Основные темы:

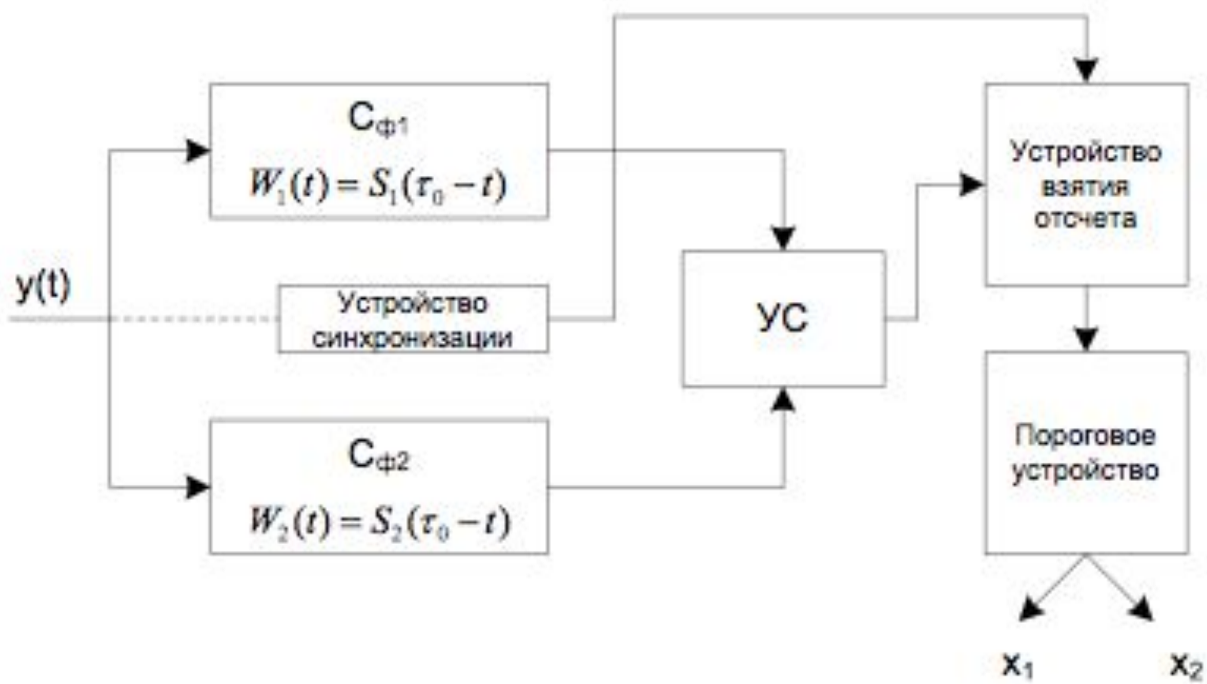
- Ошибки при синхрониации
- Beamforming
- Перераспределение частот

Ошибки при синхронизации

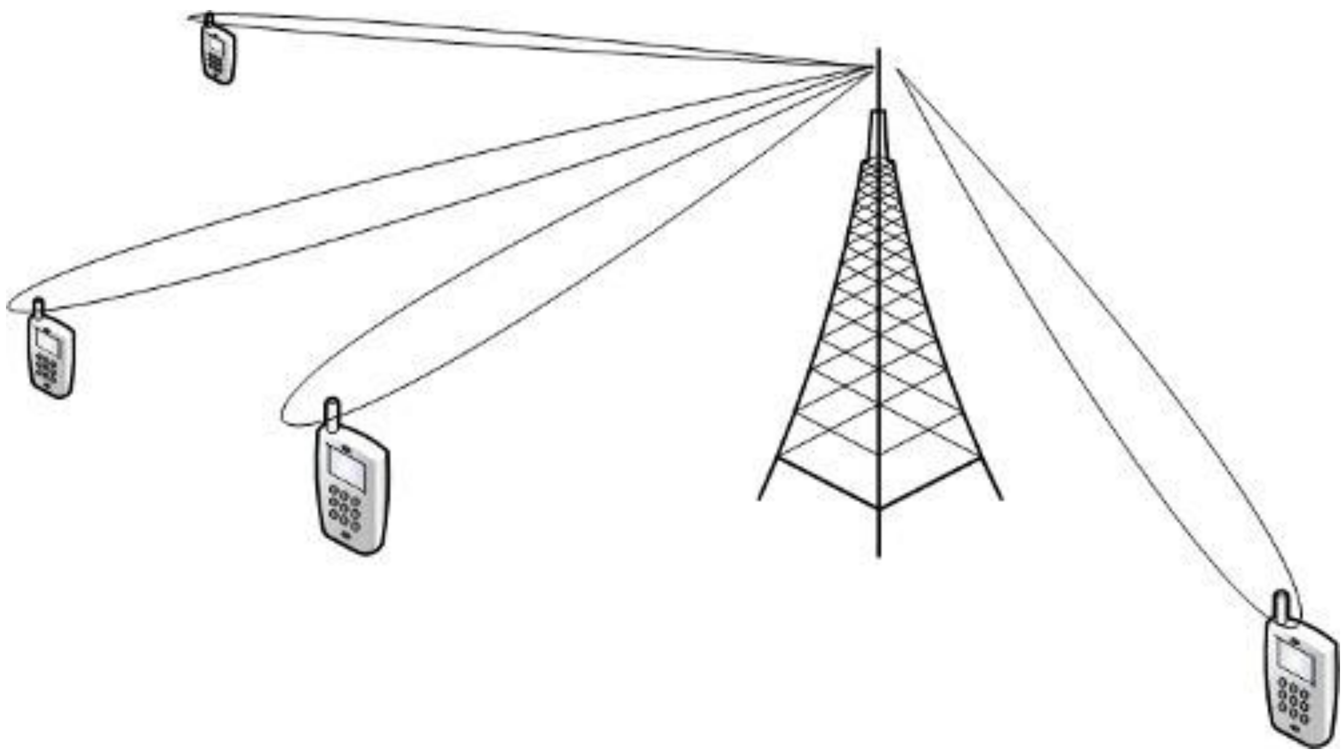
Вид синхронизации	Величина рассогласования	Требуемая P	Необходимое увеличение энергии
ВЧ частота	$\Delta f_p \le \frac{0,1}{\tau_0}$	10^{-4} - 10^{-5}	1,5 - 1,25
ВЧ фаза	$\Delta\varphi_p \le 10-15^0$	10^{-4} - 10^{-5}	1,1 – 1,15
Временная тактовая	$\Delta\tau_p \le 0,1\tau_0$	10^{-4} - 10^{-5}	1,3 – 1,5

Ошибки при синхронизации

Ошибки при синхронизации



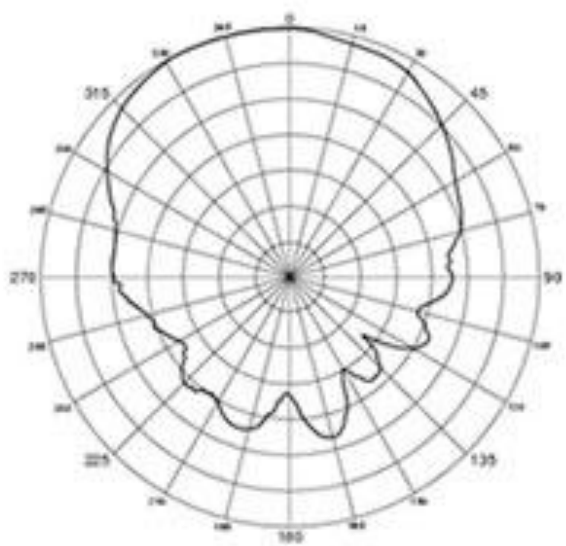
Smart Antenna



Smart Antenna

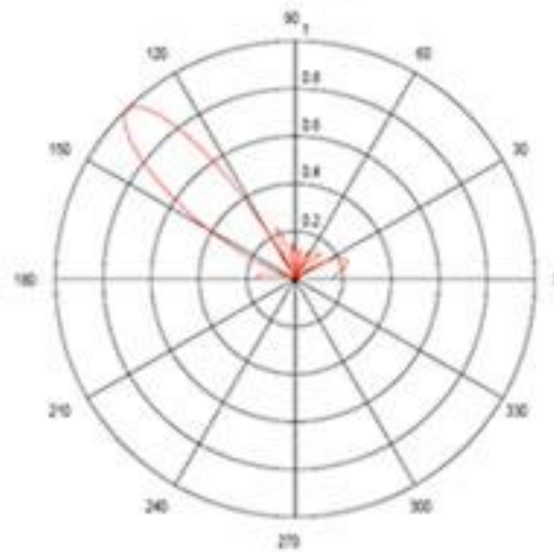
Regular Antenna:

Like a Light Bulb: radiates energy in all directions.
This results in wasted RF energy and interference.



Smart Antenna (Beamforming):

Like a Torchlight: focuses the radio beam in the needed direction.
This results in stronger signal and less wasted RF energy.



