Universidad Simón Bolívar
Departamento de Electrónica y Circuitos
EC3043 - Laboratorio de Comunicaciones
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Prelaboratorio

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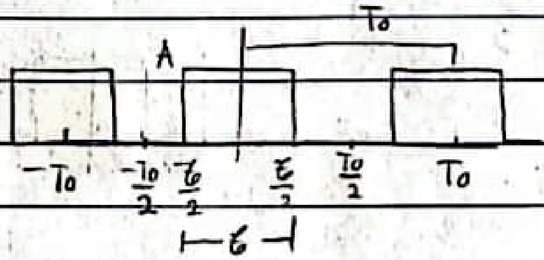
Prelaboratorio Práctica #1: Analizador de Espectro y Componentes Espectrales

(a) Calcule la serie de Fourier de señales periódicas tales como: onda cuadrada, onda rectangular (es decir, onda cuadrada con duty cycle distinto a 50%), triangular y sinusoidal (los valores de frecuencia y amplitud serán establecidos durante el laboratorio)

* Onda Rectangular
  Tren de Pulsos



Período: To

Frecuencia fundamental: $f_0 = \frac{1}{T_0}$

Frecuencia angular: $w_0 = \frac{2\pi}{T_0} = 2\pi f_0$

Coeficientes de Fourier: $C_n = \frac{1}{T_0}\int_{-\frac{\tau}{2}}^{\frac{\tau}{2}} A e^{-jnw_0 t}\, dt$

$$C_n = \frac{-A}{T_0 jnw_0}\left[e^{-jnw_0 t} \Big|_{-\frac{\tau}{2}}^{\frac{\tau}{2}} \right]$$

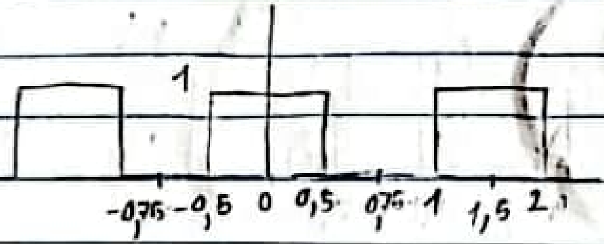
$$C_n = \frac{-A}{jn2\pi}\left[e^{-jn\pi f_0\tau} - e^{jn\pi f_0\tau} \right] \rightarrow C_n = \frac{A}{n\pi}\left(\overbrace{\frac{e^{jn\pi f_0\tau} - e^{-jn\pi f_0\tau}}{j2}}^{sen(n\pi f_0\tau)} \right)$$

$$C_n = \frac{A}{n\pi} sen(n\pi f_0\tau) \qquad sinc\,x = \frac{sen\,\pi x}{\pi x}$$

$$C_n = A f_0\tau \cdot \frac{sen(n\pi f_0\tau)}{n\pi f_0\tau} \rightarrow \boxed{C_n = A f_0\tau\, sinc(n f_0\tau)}$$

$$x(t) = \sum_{n=-\infty}^{\infty} C_n e^{jnw_0 t} \rightarrow \boxed{x(t) = \sum_{n=-\infty}^{\infty} A f_0\tau\, sinc(n f_0\tau)\, e^{jnw_0 t}}$$

* Onda Cuadrada
Duty cycle 50%



$T = 3/2$

Frecuencia fundamental: $w_0 = \frac{2\pi}{T} = \frac{4\pi}{3}$

Coeficientes de Fourier

$$C_n = \frac{1}{T}\int_{t_0}^{t_0+T} x(t)e^{-jw_0 t}\,dt \rightarrow C_n = \frac{2}{3}\int_{-3/4}^{3/4} x(t)e^{-jn(4\pi/3)t}\,dt$$

$$C_n = \frac{2}{3}\int_{-1/2}^{1/2} e^{-jn\,4\pi/3\,t}\,dt \rightarrow C_n = \frac{2}{3}\left(-\frac{3}{j4\pi n}\right)e^{-j4\pi n/3\,t}\Big|_{-1/2}^{1/2}$$

