A Method for Carrier Frequency and Phase Synchronization of Two Autonomous Cooperative Transmitters



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Scenario:

- · 2 sources transmitting information to 1 destination
- · Both sources possess the same information.

Goal:

· Maximize SNR at destination for fixed transmit powers



Alamouti Space-Time Coding:

· • 1	1 1	1
timad	lot.	

timeslot 2

Distributed Beamforming:

timeslot 1

timeslot 2

S1 transmits x_1 $-x_2^*$	S1 transmits $x_1 e^{-j\theta_{10}}$ $x_2 e^{-j\theta_{10}}$
S2 transmits x_2 x_1^*	S2 transmits $x_1 e^{-j\theta_{20}}$ $x_2 e^{-j\theta_{20}}$
D receives $y[1] = g_{10}x_1 + g_{20}x_2 + w[1]$ $y[2] = -g_{10}x_2^* + g_{20}x_1^* + w[2]$	D receives $y[1] = (g_{10} + g_{20}) x_1 + w[1] y[2] = (g_{10} + g_{20}) x_2 + w[2]$
Decision statistics: $z_{1} = g_{10}^{*}y[1] + g_{20}y^{*}[2] = (g_{10} ^{2} + g_{20} ^{2})x_{1} + g_{10}^{*}w[1] + g_{20}w^{*}[2]$ $z_{2} = g_{20}^{*}y[1] - g_{10}y^{*}[2] = (g_{10} ^{2} + g_{20} ^{2})x_{2} + g_{20}^{*}w[1] - g_{10}w^{*}[2]$	Decision statistics are the observations.
$SNR_a = \frac{(g_{10} ^2 + g_{20} ^2) \sigma_x^2}{\sigma_w^2}$	$SNR_b = rac{(g_{10} + g_{20})^2 \sigma_x^2}{\sigma_w^2} \ge SNR_a$

Problem:

- » Distributed beamformer requires strict carrier frequency and phase synchronization.
- » Bandpass transmissions must arrive in phase at the destination.
- » Sources do not have common clocks.
- » Unsynchronized carriers can cause destructive combining at destination.



How does it work?

- D transmits a sinusoidal beacon at frequency ω_0 .
- S1 and S2 tune to ω_0 with their **primary** FS-PLLs.
- $\bullet~S1$ and S2 each generate a low-power secondary beacon

Note that both sources and destination each have only one antenna.

that is phase locked to the ω_0 beacon but at frequency $\omega_1 = \frac{N_1}{M_1} \omega_0$.

• S1 and S2 transmit their secondary beacons at ω_1 .

• S1 and S2 tune to ω_1 with their secondary FS-PLLs.

• S1 and S2 each generate a carrier signal that is phase locked to the ω_1 beacon but at frequency $\omega_c = \frac{N_2}{M_2}\omega_1$.

• S1 and S2 transmit their (modulated) carriers at ω_c .

 $\bullet\,$ The bandpass transmissions from S1 and S2 arrive in phase at D.

Intuition (single-path channels):

- $\Rightarrow\,$ Channels each modeled as a propagation delay.
- ⇒ Identical delay in the forward and reverse channel pair $g_{ij}(t)$ and $g_{ji}(t)$.
- $\Rightarrow \text{ The total propagation delay for the circuit}$ $D \to S_1 \to S_2 \to D \text{ is identical to the propaga$ $tion delay for the circuit } D \to S_2 \to S_1 \to D.$
- \Rightarrow Phase shift through FS-PLLs can also be balanced to achieve in-phase arrival at D.