# Blocs Fonctionnels pour les Mobiles

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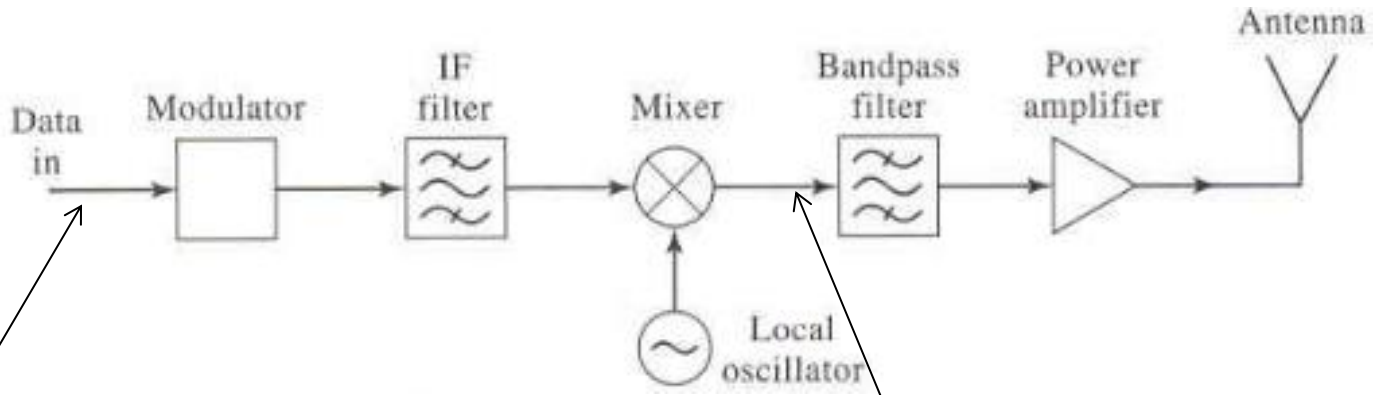
# Emetteur Basic

Données | Modulation | Upconversion | Amplification | Emission

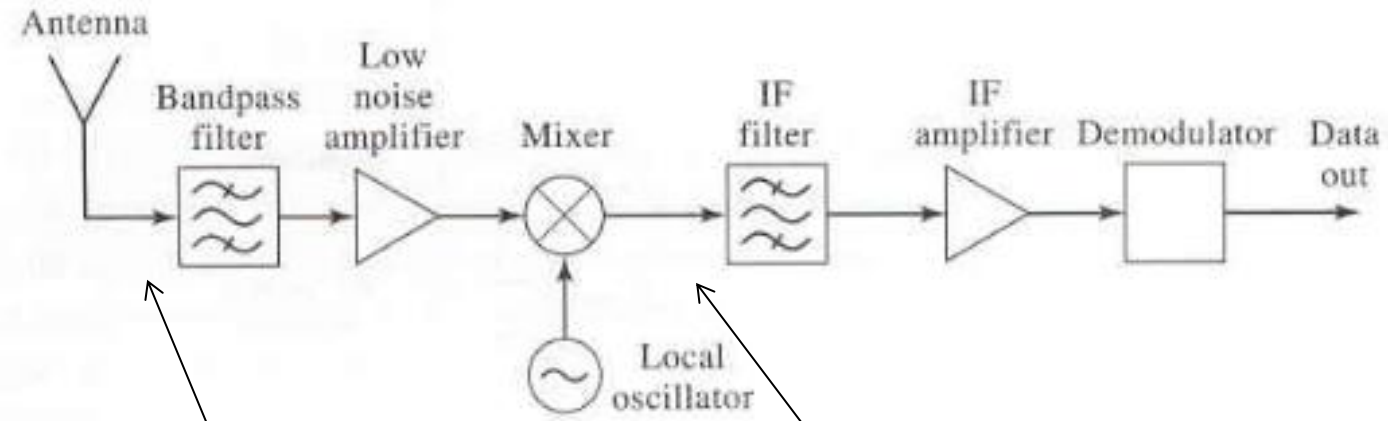



Bande de base
10-100 MHz

Fréquence de transmission
800 - 1900 MHz

# Récepteur Basic

Données | Réception | Amplification | Downconvertion | Démodulation

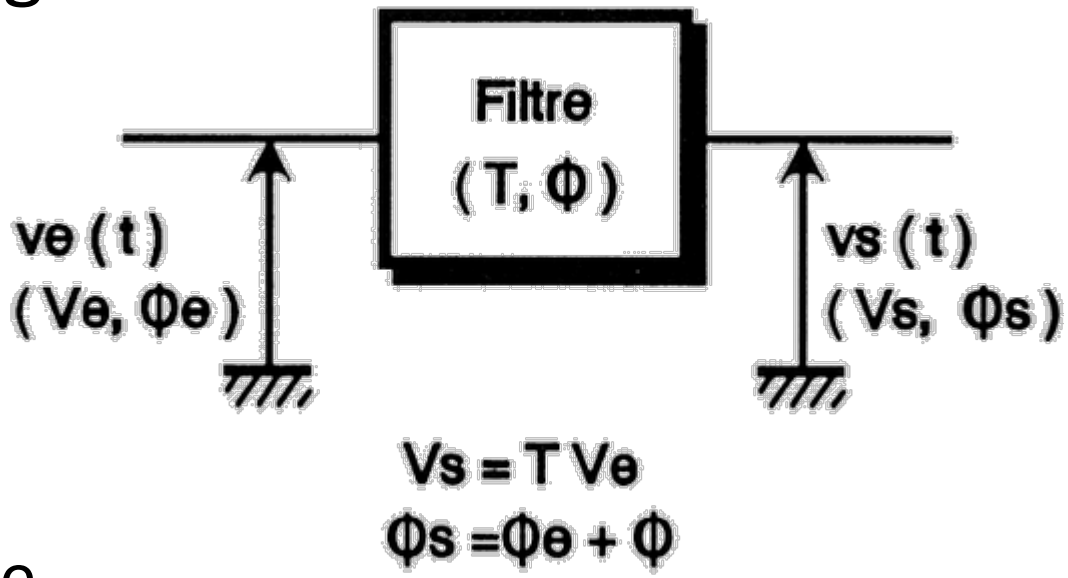



Fréquence de réception
800 - 1900 MHz

Bande de base
10-100 MHz

# Filtres analogiques

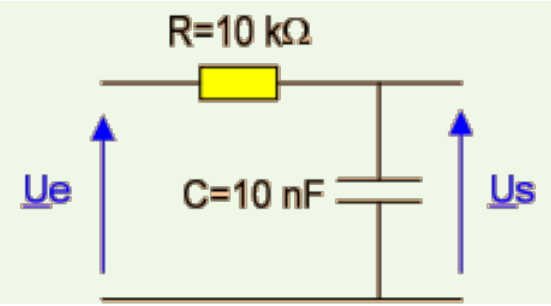
- Atténuation du signal!!
  - Amplitude
  - Phase
- Type de filtres:
  - filtre passe-haut
  - filtre passe-bas
  - filtre passe-bande
  - filtre réjecteur de bande
  - Filtre passe-tout
- Filtres actives ou passives