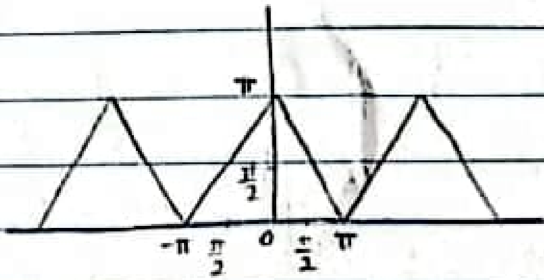
$$C_n = -\frac{1}{2j\pi n}\left(e^{-j\frac{2\pi n}{3}} - e^{j\frac{2\pi n}{3}}\right) \rightarrow \frac{1}{\pi n}\underbrace{\frac{1}{2j}\left(e^{j\frac{2\pi}{3}n} - e^{-j\frac{2\pi n}{3}}\right)}_{sen(2\pi n/3)}$$

$$\boxed{C_n = \frac{sen\left(\frac{2\pi n}{3}\right)}{\pi n}}$$

$$\boxed{f(t) = \sum_{n=-\infty}^{\infty} \frac{sen\left(\frac{2\pi n}{3}\right)}{\pi n} e^{jnw_0 t}}$$

CS Escaneado con CamScanner

* Onda Triangular



$$f(x) = \frac{a_0}{2} + \sum_{0}^{\infty} A_n \cos(wnt) \qquad A_n = \frac{2}{T}\int_{-\frac{T}{2}}^{\frac{T}{2}} f(x)\cos(nwx)\,dx$$

$$f(x) = \begin{cases} \pi + x & -\pi < x \leq 0 \\ \pi - x & 0 < x \leq \pi \end{cases} \qquad B_n = \frac{2}{T}\int_{-\frac{T}{2}}^{\frac{T}{2}} f(x)\,\text{sen}(nwx)\,dx$$

$$a_0 = \frac{2}{T}\int_{-\frac{T}{2}}^{\frac{T}{2}} f(x)\,dx \rightarrow a_0 = \frac{2}{T}\left[\int_{-\pi}^{0} \pi + x\,dx + \int_{0}^{\pi} \pi - x\,dx\right] \qquad w = \frac{2\pi}{T} = \frac{2\pi}{2\pi} = 1$$

$$a_0 = \frac{2}{2\pi}\int_0^{\pi} 2(\pi - x)\,dx \rightarrow a_0 = \frac{2}{\pi}\int_0^{\pi} \pi - x\,dx \rightarrow a_0 = \frac{2}{\pi}\left[\pi x - \frac{x^2}{2}\right]_0^{\pi}$$

$$a_0 = \frac{2}{\pi}\left[\pi^2 - \frac{\pi^2}{2}\right] = 2\pi - \pi = \boxed{\pi}$$

$$A_n = \frac{2}{2\pi}\int_0^{\pi} 2(\pi - x)\cos(nwx)\,dx \rightarrow A_n = \frac{2}{\pi}\Big[\underbrace{\pi\int_0^{\pi}\cos(nwx)\,dx}_{A} - \underbrace{\int_0^{\pi} x\cos(nwx)\,dx}_{B}\Big]$$

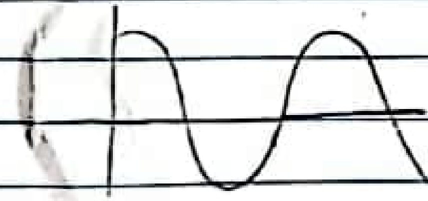
Por partes

$$A = \left[\frac{\pi\,\text{sen}(nwx)}{nw}\right]_0^{\pi} = \boxed{0} \qquad B = \frac{\text{sen}(nwx)}{nw}x - \int_0^{\pi}(1)\frac{\text{sen}(nwx)}{nw}\,dx$$

$$B = \left[\frac{\text{sen}(nwx)x}{nw} - \left(-\frac{\cos(nwx)}{(nw)^2}\right)\right]_0^{\pi} \qquad B = \frac{(-1)^n - 1}{n^2} \qquad A_n = \frac{-2(-1)^n + 2}{\pi n}$$

$$\boxed{f(x) = \frac{\pi}{2} + \sum_{n=1}^{\infty}\left(\frac{-2(-1)^n + 2}{\pi n^2}\right)\cos(wnt)}$$

