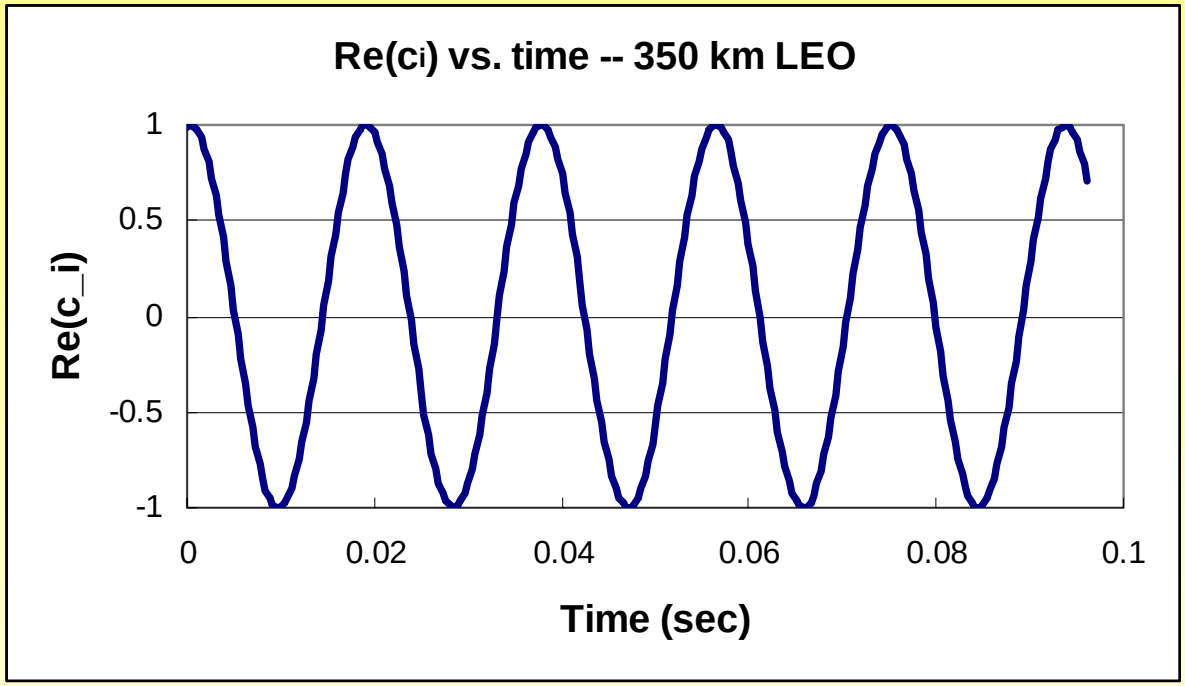
We've developed methods for wideband nulls in single-tap beamformer, too.

