E1214 Fundamentos de las Comunicaciones
E0311 Comunicaciones
E0214 Comunicaciones

Curso 2023

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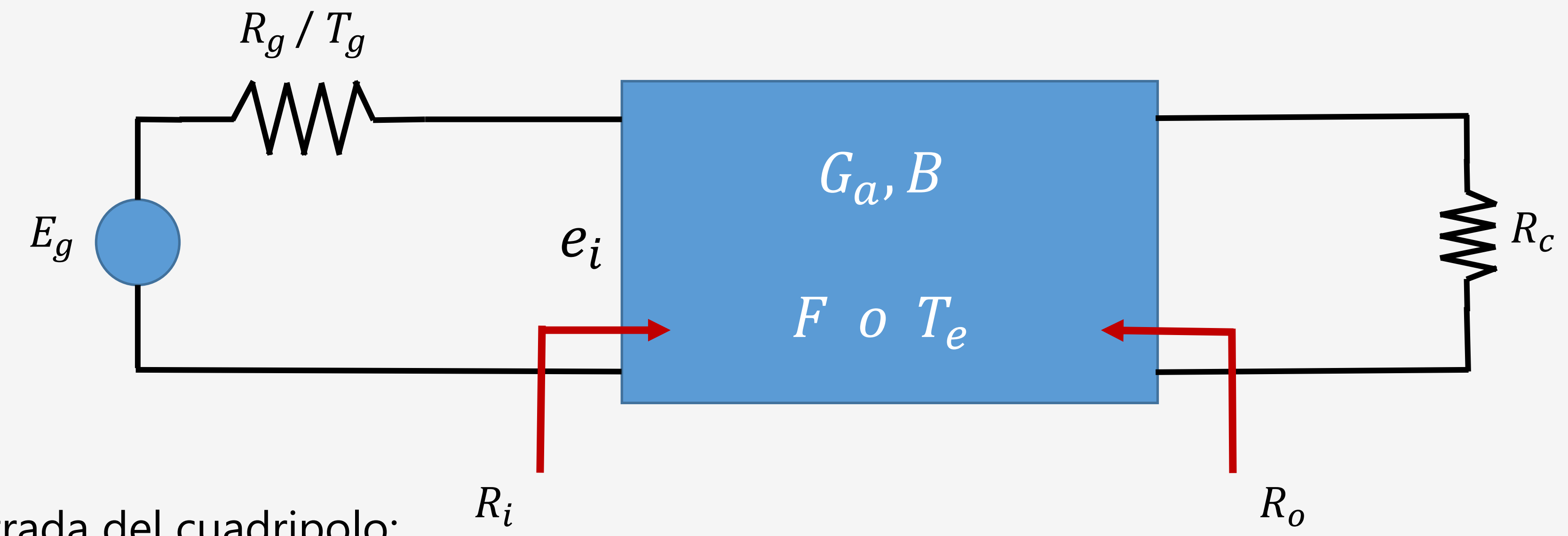
Temas a tratar

- Ruido en cuadripolos
- Cifra de ruido, Temperatura equivalente.
- Fórmula de Friis.
- Ejemplo

La Pcia. de Buenos Aires, el Rio de La Plata y Uruguay desde la ISS

Ruido en cuadripolos



A la entrada del cuadripolo:

$$S_i = \frac{e_i^2}{R_i} = E_g^2 \frac{R_i}{\left(R_g + R_i\right)^2}$$

$$S_i = \frac{E_g^2}{4R_g} \frac{4R_g R_i}{\left(R_g + R_i\right)^2} = S_{a_i} D_i$$

