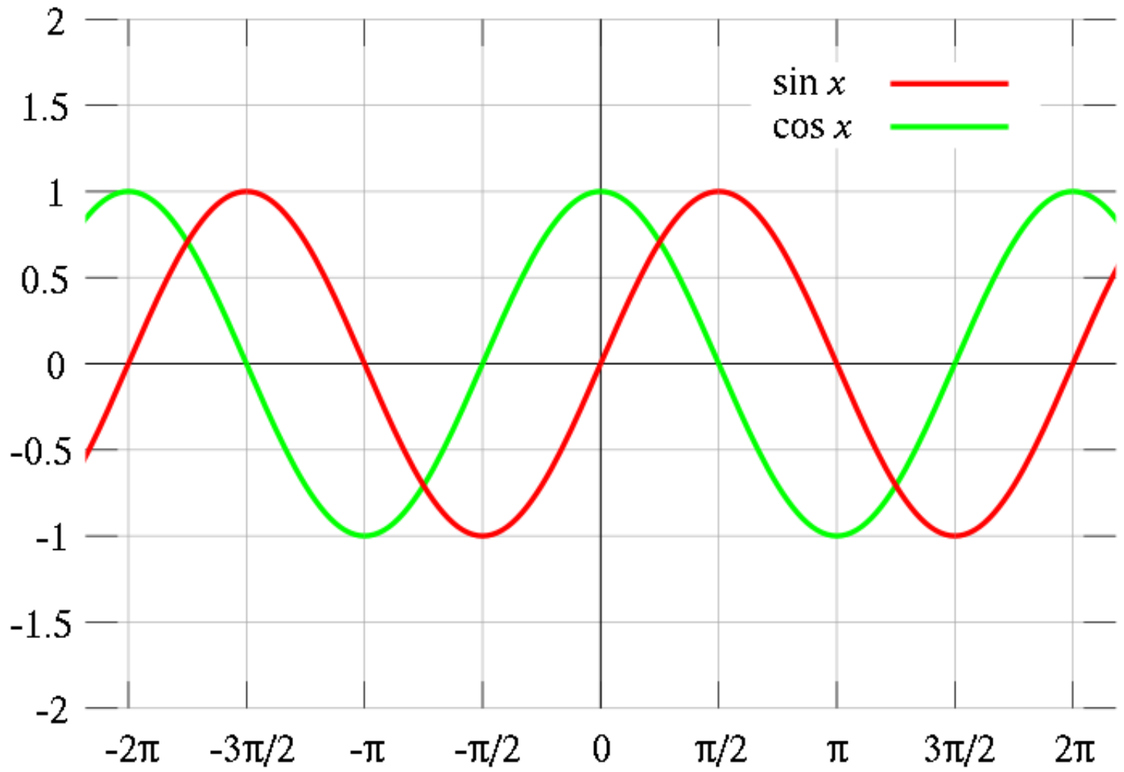
TFE4152 - Lecture 19

All radios started with Euler

Source

$$e^{ix} = cos(x) + isin(x)$$

$$e^{-ix} = cos(-x) - isin(-x) = cos(x) - isin(x)$$



$$e^{ix} = cos(x) + isin(x)$$

$$e^{-ix} = cos(-x) - isin(-x) = cos(x) - isin(x)$$

$$cos(x) = e^{ix} - isin(x)$$

