QUADRATURE AMPLITUDE MODULATION(QAM) PRINCIPLE

EEEN 462 – ANALOGUE COMMUNICATION

Friday, 21 November 2025

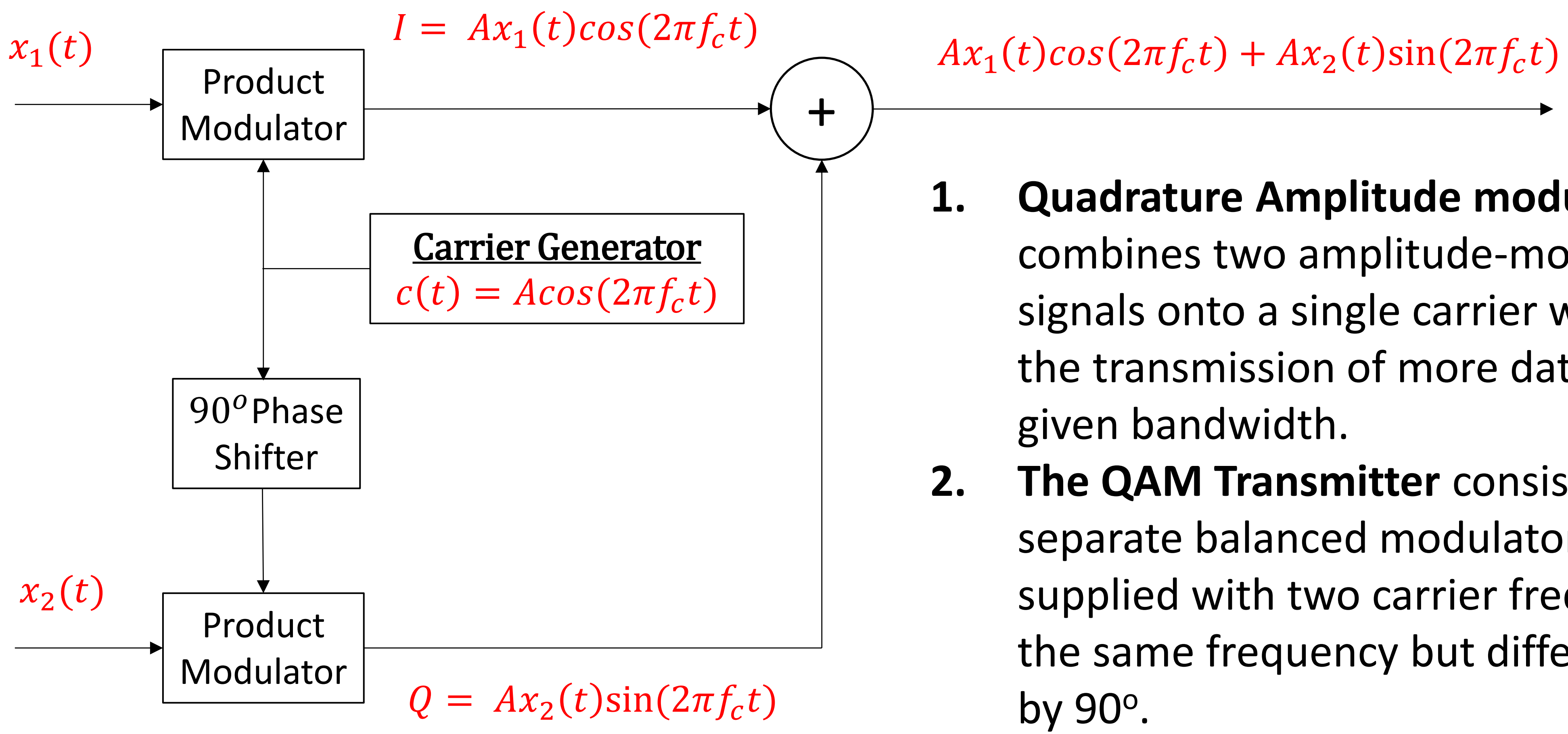
QUADRATURE AMPLITUDE MODULATION (QAM) TYPES

1. **Quadrature amplitude modulation (QAM)** may exist in either analogue or digital formats.
2. **The analogue versions of QAM** are typically used to allow multiple analogue signals to be carried on a single carrier.

   For instance, in PAL and NTSC television systems, different channels provided by QAM enable it to carry the two components of chroma or colour information.

