Holografia mikrofalowa i inne metody pomiaru krzywizny anten parabolicznych

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Zieleniec 2025, Zjazd techniczny PK UKF

Uwaga o tej prezentacji

Dla oglądających tylko slajdy – każdy slajd zawiera źródłowy materiał, warto go przeczytać.

For just watching slides without commentary. Click source, learn there. Selection of sources here was very careful.

Motywacja – dlaczego o tym rozmawiamy?

- Temat w Polsce (i po polsku) w zasadzie nie istnieje – zarówno w literaturze jak i w praktyce
- Holografia jest ogólnie nieznana radioamatorom, którzy w zasadzie nie używają żadnej zaawansowanej metody pomiarowej krzywizny reflektorów
- Amatorzy i profesjonaliści w radiokomunikacji zwykle rozwiązują problem nieosiągania parametrów przez antenę poprzez jej wymianę a nie naprawę. Ewentualnie poprzez zmianę parametrów komunikacji na niższe.

Motywacja – dlaczego o tym rozmawiamy?
John Ruze – Antena Tolerance Theory – A review (1966)
https://ieeexplore.ieee.org/document/1446714

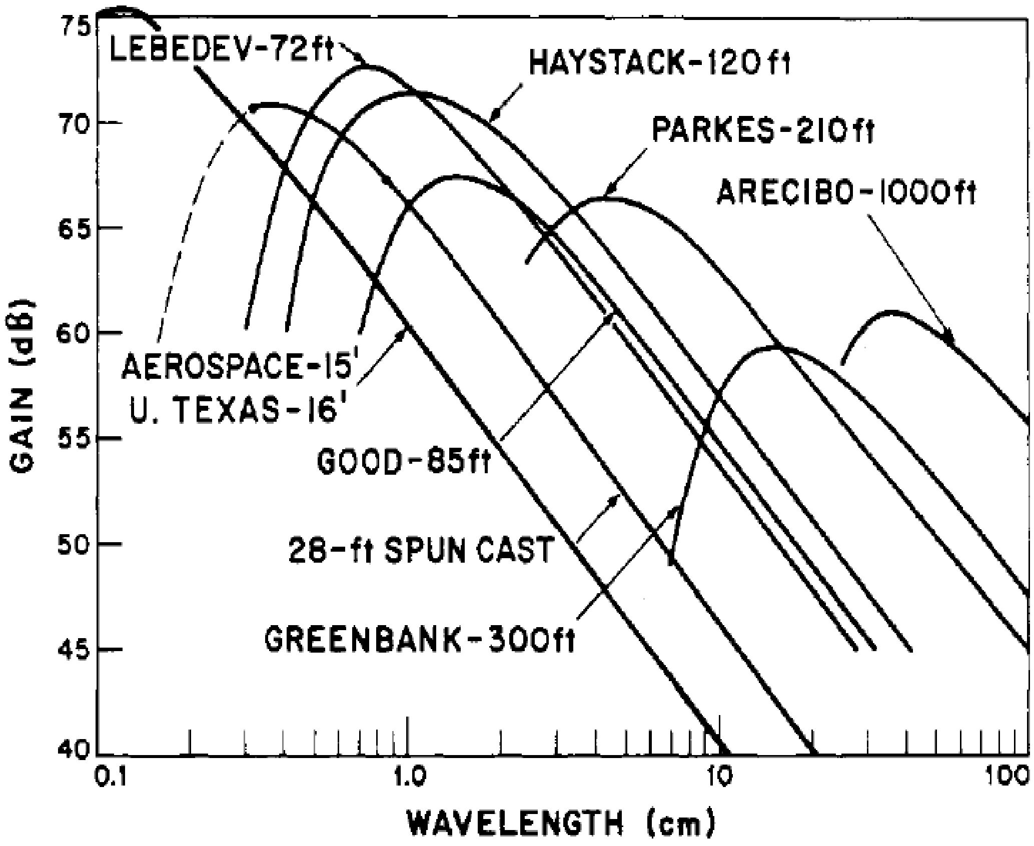


Fig. 8. Gain of large paraboloids (based on published estimates).

Motywacja – dlaczego o tym rozmawiamy?
Jacob W. M. Baars- Metrology of Reflector Antennas: A Historical Review
https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9663125

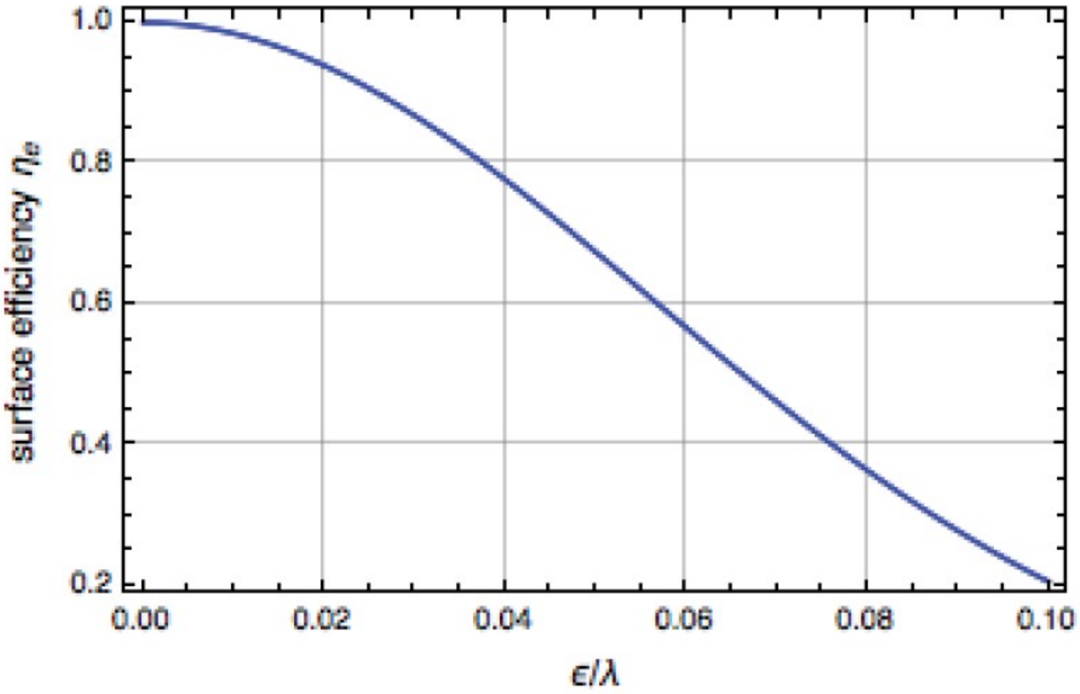


Figure 1. The "Ruze" curve shows the "surface scattering efficiency," η_S, as a function of the surface rms error, ε, normalized to the wavelength, λ.