Smart Antenna

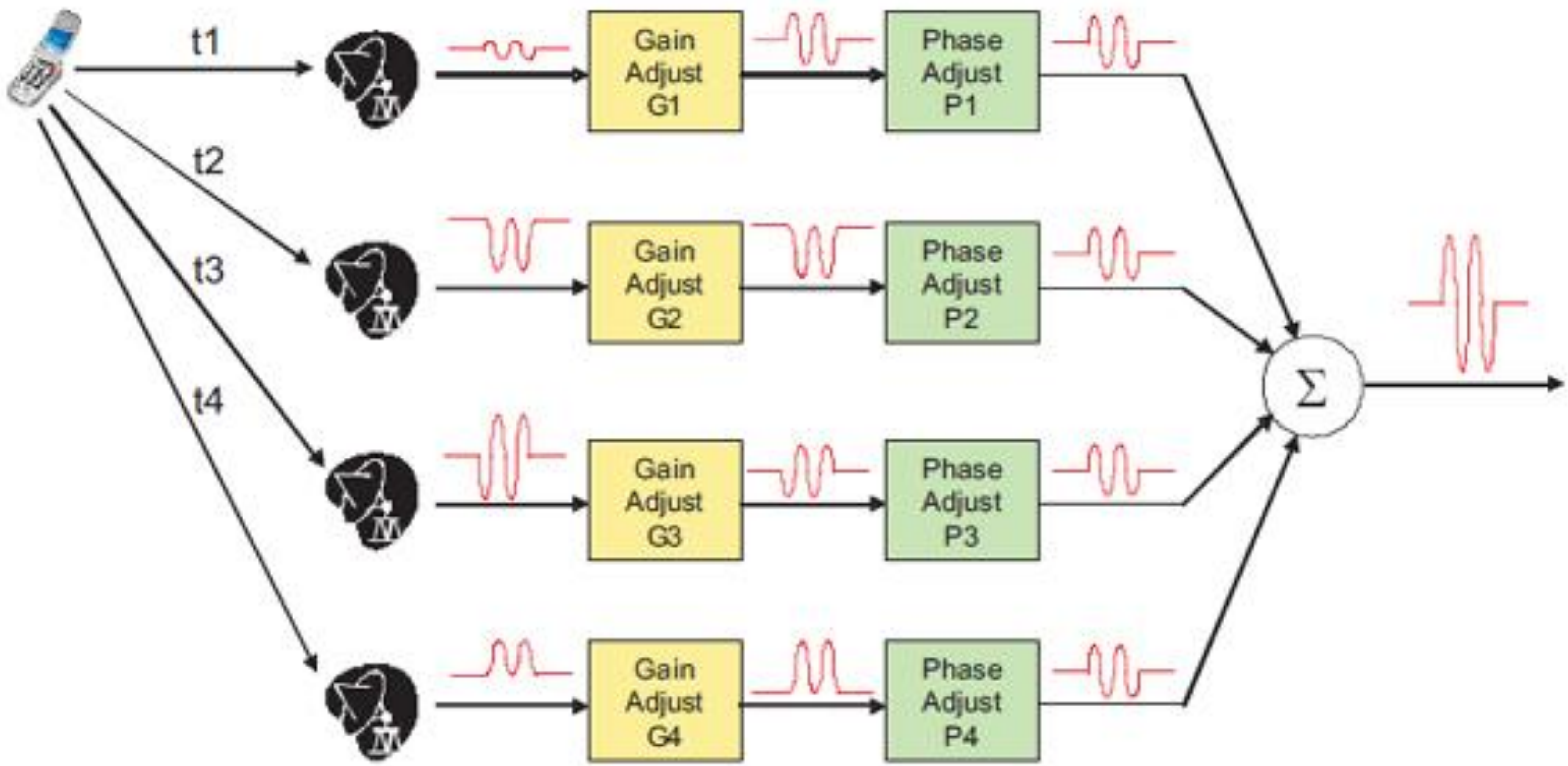
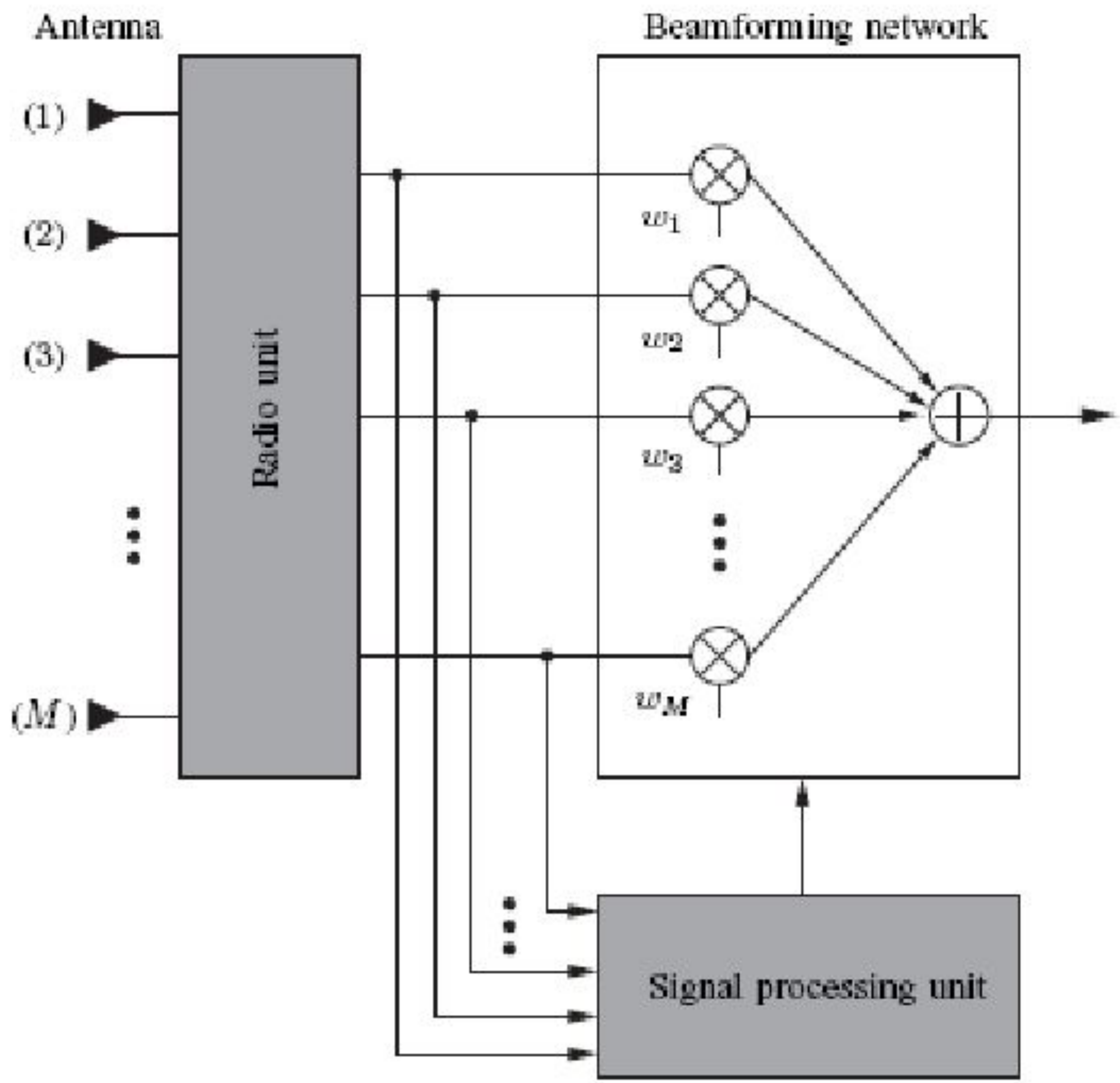
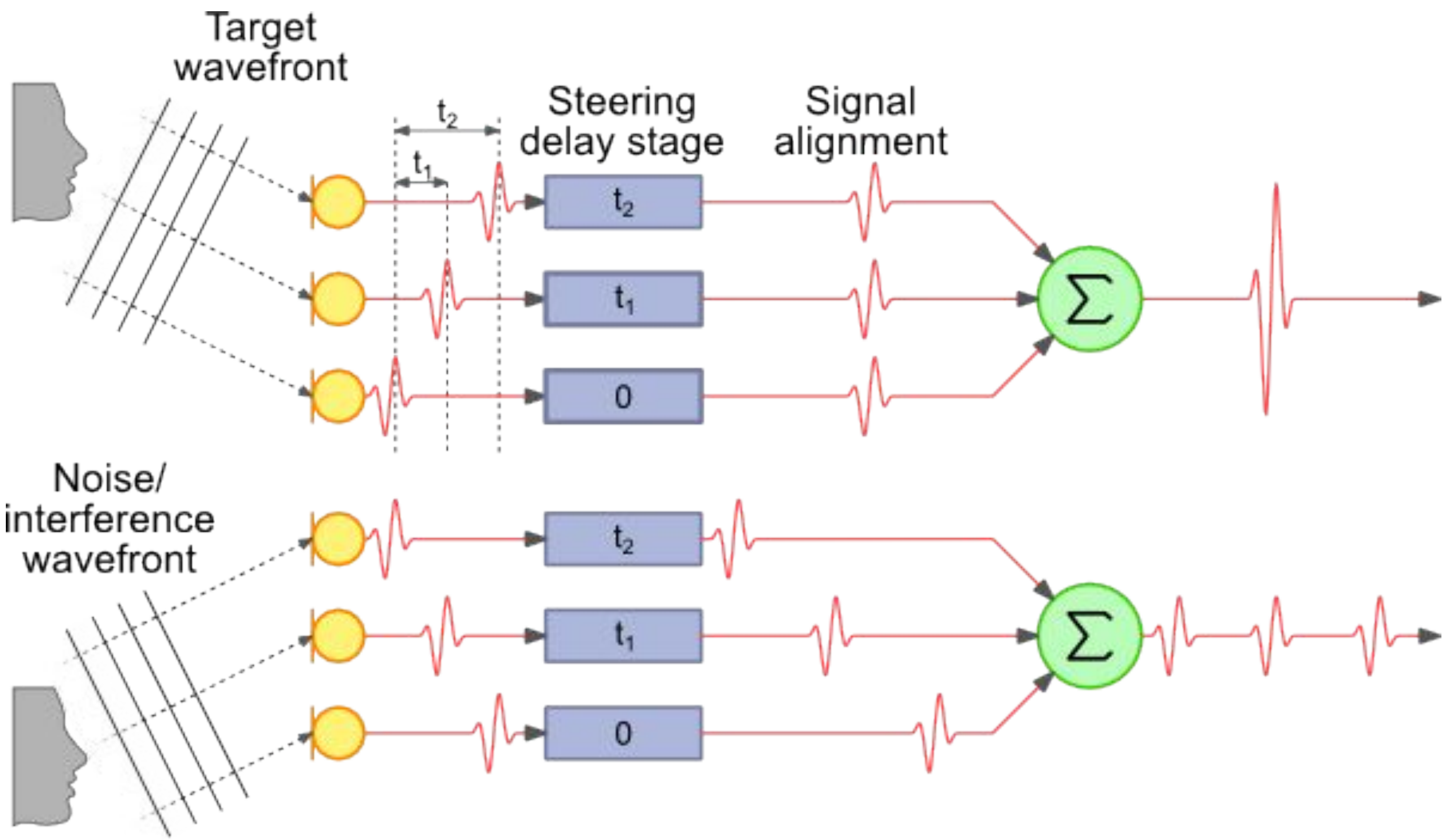