1. **Digital formats of QAM** sometimes referred to as "**Quantised QAM**" are being increasingly used for data communications and wireless communication such as cellular systems, WiMax, WiFi and Digital Video Broadcasting

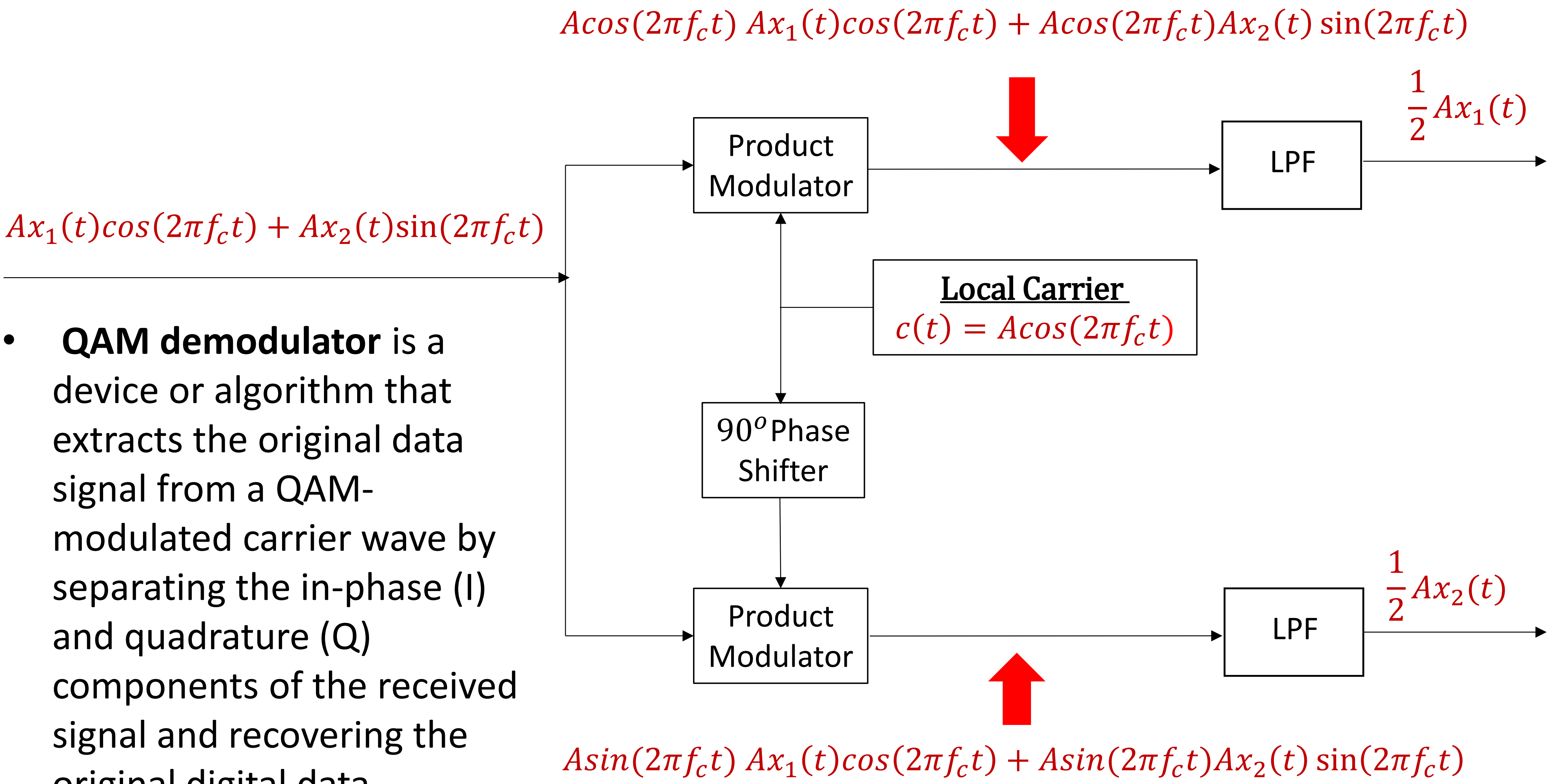
QAM ANALOGUE MODULATOR



1. **Quadrature Amplitude modulator(QA)** combines two amplitude-modulated signals onto a single carrier wave, enabling the transmission of more data within a given bandwidth.
2. **The QAM Transmitter** consists of two separate balanced modulators which are supplied with two carrier frequencies of the same frequency but differing in phase by 90º.
3. The output of the two modulators are added together to yield the signal:

