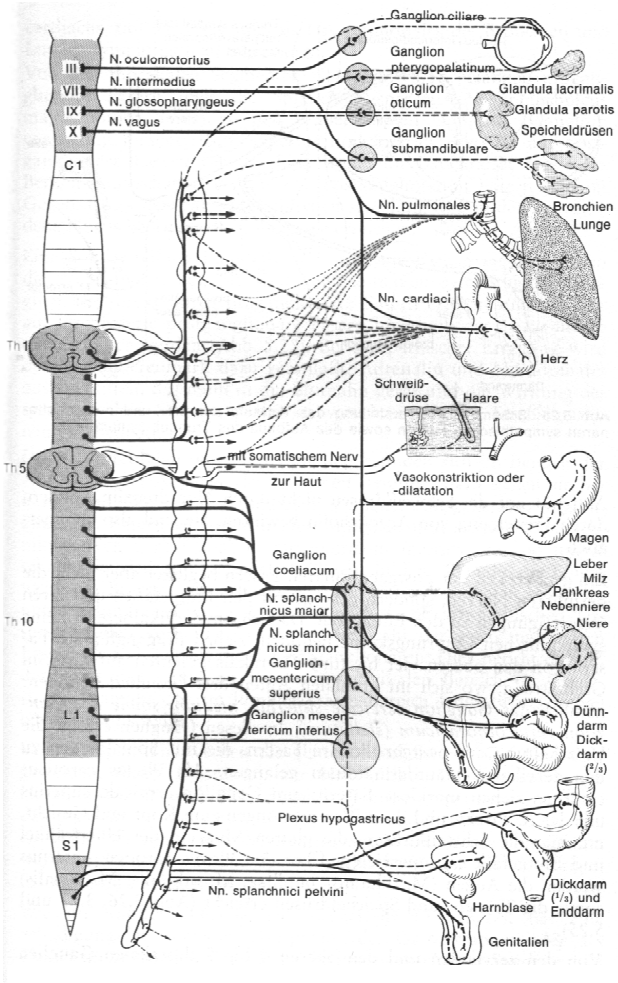
Antagonistic Redundancy

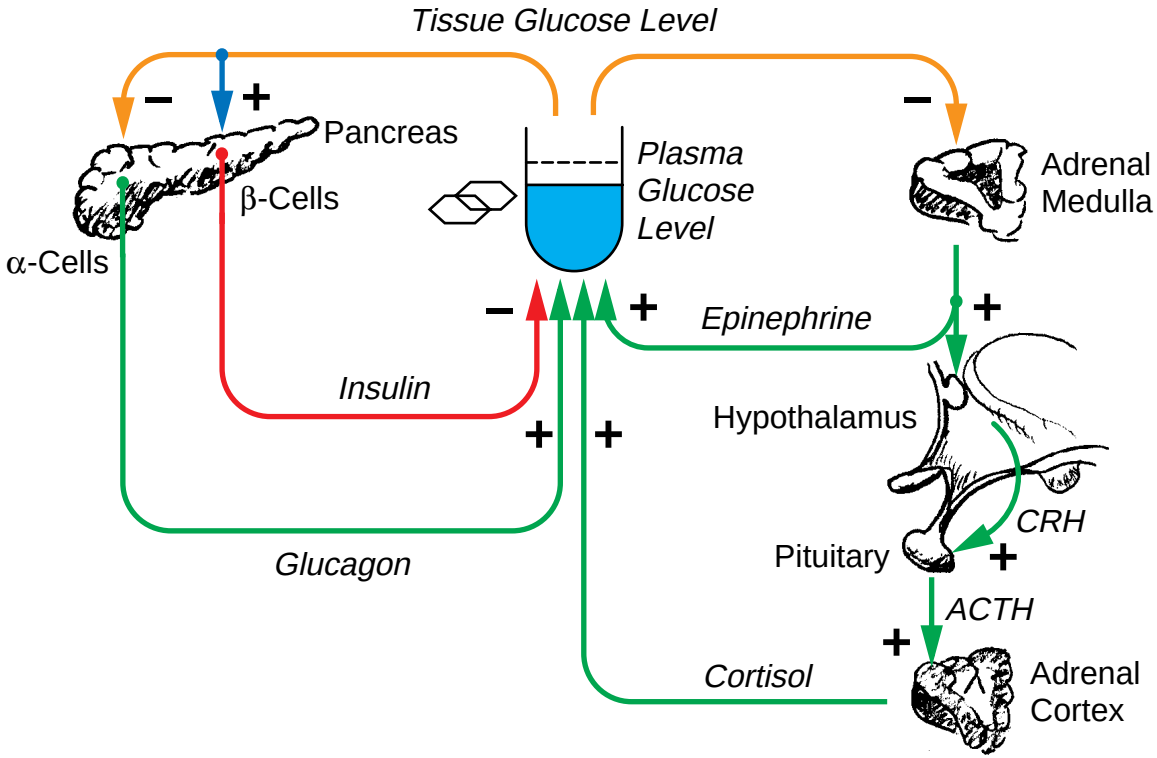
A Theory of Error-Correcting Information Transfer in Organisms

J. W. Dietrich, B. O. Boehm

Abteilung Innere Medizin I, Medizinische Klinik,
University of Ulm, F. R. Germany

