# Synthesis of antenna array radiation patterns based on closed-form transformations of array factor

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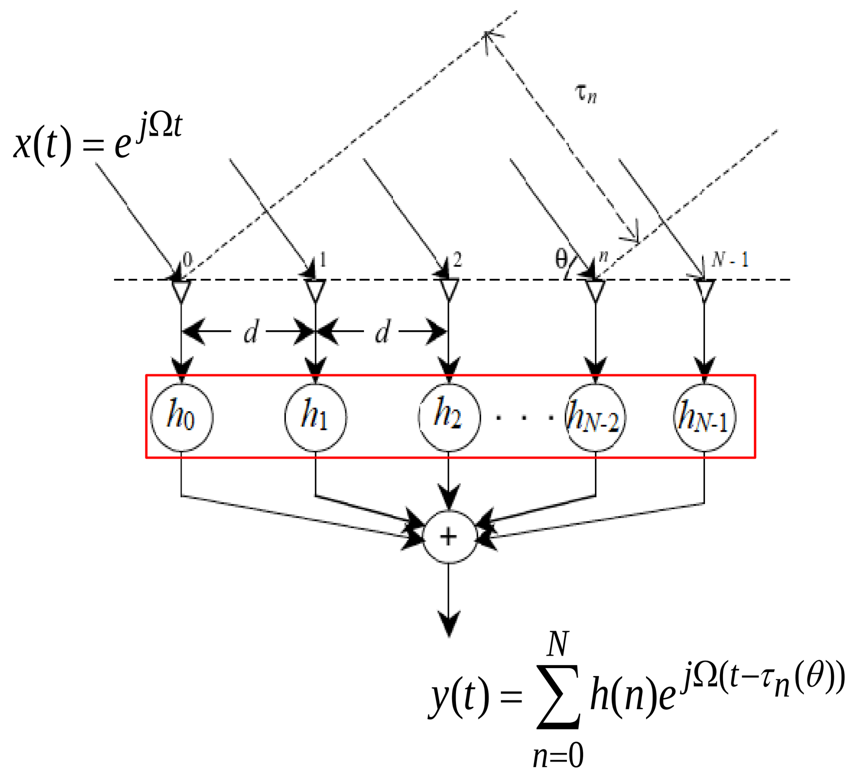
## 1. Introduction

Antenna arrays receive signals from specific direction and attenuate signals from other directions and vice versa when operating in transmitting mode. Commonly used antenna arrays are uniform linear arrays where antenna elements are equally spaced along the straight line.

They linearly combines the spatially sampled time sequences from each antenna element to obtain a scalar output time sequence in the same way as the finite-impulse-response (FIR) digital filter linearly convolves temporally sampled data.




## 2. Problem Description

The goal of this research is to develop analytical methods for the design of antenna arrays forming pencil beams and flat-top beampatterns with steep roll-off, controllable sidelobe level, and robust null steering possiblity by shaping the factor of aperture of a given array.

## 3. Methodology

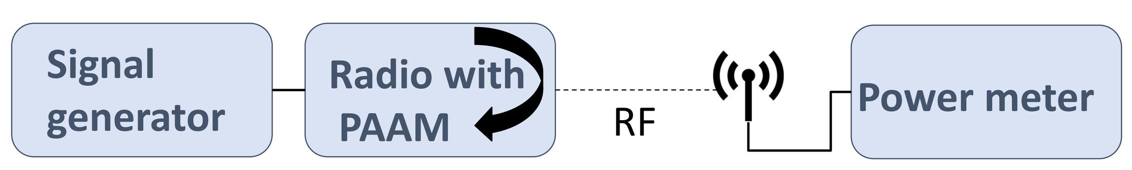
- **Polynomial sharpening** is an efficient technique for improving the amplitude response of symmetric FIR filters, suitable for the design of steep roll-off filters
- **Kaiser-Hamming polynomial** has $p$th-order tangency at $x$=1 and $q$th-order tangency at $x$=0

$$f_{p,q}(x) = x^{q+1} \sum_{r=0}^{p} \frac{(q+r)!}{q!\,r!}(1-x)^r \qquad p+q = M-1$$

- **Samadi polynomial** has $p$th-order tangency to $y$=1-$\sigma$(1-$x$) at $x$=1 and $q$th-order tangency to $y=\delta x$ at $x$=0

$$f_{p,q,\sigma,\delta}(x) = \delta x + \sum_{m=q+1}^{M} (b_{m,0} - \sigma b_{m,1} - \delta b_{m,2}) x^m$$

- Subarray techniques bring reduction in array size, while maintaining same beamwidth and sidelobe level. **Frequency response masking** is subarray technique suitable for the design of very sharp beampatterns.
- **Windowing** is a classical method for the design of uniform linear arrays forming pencil beams, where low dynamic range ratio (DRR), low sidelobe power, high directivity, and prescribed sidelobe level are desired.
- Beam steering and null stearing can be performed by **amplitude and phase perturbation** of the excitation coefficients. The verification of null steering will be performed on antenna array which operates in millimeter-wave band (28 GHz).