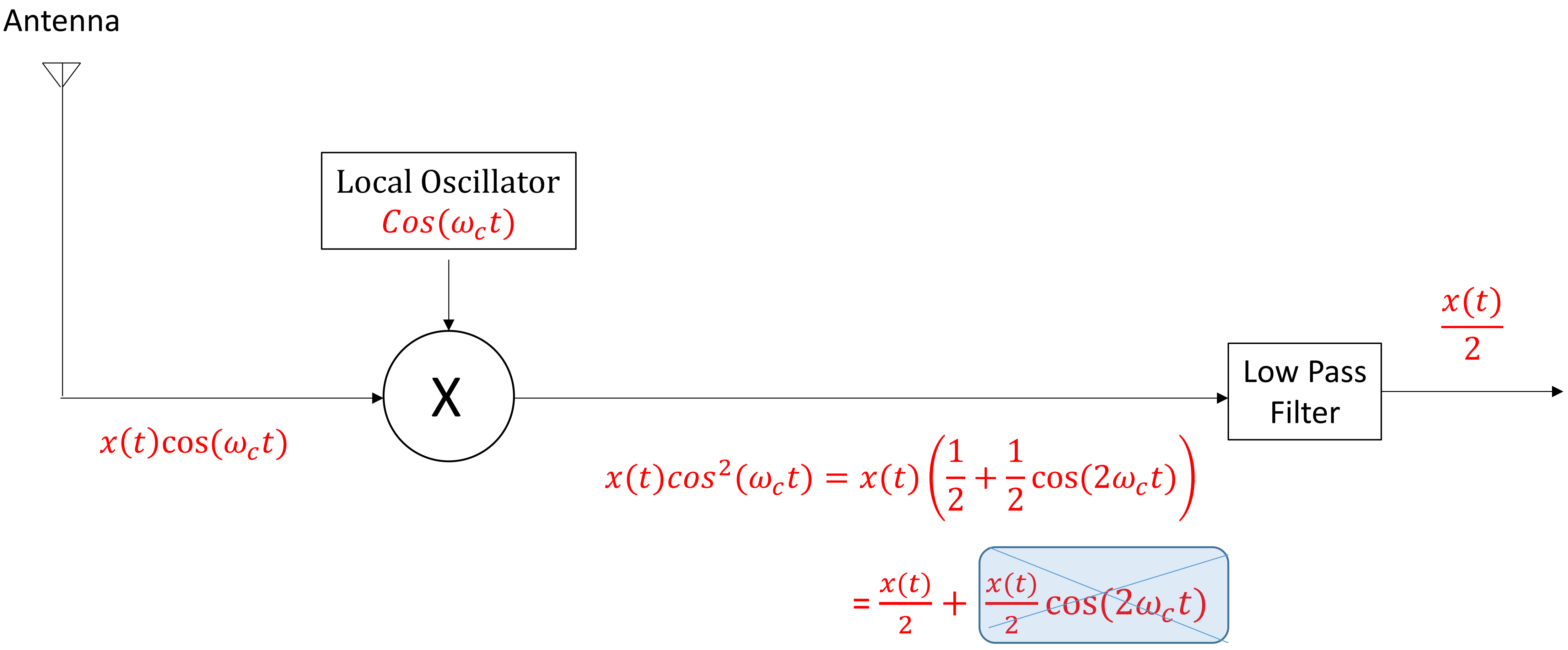
$$\boldsymbol{s(t) = Ax_1(t)cos2\pi f_c t + Ax_2(t)sin2\pi f_c t}$$