$$N_i = N_{a_i} D_i = k\,T_g\,B\,D_i$$

$$SNR_i = \frac{S_i}{N_i} = \frac{S_{a_i}}{k\,T_g\,B}$$

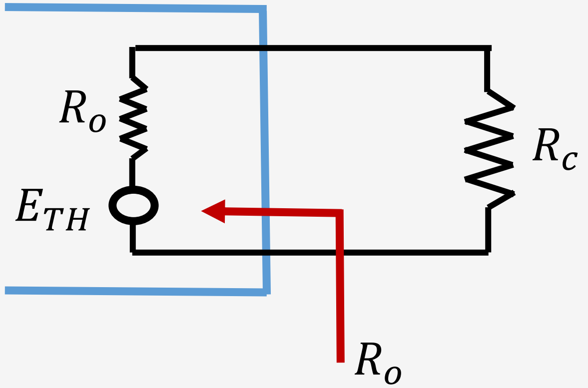
$$SNR_i = \frac{S_i}{N_i} = \frac{\overline{E_g^2}}{4\,R_g k\,T_g\,B}$$

D_i: factor de desadaptación a la entrada ($0 < D_i \leq 1$)

Ruido en cuadripolos

A la salida del cuadripolo:

D_o: factor de desadaptación a la salida $(0 < D_o \leq 1)$



$$S_o = \frac{\overline{E_{TH}^2}}{4\,R_o}\frac{4R_oR_c}{(R_o+R_c)^2} = S_{a_o}\,D_o$$

$$S_o = S_{a_i}\,G_a\,D_o = \frac{S_i}{D_i}\,G_a\,D_o$$

$$N_o = \left(\frac{N_i}{D_i}\,G_a + N_{interno}\right)D_o$$

$$\boxed{SNR_o = \frac{S_o}{N_o} = \frac{\frac{S_i}{D_i}G_a}{\frac{N_i}{D_i}\,G_a + N_{interno}}}$$

Noise Figure

$$F \triangleq \frac{SNR_i}{SNR_o}\Bigg|_{\text{Alguna condición}} \geq 1$$

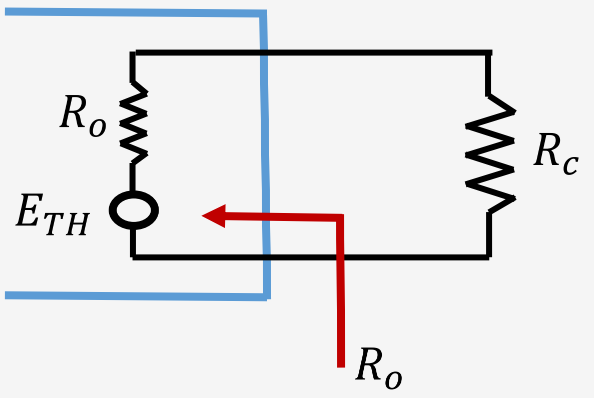
$$F = \frac{S_i}{N_i}\frac{\left(\frac{N_i}{D_i}\,G_a + N_{interno}\right)}{\frac{S_i}{D_i}G_a}\Bigg|_{\text{Alguna condición}} = 1 + \frac{N_{interno}}{N_{a_i}\,G_a}\Bigg|_{\text{Alguna condición}}$$

$$\boxed{F???? = 1 + \frac{N_{interno}}{k\,T_g\,B\,G_a}}$$

Ruido en cuadripolos

A la salida del cuadripolo:

D_o: factor de desadaptación a la salida $(0 < D_o \leq 1)$



$$S_o = \frac{\overline{E_{TH}^2}}{4\,R_o}\frac{4R_oR_c}{(R_o+R_c)^2} = S_{a_o}\,D_o$$

$$S_o = S_{a_i}\,G_a\,D_o = \frac{S_i}{D_i}\,G_a\,D_o$$

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$$\boxed{SNR_o = \frac{S_o}{N_o} = \frac{\frac{S_i}{D_i}G_a}{\frac{N_i}{D_i}\,G_a + N_{interno}}}$$

Noise Figure

$$F \triangleq \left.\frac{SNR_i}{SNR_o}\right|_{\substack{@\,T_g = T_0 \\ @\,B}} \geq 1$$

$$F = \left.\frac{S_i}{N_i}\frac{\left(\frac{N_i}{D_i}\,G_a + N_{interno}\right)}{\frac{S_i}{D_i}G_a}\right|_{\substack{@\,T_g = T_0 \\ @\,B}} = 1 + \left.\frac{N_{interno}}{N_{a_i}\,G_a}\right|_{\substack{@\,T_g = T_0 \\ @\,B}}$$

