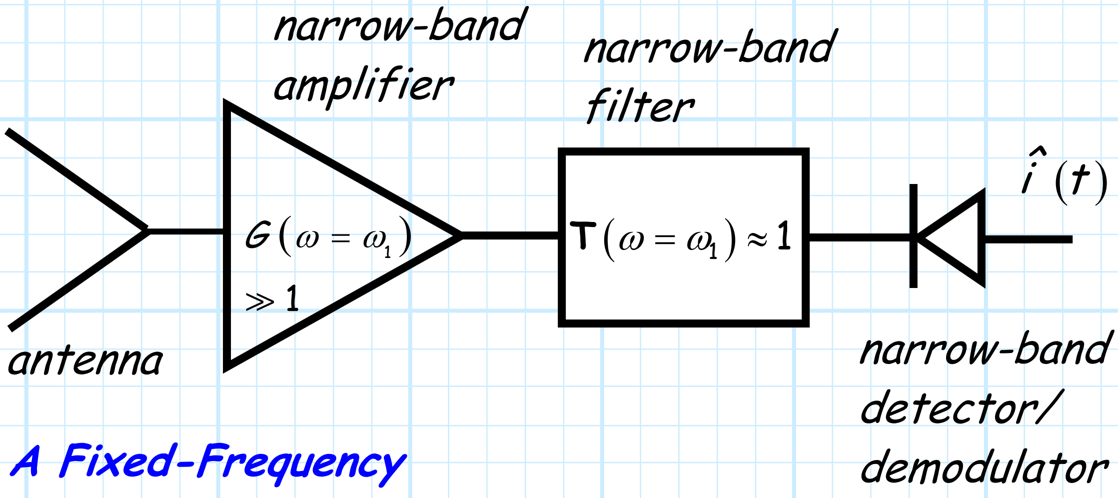
The Super-Heterodyne Receiver

Note that the heterodyne receiver would be an excellent design if we **always** wanted to receive a signal at **one** particular signal frequency (ω_1, say):