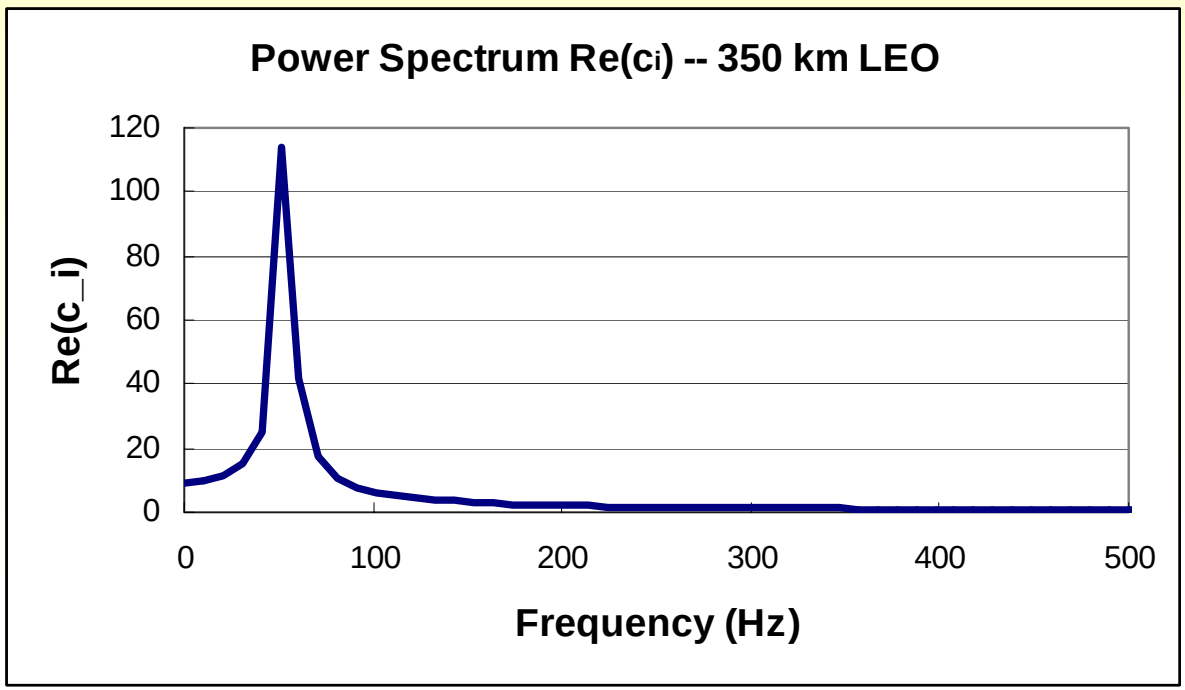


Coefficients for deterministic nulls have same temporal structure as those for adaptive nulling or for post-correlation processing.

Tracking a 350 km LEO at 10 GHz.