QAM DEMODULATOR

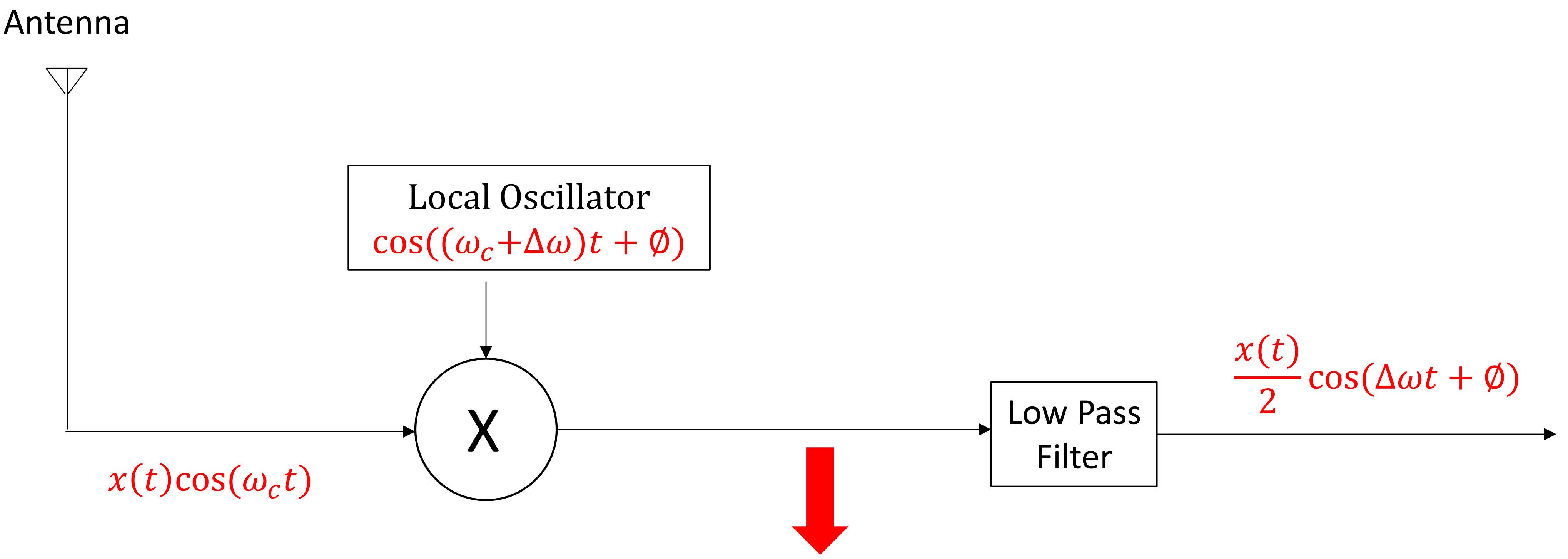


- **QAM demodulator** is a device or algorithm that extracts the original data signal from a QAM-modulated carrier wave by separating the in-phase (I) and quadrature (Q) components of the received signal and recovering the original digital data.

QAM RECEIVER IS BASED ON THE PRINCIPLE OF SYNCHRONOUS DETECTION OF DSB-SC SIGNALS



EFFECT OF PHASE & FREQUENCY ERRORS IN SYNCHRONOUS DETECTION



$$x(t)\cos(\omega_c t)\cos((\omega_c+\Delta\omega)t + \emptyset) = \frac{x(t)}{2}\{\cos(\Delta\omega t + \emptyset) + \cos(2\omega_c t + \Delta\omega t + \emptyset)\}$$

Use Trigonometric Identity

$$\cos(a)\cos(b) = \frac{1}{2}\{\cos(a-b) + \cos(a+b)\}$$

CASE OF ONLY PHASE ERROR

$$s(t) = \frac{x(t)}{2}\cos(\Delta\omega t + \emptyset)$$

Assume:

$$\Delta\omega = 0 \;\; and\; \emptyset \neq 0$$

Then:

$$s(t) = \frac{x(t)}{2}\cos(\emptyset)$$

Results:

Output is maximum when $\emptyset = 0$

Output is zero when $\emptyset = 90^0$ and is called the quadrature null effect

CASE OF FREQUENCY ERROR

$$s(t) = \frac{x(t)}{2}\cos(\Delta\omega t + \emptyset)$$

Assume:

$$\Delta\omega \neq 0 \;\; and \; \emptyset = 0$$

Then:

$$s(t) = \frac{x(t)}{2}\cos(\Delta\omega t)$$

Results:

Since $\Delta\omega$ is usually small, the output consists of x(t) multiplied by a slowly varying sinusoidal wave which causes distortion.