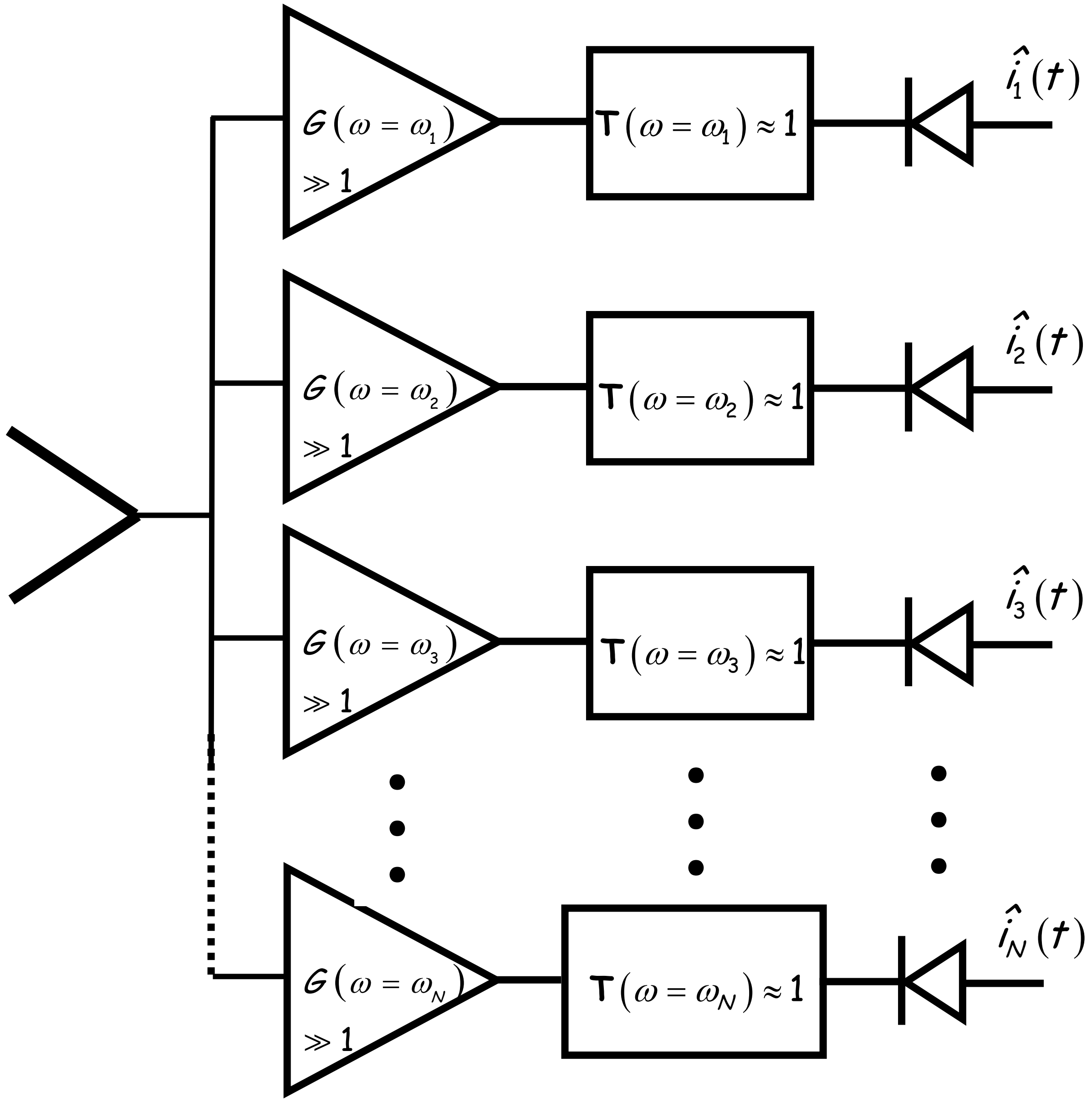
A Fixed-Frequency Heterodyne Receiver

No tuning is required!

Moreover, we can **optimize** the amplifier, filter, and detector performance for **one**—and **only** one—signal frequency (i.e., ω_1).

Q: *Couldn't we just build one of these fixed-frequency heterodyne receivers for* ***each*** *and every signal frequency of interest?*

A: Absolutely! And we sometimes (but not often) do. We call these receivers **channelized receivers**.



A Channelized Receiver

But, there are several important **problems** involving channelized receivers.

→ They're big, power hungry, and **expensive**!

For **example**, consider a design for a channelized FM radio. The FM band has a **bandwidth** of 108-88 = 20 MHz, and a channel **spacing** of 200 kHz. Thus we find that the **number** of FM **channels** (i.e., the number of possible FM radio stations) is:

$$\frac{20 \text{ MHz}}{200 \text{ kHz}} = 100 \quad \text{channels !!!}$$

Thus, a channelized **FM radio** would require **100 heterodyne receivers**!

Q: *Yikes! Aren't there* ***any*** *good receiver designs!?!*

A: Yes, there **is** a good receiver solution, one developed more than 80 years ago by—**Edwin Howard Armstrong**! In fact, is was such a good solution that it is **still** the **predominant** receiver architecture used today.

Armstrong's approach was both **simple** and **brilliant**:

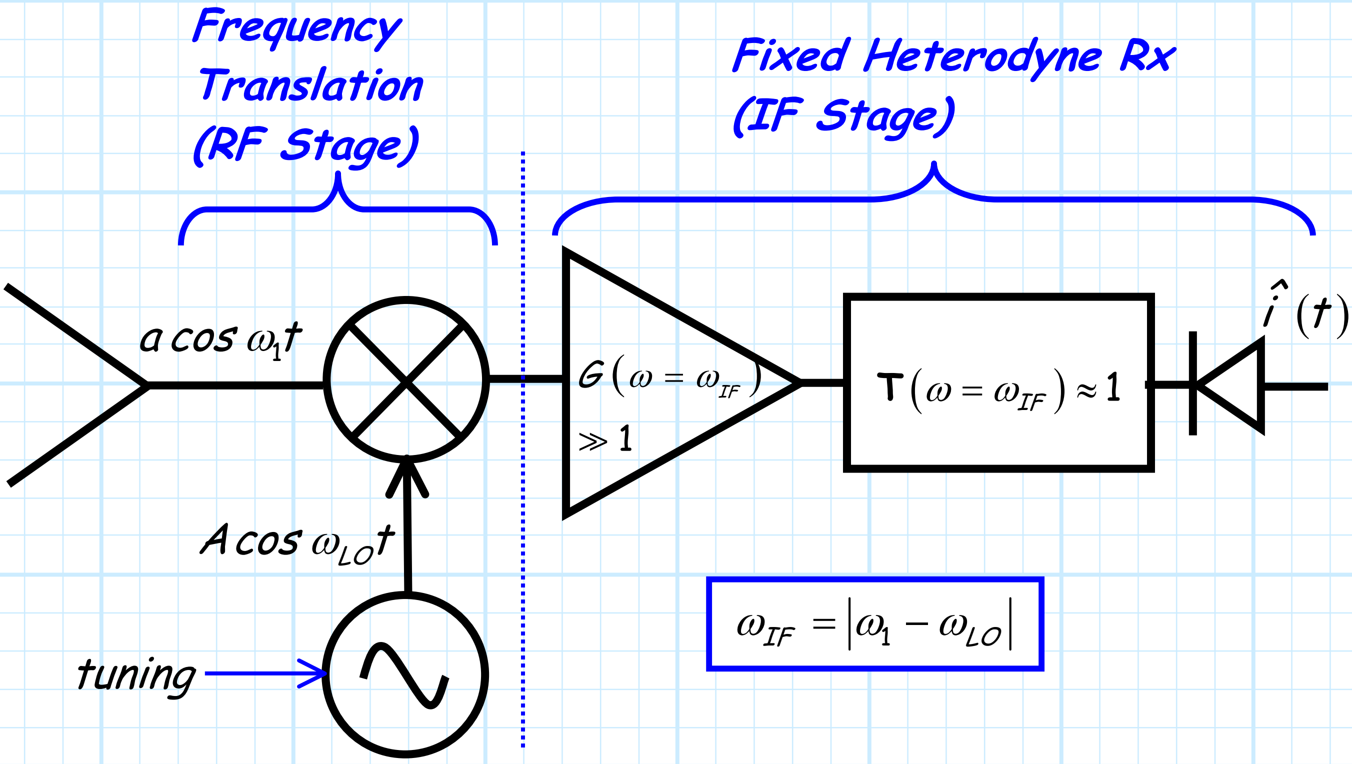
Instead of changing (tuning) the receiver hardware to match the desired signal frequency, we should change the **signal** frequency to match the receiver **hardware**!

Q: *Change the signal **frequency**? How can we possibly do **that**?*

A: We **know** how to do this! We **mix** the signal with a **Local Oscillator**!

We call this design the **Super-Heterodyne Receiver**!

A super-heterodyne receiver can be viewed as simply as a **fixed frequency heterodyne** receiver, proceeded by a **frequency translation** (i.e., down-conversion) stage.



A Simple Super-Het Receiver Design

The **fixed** heterodyne receiver (the one that we match the signal frequency **to**), is known as the **IF stage**. The fixed-frequency ω_{IF} that this heterodyne receiver is designed (and optimized!) for is called the **Intermediate Frequency** (IF).

Q: *So what is the value of this Intermediate Frequency* ω_{IF} *?? How does a receiver design engineer choose this value?*

A: **Selecting** the "IF frequency" value is perhaps the most **important** choice that a "super-het" receiver designer will make. It has **many** important ramifications, both in terms of **performance** and **cost**.

* We will discuss most of these ramifications **later**, but right now let's simply point out that the IF should be selected such that the cost and performance of the (IF) **amplifier**, (IF) **filter**, and detector/**demodulator** is **good**.