# Filtres analogiques

- Filtres passe-bas
  - passif

$$T(\omega) = \left|\frac{1}{1+jRC\omega}\right| = \frac{|1|}{|1+jRC\omega|} = \frac{1}{\sqrt{1+(RC\omega)^2}}$$



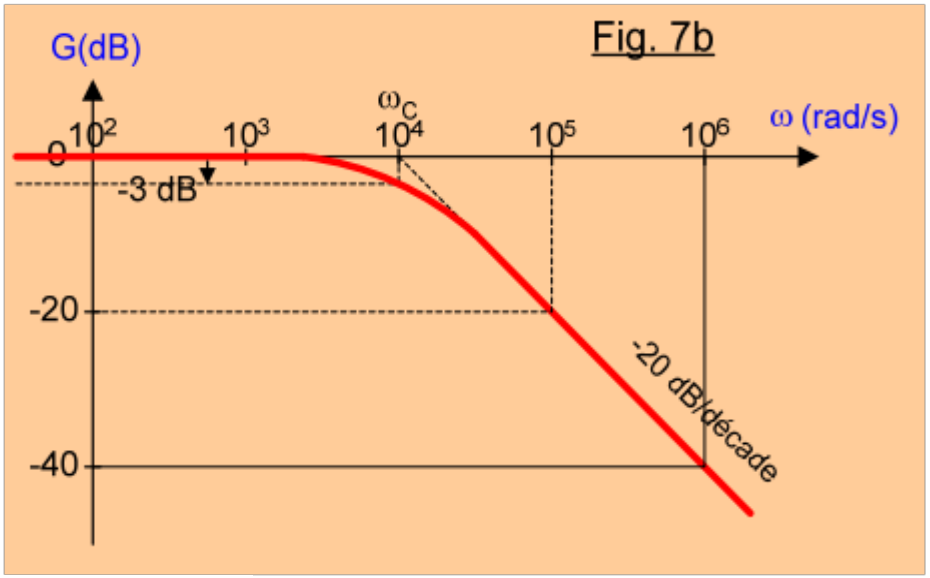

$$\underline{U_S} = \frac{\underline{Z_C}}{\underline{Z_R}+\underline{Z_C}}\underline{U_E} = \frac{\frac{1}{jC\omega}}{R+\frac{1}{jC\omega}}\underline{U_E} = \frac{1}{1+jRC\omega}\underline{U_E}$$

$$\underline{T}(\omega) = \frac{\underline{U_S}}{\underline{U_E}} = \frac{1}{1+jRC\omega}$$

Fonction de transfert normalisée

- Diagramme de Bode du gain

$$G(\omega) = 20\cdot\log_{10} T(\omega) = -20\cdot\log_{10}\left(\sqrt{1+(RC\omega)^2}\right)$$




$$f_C = \frac{1}{2\pi RC}$$

Fréquence de coupure

# Filtres analogiques

- Diagramme de Bode

$$P_{dB} = 10Log_{10}(P) \qquad H_{dB} = 20Log_{10}(H) = 20Log_{10}\left(\left|\frac{\overline{V_s}}{\overline{V_e}}\right|\right)$$

$$H_{dB} = 20Log(H) = 20Log\left(\frac{1}{\sqrt{1+x^2}}\right) = -20Log\left(\sqrt{1+x^2}\right)$$

$$\lim_{x>>1} H_{dB} = -20Log\left(\sqrt{x^2}\right) = -20Log(x)$$

$$\lim_{x<<1} H_{dB} = -20Log\left(\sqrt{1}\right)$$

$$\lim_{x=1} H_{dB} = -20\log\sqrt{2} = -3\text{dB}$$

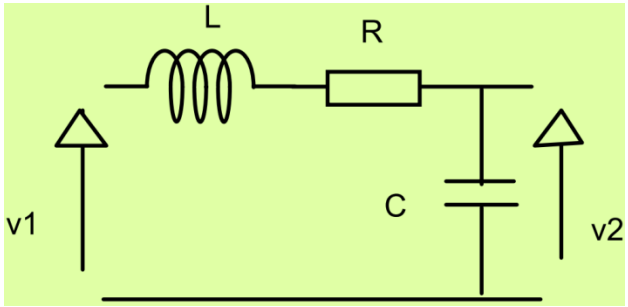
**Bande passante BP**

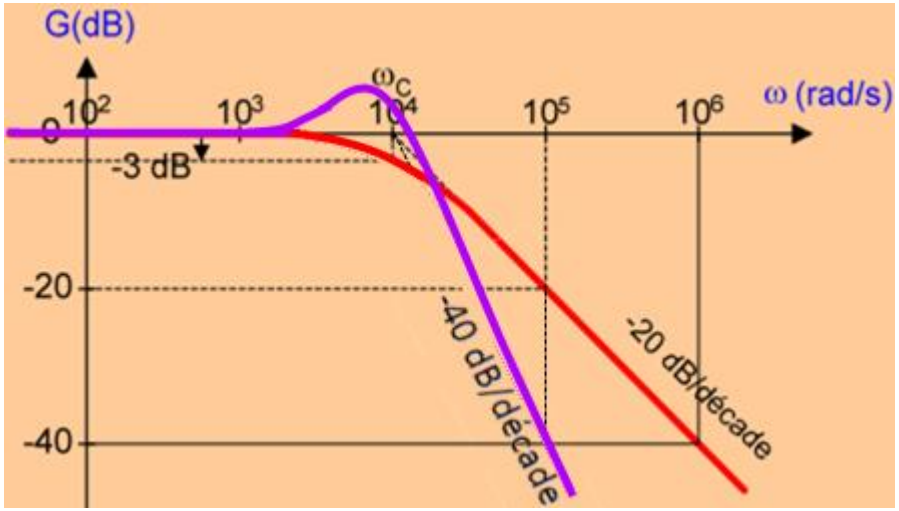
$$\frac{H_{\max}}{\sqrt{2}} \leq H \leq H_{\max}$$

**Fc=fréquence de coupure à 3dB**

# Filtres analogiques

- Filtres passe-bas 2º ordre
  - passif




$$\frac{v_2}{v_1} = \frac{\frac{1}{Cp}}{Lp + R + \frac{1}{Cp}} = \frac{1}{LCp^2 + RCp + 1}$$