Holografia jako metoda

- Metoda „ostateczna” – ten pomiar weryfikuje antenę w każdym aspekcie
- Pomiar jest radiowy – powierzchnia odbijająca może być ukryta pod laminatem, a jeśli antena jest złożona z wielu reflektorów to w pomiarze biorą one udział jako całość
- Dla dużych anten dokładność pomiaru holograficznego jest trudna do osiągnięcia jakąkolwiek inną metodą

Holografia jako metoda

- Bardzo wymagająca technicznie – potrzebna jest na starcie antena z doskonałymi napędami i stabilna mechanicznie
- Pomiar polega na pomiarze amplitudy i fazy sygnału o częstotliwościach zwykle rzędu dziesiątek GHz
- Bardzo trudna metrologicznie (trzeba uwzględnić wiele różnych zjawisk aby dokonać pomiaru)
- Paradoksalnie tania i dająca się dobrze automatyzować

Geoffrey Carlyle James-

MICROWAVE HOLOGRAPHY OF LARGE REFLECTOR ANTENNAS

https://figshare.utas.edu.au/articles/thesis/Microwave_holography_of_large_reflector_antennas/23232710/1/files/40943114.pdf

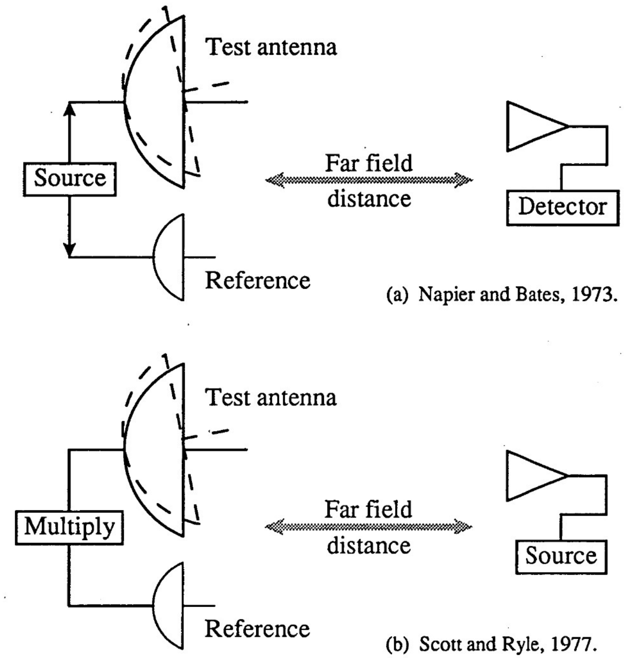
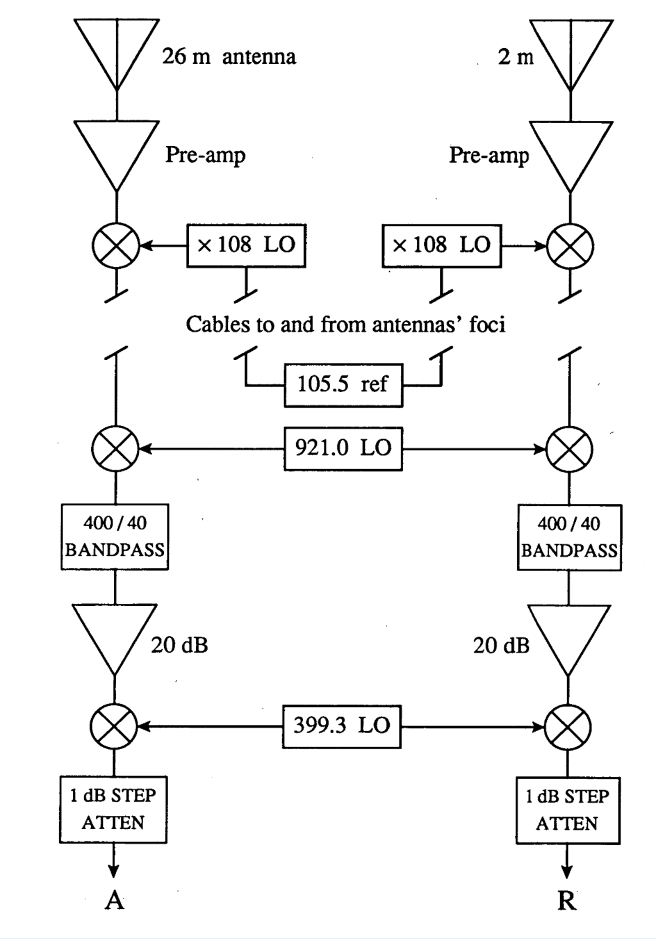


Figure 1.2: Two methods of recording the complex far field pattern of an antenna: (a) formation of a hologram by summing radiation from the test antenna with a reference wave, and (b) measuring phase and magnitude by multiplying signals received by test and reference antennas for an incoming plane wave.