Figure 1. Typical Cell Phone Beamforming System

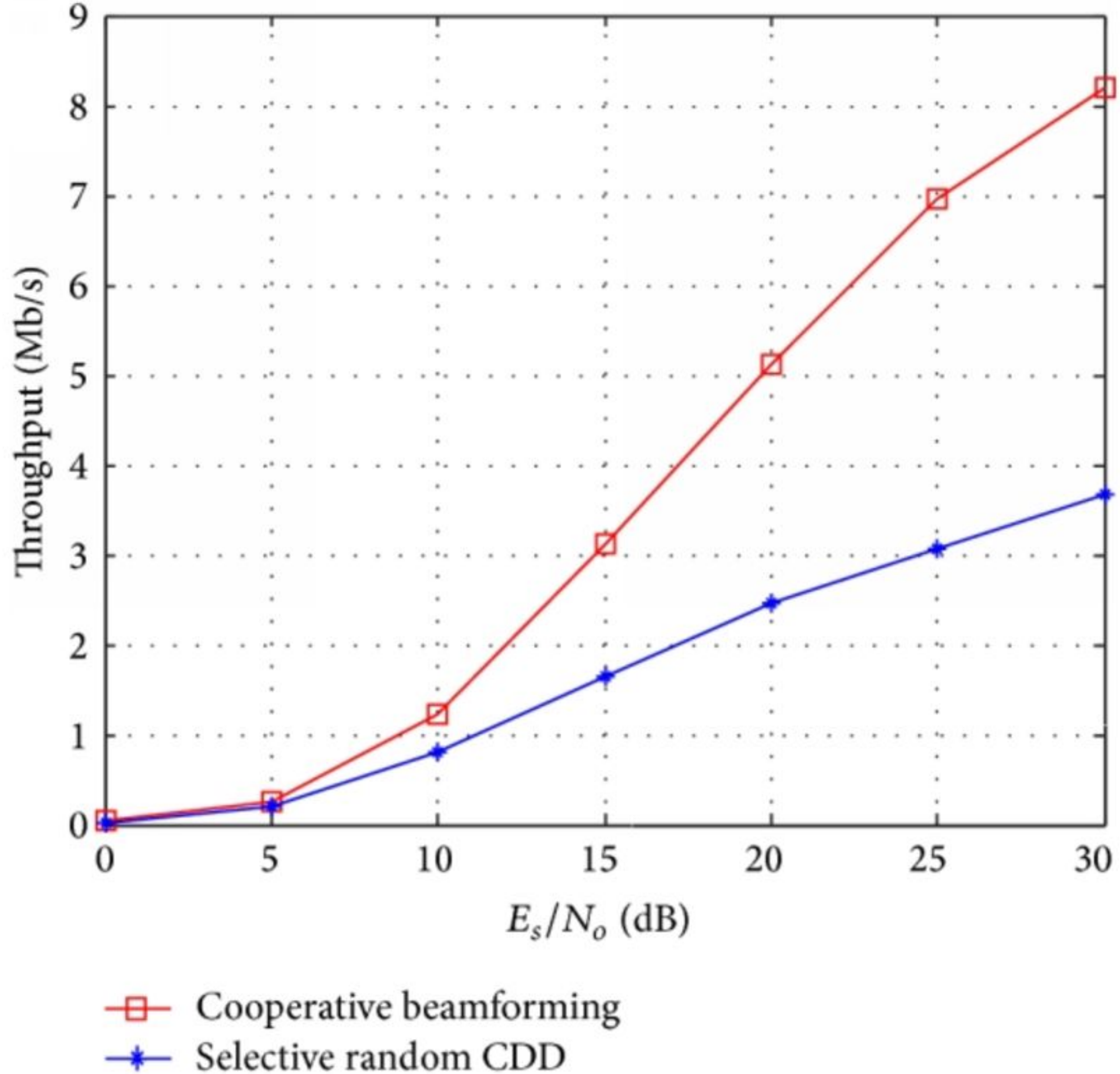
Smart Antenna



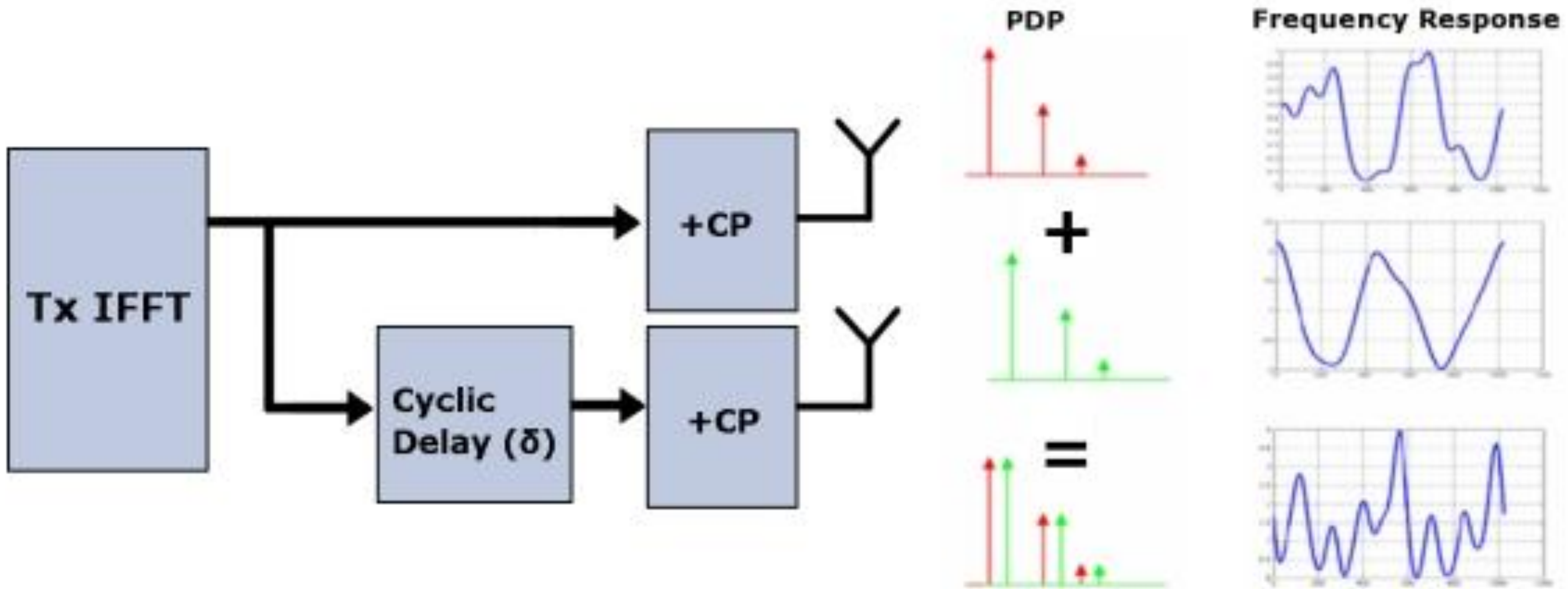
Smart Antenna



Smart Antenna

