B. Receivers

We're **finally** done studying microwave components! We can now take our palette of components and construct useful radio **systems**—specifically, a microwave **receiver**.

1) Select one (and **only** one) **desired** signal from the electromagnetic spectrum, **amplify** it, and present it to a detector/demodulator, so the **information** encoded on it can be recovered.

2) Reject (i.e., attenuate) all other signals, so that the **only** signal to reach the demodulator is the **desired** signal.

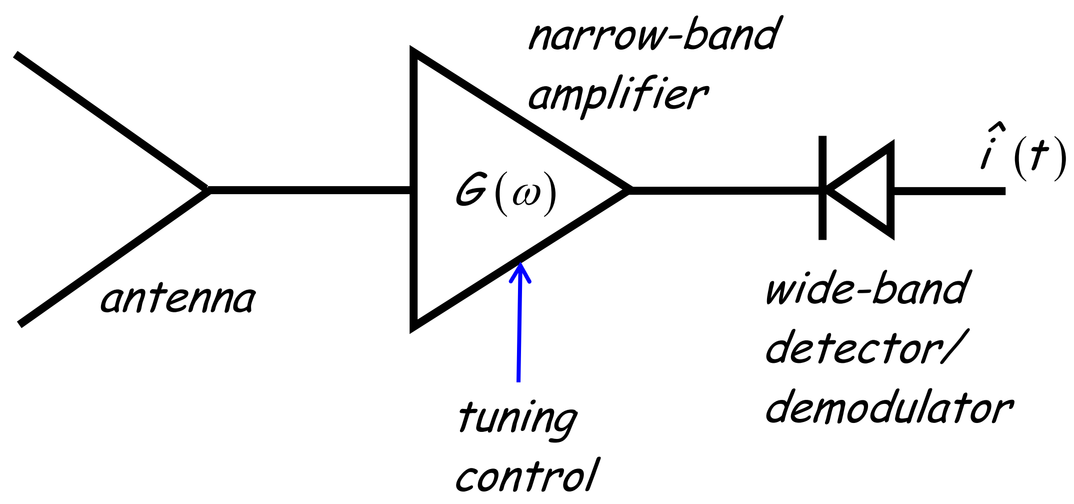
We find that the signals occupying the electromagnetic spectrum exist over an extremely large range of **frequencies**, and an extremely large (dynamic) range of **powers**—this makes receiver design **very** challenging!

1. The Heterodyne Receiver

HO: The Heterodyne Receiver

The Heterodyne Receiver

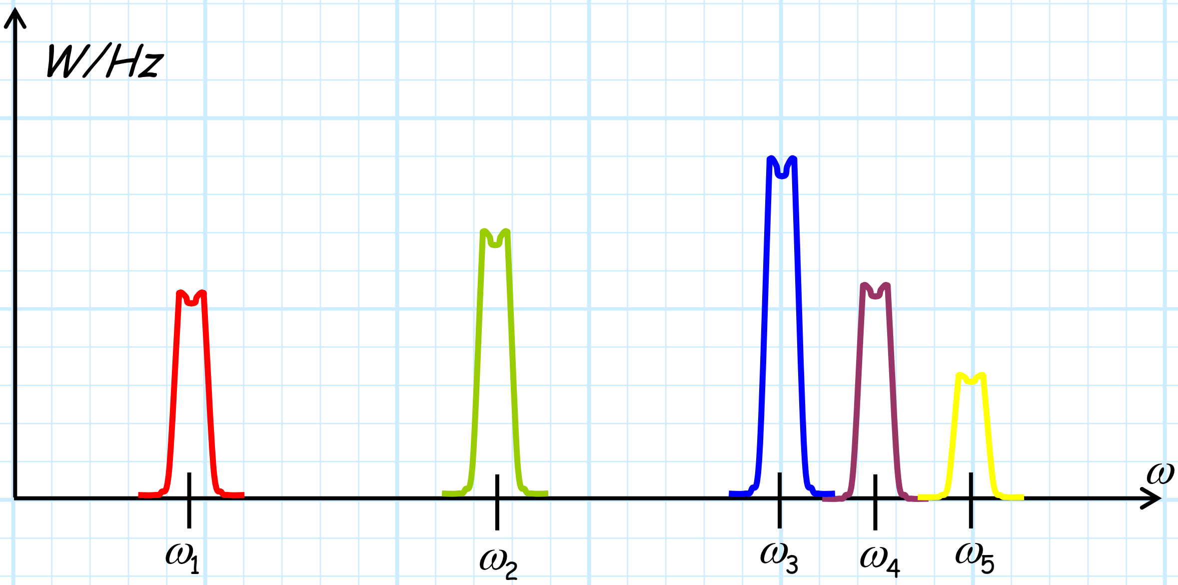
The **original** radio receiver design was the **heterodyne** receiver.