$$H(\omega) = \frac{1}{1 - LC\omega^2 + jRC\omega}$$

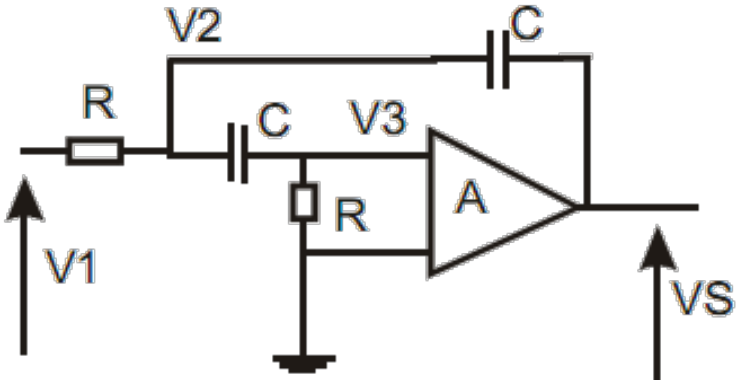
Fonction de transfert normalisée

$$f_c = \frac{1}{2\pi\sqrt{LC}}$$

Fréquence de coupure

# Filtres analogiques

- Filtres passe-bas 2º ordre
  - actif



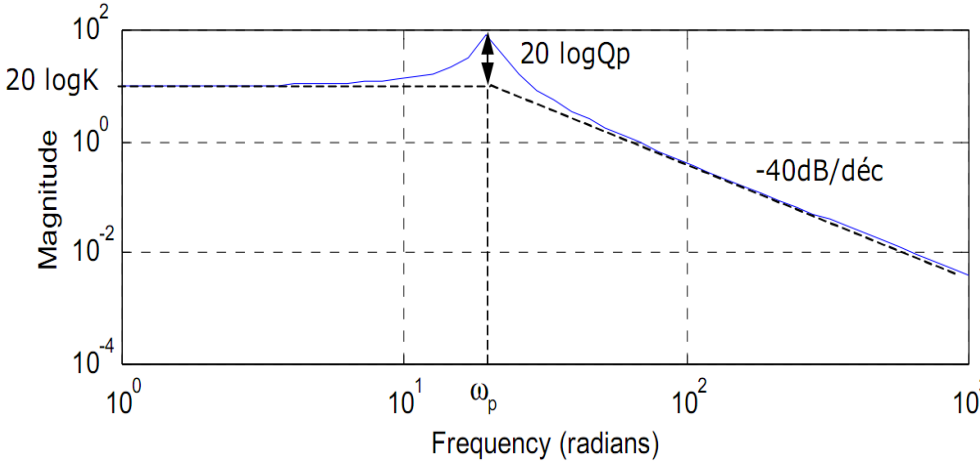

$$\frac{v_1 - v_2}{R} + (v_3 - v_2)Cp + (v_S - v_2)Cp = 0$$

$$(v_2 - v_3)Cp - \frac{v_3}{R} = 0$$

$$v_S = -Av_3 \qquad \text{Y=1/R}$$

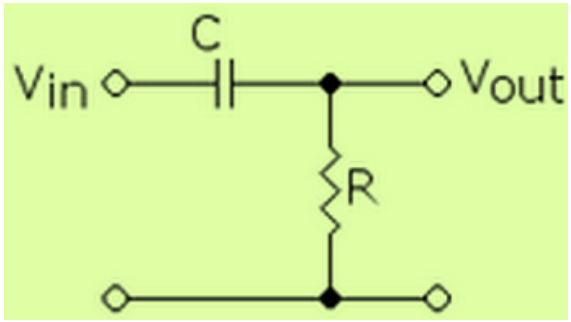
$$\frac{v_S}{v_1} = \frac{-AYCp}{Y^3 + 3YCp + (1+A)C^2p^2}$$

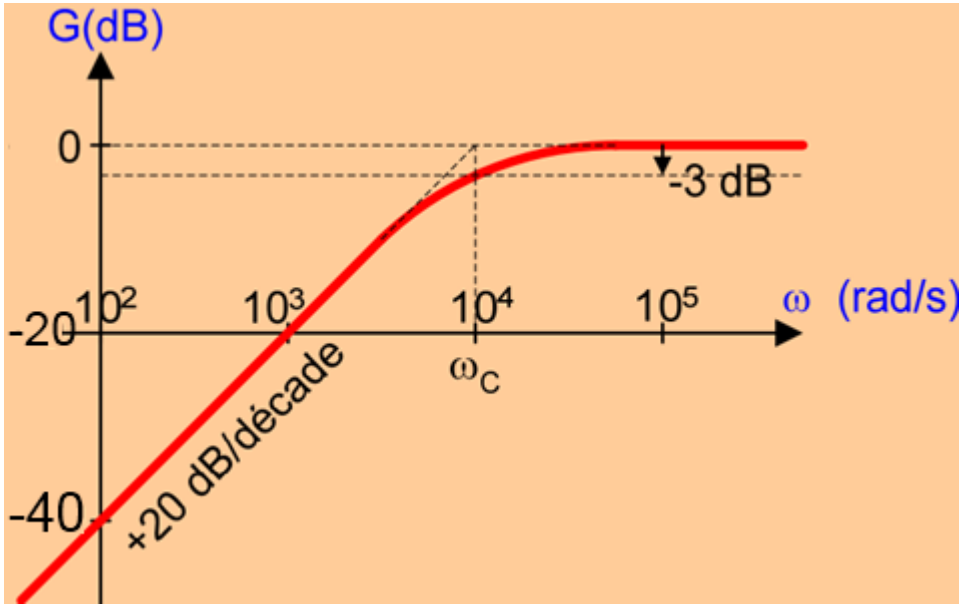
$$Q = \frac{\sqrt{1+A}}{3}$$



# Filtres analogiques

- Filtres passe-haut
  - passif




$$H(j\omega) = \frac{v_o}{v_i} = \frac{jRC\omega}{1 + jRC\omega}$$

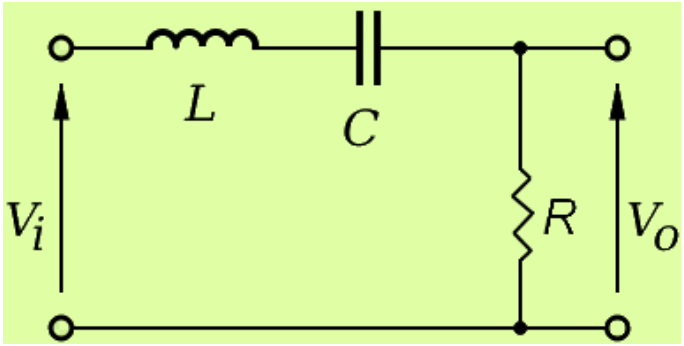
Fonction de transfert normalisée

$$f_C = \frac{1}{2\pi RC}$$

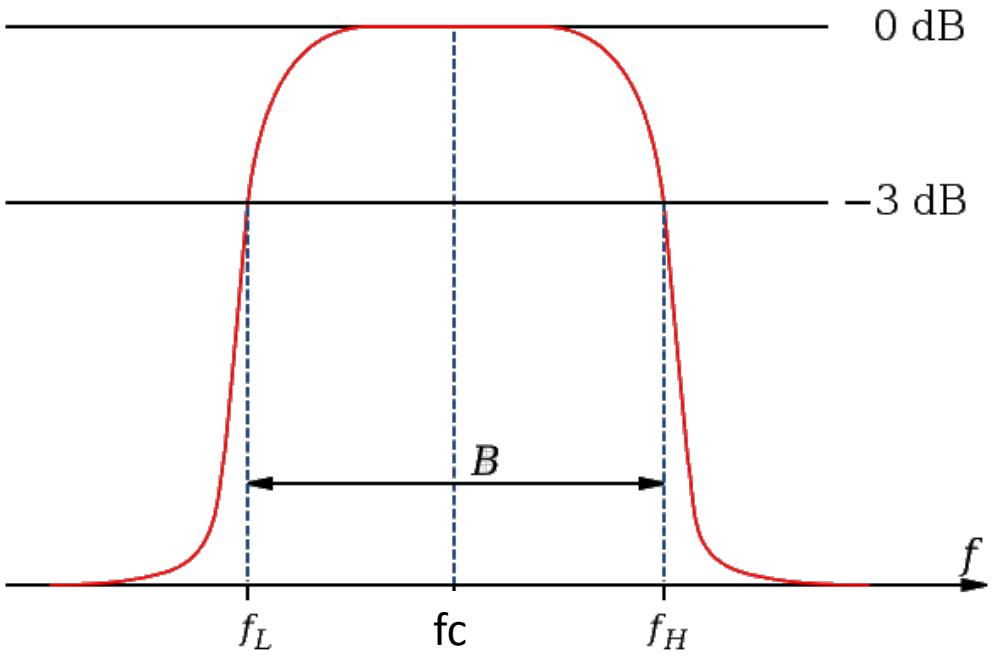
Fréquence de coupure

# Filtres analogiques

- Filtres passe-bande
  - passif




$$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$




$$h(j\omega) = \frac{1}{1 + jQ\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)}$$