Geoffrey Carlyle James

MICROWAVE HOLOGRAPHY OF LARGE REFLECTOR ANTENNAS

https://figshare.utas.edu.au/articles/thesis/Microwave_holography_of_large_reflector_antennas/23232710/1/files/40943114.pdf



David J. Rochblatt - Microwave Antenna Holography

https://descanso.jpl.nasa.gov/monograph/series10/08_Reid_chapt8.pdf

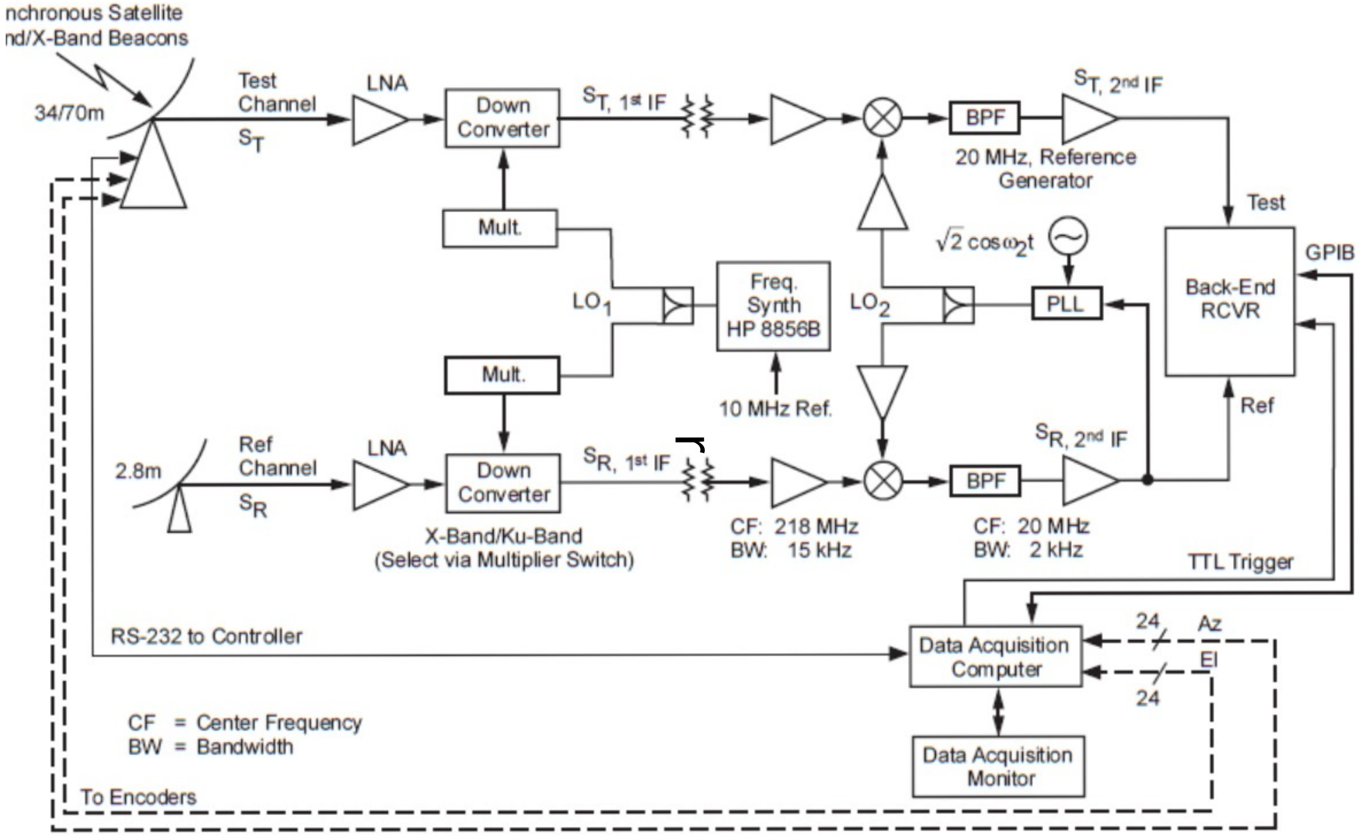
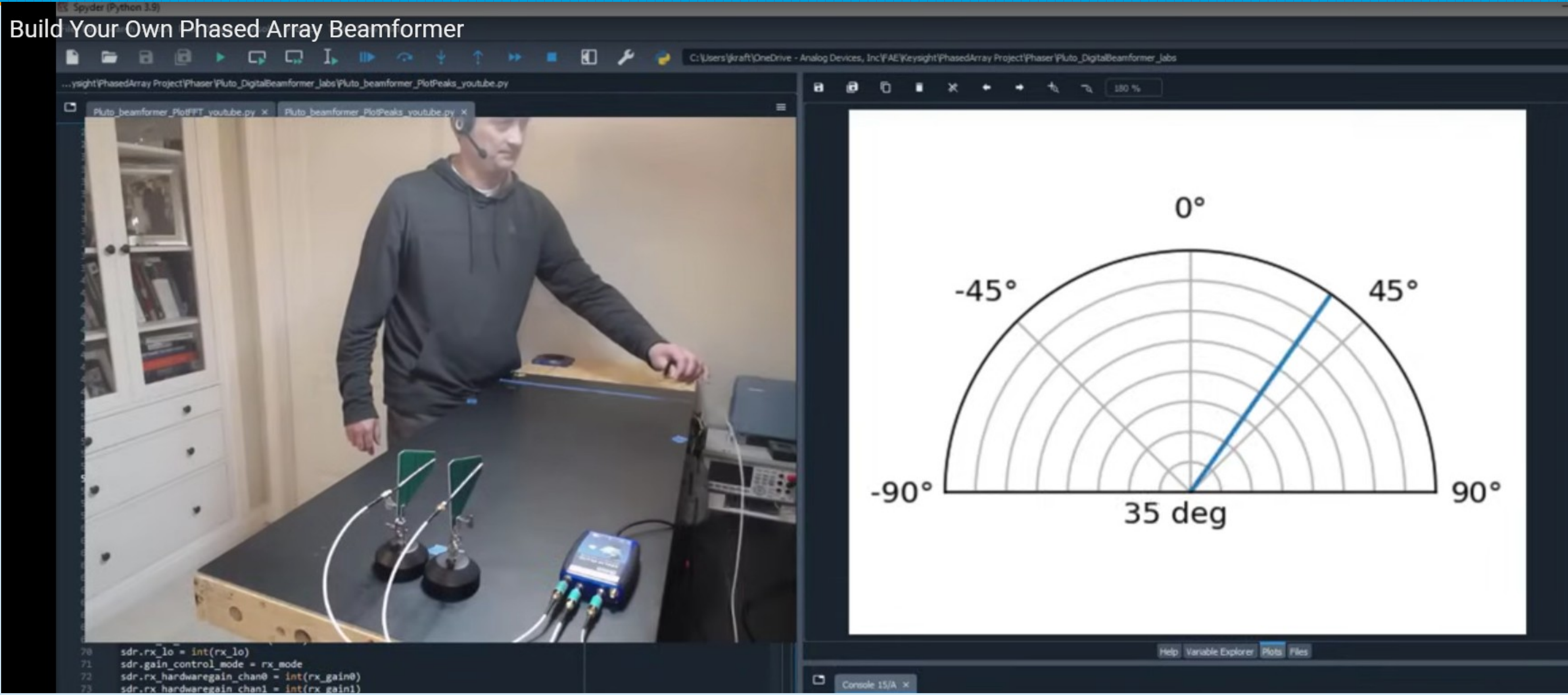