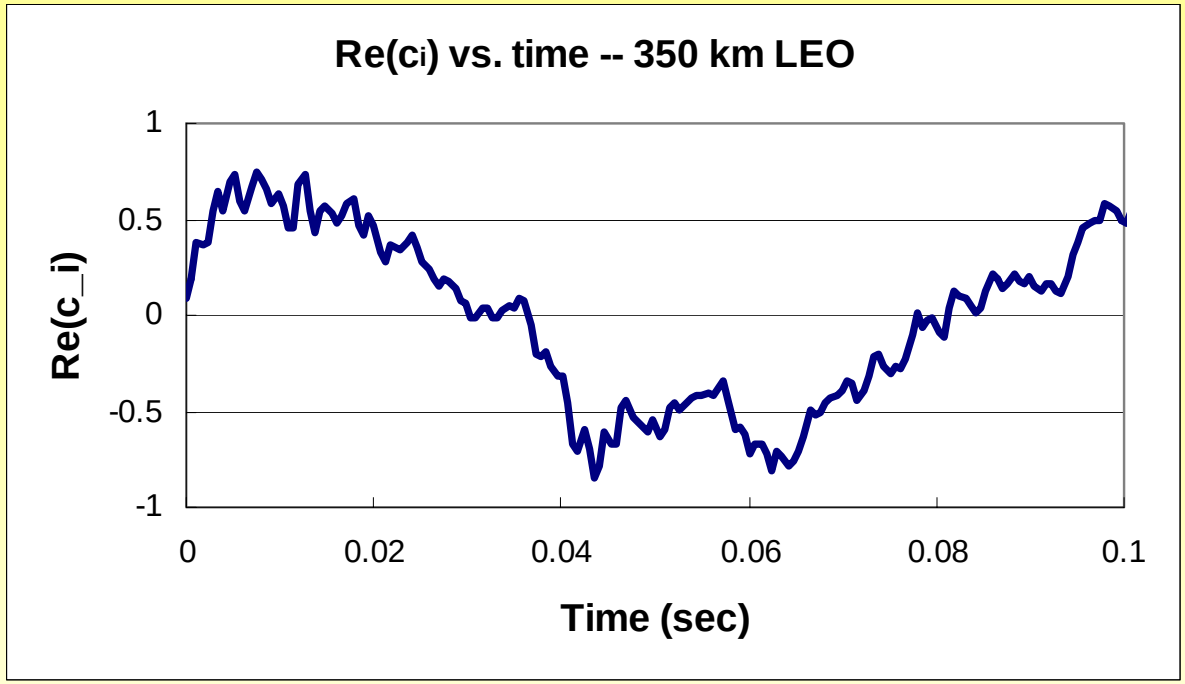
50 Hz typical

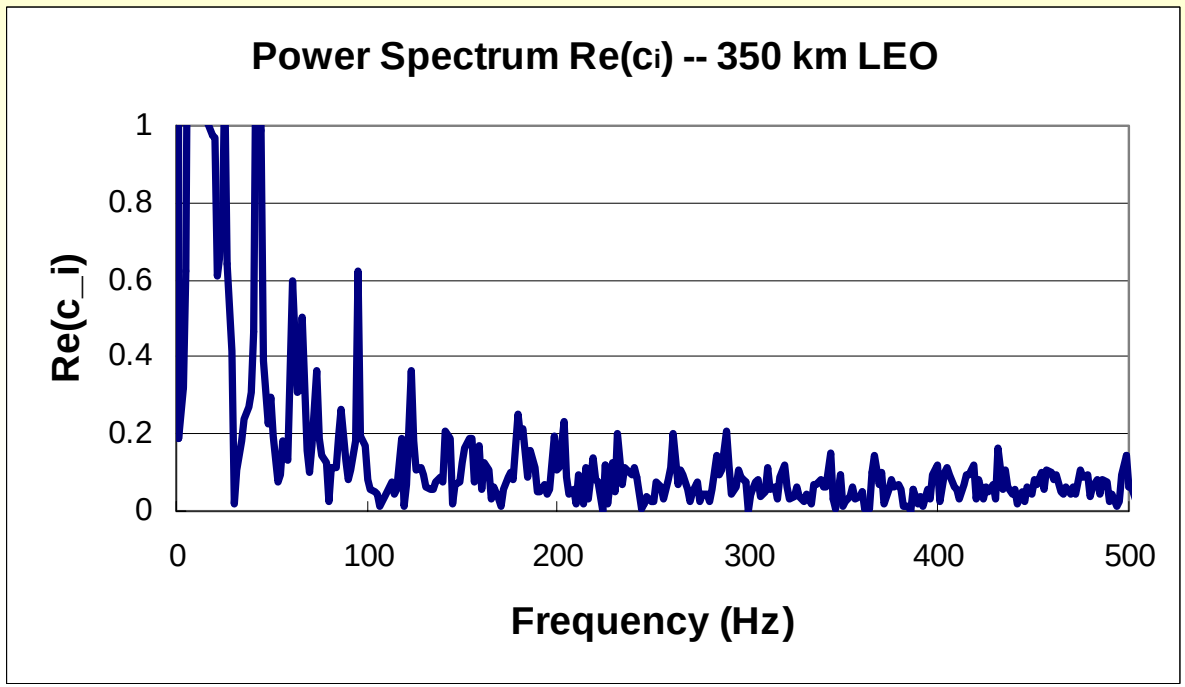




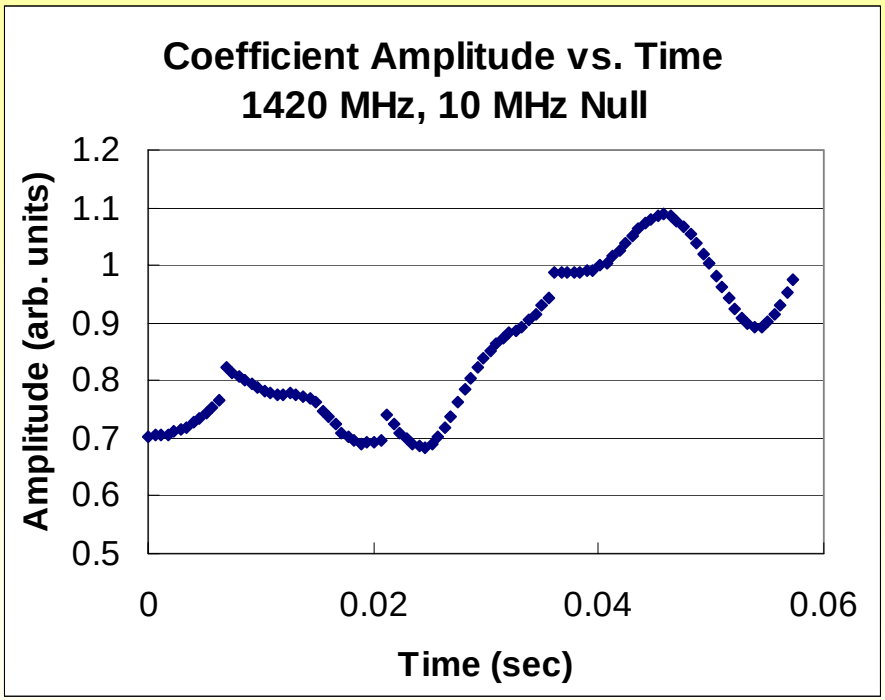
Tracking a 350 km LEO at 10 GHz.