* Onda sinusoidal $x(t) = A\cos(w_0 t + \phi)$



$$x(t) = A(\cos w_0 t \cos\phi - \text{sen}\, w_0 t\, \text{sen}\,\phi)$$

$$x(t) = A\cos\phi\left[\frac{e^{jw_0t}+e^{-jw_0t}}{2}\right] - A\,\text{sen}\,\phi\left[\frac{e^{jw_0t}-e^{-jw_0t}}{2j}\right]$$

$$x(t) = \sum_{n}^{\infty} A_n e^{jnw_0t}$$

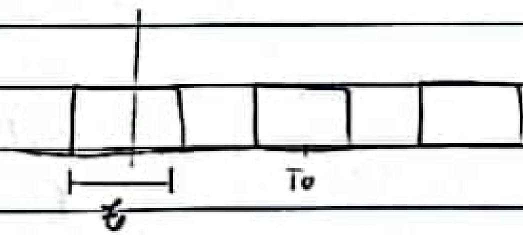
$$x(t) = \left(A\cos\phi - \frac{A}{j}\text{sen}\,\phi\right)/2 \cdot e^{jw_0t} + \left(A\cos\phi + \frac{A}{j}\text{sen}\,\phi\right)/2\, e^{-jw_0t}$$

$$= \frac{A}{2}e^{j\phi}\cdot e^{jw_0t} + \frac{A}{2}e^{-j\phi}e^{-jw_0t}$$

Coeficientes de Fourier: $a_1 = \frac{A}{2}e^{j\phi}$; $a_{-1} = \frac{A}{2}e^{-j\phi}$

② Calcule la Potencia de las señales anteriores en función de los parámetros que las definen, y cómo estimarla a partir del teorema de Parseval y los coeficientes de la serie.

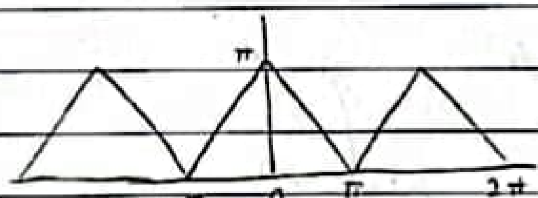
* Señal Cuadrada y rectangular $P=\frac{1}{T_0}\int_0^{T_0}|x(t)|^2dt$



$$P=\frac{1}{T_0}\int_{-\frac{\tau}{2}}^{\frac{\tau}{2}}A^2dt \rightarrow P=\frac{A^2}{T_0}\int_{-\frac{\tau}{2}}^{\frac{\tau}{2}}dt$$

$$P=\frac{A^2}{T_0}\left(\frac{\tau}{2}+\frac{\tau}{2}\right) \rightarrow \boxed{P=\frac{A^2\tau}{T_0}}$$

* Señal Triangular



$$f(x)=\begin{cases}\pi+x & -\pi<x\leq 0\\ \pi-x & 0<x\leq\pi\end{cases}$$

$T=2\pi$

$$P=\frac{1}{T_0}\int_0^{T}|x(t)|^2dt$$

$$P=\frac{1}{2\pi}\int_{-\pi}^{0}\pi+t\,dt+\frac{1}{2\pi}\int_0^{\pi}\pi-t\,dt \qquad P=\frac{1}{2\pi}\int_0^{\pi}2(\pi-t)dt \qquad P=\frac{1}{2\pi}\int_0^{\pi}(2\pi-2t)dt$$

$$P=\frac{1}{2\pi}\left(\int_0^{\pi}2\pi dt-\int_0^{\pi}2t\,dt\right) \qquad P=\frac{1}{2\pi}\left(2\pi t\Big|_0^{\pi}-\cancel{2}\cdot\frac{t^2}{\cancel{2}}\Big|_0^{\pi}\right)$$

$$P=\frac{1}{2\pi}\left(2\pi(\pi-0)-(\pi^2-0^2)\right) \qquad P=\frac{1}{2\pi}(2\pi^2-\pi^2) \qquad \boxed{P=\frac{\pi}{2}}$$