Fig. 8-4. Antenna microwave holography block diagram (notations defined in Section 8.3).

Simple hardware possible ? 2x Wavelab + PlutoSDR ?

https://www.youtube.com/watch?v=2QXKuEYR4Bw2



David J. Rochblatt - Microwave Antenna Holography

https://descanso.jpl.nasa.gov/monograph/series10/08_Reid_chapt8.pdf

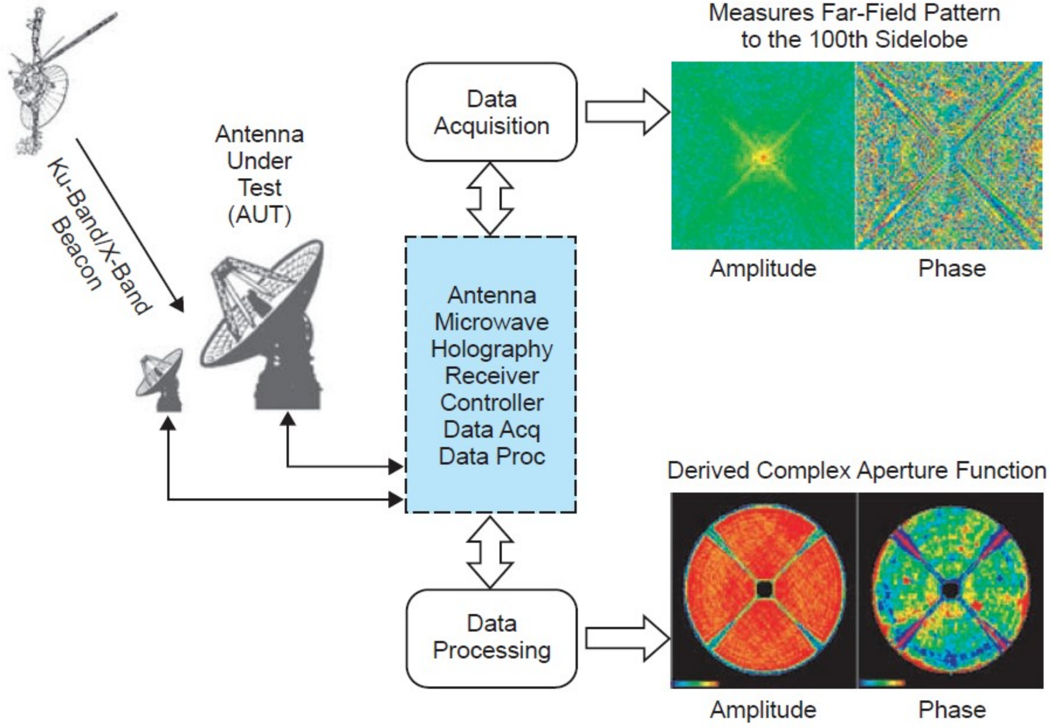
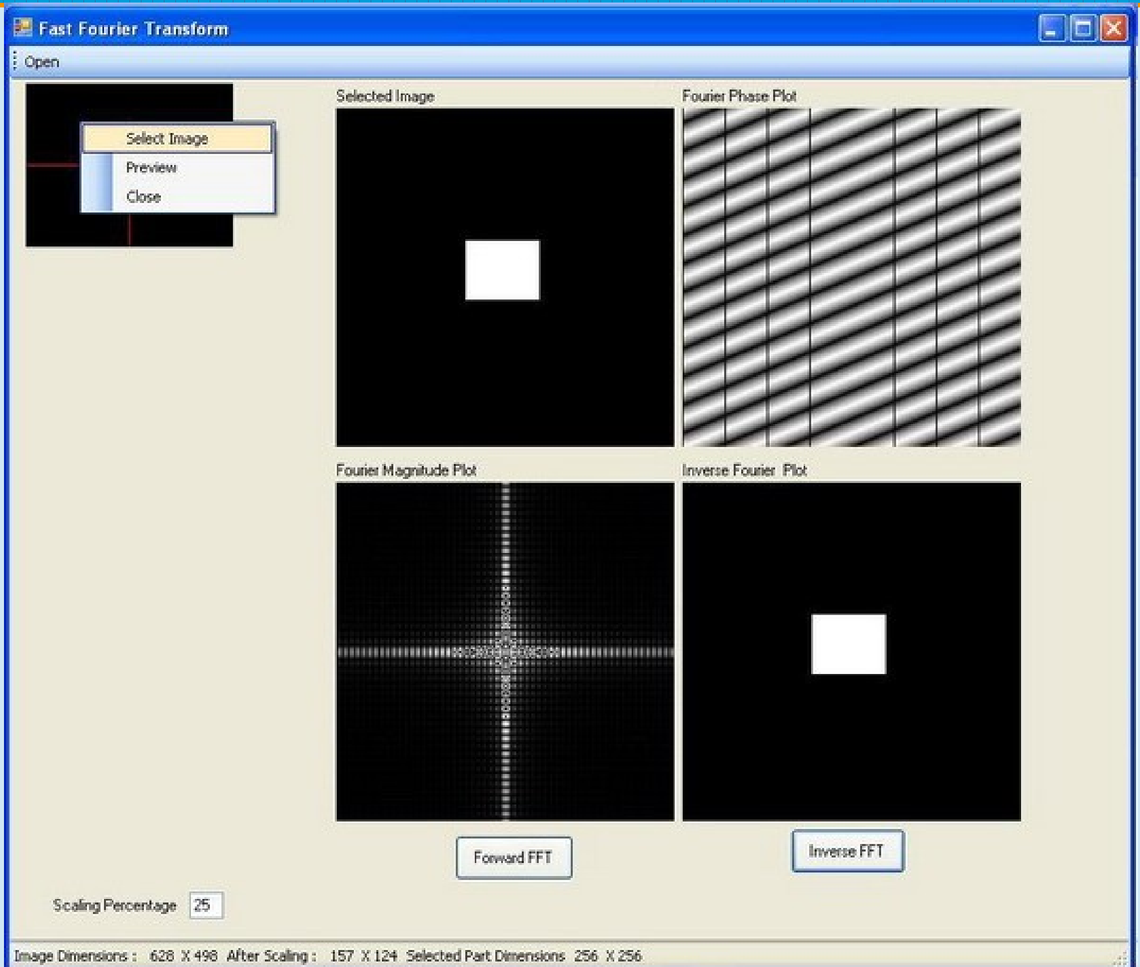