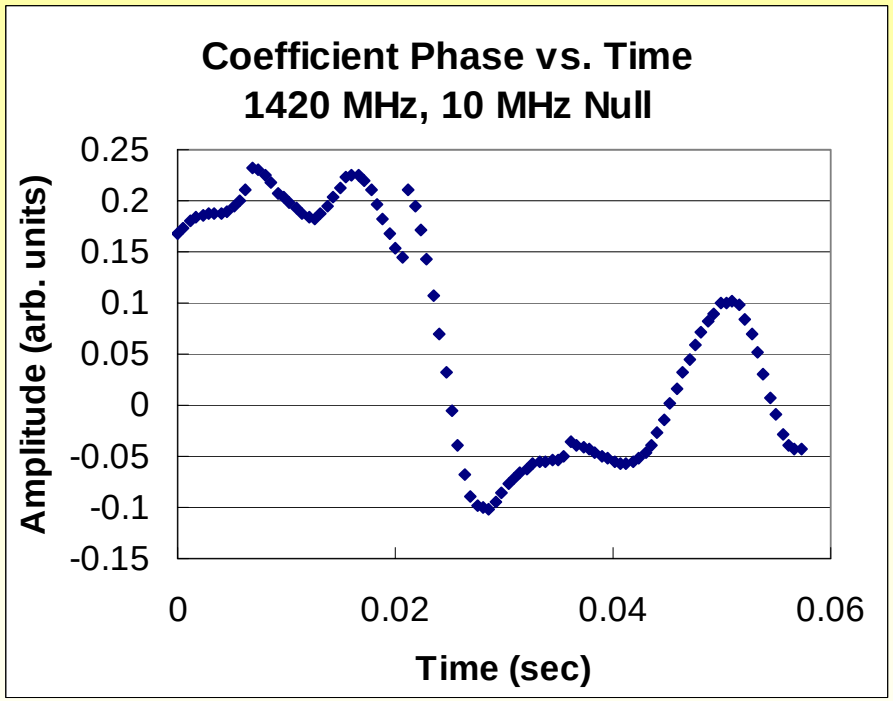
nothing typical!





c(*t*) shows near-discontinuities





$$\vec{k} \approx \vec{k}_0 + \vec{k}_1 t + \vec{k}_2 t^2 + \ldots$$

is a bad approximation.

Correct analysis.

- c_i contains a SUM over frequencies

$$B_{S-I} = \sum_i e^{-i\vec{k}_S \cdot \vec{x}_i} \left[1 - \frac{e^{i\vec{k}_I \cdot \vec{x}_i}}{N} \sum_j e^{-i\vec{k}_I \cdot \vec{x}_j} \right] s_i$$