CARRIER ACQUSITION IN DBSC-SC SYSTEMS

1. **In DSB-SC (Double-Sideband Suppressed-Carrier) systems**, carrier acquisition at the receiver is crucial because the carrier signal is not transmitted, and the receiver needs to regenerate it for demodulation.
2. Two methods are generally used to acquire the carrier in DBSB-SC systems, i.e
   a) Use of Pilot carrier
   b) Costas receiver

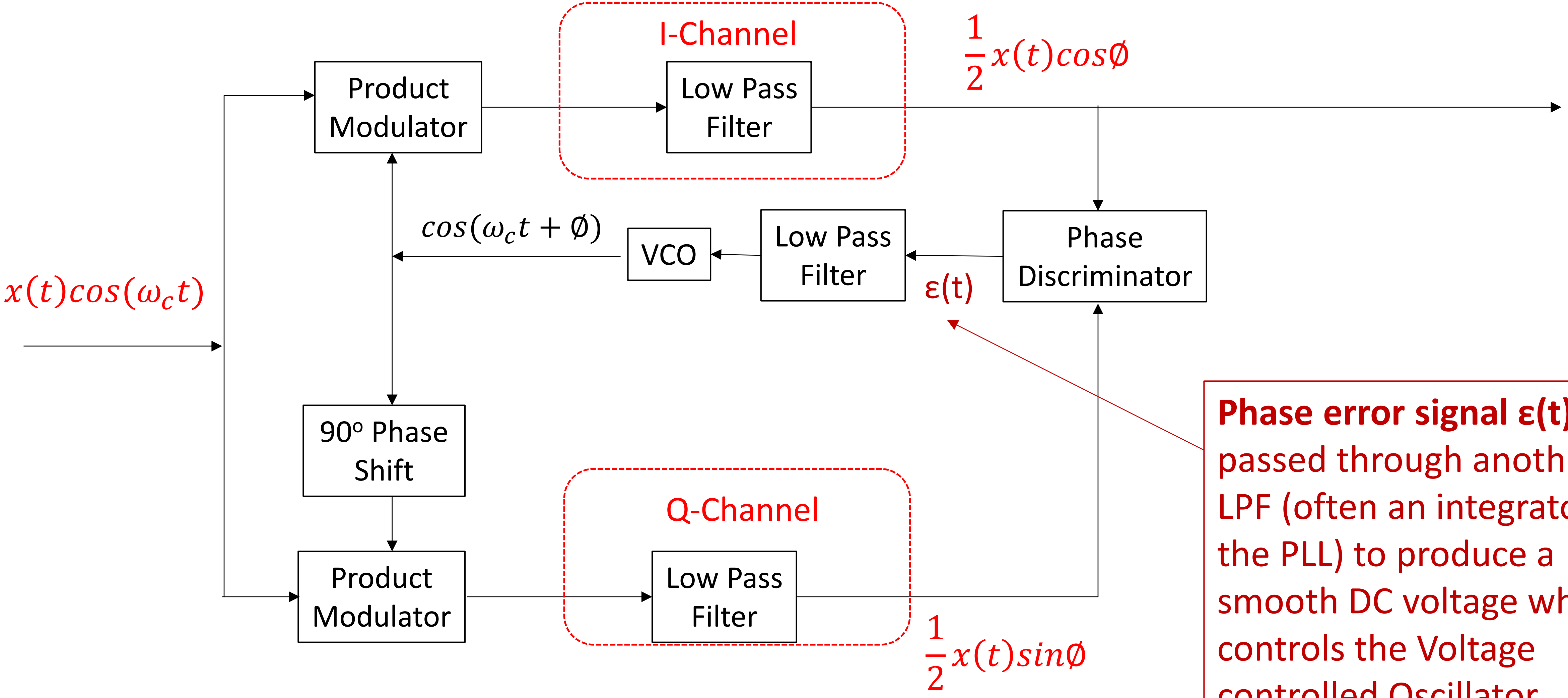
USE OF PILOT CARRIER

1. A small value of the carrier is transmitted alongside the DBSB-SC signal
2. The small carrier signal is called the pilot carrier and separated from the signal at the receiver by using appropriate filters, amplified and used to phase-lock the locally generated carrier.
3. This system is also referred to as partially suppressed carrier system.

COSTAS RECEIVER /01

1. **A Costas receiver** is a phase-locked loop (PLL) circuit used in communication receivers to recover the carrier frequency from a modulated signal, particularly for suppressed-carrier modulation schemes like DSB-SC.
2. **Core principle of the Costas receiver** is to use **a Phase-Locked Loop (PLL) structure with in-phase (I) and quadrature (Q) arms to simultaneously demodulate the signal and extract a phase error signal.** This **error signal is used to lock a Voltage-Controlled Oscillator (VCO) to the correct frequency and phase**.
3. **Costas Loop was invented** by the American engineer John P. Costas in 1956

COSTAS RECEIVER /02



Phase error signal ε(t) is passed through another LPF (often an integrator in the PLL) to produce a smooth DC voltage which controls the Voltage controlled Oscillator.