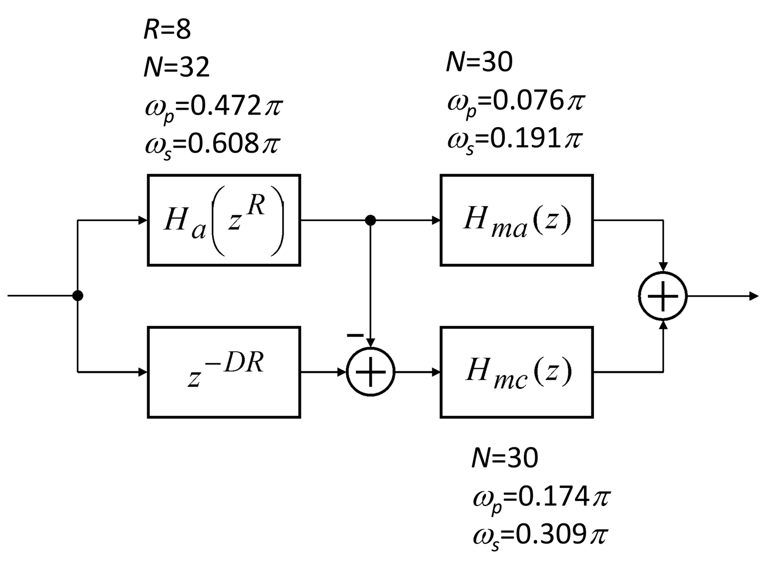

Sinus wave from signal generator

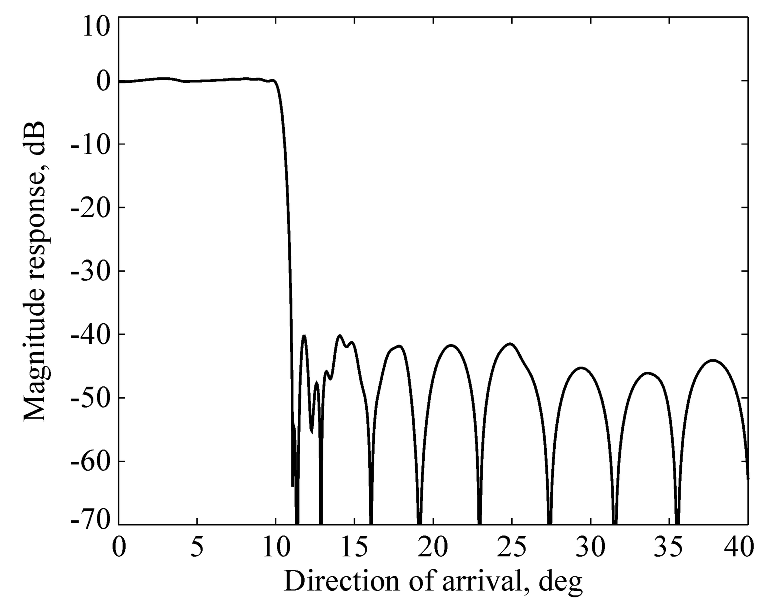
Radio with PAAM rotates 360°

Power meter on spectrum analyzer to verify null steering method

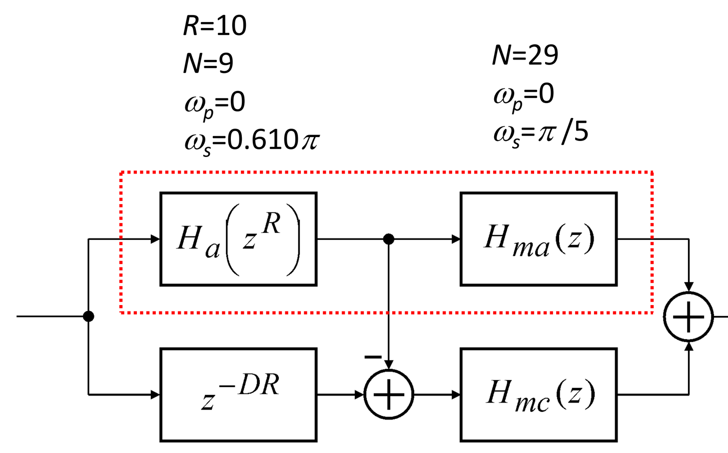
## 4. Results

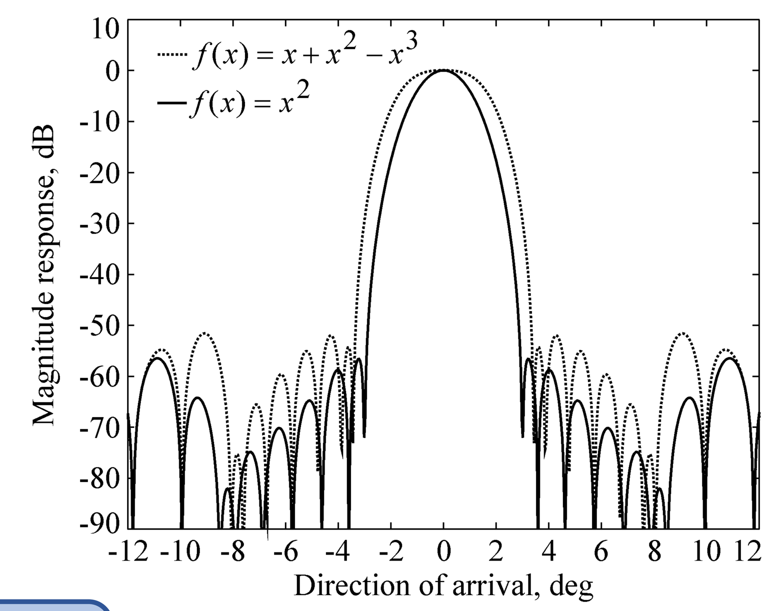
### Wide angle beamformer



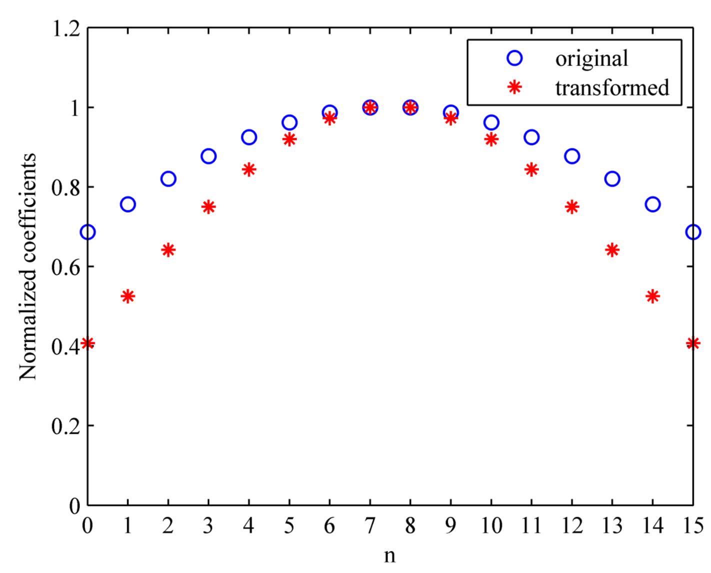