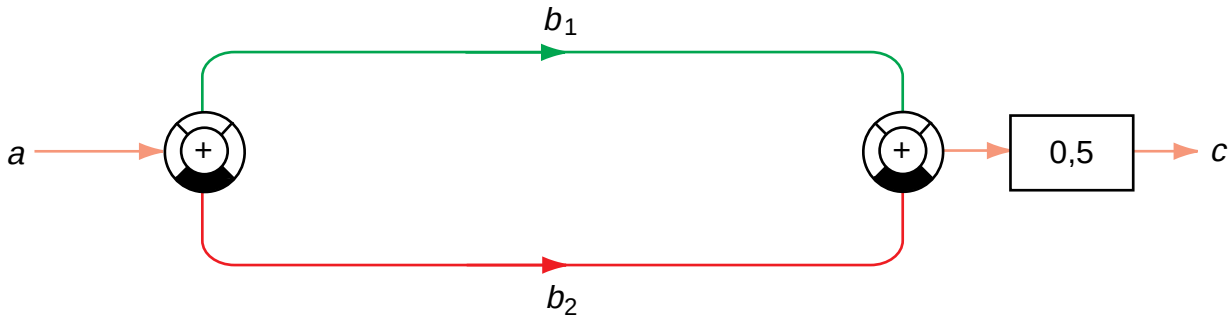
Antagonistic Redundancy





Antagonistic Redundancy

Subtractive AR



$$b_1 = a$$

$$b_2 = -a$$

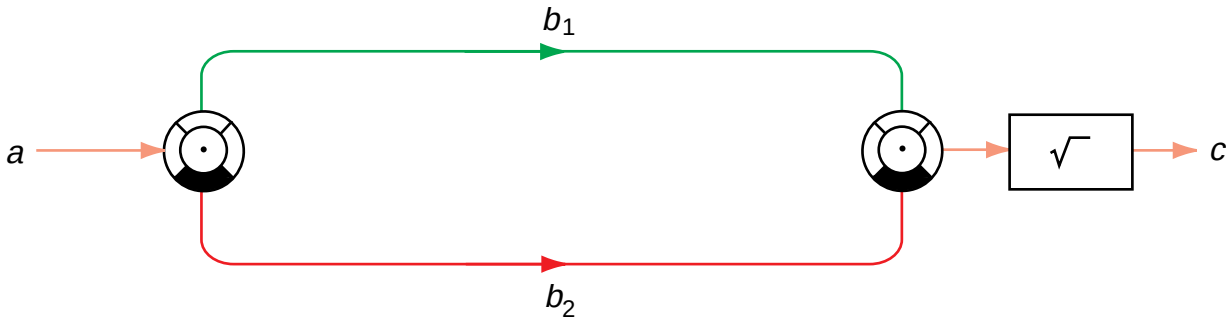
$$\vec{b}_1 = G_{ij}a$$

$$c = \frac{b_1 - b_2}{2} = a$$

$$c = H_{ij}\vec{b}$$

Antagonistic Redundancy

Divisive AR



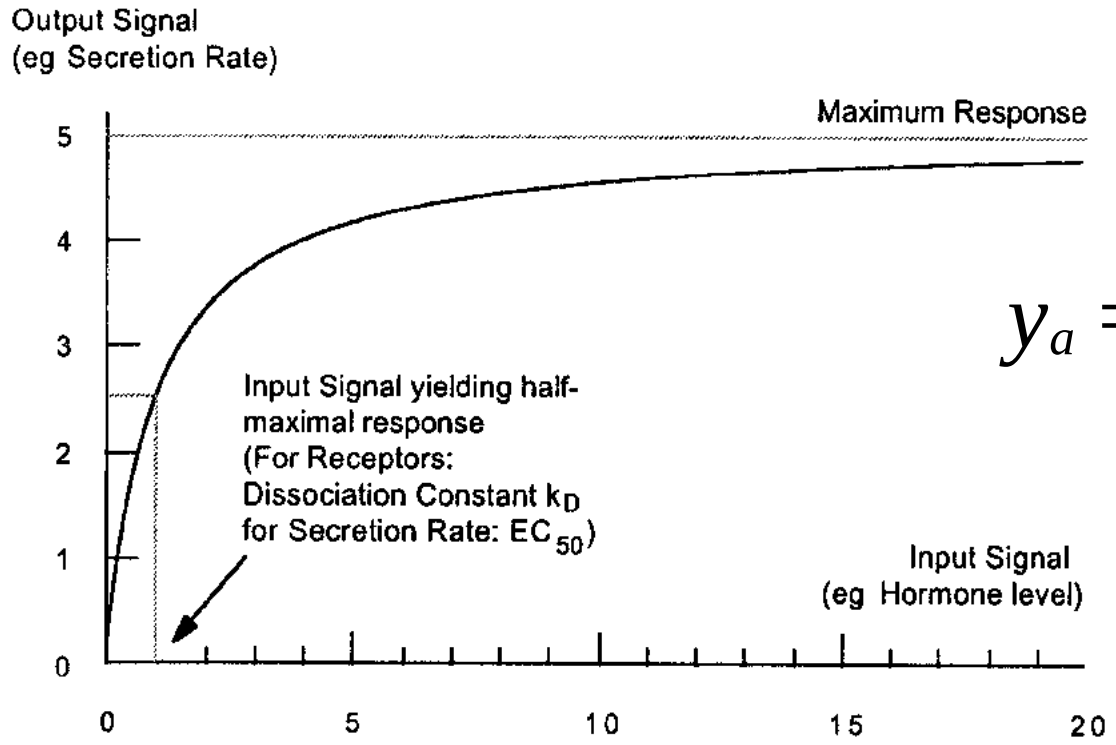
$$b_1 = a$$

$$b_2 = \frac{1}{a}$$

$$c = \sqrt{\frac{b_1}{b_2}} = a$$

Antagonistic Redundancy