Fonction de transfert normalisée

$$f_c = \frac{1}{2\pi\sqrt{LC}}$$

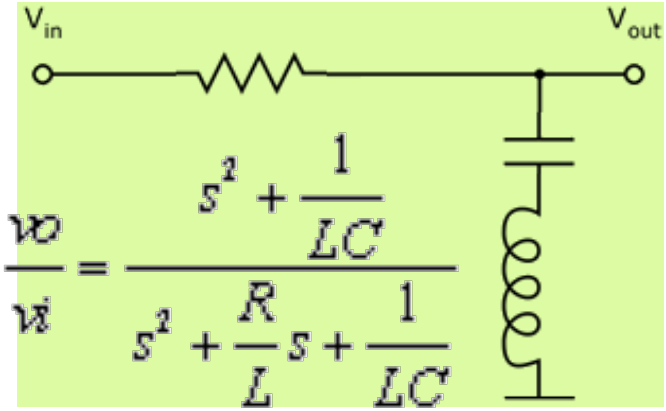
Fréquence de coupure

$$BW = \frac{f_{cH} - f_{cL}}{f_c}$$

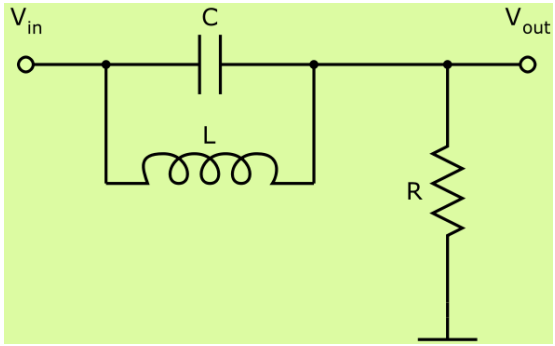
Bande passante

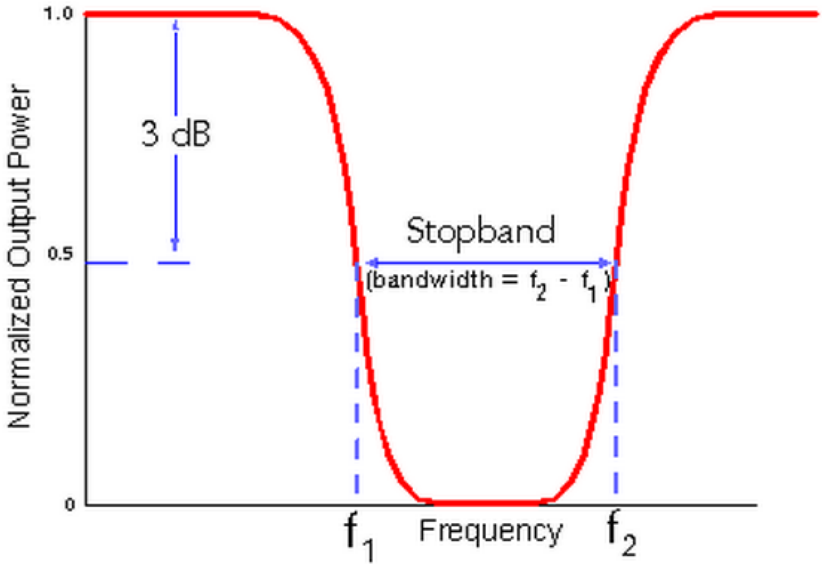
# Filtres analogiques

- Filtres coupe-bande
  - passif




Fonction de transfert normalisée




$$f_c = \frac{1}{2\pi\sqrt{LC}}$$

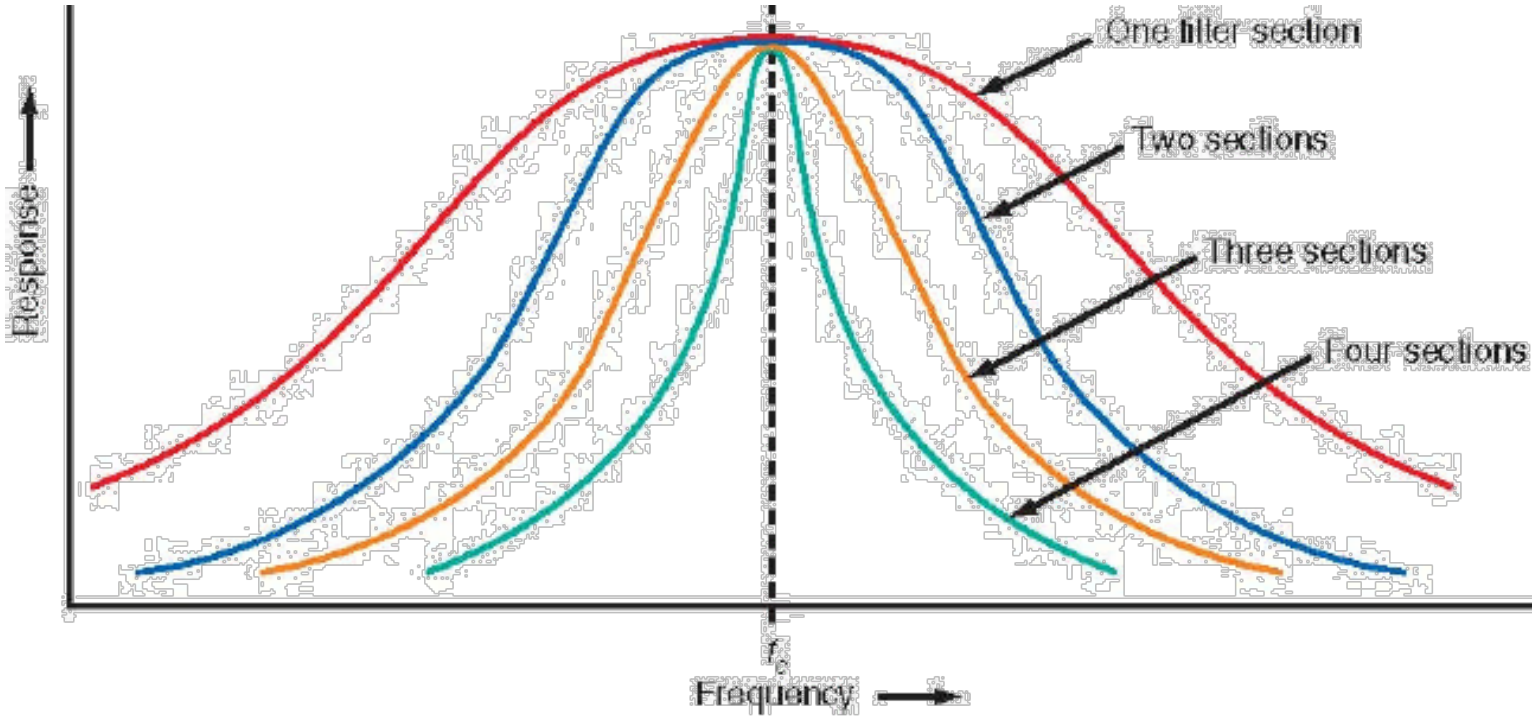
Fréquence de coupure

$$BW = \frac{f_{cH} - f_{cL}}{f_c}$$

Bande rejeté

# Filtres analogiques

- Ordre du filtre



# Filtres

- Types de filtre
  - **Filtre éléments discrets**
  - **Filtre piézoélectrique**
  - **Filtre céramique**
  - **Filtre cavité**
  - **Filtre microruban…**