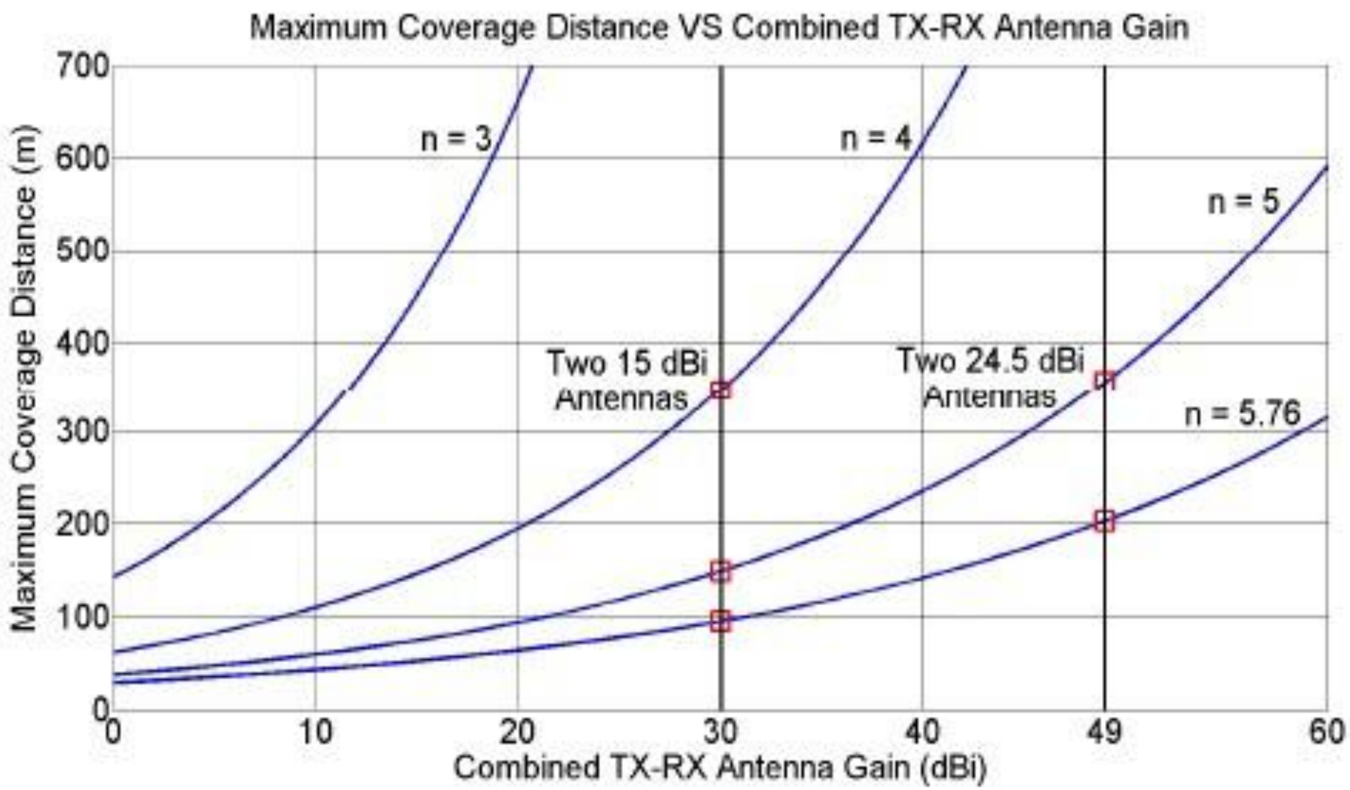


Smart Antenna



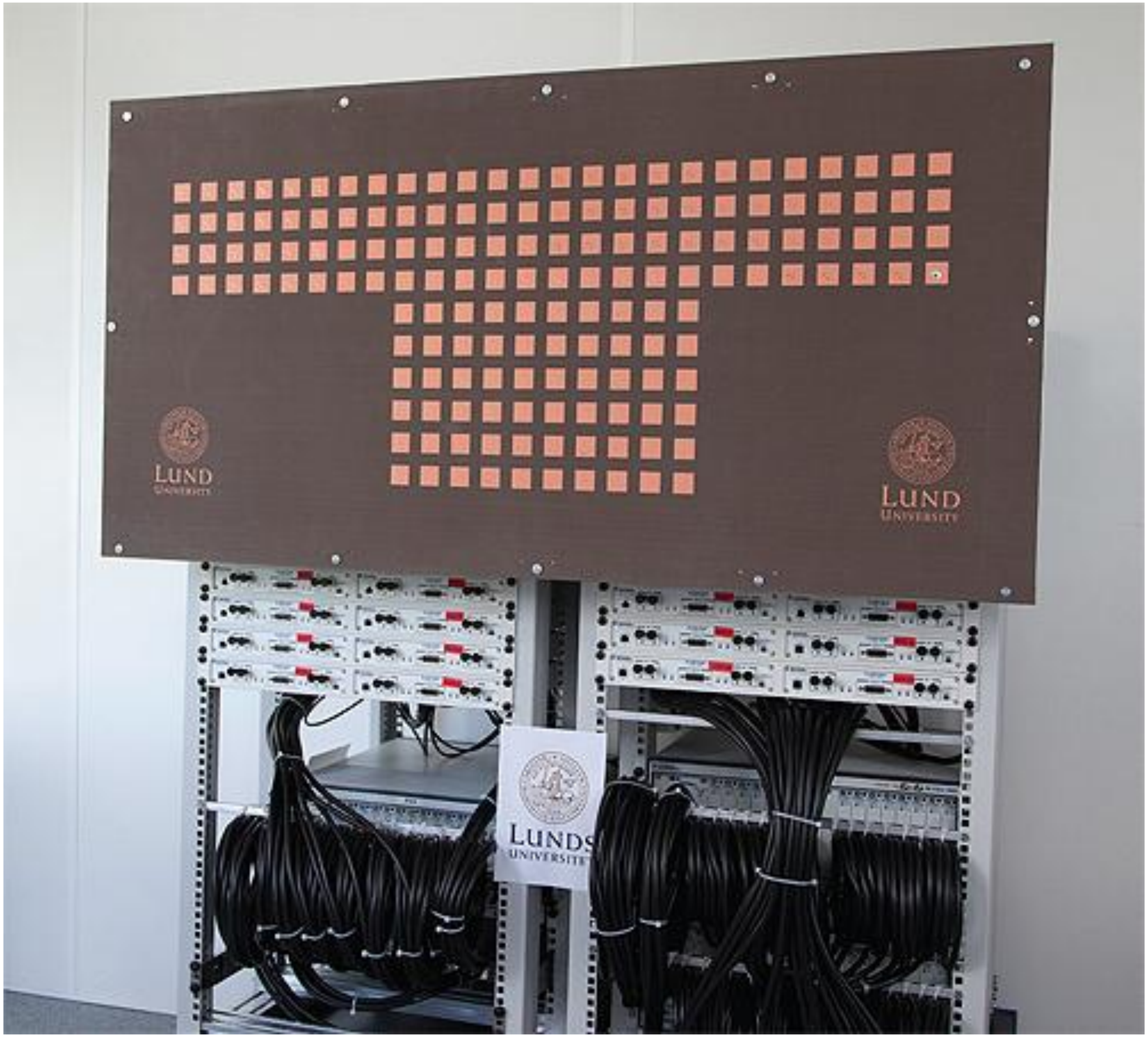
Smart Antenna

METIS Deliverable D 8.4, “METIS final project report”

