Communication systems

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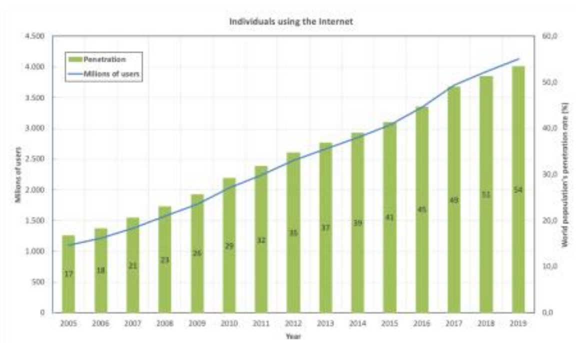
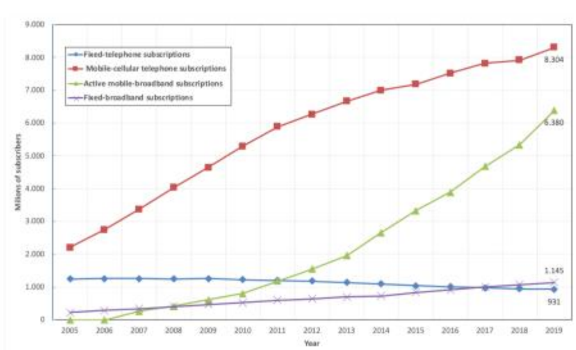
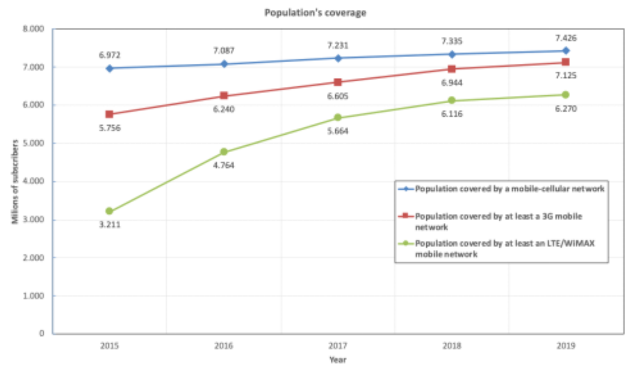
ELECTRONICS AND COMMUNICATIONS SYSTEMS
COMPUTER ENGINEERING

- Some data from the International Telecommunication Union (ITU).....
- The number of people with access to mobile communications is higher than those with access to working toilets (around 4.5 billions)
- The number of people that owns a mobile phone is larger than the number of people that owns/uses a toothbrush (around4 billion)







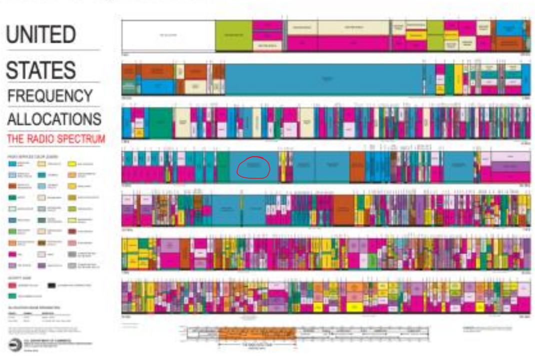
Syllabus

- 1. Radio transmissions
- 2. The wireless propagation channel
- 3. Multi-user communications
- 4. Cellular systems
- 5. Mobile communications standards

1. Radio transmissions

- Introduction to analog and digital wireless systems
- Analog systems: FM radio
- Software defined radio principles
- SDR exercitation: FM receiver implementation with SDR and Matlab
- Digital systems: PAM modulation

The radio spectrum

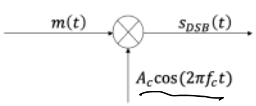


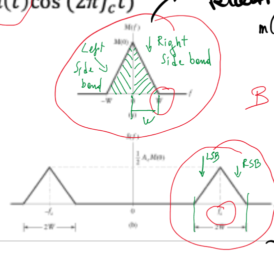
Analog Communications

Analog communications: amplitude modulation dual side band (AM-DSB)