# Filtre piézoélectrique

## Contexte

**Dual Band 900 MHz / 1.8 GHz**

*Hétérogénéité = challenges*

**Co-Intégration ICs, passifs et RFMEMS**

**Partitionnement & co-design HW/SW**

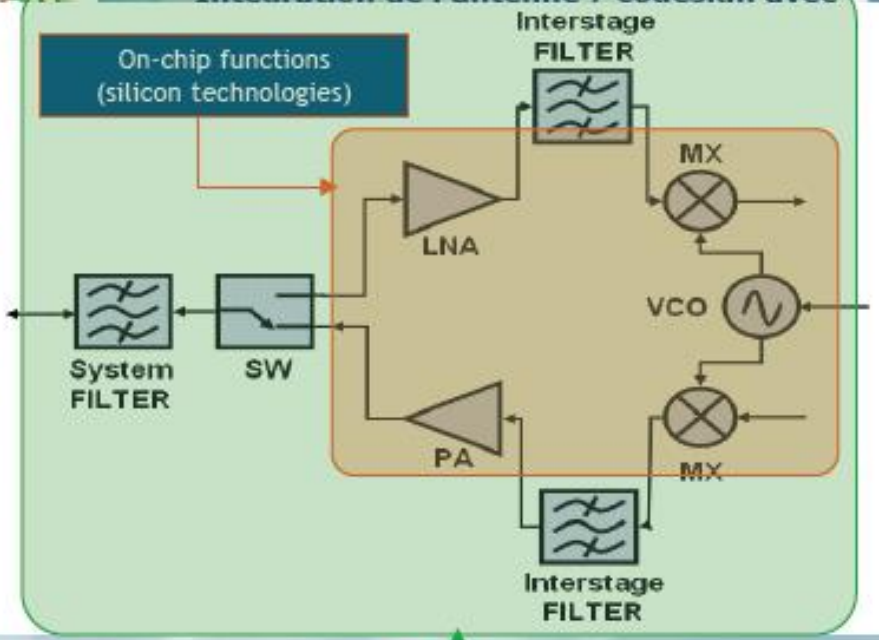
**Intégration de l'antenne / codesign avec**

*280 composants discrets passifs pour 15 ICs.*

*80% des composants sont passifs !*

+

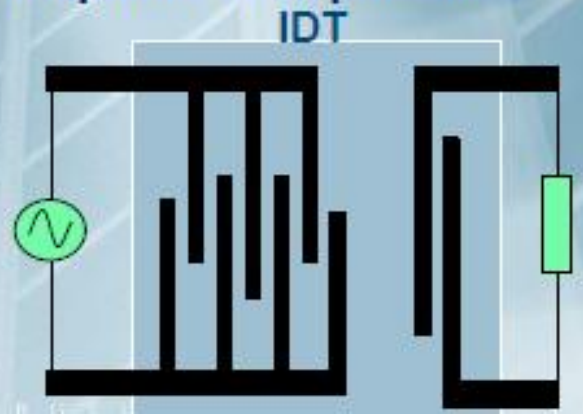
**WCDMA**
**802.11.x: WLANs**
**802.16a: WIMAX ...**

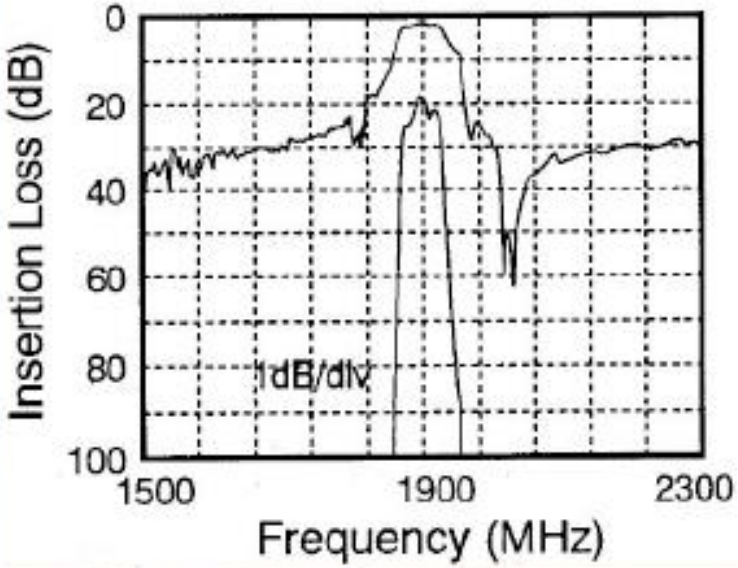


# Filtre piézoélectrique

## Technologie SAW


- onde acoustique guidée par la surface
- pertes de propagation importantes
- filtres ⇒ IDTs (FIR) ou
  résonateurs (Ladder ou Lattice)
- limité en fréquence et en puissance

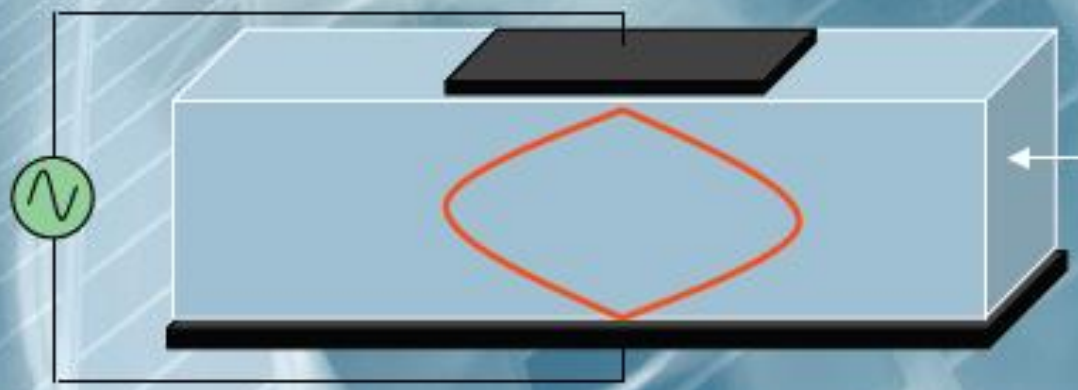



| | |
|---|---|
| $F_0$ | 1.9 GHz |
| IL | 2.0 dB |
| BW | 80 MHz |
| Taille | 2.5x2.0x0,9 mm³ |