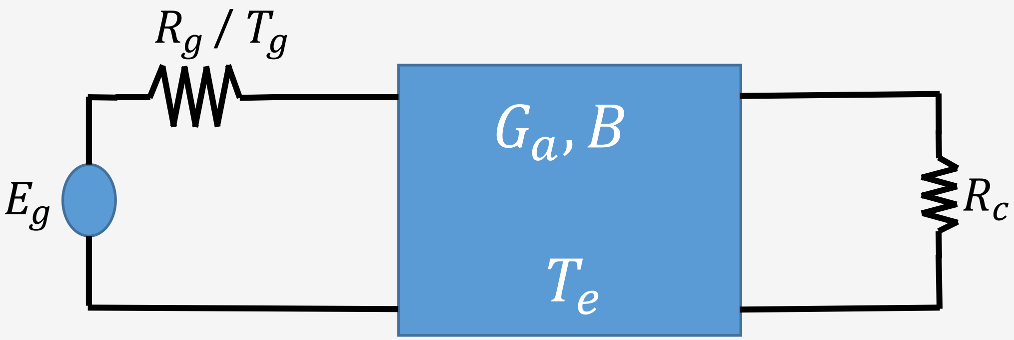
$$\boxed{F = 1 + \frac{N_{interno}}{k\,T_0\,B\,G_a}}$$

Ruido en cuadripolos

$$\boxed{F = 1 + \frac{N_{interno}}{k\ T_0\ B\ G_a}}$$

$$F = \frac{k\ T_0\ B\ G_a + k\ T_e\ B\ G_a}{k\ T_0\ B\ G_a} \longrightarrow \boxed{F = 1 + \frac{T_e}{T_0}}$$

$$\boxed{T_e = (F - 1)\ T_0}$$



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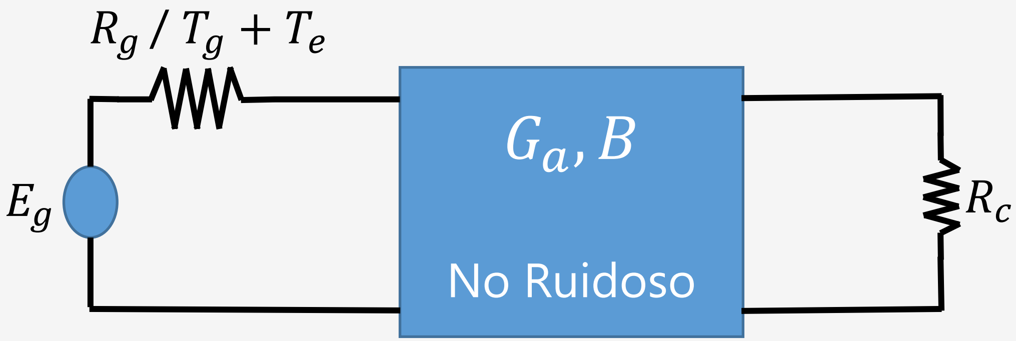
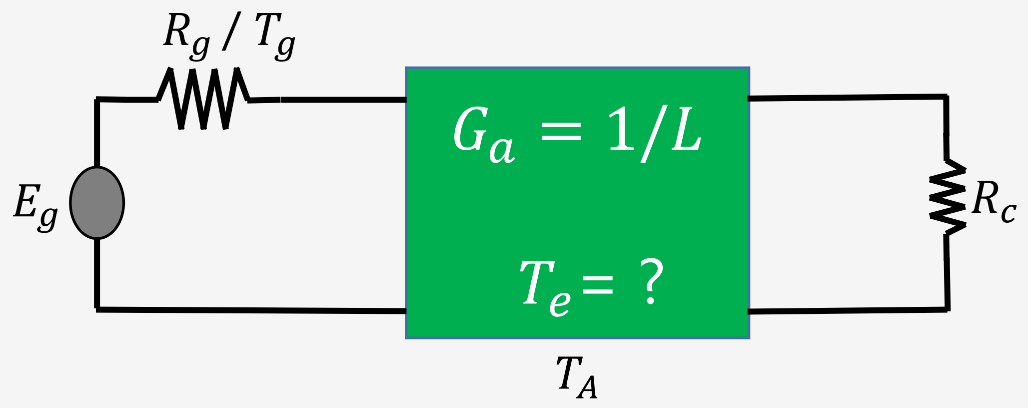