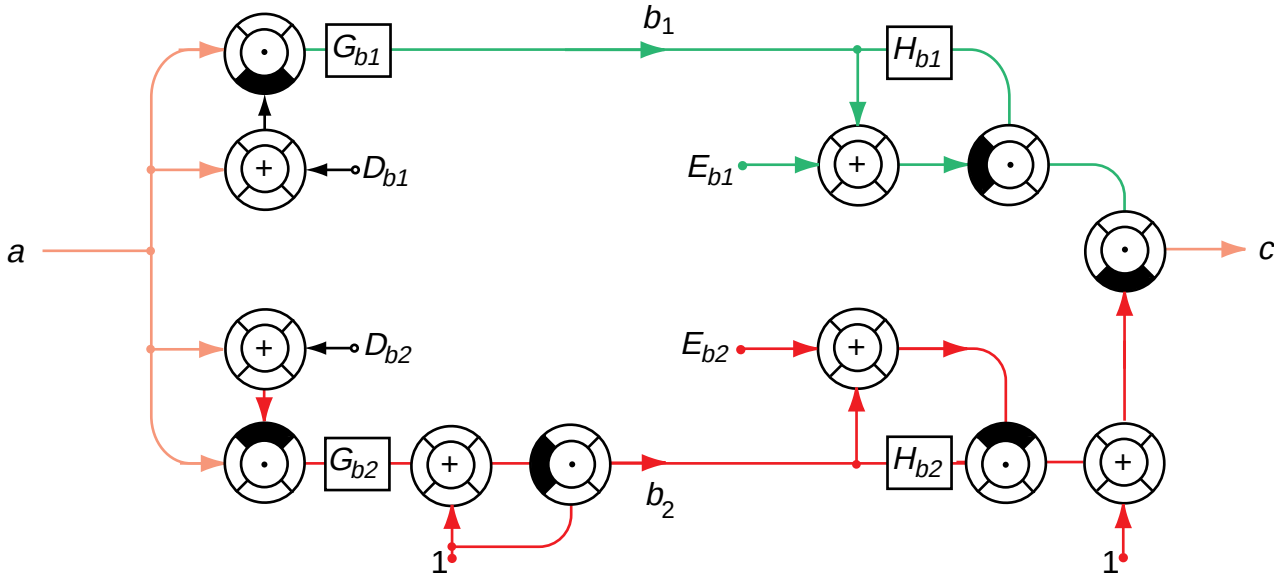
MMH Kinetics



$$y_a = \frac{G x_e}{D - x_e}$$

Antagonistic Redundancy

AR with MMH Kinetics



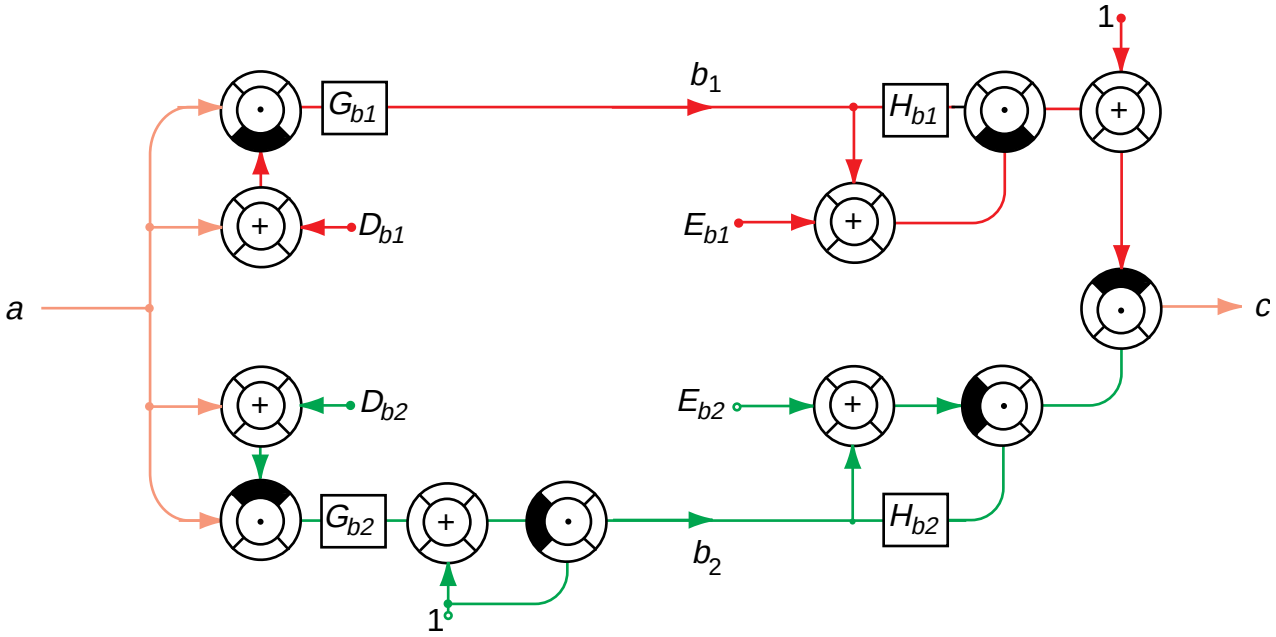
$$b_1 = \frac{G_{b_1} a}{D_{b_1} + a}$$

$$b_2 = \frac{1}{1 + \frac{G_{b_2} a}{D_{b_2} + a}}$$

$$c = \frac{G_{b1} H_{b1} a}{(D_{b1} + a)(E_{b1} + \frac{G_{b1}\, a}{D_{b1} + a})(1 + \frac{H_{b2}(D_{b2} + a)}{D_{b2} + a + E_{b2} a + D_{b2} E_{b2} + E_{b2} G_{b2} a})}$$