- The AM-DSB modulation is probably the simplest modulation possible

$$s_{DSB}(t) = A_c m(t) \cos(2\pi f_c t)$$





LEFT SIDE BAND = RIGHT SIDE BAND

$m(t)$ is a real signal

$\Downarrow$

Hermitian symmet → SIMMETRIA HERMITIANA

B

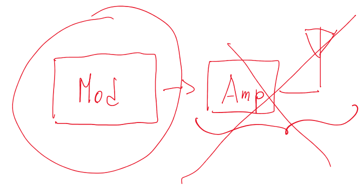
$M(-f) = M(f)^*$

$|M(-f)| = |M(f)|$

Bandwidth is double with respect to the baseband

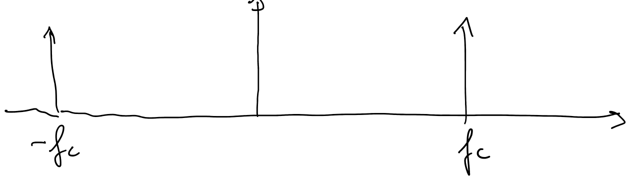
$$M(-f) = M(f)^*$$

$$|M(-f)| = |M(f)|$$



MODULATED SIGNAL OCCUPA IL DOPPIO DELLA BANDA MA LA QUANTITÀ DI INFORMAZIONE È LA STESSA -

$$\cos(2\pi f_c t) \rightleftharpoons \underbrace{\frac{1}{2}\delta(f-f_c) + \frac{1}{2}\delta(f+f_c)}$$



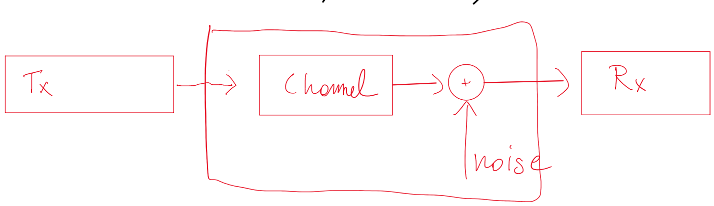
modulating signal

$$s(t) = m(t) \cdot \cos(2\pi f_c t)$$

$$S(f) = M(f) \otimes \left(\frac{1}{2}\delta(f-f_c) + \frac{1}{2}\delta(f+f_c)\right)$$

$$S(f) = \frac{1}{2} M(f-f_c) + \frac{1}{2} M(f+f_c)$$

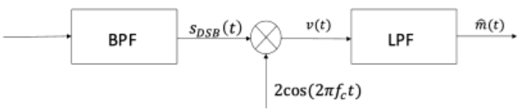
$$y(t) = x(t) \otimes \delta(t-t_0) = y(t-t_0)$$

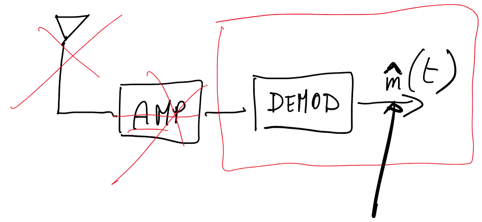


SCHEMA DI UN SISTEMA DI COMUNICAZIONE

DSB coherent detection

- Neglecting for the moment the effect of the noise and of the propagation channel, recovery of $m(t)$ from $s_{DSB}(t)$ is possible with coherent detection.





ESTIMATED NOT EXACT

PUO' ESSERE CHE $\hat{m}(t) \neq m(t)$

↳ CANALE

AMPLITUDE CONSTANT PORTANTE DA [illegible]

$$s_{DSB}(t) = A_c m(t) \cos(2\pi f_c t)$$

$$\cos^2(x) = \frac{1}{2}(1 + \cos 2x)$$

MOLTIPLICO DI NUOVO PER IL COSENO

$$v(t) = s_{DSB}(t) \cdot 2\cos(2\pi f_c t) = 2A_c m(t) \cos^2(2\pi f_c t)$$

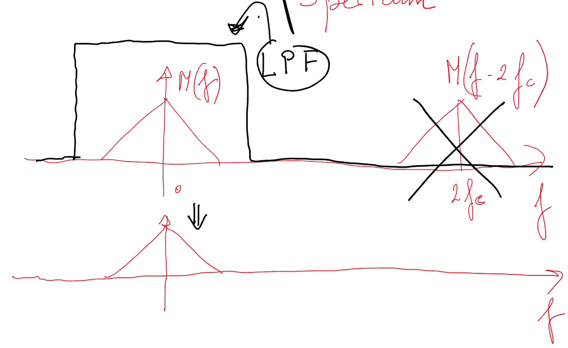
$$= \cancel{2} A_c m(t) \frac{1}{\cancel{2}} \left(1 + \cos(2\pi 2 f_c t)\right)$$