# Filtre piézoélectrique

## Technologies BAW



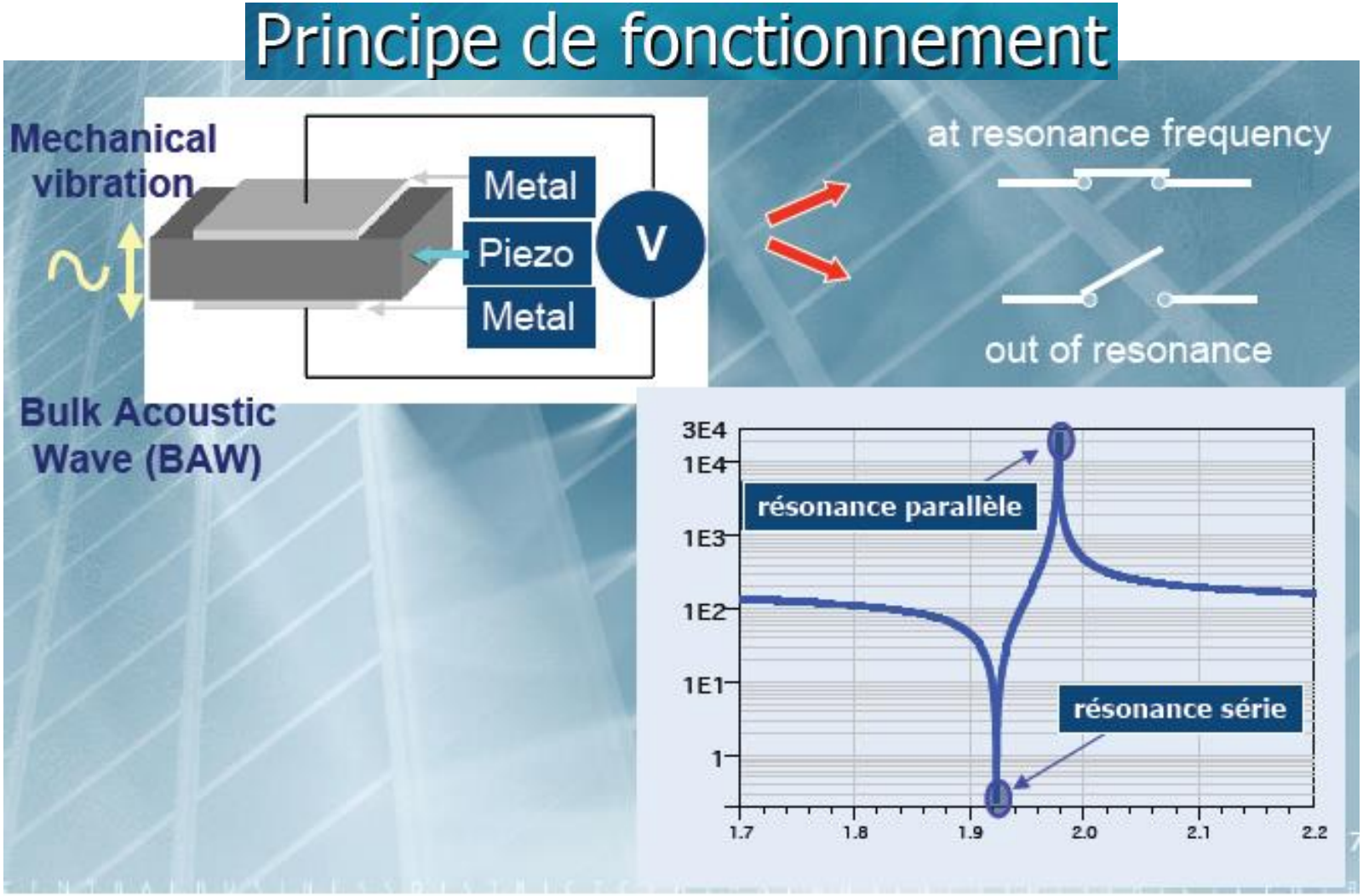

- l'onde acoustique est confinée dans le matériau piézoélectrique
- pertes de propagation moins importantes
- filtres ⇒ résonateurs couplés électriquement (Ladder, Lattice)

  résonateurs couplés acoustiquement (SCF, CRF)

Réduction de $10^4$ des longueurs d'ondes ⇒ résonateur 100µm en bande S

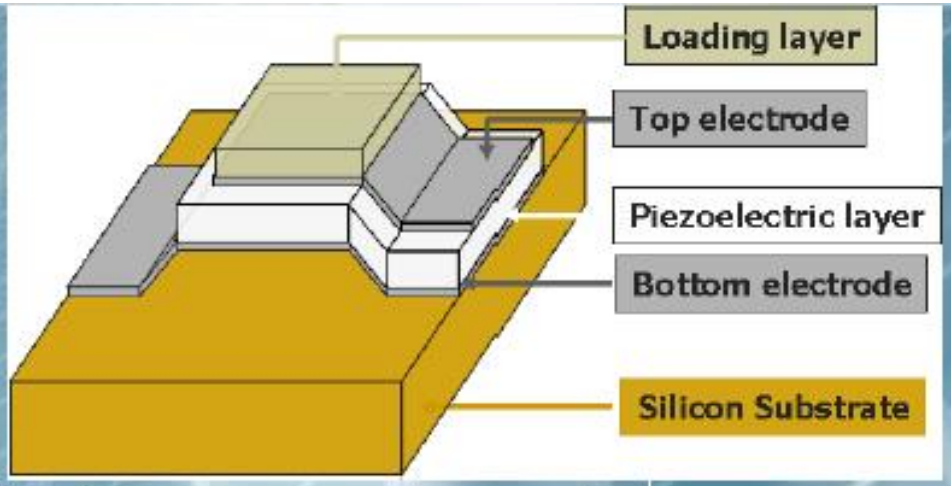
Très haut coefficient de qualité : 400 pour du ZnO à 900 MHz

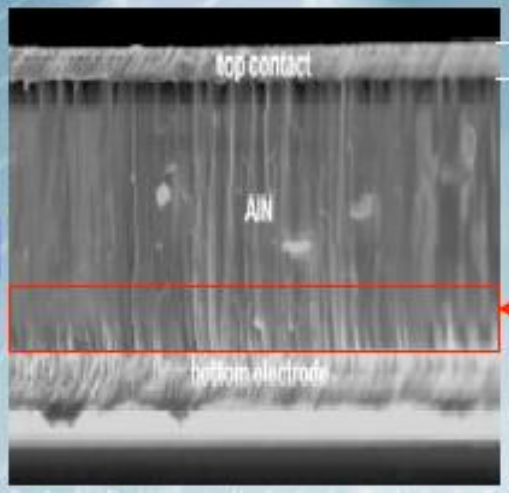
# Filtre piézoélectrique



# Filtre piézoélectrique

## FBAR (Film Bulk Acoustic Resonator)




thin electrodes
**high ohmic losses**

thin piezoelectric layer
**low material quality factor**

**Avantages**

- énergie confinée dans le matériau piézoélec >> pertes moins importantes;
- peu de couches
- intégration SoC