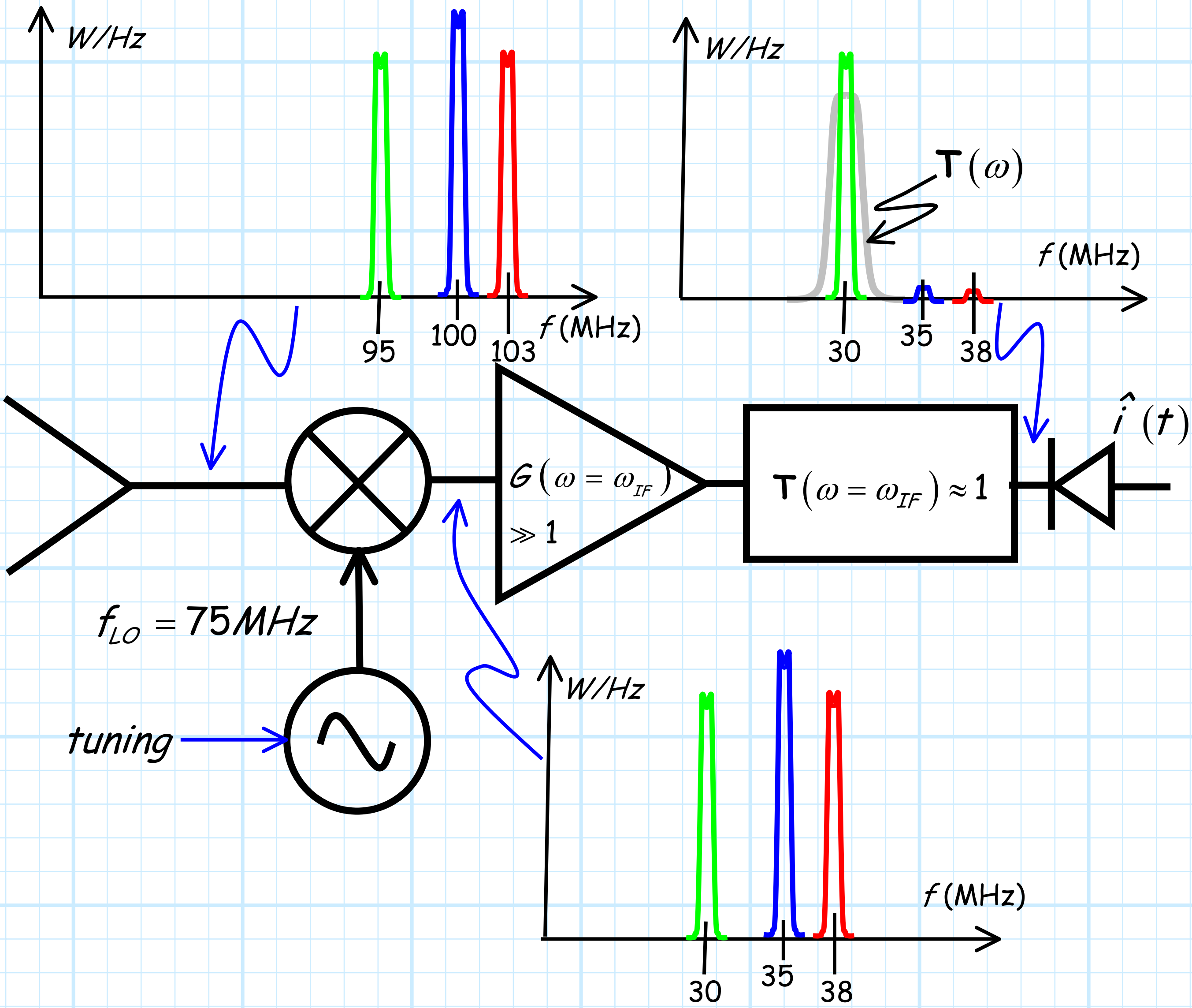
* Generally speaking, as we go **lower** in frequency, the cost of components go **down**, and their performance **increases** (these are both good things!). As a result, the IF frequency is **typically** (but **not** always!) selected such that it is much **less** (e.g., an order of magnitude or more) than the RF signal frequencies we are attempting to demodulate.

* Therefore, we typically use the mixer/LO to **down-convert** the signal frequency from its relatively **high RF** frequency to a relatively **low IF** frequency. We are thus interested in the **second-order** mixer term $|\omega_{RF} - \omega_{LO}|$.