Antagonistic Redundancy

Inverting AR with MMH Kinetics



$$b_1 = \frac{G_{b_1} a}{D_{b_1} + a}$$

$$b_2 = \frac{1}{1 + \frac{G_{b_2} a}{D_{b_2} + a}}$$

$$c = \frac{H_{b2}}{\left(1 + \frac{G_{b2} a}{D_{b2} + a}\right)\left(E_{b2} + \frac{1}{1 + \frac{G_{b2} a}{D_{b2} + a}}\right)\left(1 + \frac{H_{b1} G_{b1} a}{(D_{b1} + a)\left(E_{b1} + \frac{G_{b1} a}{D_{b1} + a}\right)}\right)}$$

Antagonistic Redundancy

Results

Subtractive AR

$$b_1 = a + z$$
$$b_2 = -a$$
$$\Rightarrow c = a + \frac{z}{2}$$

$$b_1 = a + z$$
$$b_2 = -a + z$$
$$\Rightarrow c = a$$

Divisive AR

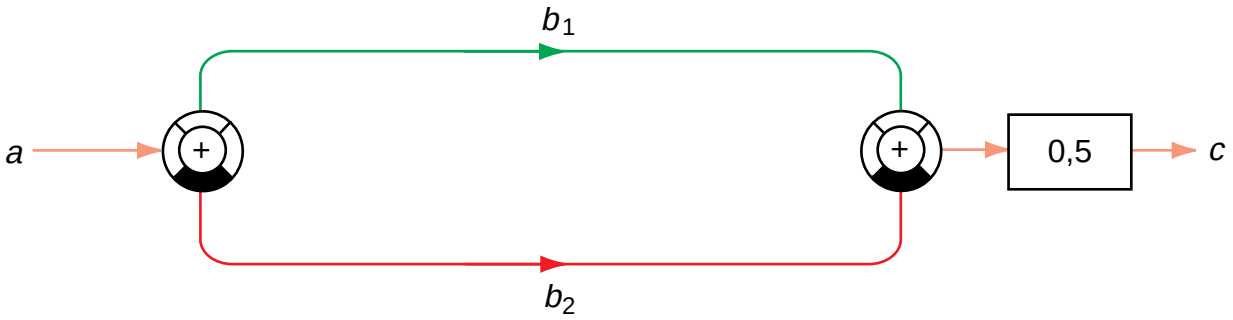
$$b_1 = az$$
$$b_2 = \frac{1}{a}$$
$$\Rightarrow c = a\sqrt{z}$$

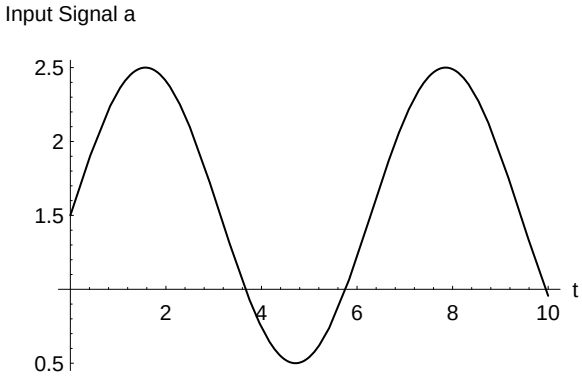
$$b_1 = az; b_2 = \frac{z}{a}$$
$$c = \sqrt{\frac{az}{\frac{z}{a}}} = a$$