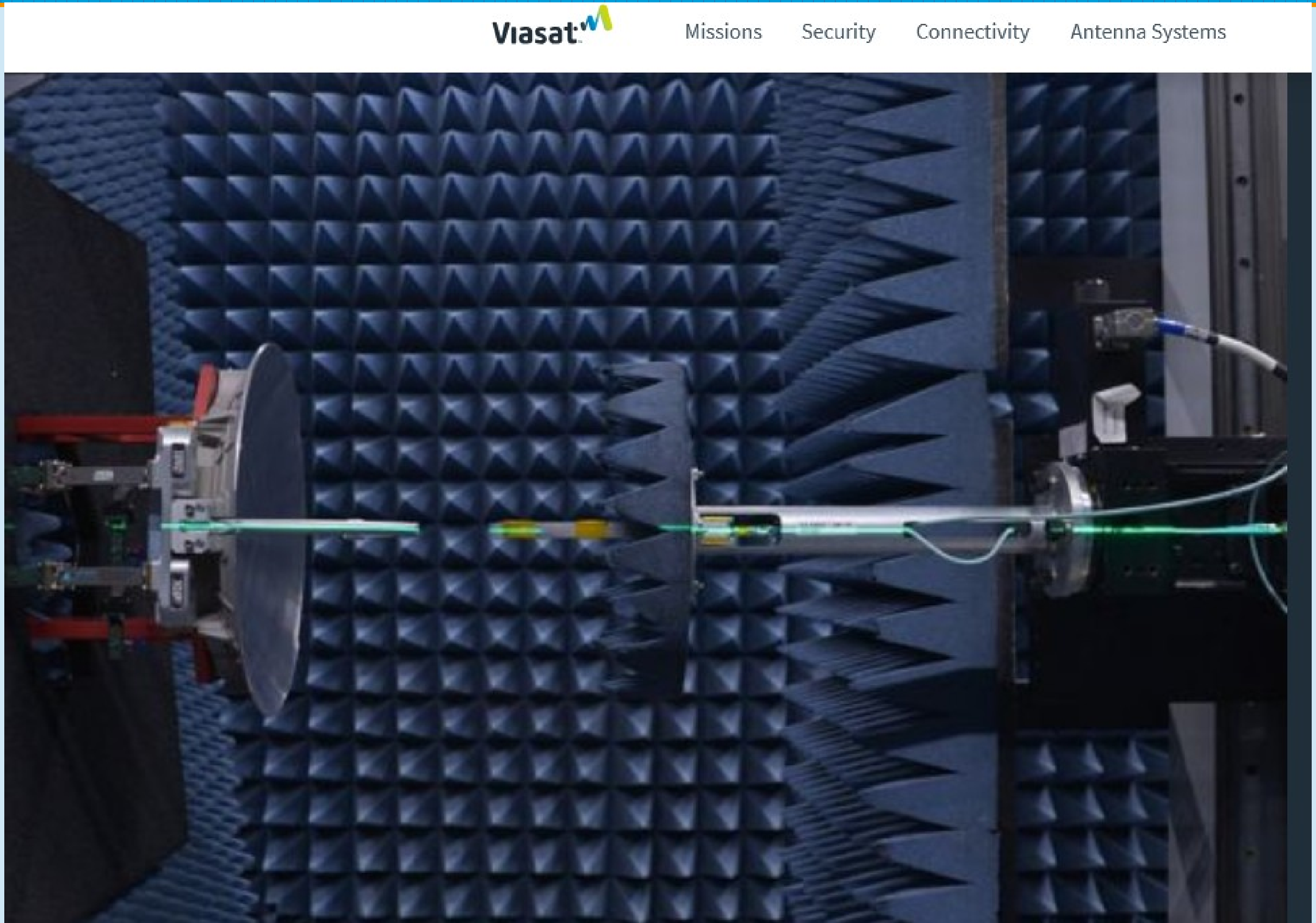
Fig. 8-1. Antenna microwave holography activities diagram.