Atenuador Pasivo



L: atenuación

$$N_{a_i} = k\, T_g\, B = \frac{N_i}{D_i}$$

$$N_{a_o} = k\left(T_g + T_e\right) B\, G_a$$

Si consideramos $T_g = T_A$

$$N_{a_o} = k\, T_A\, B$$

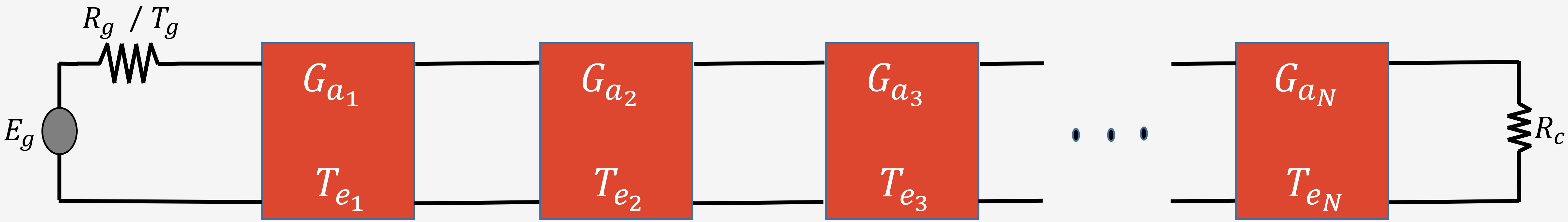
$$k\,(T_A + T_e)\, B\, G_a = k\, T_A\, B \longrightarrow \boxed{T_e = (L-1)T_A}$$

$$\boxed{F = 1 + \frac{(L-1)\, T_A}{T_0}}$$

Si $T_A = T_0 = 290\mathrm{K}$

$$\boxed{F = L}$$

Cuadripolos en cascada. Fórmula de Friis.



A la salida del primer cuadripolo: $N_{a_1} = k(T_g + T_{e_1})B\ G_{a_1} = k\ (T_g + T_{e_1})G_{a_1}\ B$

A la salida del segundo cuadripolo: $N_{a_2} = k\left((T_g + T_{e_1})G_{a_1} + T_{e_2}\right)B\ G_{a_2} = k\ \left(T_g + T_{e_1} + \frac{T_{e_2}}{G_{a_1}}\right)G_{a_1}G_{a_2}\ B$

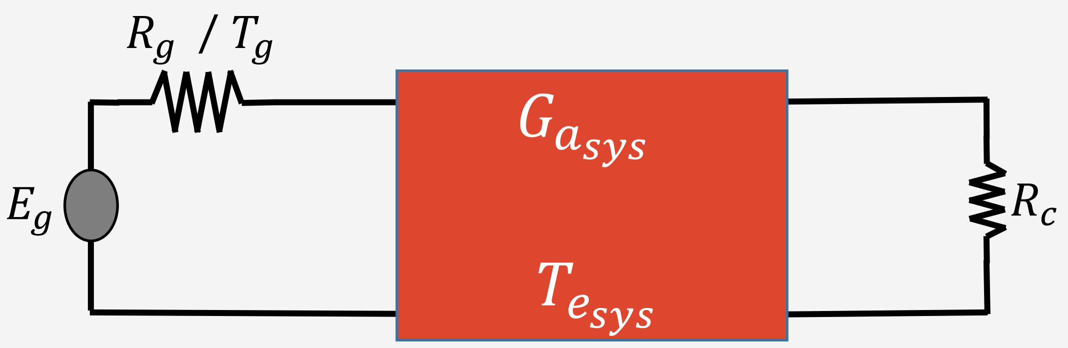
Generalizando: $N_{a_N} = k\left(T_g + T_{e_1} + \frac{T_{e_2}}{G_{a_1}} + \frac{T_{e_3}}{G_{a_1}G_{a_2}} + \cdots + \frac{T_{e_N}}{G_{a_1}G_{a_2}G_{a_3}\ldots G_{a_{N-1}}}\right)B\ G_{a_1}G_{a_2}G_{a_3}\ldots G_{a_N}$