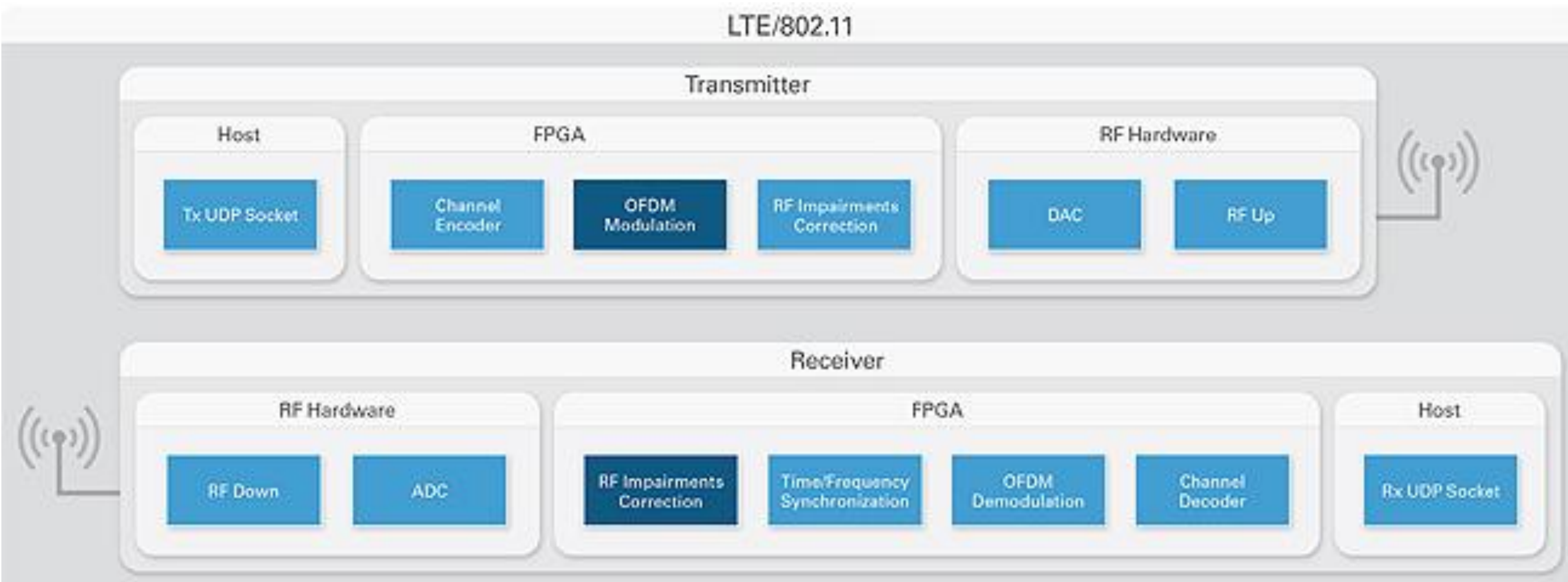


Maximum coverage distance at 28 GHz with 119 dB maximum path loss dynamic range without antenna gains and 10 dB SNR, as a function of path loss exponent n.

Smart Antenna

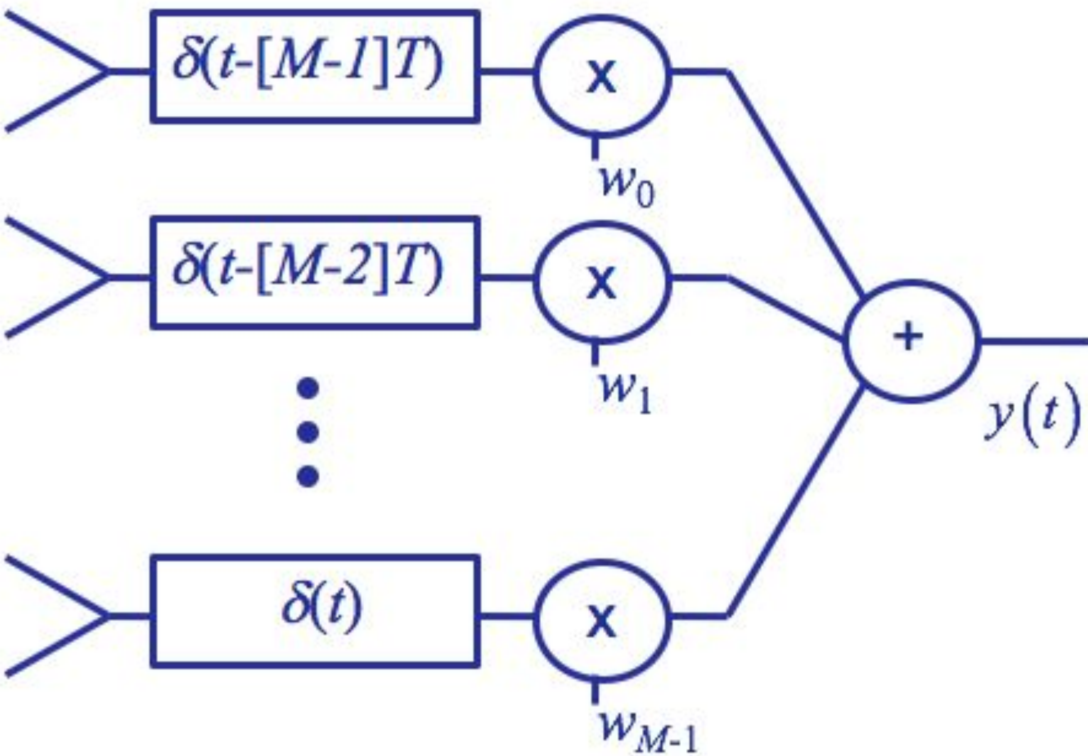


Smart Antenna



Beamforming

Timed array

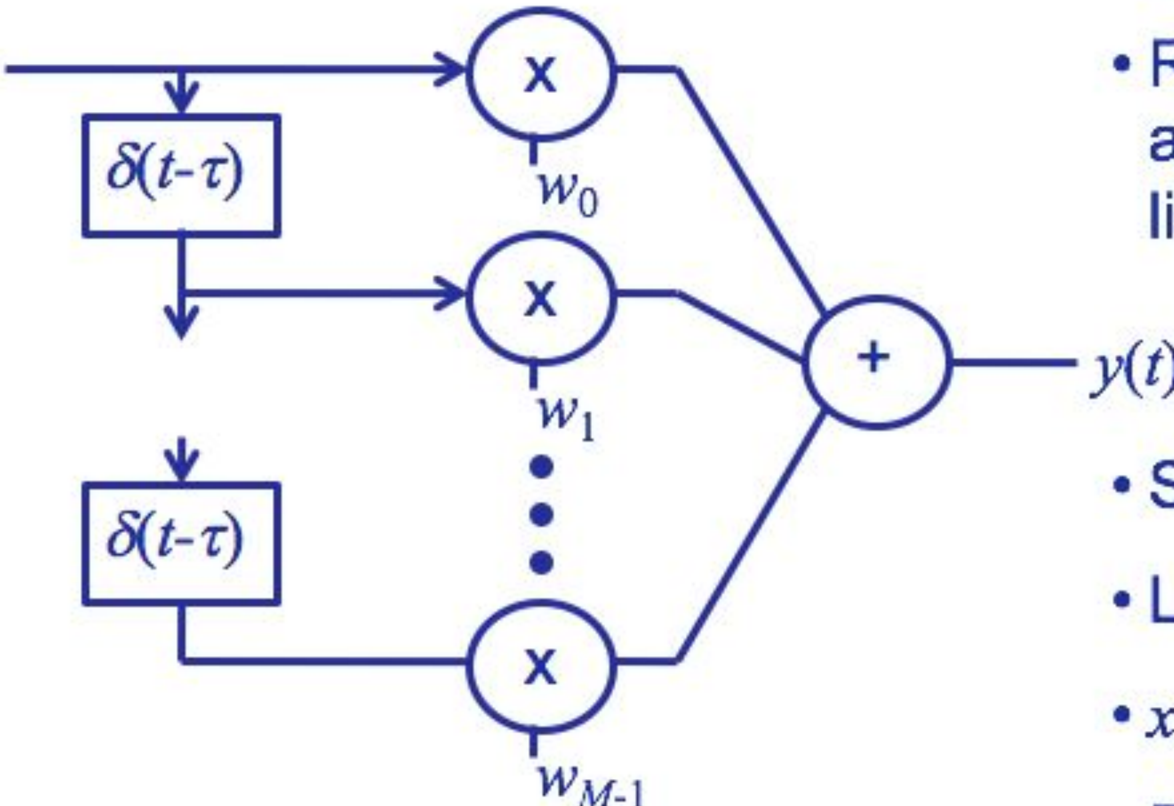


- When $T=\tau$, the channels are all time aligned
- w_m are beamformer weights

$$y(t)=\sum_{m=0}^{M-1} w_m x_m\left(t-[M-m-1]T\right)$$

- Gain in direction θ is $\sum w_m$. Less in other directions due to incoherent addition.

Beamforming



- Let $T=0$ (broadside)
- Represent signal delay across array as a delay line
- Sample: $x[n]=x_0\,(nT)$
- Looks like an FIR filter!
- $x[n]*w[n]$
- Design w with FIR methods

Beamforming

Suppose you want to for many beams at once, in different directions.
If beam k steered to θ_k , has strongest signal, we assume sources is in that direction.