* Señal sinusoidal $x(t) = A\cos w_0 t$

$$P = \frac{1}{T_0}\int_0^{T_0} A^2\cos^2 w_0 t\, dt \qquad C.V \rightarrow u = w_0 t \quad u \rightarrow 0 \quad dt = \frac{1}{w_0}du \quad w_0 = \frac{2\pi}{T_0}$$

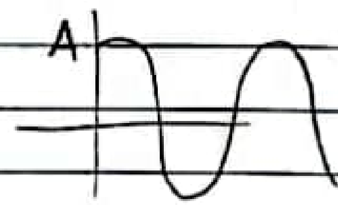
$$du = w_0\,dt \quad u \rightarrow w_0 T_0$$

$$P = \frac{A^2}{T_0}\int_0^{w_0T_0}\frac{1}{w_0}\cos^2 u\,du \rightarrow P = \frac{A^2}{T_0}\int_0^{2\pi}\frac{T_0}{2\pi}\cos^2 u\,du \rightarrow P = \frac{A^2}{\cancel{T_0}}\cdot\frac{\cancel{T_0}}{2\pi}\int_0^{2\pi}\cos^2 u\,du$$

$$P = \frac{A^2}{2\pi}\left[\left(\frac{1}{2}u + \frac{sen(2u)}{4}\right)\Big|_0^{2\pi}\right]$$

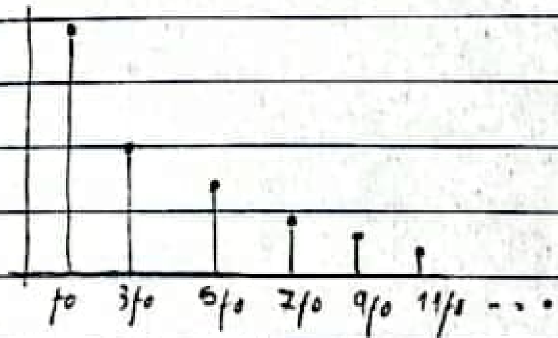
$$P = \frac{A^2}{2\pi}\left[\frac{2\pi}{2} + \overset{0}{\cancel{\frac{sen(4\pi)}{4}}} - \overset{0}{\cancel{\frac{0}{2}}} - \overset{0}{\cancel{\frac{sen(0)}{4}}}\right]$$

$$P = \frac{A^2\cancel{\pi}}{2\cancel{\pi}} \qquad \boxed{P = \frac{A^2}{2}}$$

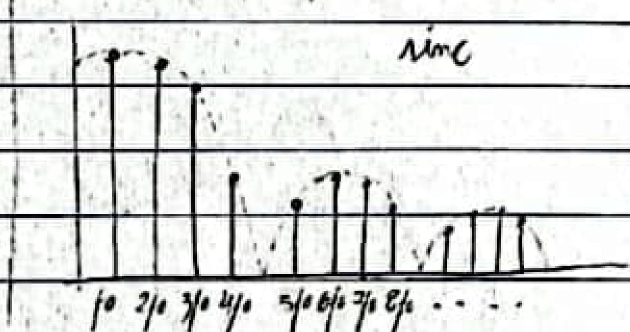


③ Realice el espectro unilateral (solo parte positiva) de la representación en Serie de Fourier de las señales anteriores.