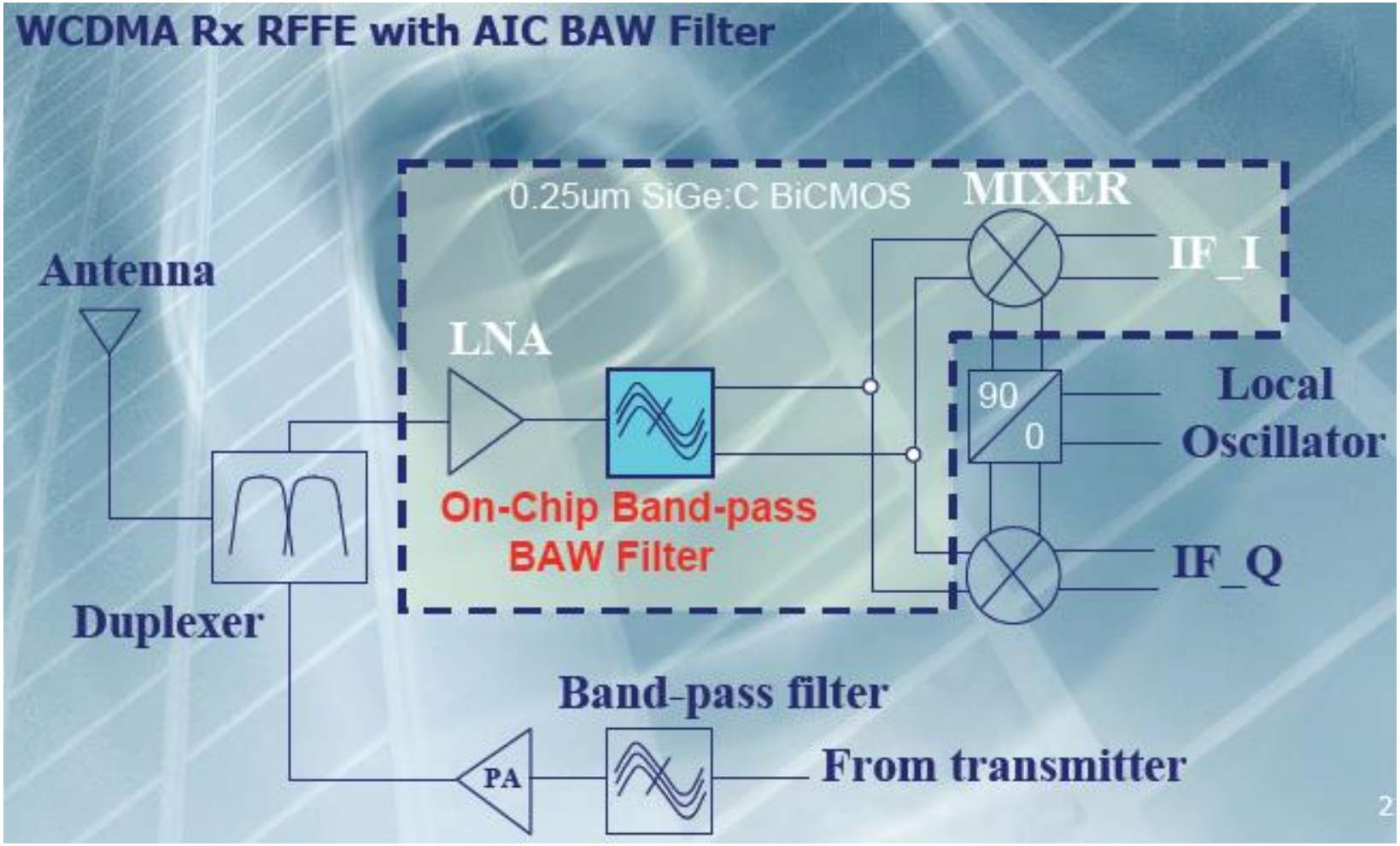
**Inconvénients**

- membrane de support
- processus de fabrication
- dissipation thermique plus difficile