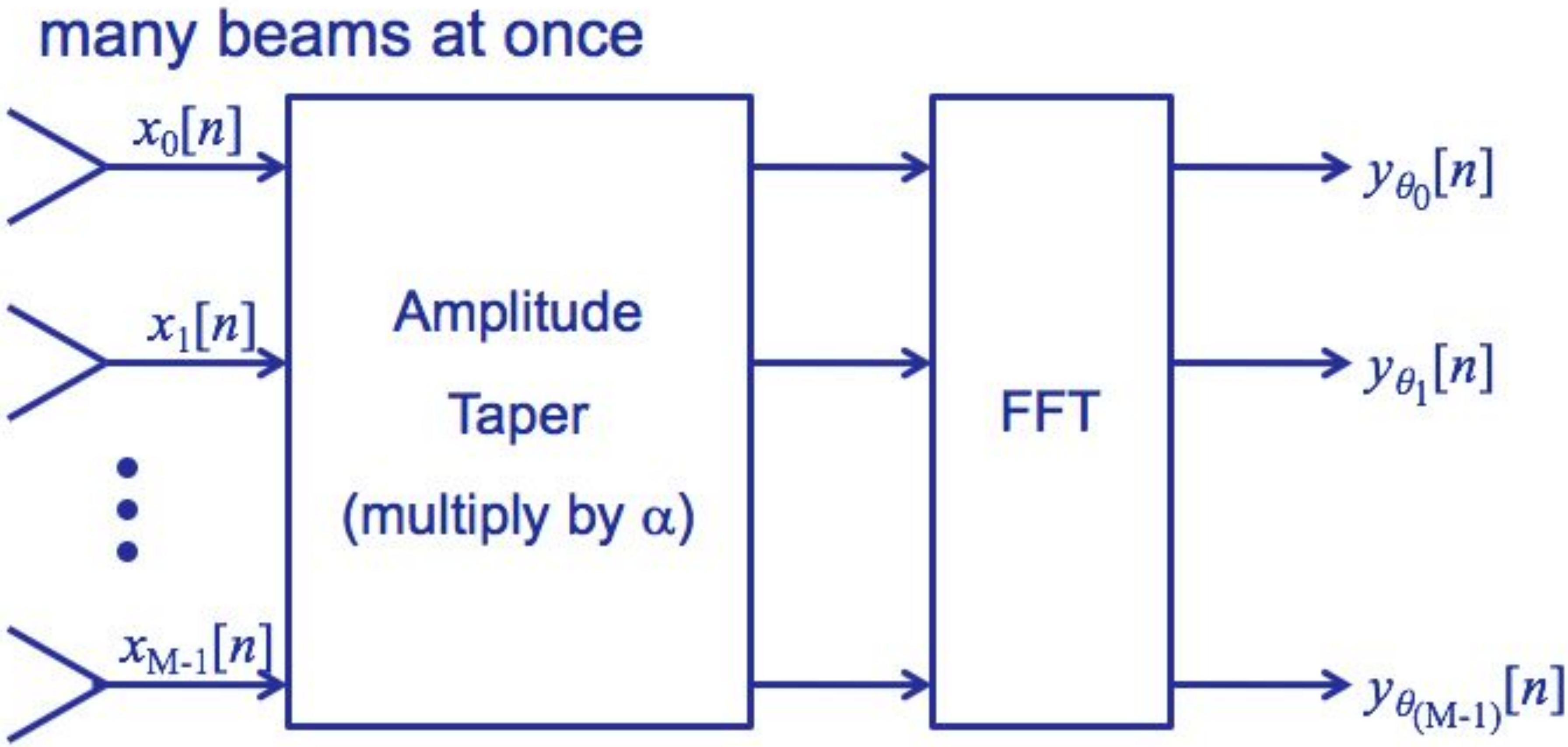
$$y_k[n] = \mathbf{w}_k^H \mathbf{x}[n]$$

$$\mathbf{w}_k = \left[\alpha_0, \alpha_1 e^{-j\zeta_k}, \cdots, \alpha_{M-1} e^{-j(M-1)\zeta_k}\right]^T,$$

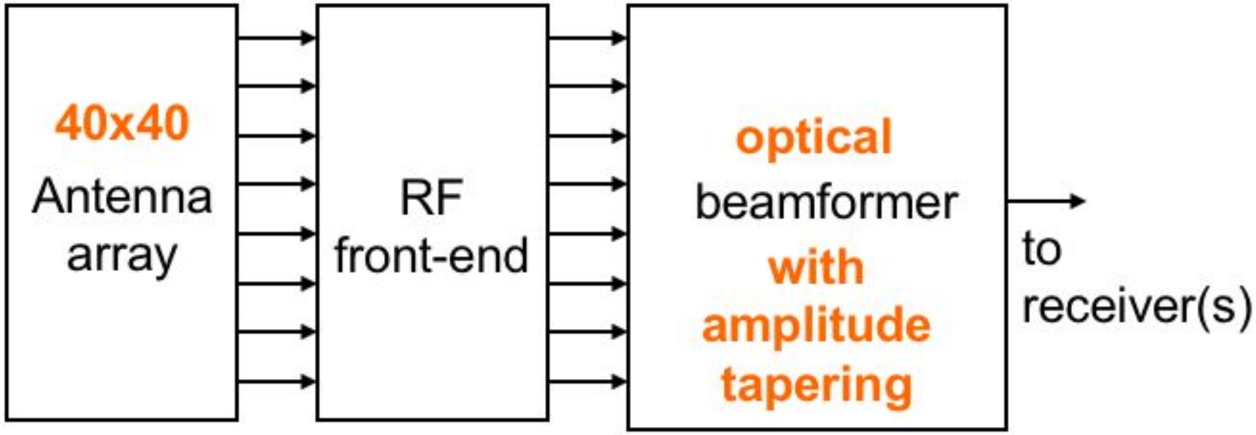
$$\zeta_k = \frac{2\pi f_0 d}{c}\sin\theta_k = \frac{k2\pi}{M}$$

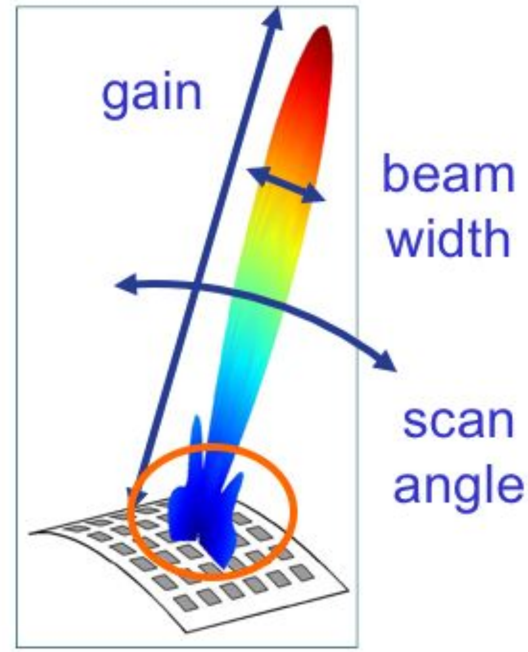
$$y_k[n] = \sum_{m=0}^{M-1} \alpha_m \mathbf{x}_m[n] e^{-jm\zeta_k} = \sum_{m=0}^{M-1} \alpha_m \mathbf{x}_m[n] e^{-j\frac{mk2\pi}{M}}$$