A Heterodyne Receiver

The **desired** radio signal was selected by **tuning** a narrow-band amplifier!

For **example**, say at the output of the antenna we find the following **signal spectrum**.



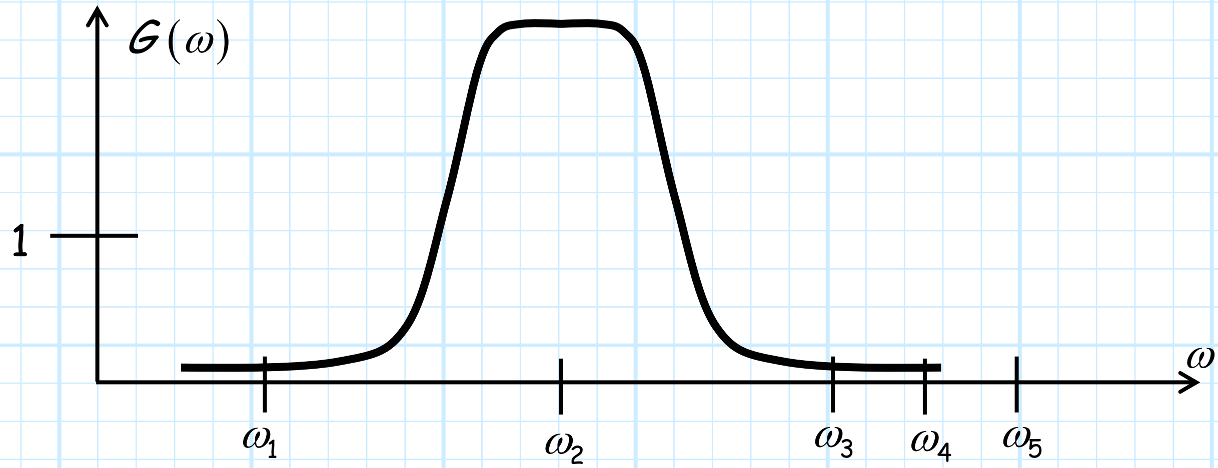
Each signal represents a **different** radio channel.

If **all** of these signals reach the detector/demodulator, the output $\hat{i}(t)$ will be a **confused mess**!

> It is the job of the receiver to select **one** signal, **amplify** it, and present that one (and **only** one) signal to the **detector/demodulator**!

Thus, the receiver must simultaneously **suppress all** of the other signals that come out of the antenna.

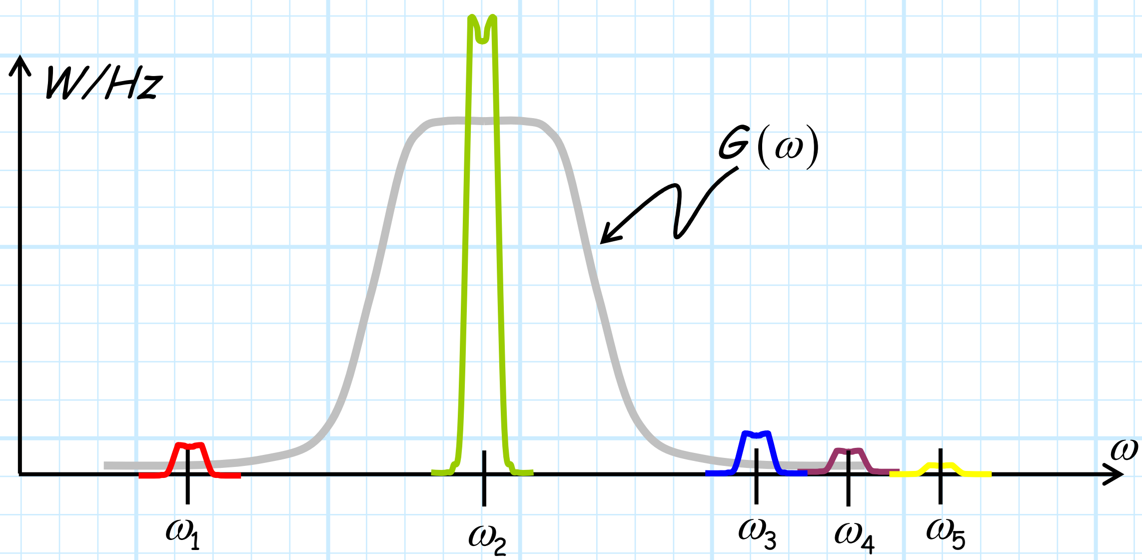
For **example**, we might tune our amplifier to frequency ω_2:



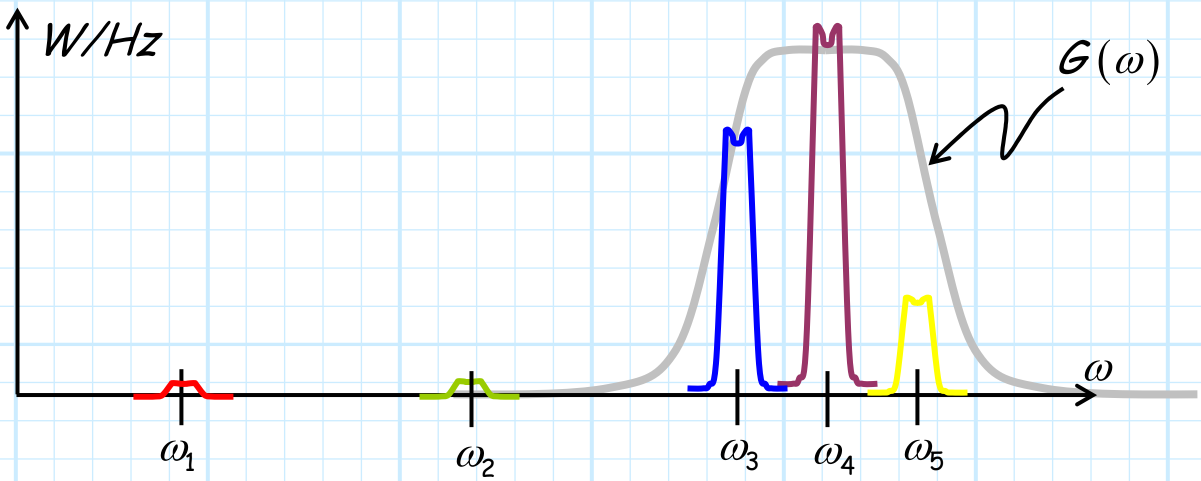
Therefore, the gain **in** the pass-band is **large** ($G(\omega) \gg 1$), while **outside** the pass-band the gain is **small** ($G(\omega) \ll 1$).

As a result, the signal at frequency ω_2 is **amplified**, while the signals at **all** other frequencies are attenuated (i.e., rejected) → **only** the signal at ω_2 reaches the detector!

Thus, the signal spectrum **at the detector/demodulator** would look like this:



Now, say we **tune** the amplifier to select the signal at frequency ω_4:

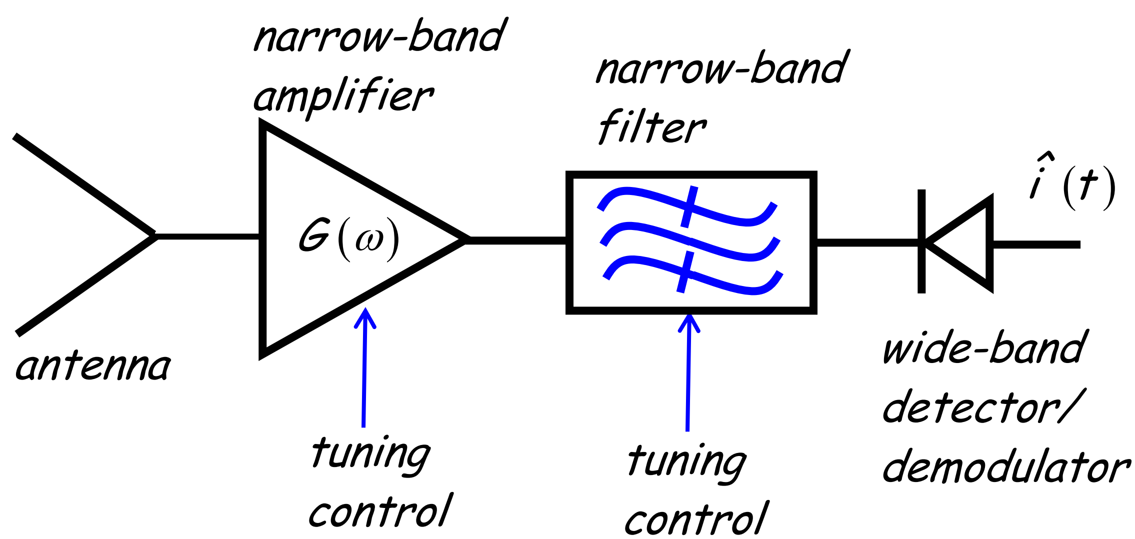


YIKES!! WE HAVE A **PROBLEM**!!