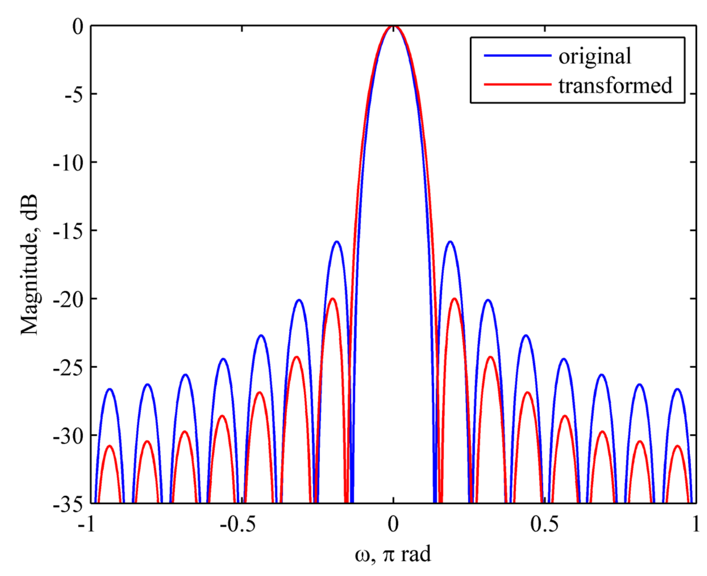

### Narrow angle beamformer



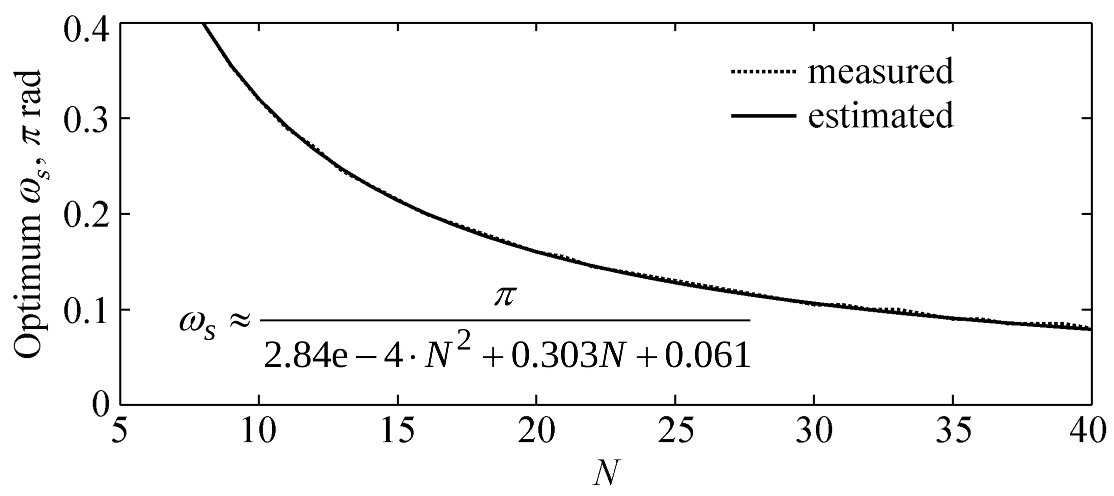




### Transformed raised-cosine beam

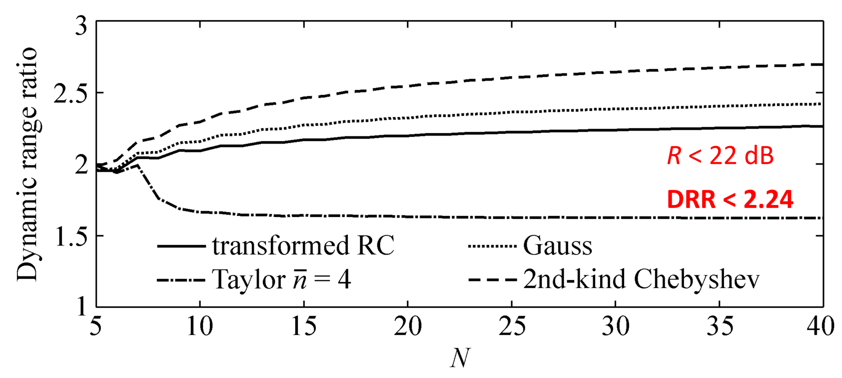


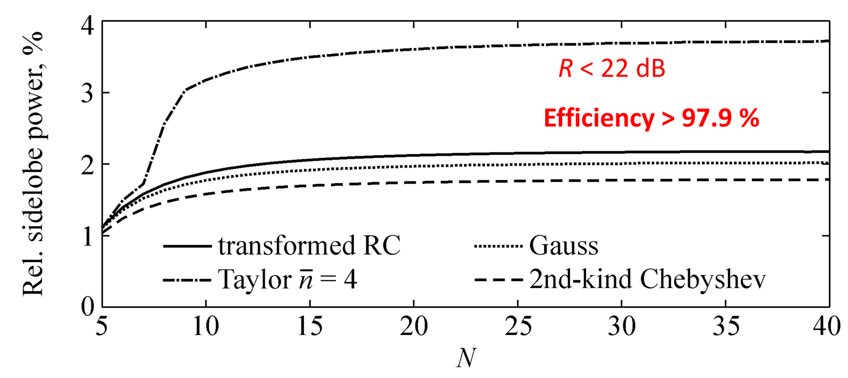




For a given R, the transform allows finding of the edge ωs which yields an optimum window.




For 5 ≤ N ≤ 40 and 15 dB ≤ R ≤ 55 dB, **optimum beamwidth, DRR**, and **directivity** are achieved for the same ωs.




## 5. Conclusion

Analytical methods for the design of antenna array radiation pattern have been proposed. They bring reduced number of elements, steep roll-off beampatterns, beampatterns with prescibed sidelobe level, and radiation patterns with steered null which will be verified in millimeter wave band.

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