Beamforming: FFT Implementation



System overview

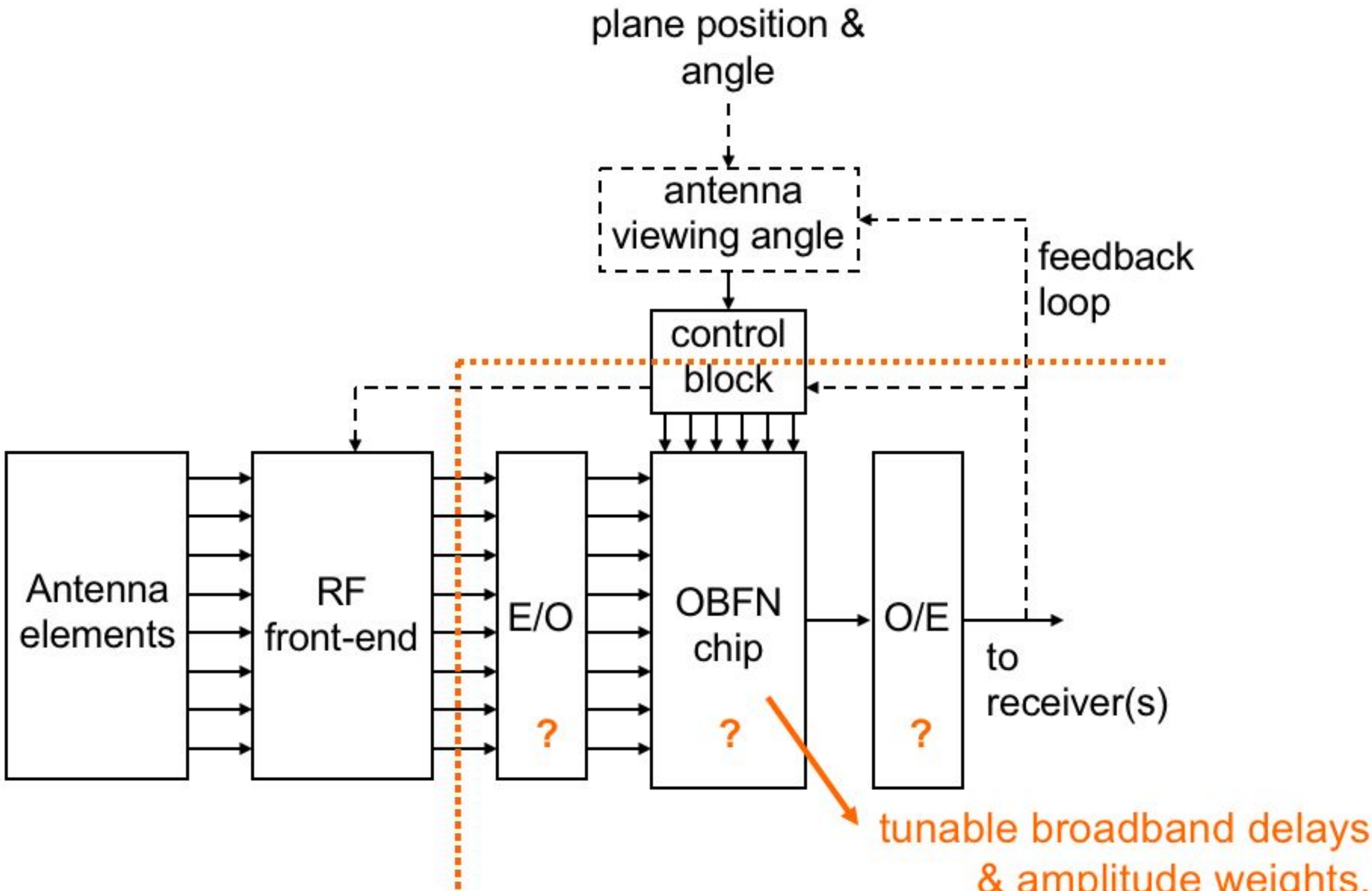




Frequency range: 10.7 – 12.75 GHz (K_u band)
Polarization: 2 linear (H/V)
Scan angle: -60 to +60 degrees
Gain: > 32 dB
Selectivity: << 2 degrees $\rightarrow$ Continuous delay tuning required !
No. elements: ~1600
Element spacing: ~λ/2 (~1.5 cm, or ~50 ps)
Maximum delay: ~2 ns
Delay compensation by phase shifters? $\rightarrow$ beam squint at outer frequencies!

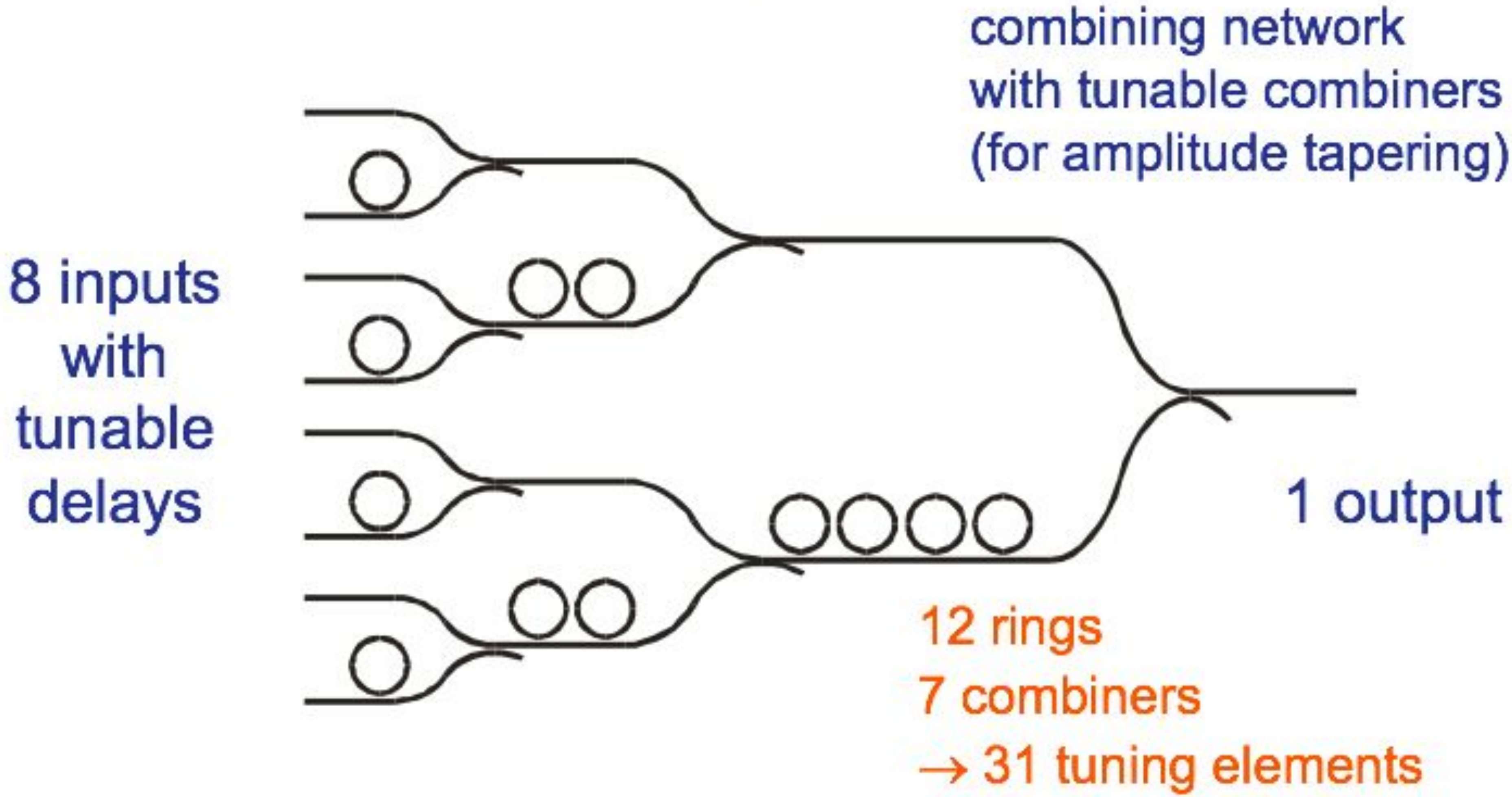
$\rightarrow$ (Broadband) time delay compensation required !