$$-isin(x) = e^{-ix} - cos(x)$$

$$cos(x) = e^{ix} + e^{-ix} - cos(x)$$

$$2cos(x) = e^{ix} + e^{-ix}$$

$$2cos(x) \times 2cos(y) = (e^{ix} + e^{-ix}) \times (e^{iy} + e^{-iy})$$

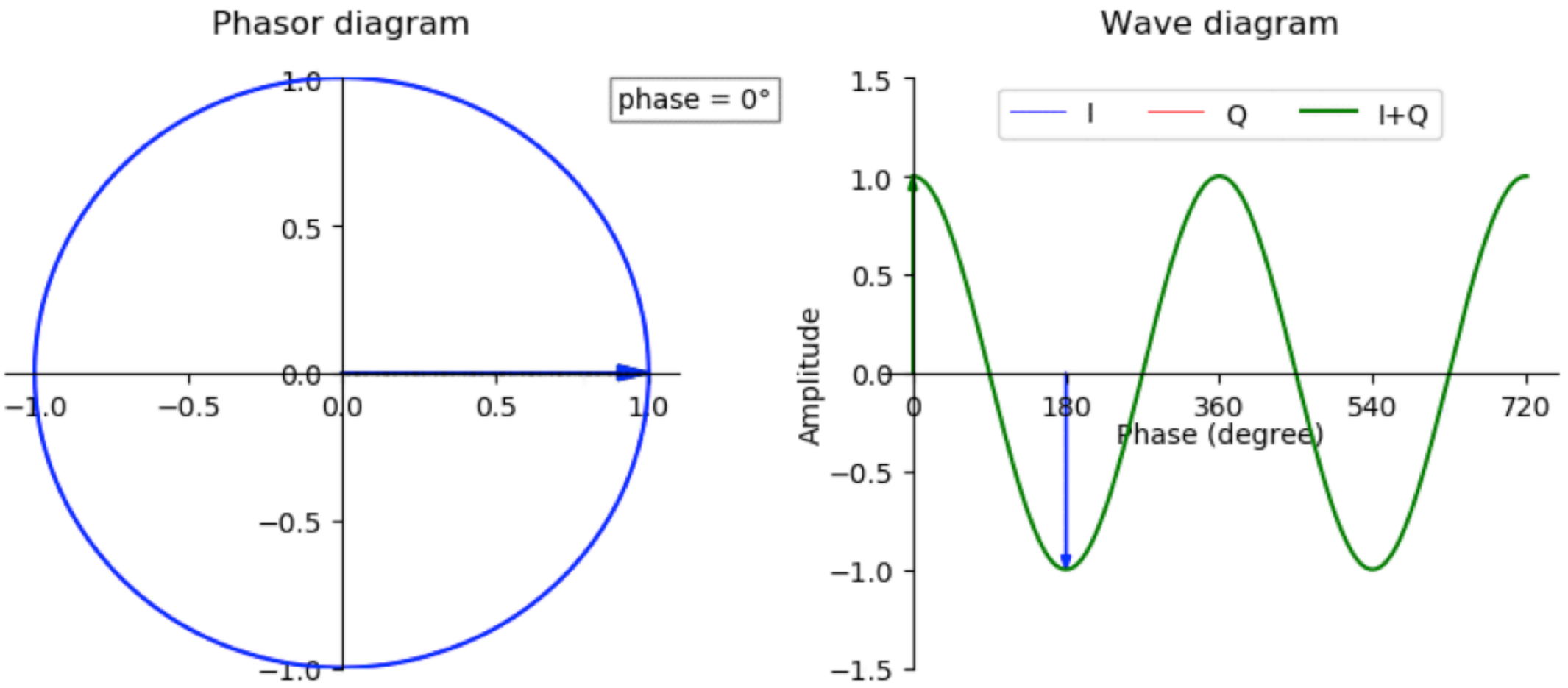
$$\rightarrow e^{ix}e^{iy} + e^{-ix}e^{iy} + e^{ix}e^{-iy} + e^{-ix}e^{-iy}$$