Dwuwymiarowa FT

https://www.codeproject.com/Articles/44166/2D-FFT-of-an-Image-in-C



To też jest holografia mikrofalowa.
http://viasat.com



Pole dalekie <– FT –> pole bliskie
https://ieeexplore.ieee.org/document/1451288

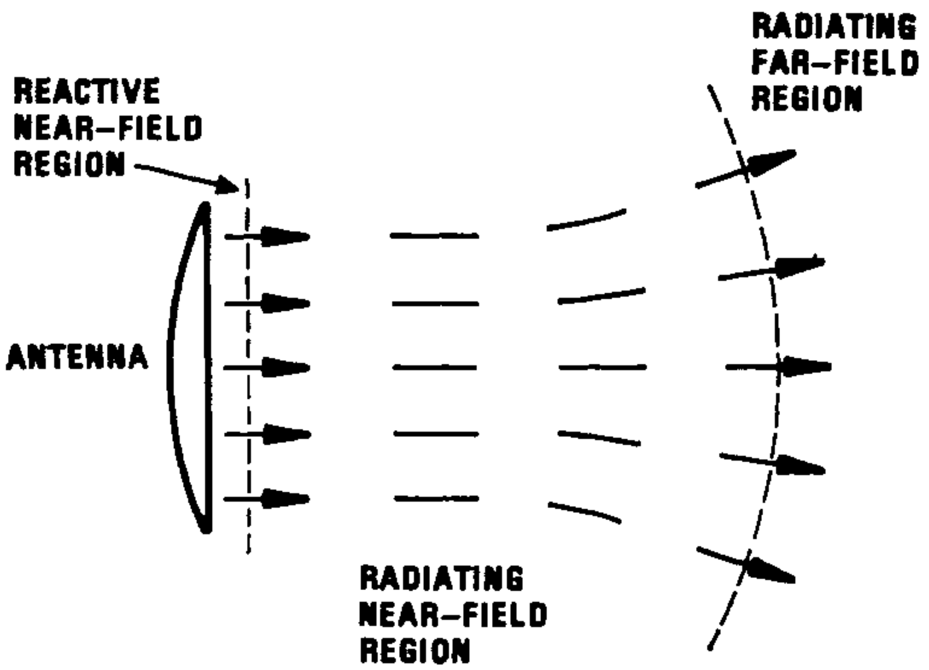


Fig. 2. Pictorial representation of the three regions surrounding an antenna.

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https://descanso.jpl.nasa.gov/monograph/series10/08_Reid_chapt8.pdf

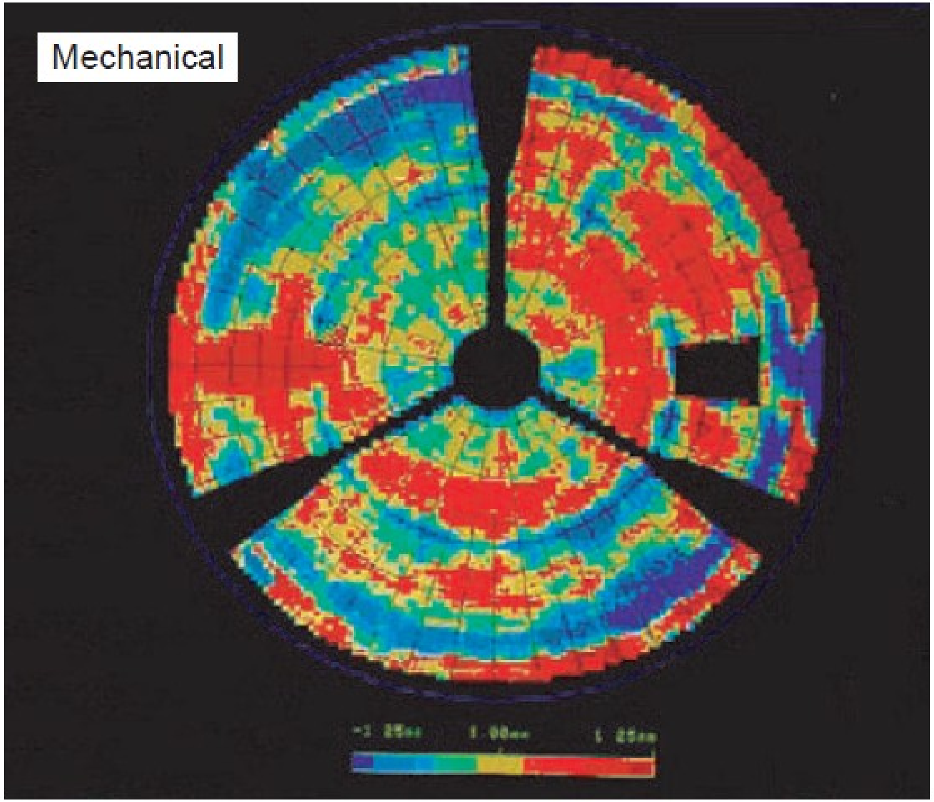

Fig. 8-13. DSS-13 after the initial theodolite setting.

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https://descanso.jpl.nasa.gov/monograph/series10/08_Reid_chapt8.pdf