Optical beam former

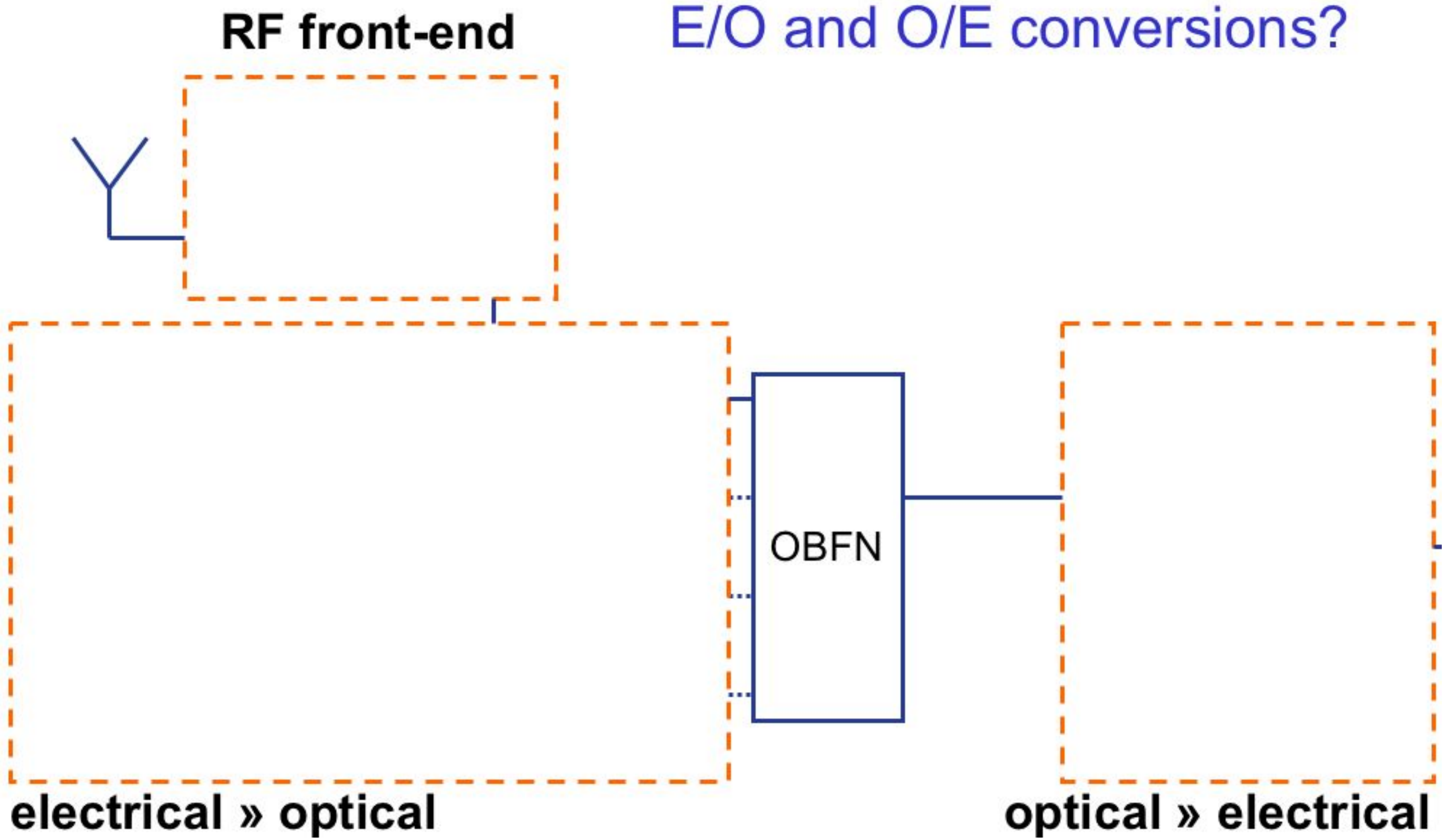


Optical beamformer

8x1 Optical beam forming network (OBFN)



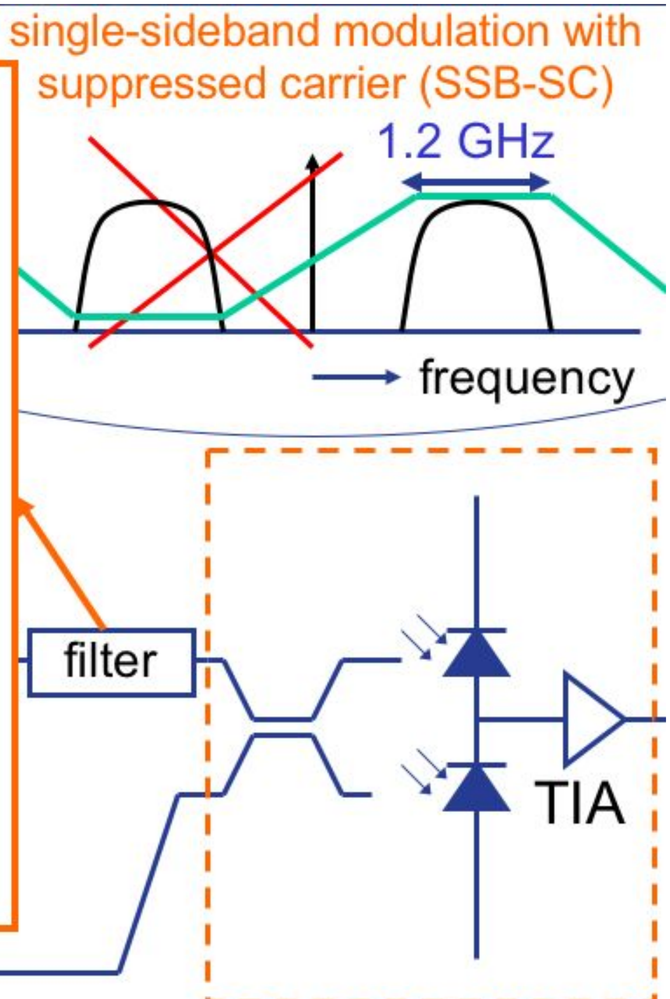
Optical beamformer



Optical beamformer

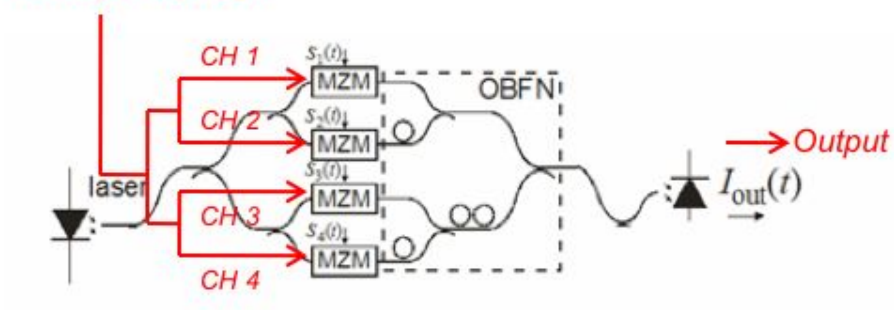
Filter requirements:

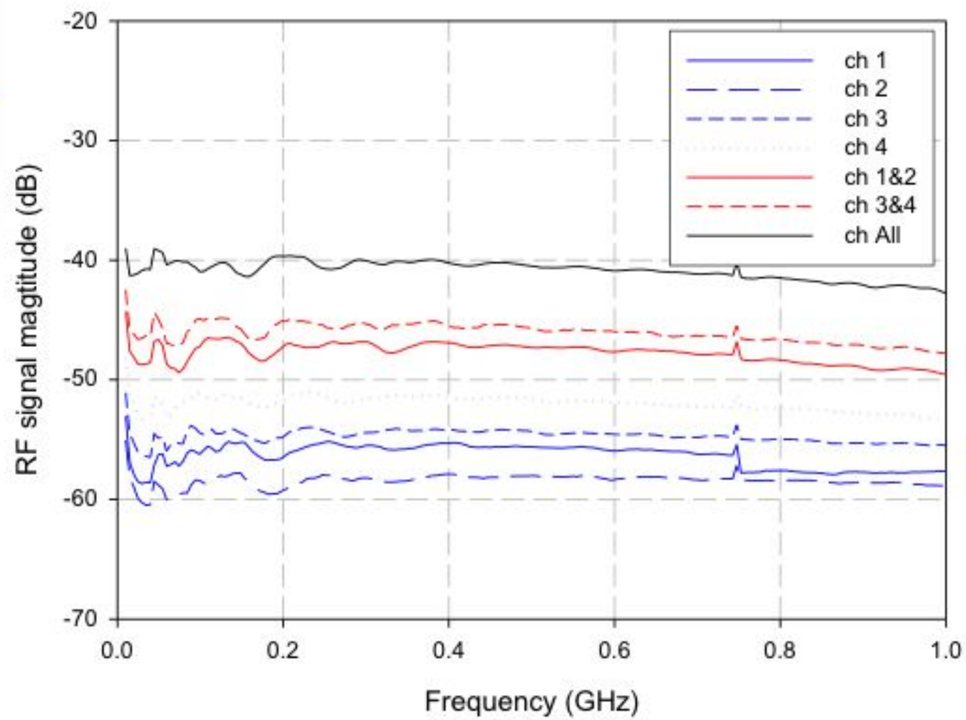
- Broad pass band and stop band (1.2 GHz);
- 1.9 GHz guard band;
- High stop band suppression;
- Low pass band ripple and dispersion;
- Low loss;
- Compact;
- Same technology as OBFN.



Optical beamformer

Signal combination measurements



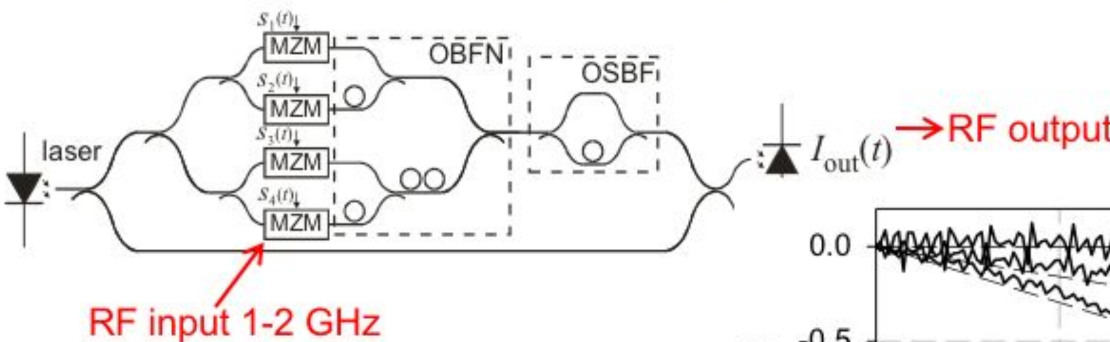


Measured output RF power of beamformer with intensity modulation and direct detection, for

- 1 channel,
- 2 combined channels,
- 4 combined channels

Optical beamformer

RF phase response measurements



Measured RF phase response of one beamformer channel, for different delay values.