$$\rightarrow e^{i(x+y)} + e^{-i(x-y)} + e^{i(x-y)} + e^{-i(x+y)}$$

$$\rightarrow (e^{i(x+y)}e^{-i(x+y)}) + (e^{i(x-y)} + e^{-i(x-y)})$$

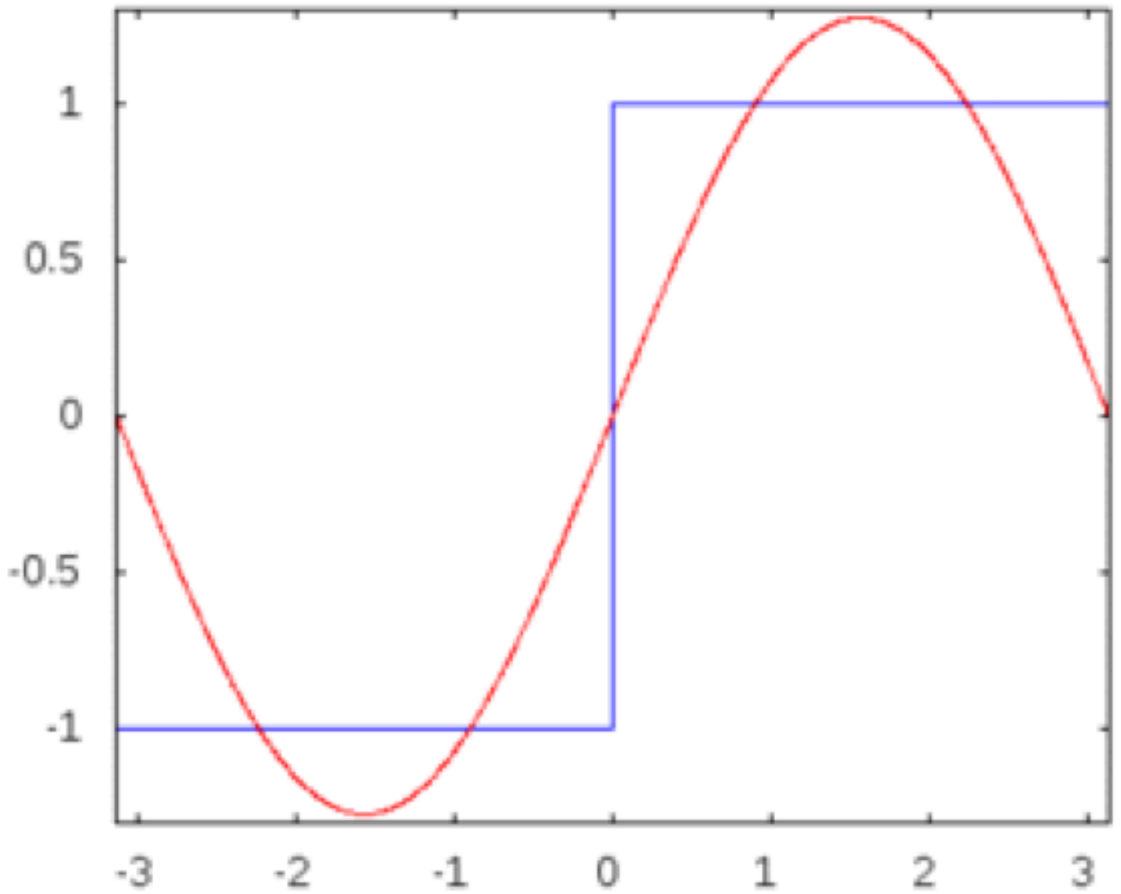
$$\Rightarrow 2cos(x) \times 2cos(y) = 2cos(x+y) + 2cos(x-y)$$

$$\Rightarrow cos(x) \times cos(y) = cos(x+y) + cos(x-y)$$


Phasor diagram
phase = 0°
1.0
0.5
0.0
−0.5
−1.0
−1.0
−0.5
0.0
0.5
1.0
Wave diagram
I
Q
I+Q
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
Amplitude
0
180
360
540
720
Phase (degree)

An ideal square wave is an infinite sum of odd harmonics

$$x(t) = \frac{4}{\pi} \sum_{k=1}^{\infty} \frac{sin(2\pi(2k-1)ft)}{2k-1}$$



Complex Signal Processing is Not Complex

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Complex Signal Processing is Not Complex

Kenneth W. Martin, *Fellow, IEEE*

***Abstract*—Wireless systems often make use of the quadrature relationship between pairs of signals to effectively cancel out-of-band and interfering in-band signal components. The understanding of these systems is often simplified by considering both the signals and system transfer functions as *"complex"* quantities. The complex approach is especially useful in highly integrated multistandard receivers where the use of narrow-band fixed-coefficient filters at the RF and high IF must be minimized. This paper first presents a tutorial review of complex signal processing for wireless applications. The review emphasizes a graphical and pictorial description rather than an equation-based approach. Next, a number of classical modulation architectures are described using this formulation. Finally, more recent developments such as complex filters, image-reject mixers, low-IF receivers, and oversampling analog–digital converters are discussed.**

***Index Terms*—Communication systems, complex signal processing, filters, frequency modulation, mixers, wireless receivers.**

I. Introduction

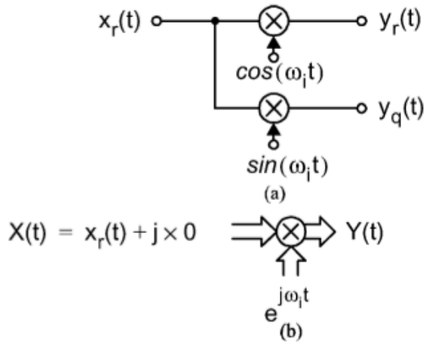

Fig. 1. SFG of an quadrature mixer using (a) a real SFG and (b) a complex SFG.

As an example, consider the popular "*quadrature*" mixer with a *real* input as shown in Fig. 1. In the complex SFG, two real multiplications have been replaced by a single complex multiplication. Furthermore, since in the time domain, we have

Thanks!