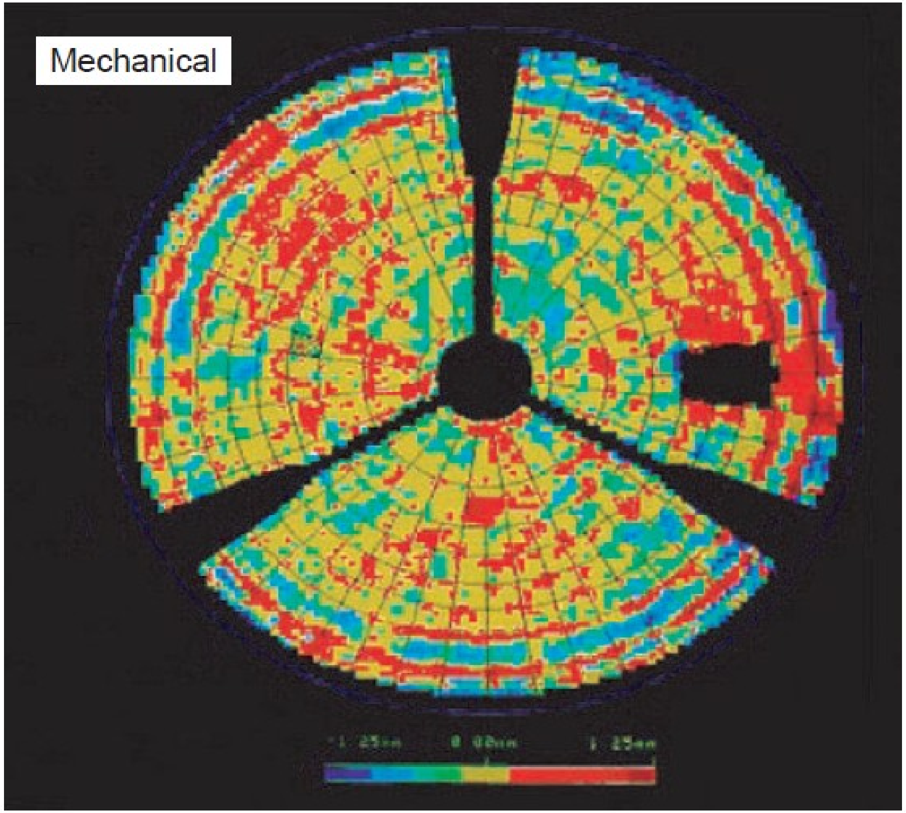
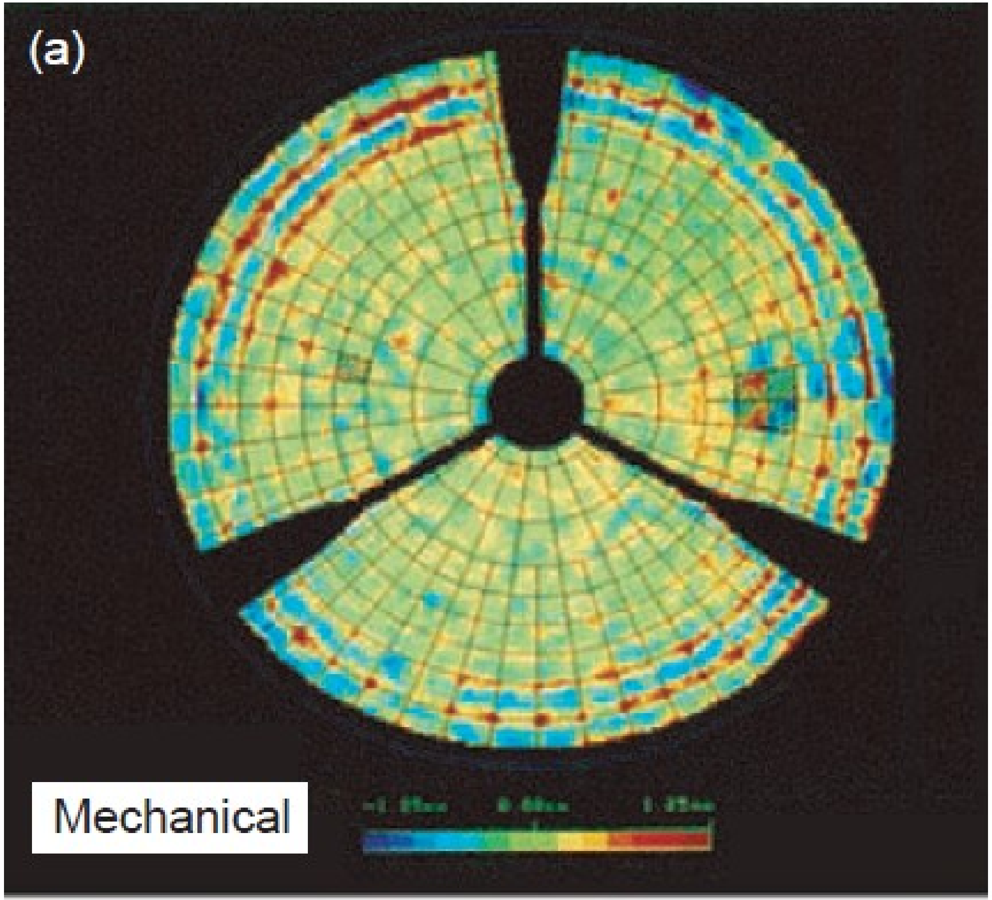


Fig. 8-14. DSS-13 after first application of holography.


(a)
Mechanical

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https://descanso.jpl.nasa.gov/monograph/series10/08_Reid_chapt8.pdf

Table 8-1. Holography historical data.

Antenna Diameter (m)	DSS*	Date	Meas. Freq. (GHz)	Resolution (m)	Elevation (deg)	Initial rms (mm)	Final rms (mm)	Gain Improvement (dB) Frequency Band S	X	Ka
70-m Antennas										
70	14	4/88	12.198	0.42	47.0	**1.26**	**0.64**	0.05	0.64	9.3
70	43	10/87	12.750	0.44	47.0	**1.18**	**0.65**	0.04	0.59	8.5
70	63	7/87	11.451	0.42	42.0	**1.58**	**0.65**	0.09	1.17	16.9
DSS-13 34-m R&D Antenna										
34	13	9/90	12.198	0.32	46.0	**0.88**	**0.43**	0.02	0.32	4.6
34	13	1/92	12.198	0.32	46.0	**0.68**	**0.37**	0.01	0.18	2.5
34	13	2/94	12.198	0.32	46.0	**0.38**	**0.31**	0.002	0.03	0.32
34-m Operational Antennas										
34	24	5/94	11.922	0.33	46.3	**0.50**	**0.25**	0.007	0.1	1.27
34	25	6/96	11.913	0.33	47.0	**0.50**	**0.25**	0.007	0.1	1.27
34	26	10/96	11.913	0.33	47.0	**0.42**	**0.25**	0.004	0.05	0.76
34	54	5/98	12.502	0.32	43.2	**0.79**	**0.32**	0.02	0.25	4.0
34	34	6/98	12.748	0.315	48.3	**0.47**	**0.26**	0.006	0.08	1.2
34	55	7/03	11.450	0.33	43.1	**0.90**	**0.25**	0.03	0.41	5.8