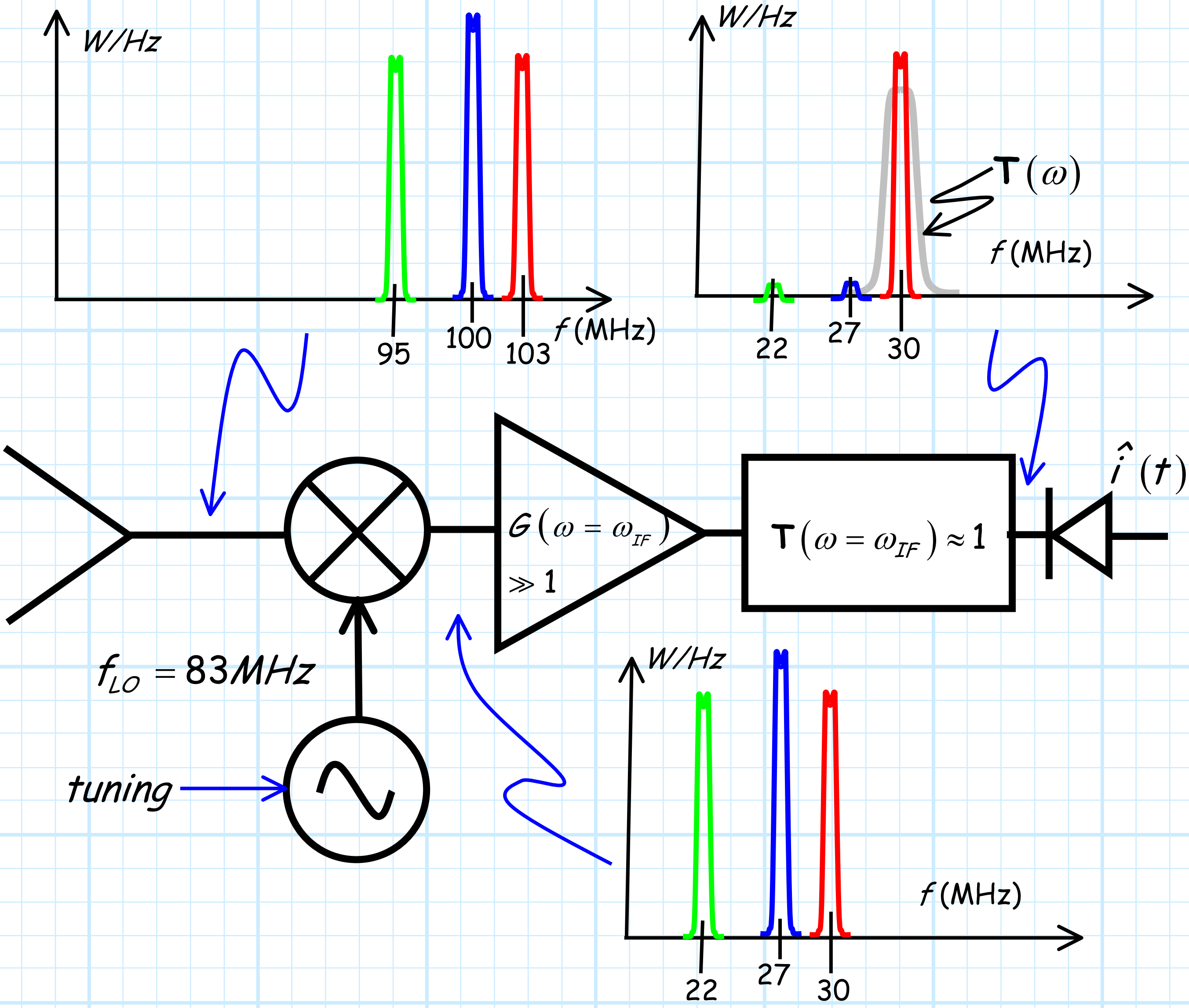
As a result, we must **tune** the LO so that $\left|\omega_1 - \omega_{LO}\right| = \omega_{IF}$—that is, if we wish to demodulated the RF signal at frequency ω_1!

For example, say there exits radio signals (i.e., radio stations) at 95 MHz, 100 MHz, and 103 MHz. Likewise, say that the **IF** frequency selected by the receiver design engineer is **f_{IF} = 20 MHz.**

We can tune to the station at **95 MHz** by setting the Local Oscillator to 95-20=**75 MHz**:



Or, we could tune to the station at **103 MHz** by tuning the **Local Oscillator** to 103-20=**83 MHz**:



Q: *Wait a second! You mean we need to **tune** an oscillator. How is that any **better** than having to **tune** an amplifier and/or filter?*

A: Tuning the LO is **much** easier than tuning a band-pass filter. For an oscillator, we just need to change a **single** value—its **carrier frequency**! This can typically be done by changing a **single** component value (e.g., a varactor diode).

Contrast that to a **filter**. We must somehow change its center frequency, **without** altering its bandwidth, roll-off, or phase delay. Typically, this requires that **every** reactive element in the filter be altered or changed as we modify the center frequency (remember all those **control knobs**!).

RADIO NEWS FOR FEBRUARY, 1934

453

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Karl Hassel, Chief Engineer, Zenith Radio Corporation.
Homer Hogan, Gen. Manager, Radio Station KYW, Chicago.
R. MacGregor, Service Manager and Sales Engineer, Transformer Corporation of America (Clarion).
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