$\boxed{T_{e_T} = T_g + T_{e_{sys}}}$

$\boxed{T_{e_{sys}} = T_{e_1} + \frac{T_{e_2}}{G_{a_1}} + \frac{T_{e_3}}{G_{a_1}G_{a_2}} + \cdots + \frac{T_{e_N}}{G_{a_1}G_{a_2}G_{a_3}\ldots G_{a_{N-1}}}}$

$\boxed{G_{a_{sys}} = G_{a_1}G_{a_2}G_{a_3}\ldots G_{a_N}}$

Cuadripolos en cascada. Fórmula de Friis.



$\equiv$

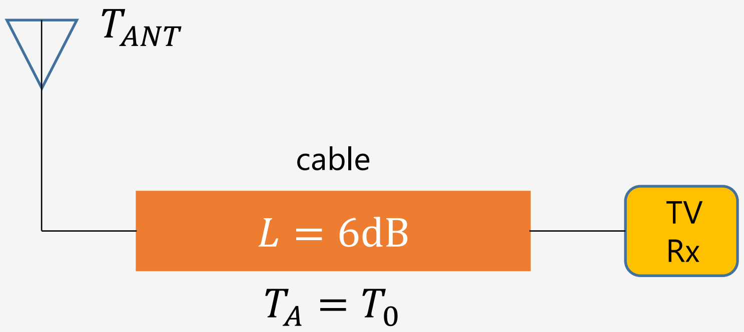
$$T_{e\,sys} = T_{e_1} + \frac{T_{e_2}}{G_{a_1}} + \frac{T_{e_3}}{G_{a_1} G_{a_2}} + \cdots + \frac{T_{e_N}}{G_{a_1} G_{a_2} G_{a_3} \ldots G_{a_{N-1}}}$$

$$T_{e_T} = T_g + T_{e\,sys}$$

$$F_{sys} = 1 + \frac{T_{e_{sys}}}{T_0}$$

$$\boxed{F_{sys} = F_1 + \frac{F_2 - 1}{G_{a_1}} + \frac{F_3 - 1}{G_{a_1} G_{a_2}} + \cdots + \frac{F_N - 1}{G_{a_1} G_{a_2} G_{a_3} \ldots G_{a_{N-1}}}}$$