$$= A_c m(t) + A_c m(t) \cos(2\pi 2 f_c t)$$

↗ Baseband ↗ component @ $2f_c$

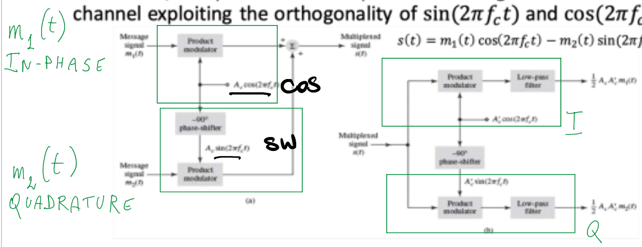
↳ LOW PASS FILTER

Spectrum



Analog Quadrature Amplitude Modulation

- To double the amount of information transmitted on a given bandwidth, it is possible to multiplex two DSB signal on the same channel exploiting the orthogonality of $\sin(2\pi f_c t)$ and $\cos(2\pi f_c t)$



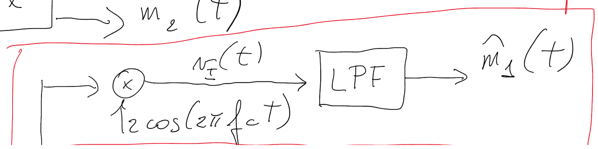
Use the same bandwidth to double the number of transmitted signals

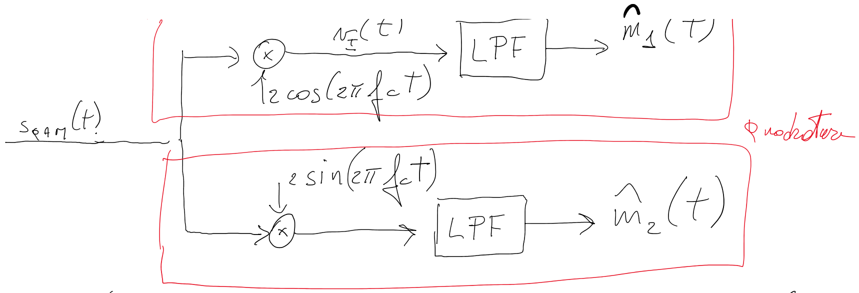
↳ TRASMETTO 2 SEGNALI

SENO E COSENO SONO ORTOGONALI

$$S_{QAM}(t) = \underbrace{A_c m_1 \cos(2\pi f_c t)}_{DSB} - \underbrace{A_c m_2(t) \sin(2\pi f_c t)}_{DSB}$$

In-phase





$$v_I(t) = 2\left(A_c m_1(t)\cos(2\pi f_c t) - A_c m_2(t)\sin(2\pi f_c t)\right)\cos(2\pi f_c t)$$

$$= \underbrace{2A_c m_1(t)\cos^2(2\pi f_c t)} - 2A_c m_2(t)\sin(2\pi f_c t)\cos(2\pi f_c t)$$

$$\sin\alpha\cos\alpha = \frac{1}{2}\sin 2\alpha$$

$$= \underset{①}{A_c m_1(t)} + \underset{②}{\cancel{A_c m_1(t)\cos(2\pi 2 f_c t)}} - \underset{③}{\cancel{A_c m_2(t)\sin(2\pi 2 f_c t)}}$$

$$\Downarrow \text{LPF}$$

$$\boxed{\begin{cases} \hat{m}_1(t) = A_c m_1(t) \\ \hat{m}_2(t) = A_c m_2(t) \end{cases}}$$

QAM Spectrum is symmetric w.r.t. f_c?

In case of DSB