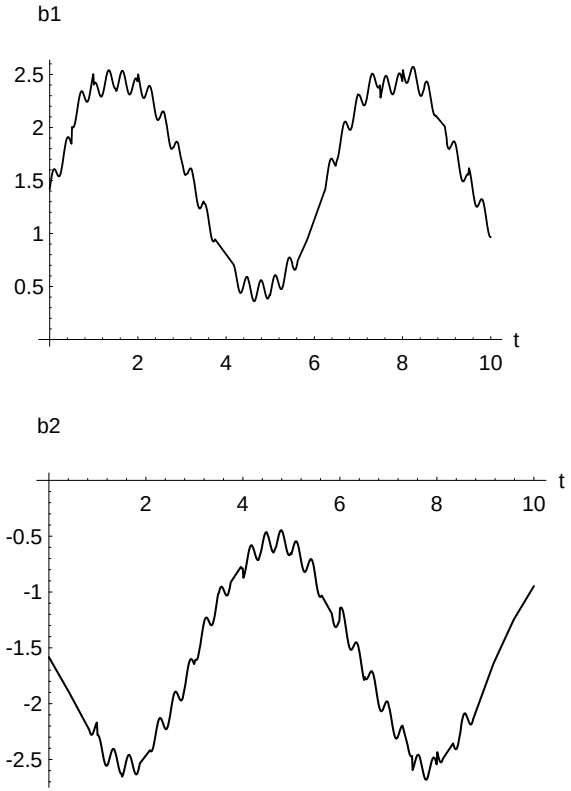
Antagonistic Redundancy

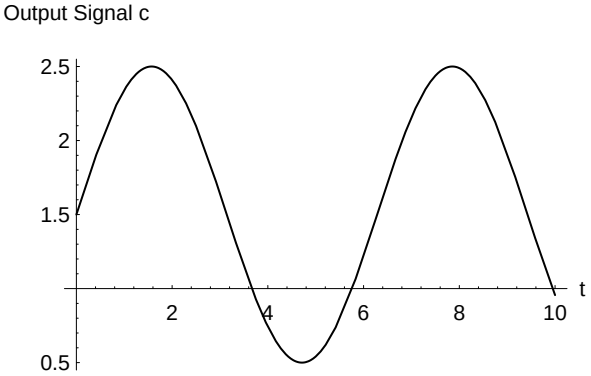
Results

Subtractive AR





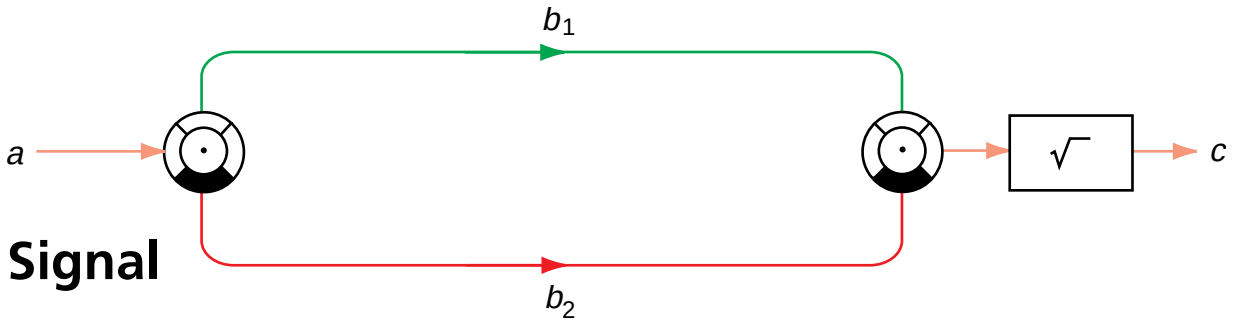


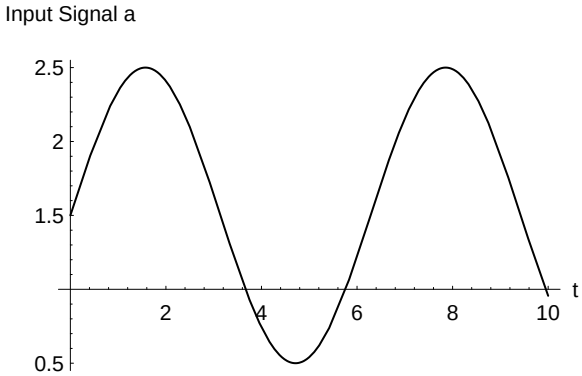


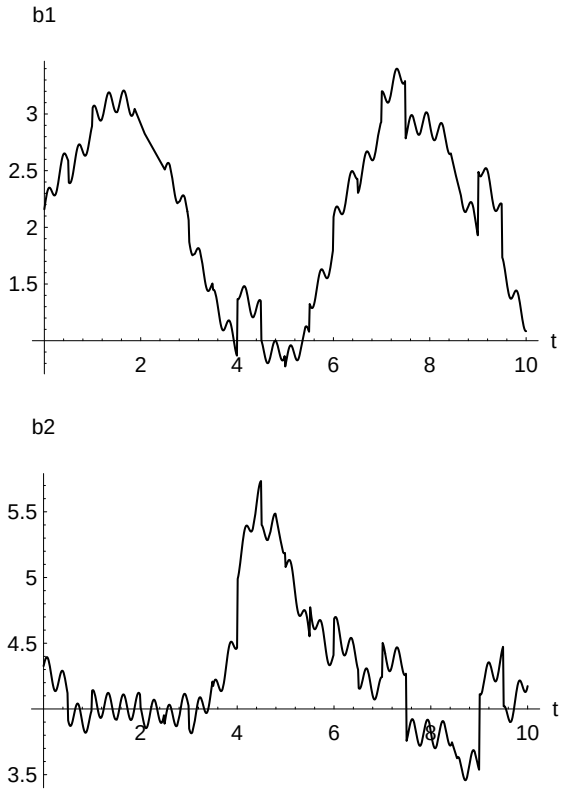
Antagonistic Redundancy

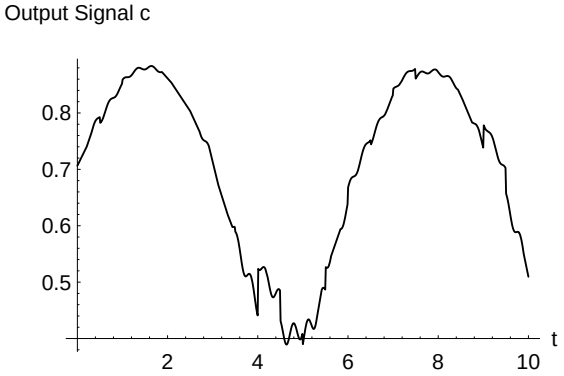
Results

Divisive AR with Additive Disturbing Signal





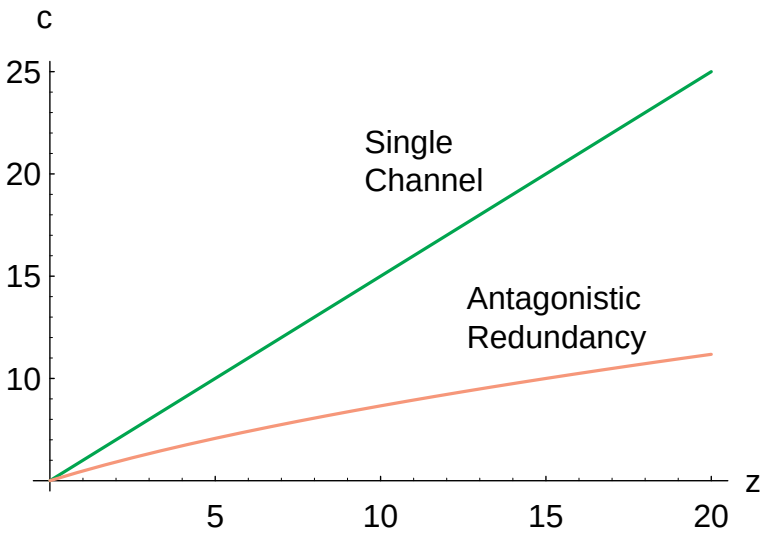




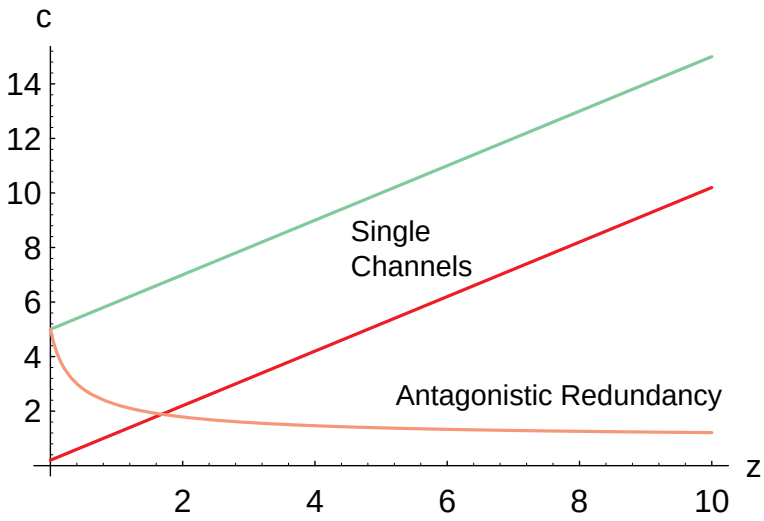
Antagonistic Redundancy

Results

Divisive AR with Additive Disturbing Signal



One Channel affected

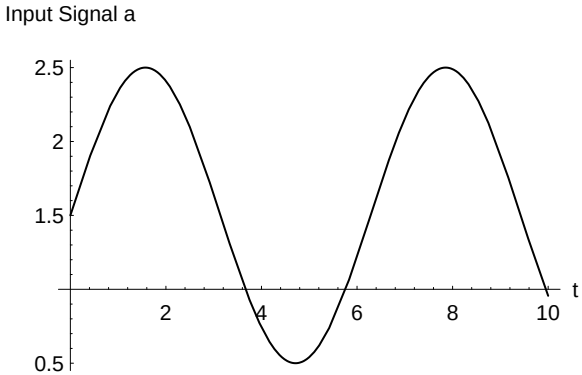


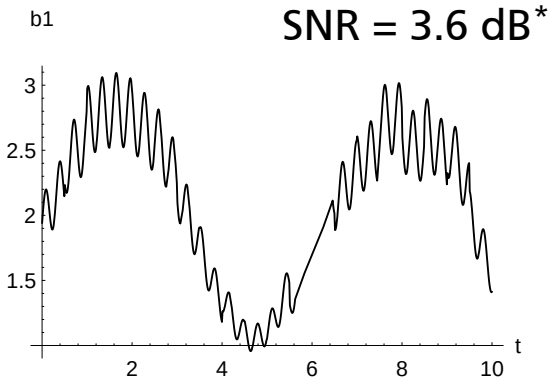