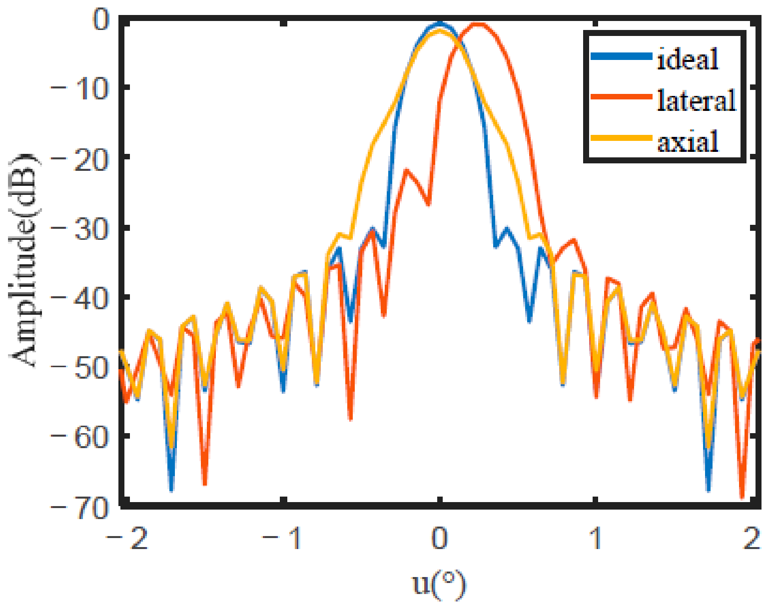

Figure 6. The far-field pattern caused by the feed offset. The blue curve is the ideal far-field pattern; the yellow curve is the far-field pattern caused by the axial offset of 0.5λ; and the orange curve is the far-field pattern caused by the lateral offset of 0.5λ.

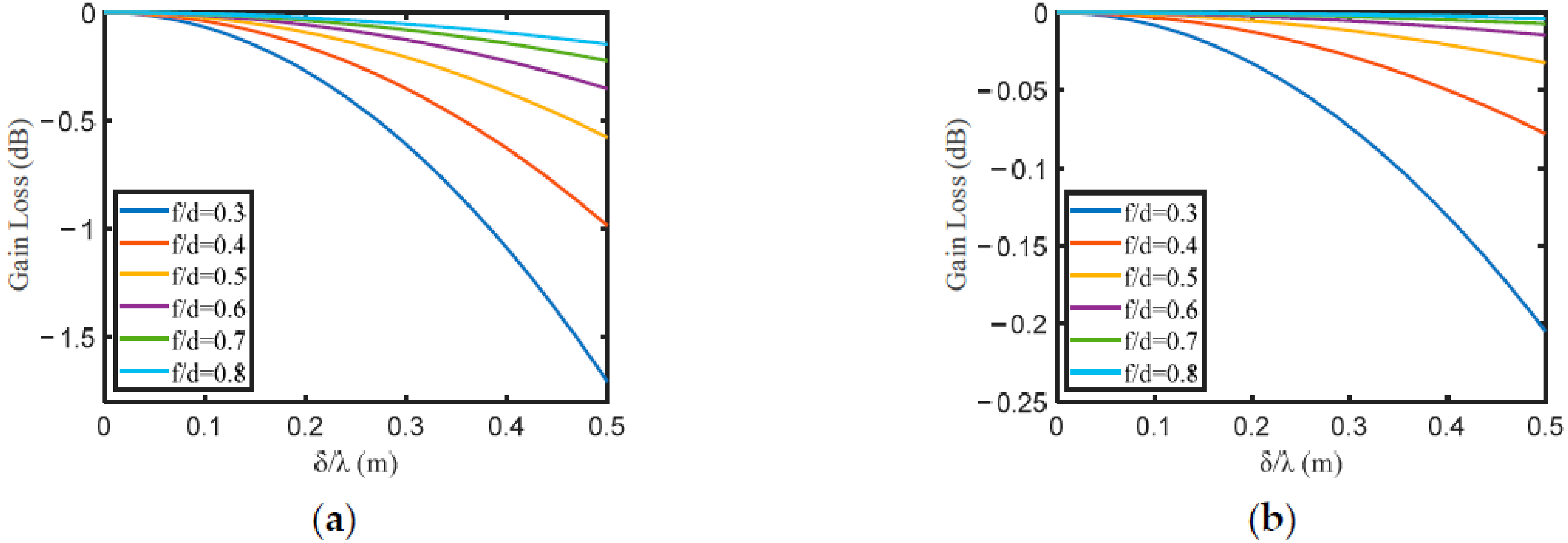

Figure 7. The relationships between the gain loss of different antenna focal diameter ratios and the feed offset error: (**a**) the influence of the axial offset error of the feed with different focal diameter ratios on the gain loss of the antenna; (**b**) the influence of the lateral offset error of the feed with different focal diameter ratios on the gain loss of the antenna.

Evaluation of the ALMA Prototype Antenna

https://www.researchgate.net/publication/1789859_Evaluation_of_the_ALMA_Prototype_Antennas

6.1 Surface Accuracy Performance

6.1.1 Holography

The specification requires the antenna to have a surface accuracy of $25\mu m$ RMS with a goal of $20\mu m$. The initial surface setting was performed by AEC with a Leica laser-tracker to $50\mu m$ RMS. Equipment and methodology for the holographic measurements were identical to those used on the VertexRSI antenna (see §5.1.1).

The first holographic measurements of the AEC antenna indicated that the position of the feed in the nominal "mechanical" primary focus was displaced from the focus of the best–fit paraboloid by ~ -5mm in Y and $\sim +12$mm in Z. As the positioning of the holography signal feed was not nearly as stable as it was on the VertexRSI antenna, we felt that the contractor–determined focus of the reflector was more reliable. Hence, no refocus setting of the AEC antenna surface was made. This has been confirmed by recent measurements of the apex location by the contractor who determined displacements of -9mm in Y and $+8$mm in Z.

Holografia vs inne metody

- Przechodzimy do:
- Jacob W. M. Baars
- Metrology of Reflector Antennas: A Historical Review
- https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9663125