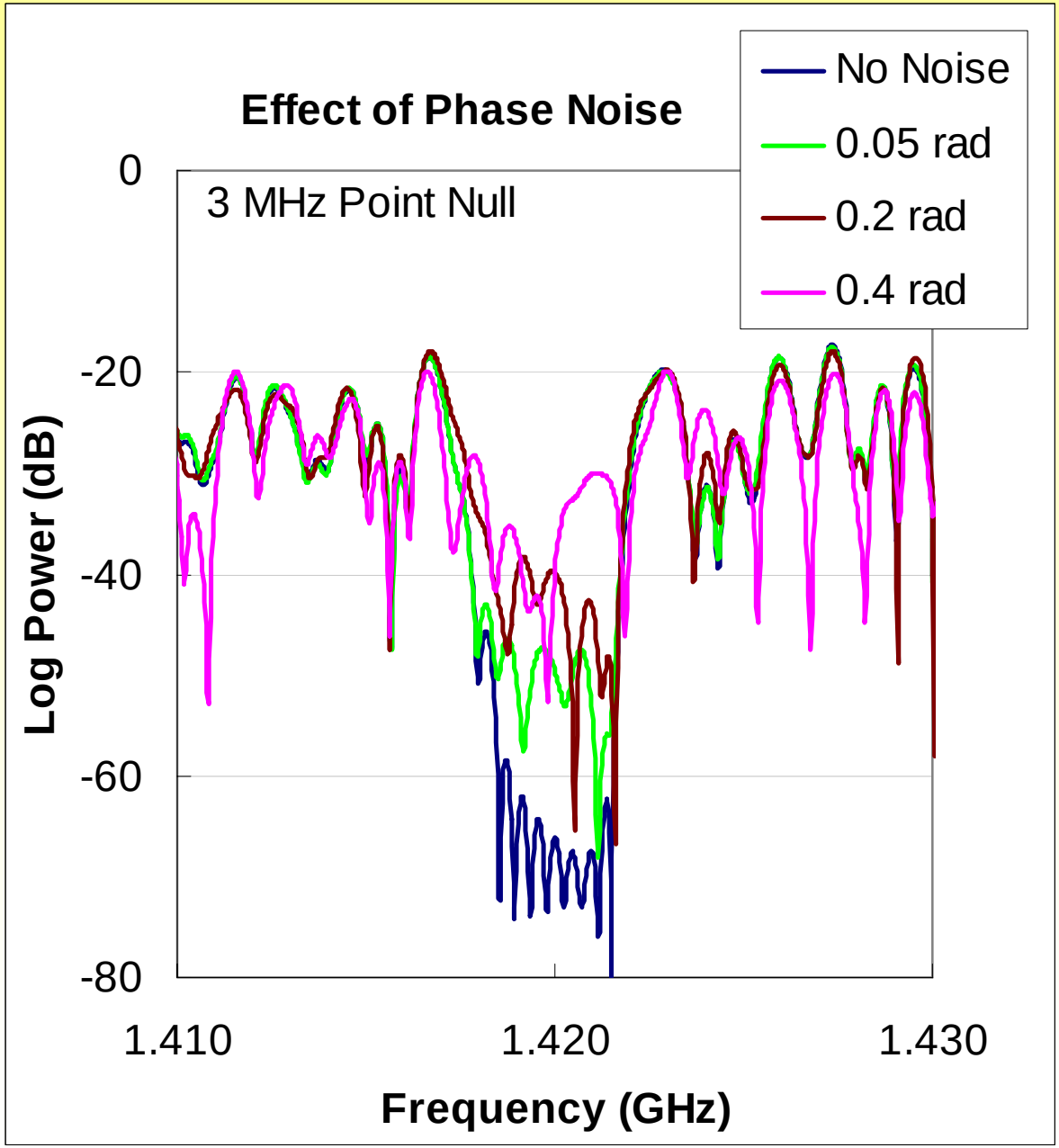
- Taylor's series is advantageous to no higher than 2 terms, good for 0.001 sec.

$$c_i = \left(\mathrm{Re}(c_i), \mathrm{Im}(c_i)\right), \quad c_i = c_{i,0} + c_{i,1} t + \ldots$$

200x harder than we first thought!

Simulations also tell us the numerical precision and accuracy required.

1° phase accuracy needed



Extrapolate to SKA

- Max update frequency: $\nu_{\max} = \frac{2 d f v}{c h}$

where

d = array size, f = max observation frequency

v = LEO velocity = 8 km/s

h = LEO height, c = light speed

- $\nu_{\max}$ = 900 Hz at ATA **= correlator dump rate**

- **$\nu_{\max}$ ~ 1 MHz at SKA (BF and Corr)**
- **0.01° precision**

Come and see our poster:

“Using Multiple Beams to Distinguish RFI from ETI Signals”

This and other work:

www.gerryharp.com

ATA memo series:

intranet.seti.org/ata

Ask me for site/password