Both Channels affected

Antagonistic Redundancy

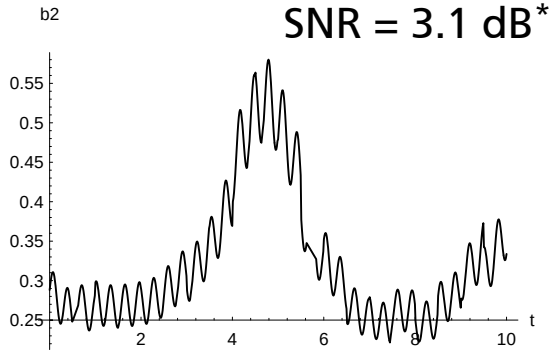
Results

AR with MMH Kinetics

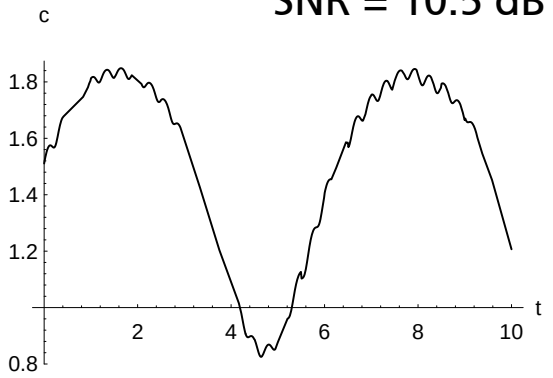




SNR = 3.6 dB*



SNR = 3.1 dB*



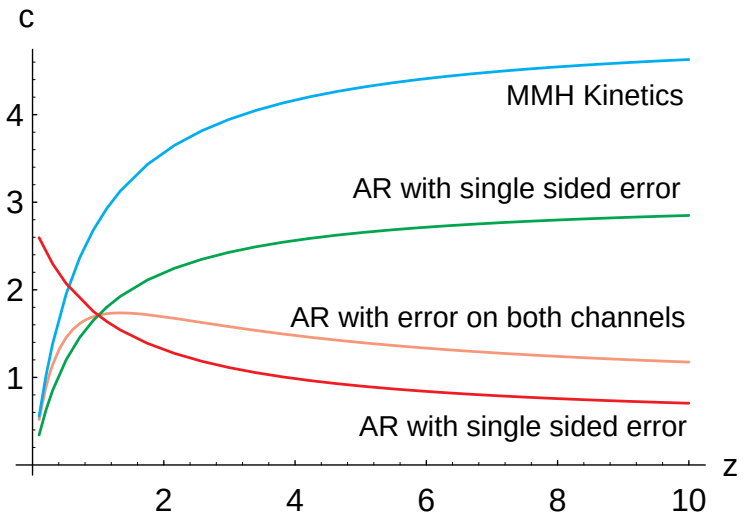
SNR = 10.5 dB*

*relatad to net amplitudes of input sine wave and noise signal, respectively

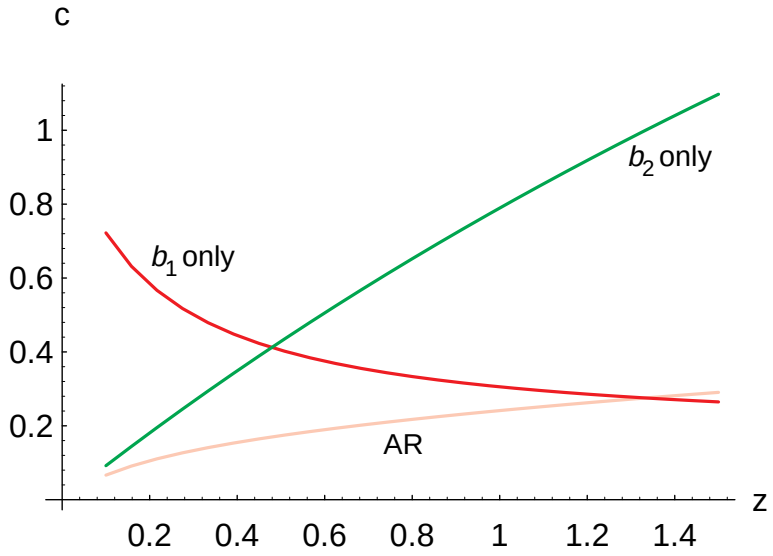
Antagonistic Redundancy

Results

AR with MMH Kinetics



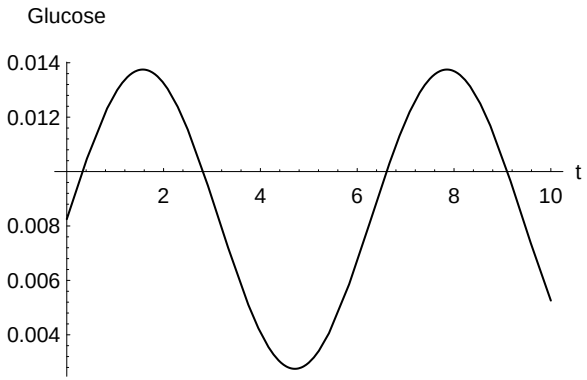
Inverting AR with MMH Kinetics

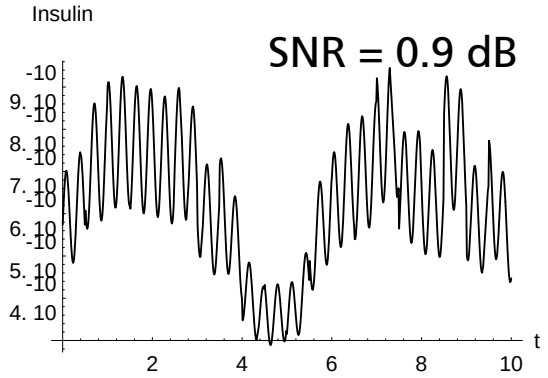


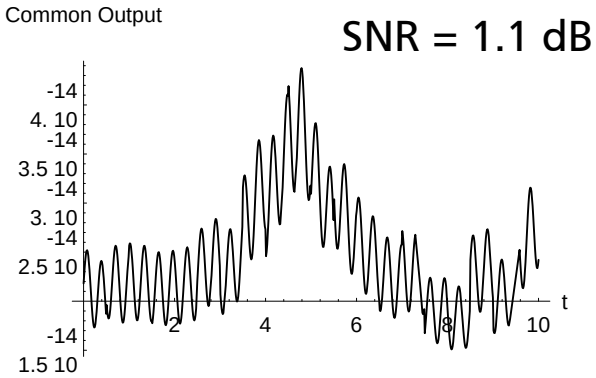
Antagonistic Redundancy

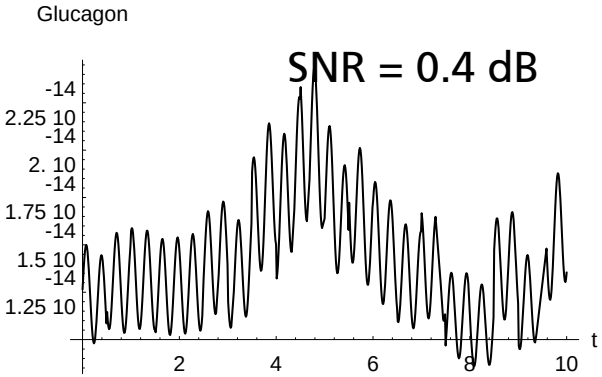
Results