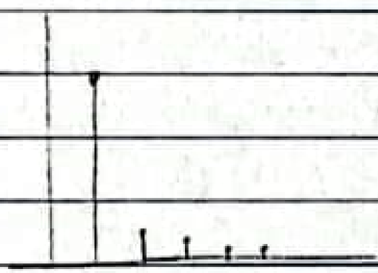
* Onda Cuadrada



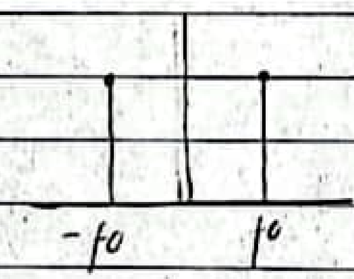
* Onda rectangular



* Onda Triangular

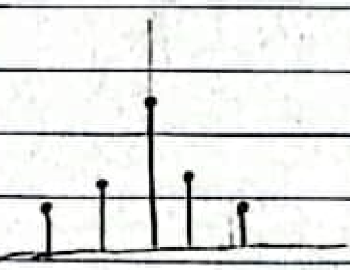


* Onda Senoidal (coseno)



④ Investigue las bandas de servicios comerciales, como radio FM, TV Abierta, TV Digital Abierta, Banda celulares. También la forma espectral esperada de cada una de estos tecnologías

* La banda de FM generalmente usa las frecuencias de los 87,5 MHz hasta los 108 MHz



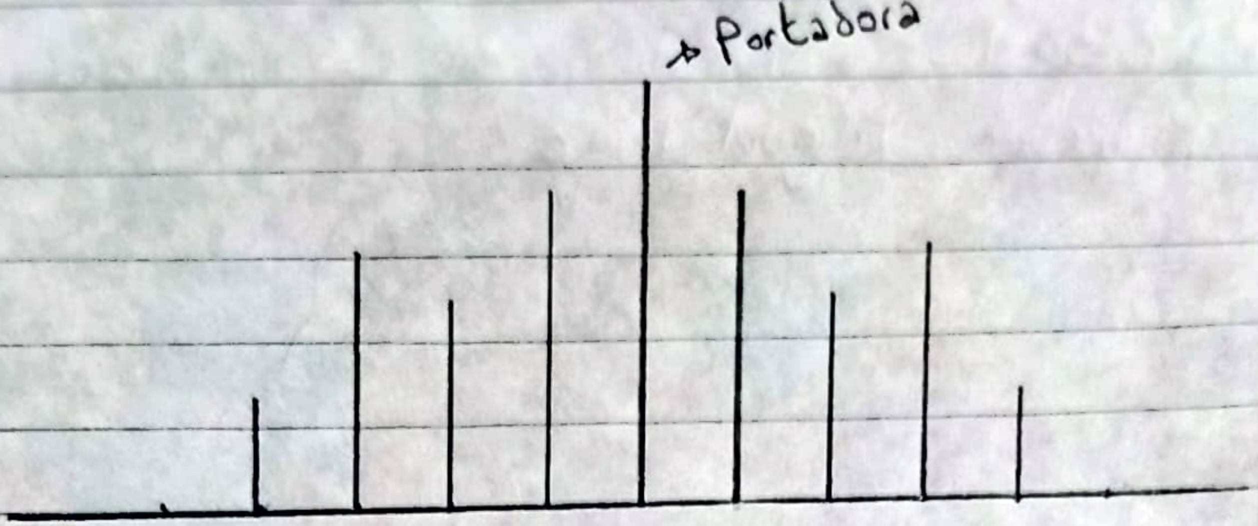
* La TV abierta usa frecuencia desde 59,75 MHz hasta 215,75 MHz (América)