The amplifier bandwidth is **not** sufficiently narrow to **reject** completely the signal at frequency ω_5, nor the signal at ω_3.

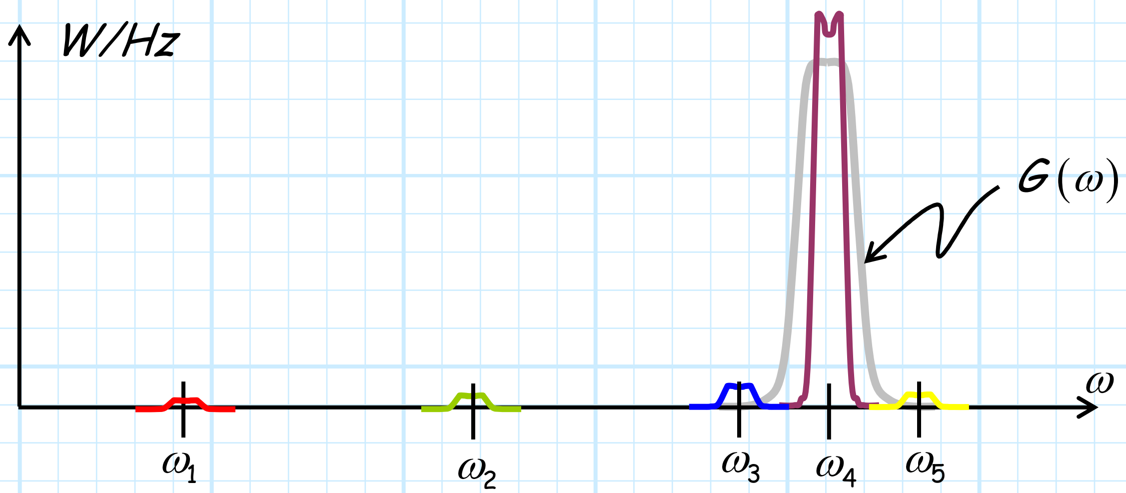
We say that this receiver has poor **selectivity** → we need to **improve** it!

Early radio engineers improved heterodyne **selectivity** by adding a **tunable**, narrow, **band-pass filter**:



A Selective Heterodyne Receiver

Therefore, if we tune **both** the amplifier and filter to frequency ω_4, we might get:



Much better selectivity !!!

Note that the selectivity (i.e. **bandwidth**) of the receiver should be **just** wide enough to allow the **entire** signal bandwidth to pass (undistorted!) to the detector.

Moreover, the roll-off of filter must be **steep** enough sufficiently **attenuate** radio signals in **adjacent channels**.

Q: *Why don't we **still** use this receiver design?*

A: Because a heterodyne Rx has **many problems**!!!

Problem #1

It is very **difficult** to **tune** an amplifier and/or filter!

* We change the frequency **response** of an amplifier/filter by changing the **values** of the **reactive** components (i.e., inductors and capacitors).

* But, the center frequency and bandwidth of an amplifier/filter are related to the inductor and capacitor values in very **indirect** and **complex** ways.

* Additionally, a filter of high selectivity (i.e., "fast **roll-off**") will be a filter of **high order** → high order means **many** inductors and capacitors!

Result: Tuning a good heterodyne receiver can be very **difficult**, requiring a **precise** adjustment of **many** control knobs!

Problem #2

The signal reaching the detector can be any one of many frequencies (e.g., $\omega_1, \omega_2, \omega_3, \omega_4$) distributed across a very wide bandwidth.

As a result, the detector must be **wideband**!

Unfortunately we find that a good wideband detector/demodulator is difficult to build. Generally speaking, a detector/demodulator will work well at some frequencies, but less well at others.

Q: *So how do we fix these problems??*

A: We can't! Instead, we use **yet another** of Edwin Howard Armstrong's inventions:

→ The **Super-Heterodyne** Receiver ! ←

*A 1920's-30's advertisement extolling the virtues of the **super-heterodyne** radio receiver. Note the price!*