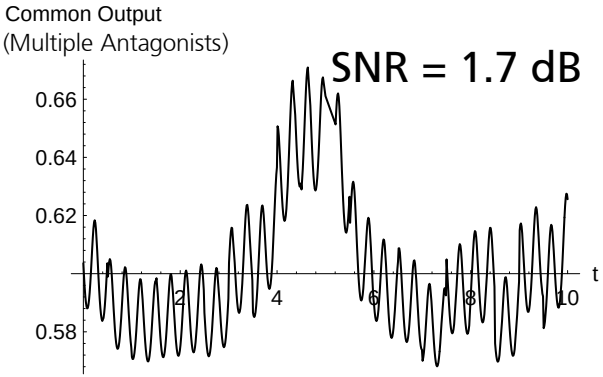
Control of Plasma Glucose







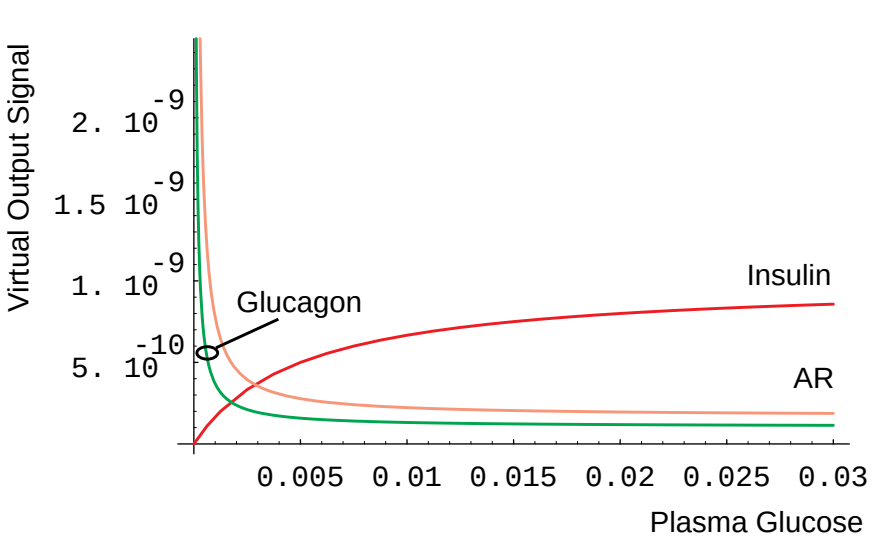




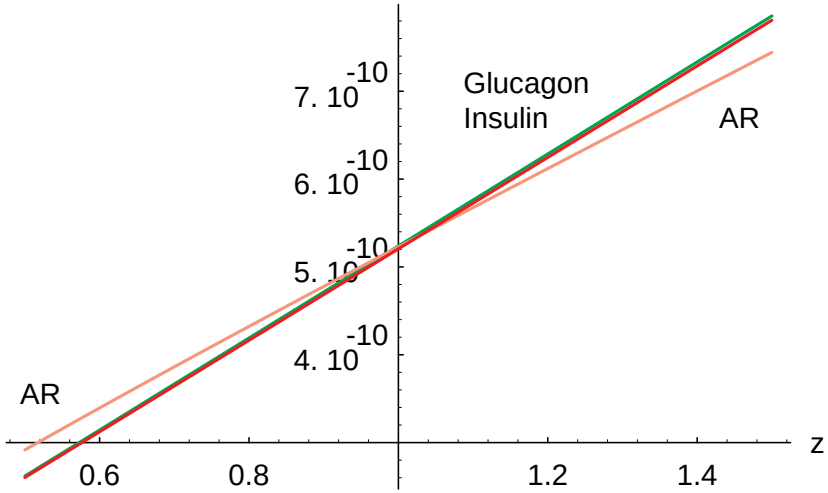
Antagonistic Redundancy

Results

Control of Plasma Glucose



Dependency from Glucose



Dependency from Error Signal z

Antagonistic Redundancy

Perspective

Different Functions of AR:

- **Error correction**
- **Widening of control capacity by enabling negative signals [Clynes 1969]**
- **Stiffness control in feedback control systems [Sachsse 1971]**

Antagonistic Redundancy

Perspective

Embodiments and Implementations:

- Hormonal System:
  - GHRH / Somatostatin
  - TRH / Somatostatin
  - Insulin / Glucagon
  - Leptin / Ghrelin
  - PTH / Calcitonin
  - …?
- Peripheral Autonomous and Somatic Nervous System
  - Sympathetic / parasympathetic innervation
  - Innervation of antagonistic sceletal muscles
  - Temperature Perception
- Central Nervous System?
- Immune System?
- Intracellular Circuits?

Antagonistic Redundancy

Perspective

Disorders potentially associated with impaired AR:

- **Pancreoprivic “brittle” diabetes in patients who underwent pancreatectomy or suffered from chronic pancreatitis**
- **Instable respiratory control in patients with COPD**
- **Leptin deficiency in those bulimic patients who show high frequency of bingeing/vomiting**
- **…?**