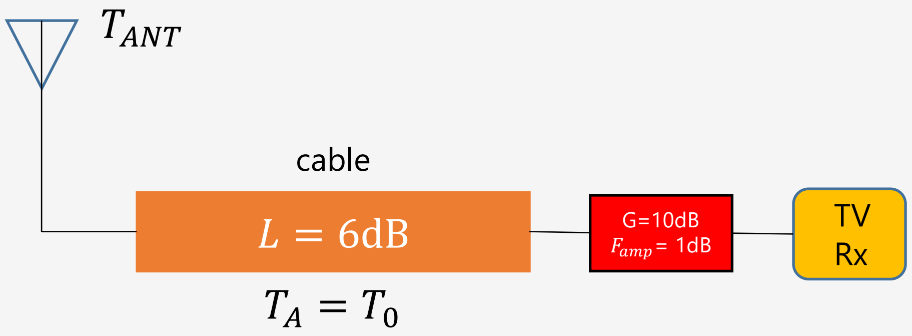
Ejemplo



6dB ≅ 4 veces

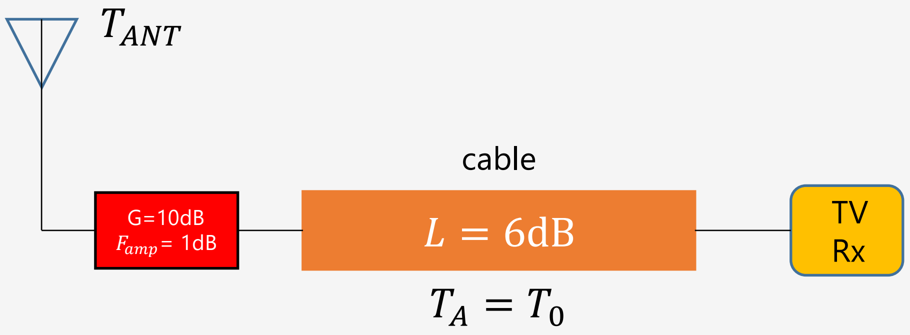
1dB ≅ 1,258 veces

10dB =10 veces



$$F_{cable-amp} = F_{cable} + \frac{F_{amp} - 1}{G_{cable}}$$

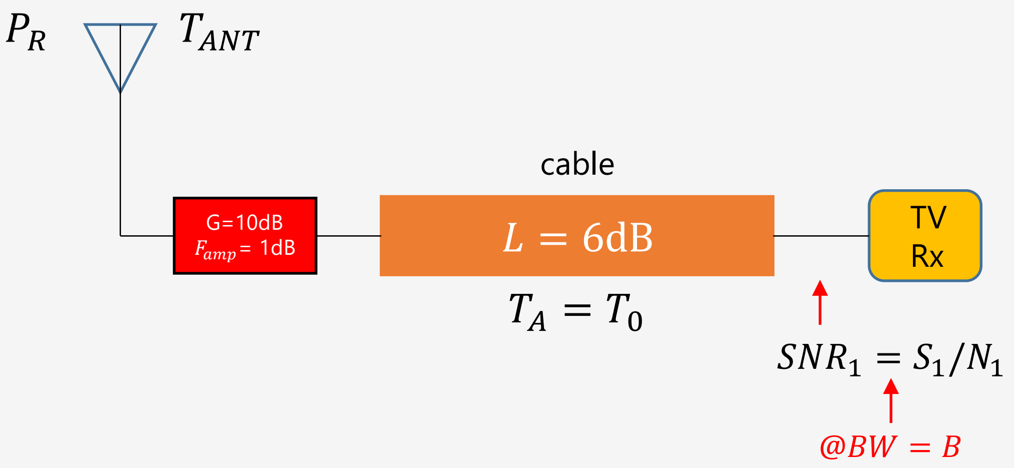
$$F_{cable-amp} = 4 + 0{,}258\,.\,4 = 5{,}032 \cong 7\text{dB}$$



$$F_{amp-cable} = F_{amp} + \frac{F_{cable} - 1}{G_{amp}}$$

$$F_{amp-cable} = 1{,}258 + \frac{3}{10} = 1{,}558 \cong 1{,}92\text{dB}$$

Ejemplo



$$T_{e_T} = T_{ANT} + T_{sys}$$

$$T_{e_T} = T_{ANT} + T_{e_{amp}} + \frac{T_{e_{cable}}}{G}$$

$$SNR_1 = \frac{P_R}{k\, T_{e_T}\, B}$$

$@BW = B$

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Características	**Radiotelescopio Carlos Varsavsky**
Diametro [mts]	30
Ancho de haz 3dB [°]	0.5
Montura	Ecuatorial
Frecuencia central [MHz]	1400
Ancho de banda de RF [MHz]	300
Polarización	1
Temperatura de receptor [K]	~110
Ancho de banda Instantáneo de adquisición, máximo [MHz]	112

www.iar.unlp.edu.ar

Fuentes:

- Principles of Communications, 5/E by Rodger Ziemer and William Tranter, John Wiley & Sons. Inc.
- Probability, random variables, and stochastic processes (McGraw-Hill series in electrical engineering). Athanasios Papoulis.
- IAR www.iar.unlp.edu.ar

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