* La TV digital abierta en Venezuela usa frecuencia desde 521 MHz hasta 539 MHz

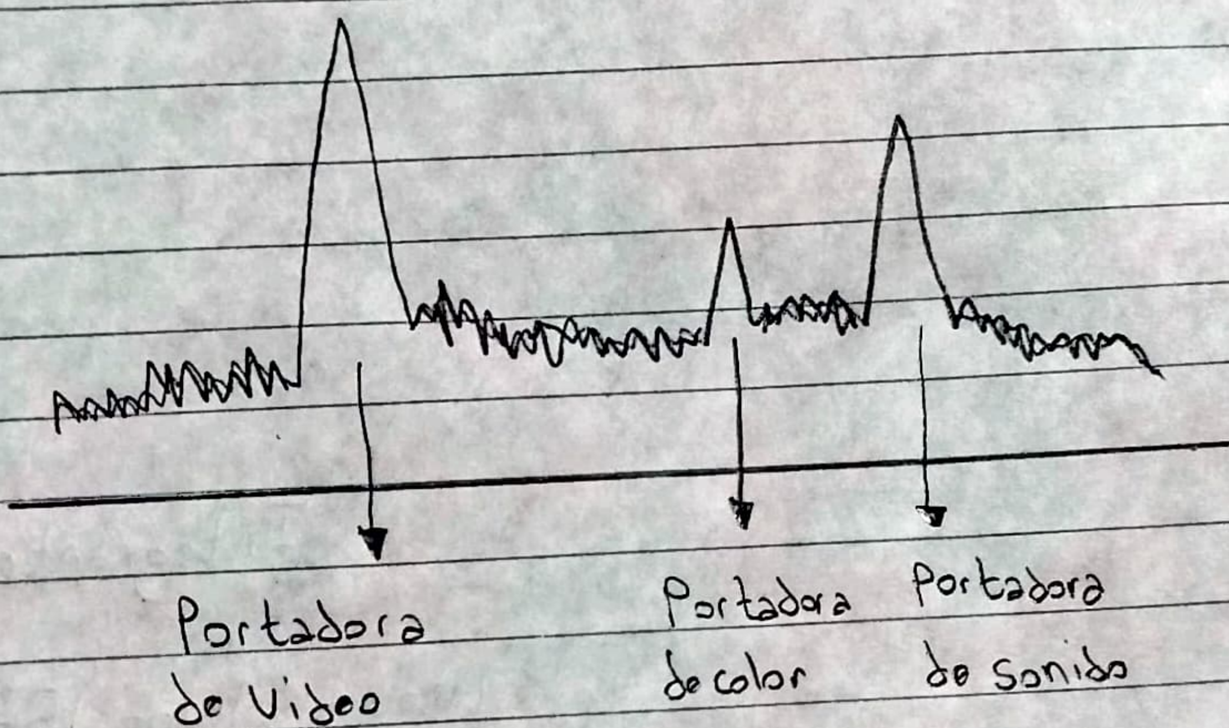
* Banda celulares o GSM. En Venezuela se usa GSM-850 y GSM-900/1800

GSM	Subida (MHz)	Bajada (MHz)
850	924 - 849	869 - 894
900	890 - 915	935 - 960
1800	1710 - 1785	1805 - 1880

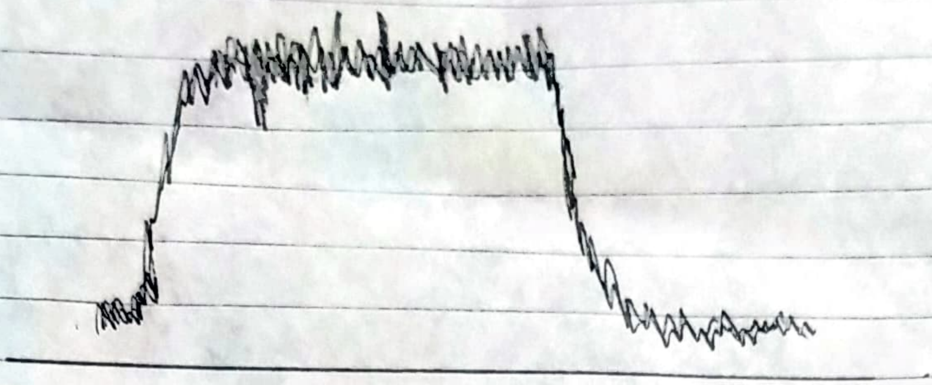
Forma espectral Radio FM



Forma espectral TV Abierta



* Forma espectral Tv Digital Abierta



* Forma espectral Bandas celulares