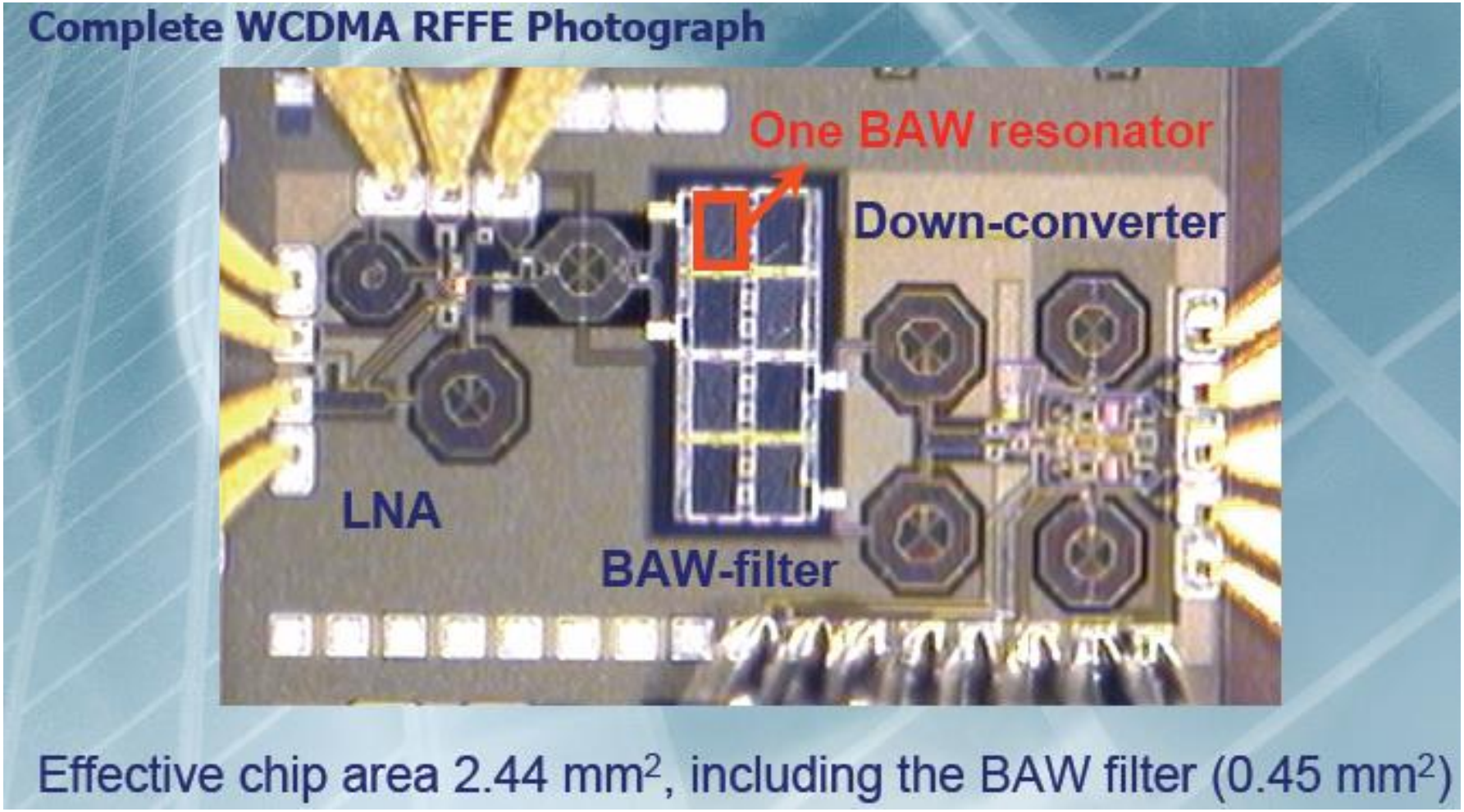
**Fondeurs**

ST, Agilent, INFINEON

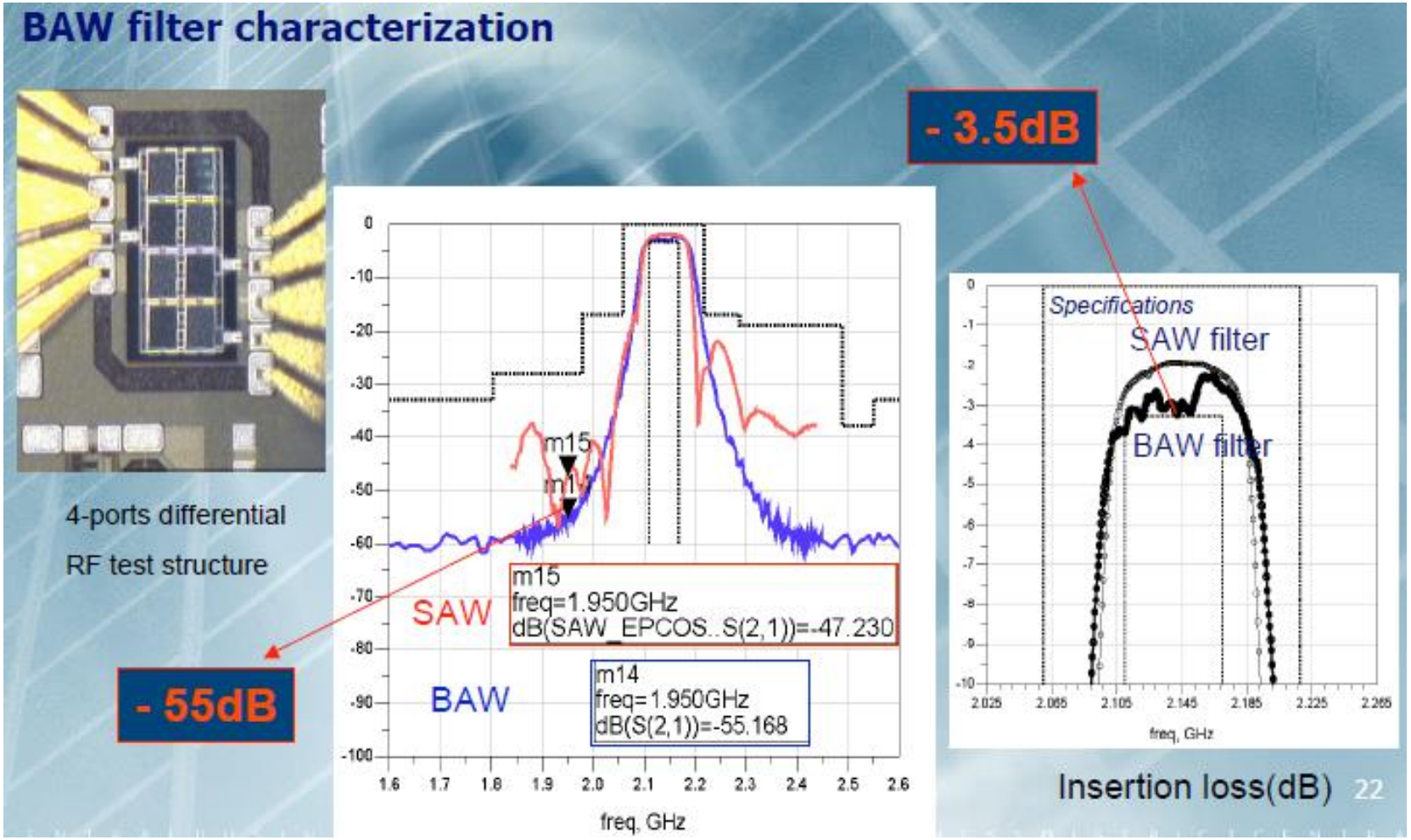
# Filtre piézoélectrique



# Filtre piézoélectrique



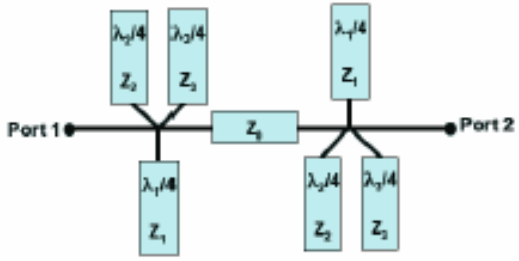
# Filtre piézoélectrique



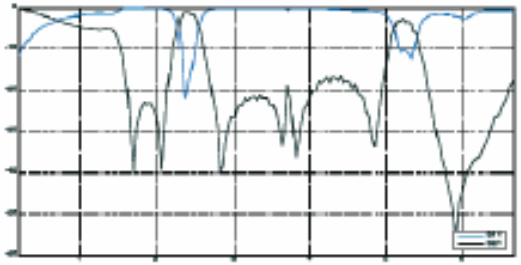
# Filtre Multi-bande

## Illustration "filtres multibandes »

### WLAN Dual-Band BPF 2.4 / 5.2 GHZ




stepped impedances resonator
=> enhanced control of the periodic behavior
->achieving a center frequency ratio greater than 2.

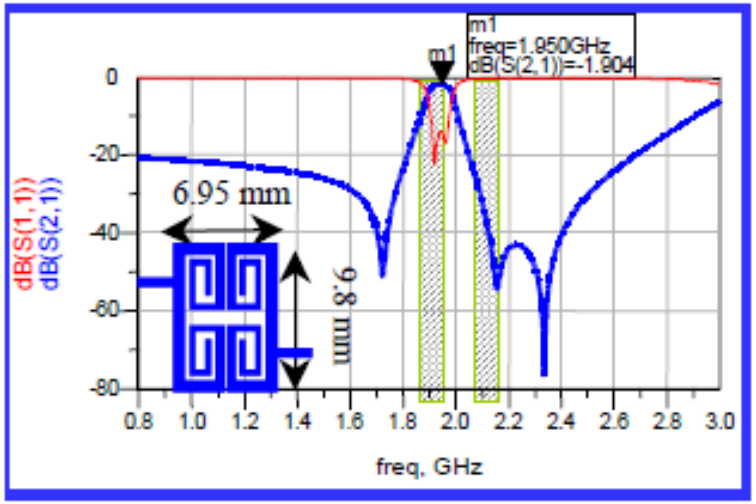


**IL @ 2.4GHz = 1.25 dB**
**BW @ 2.4GHz = 80 MHz**

**IL @ 5.8 GHz = 1.1 / 2.4 dB**
**BW @ 5.5GHz = 600 MHz**

**Filtre Multi-bandes sur LCP**

## Exemple de travaux réalisés au LEST




**Filtre très sélectif**

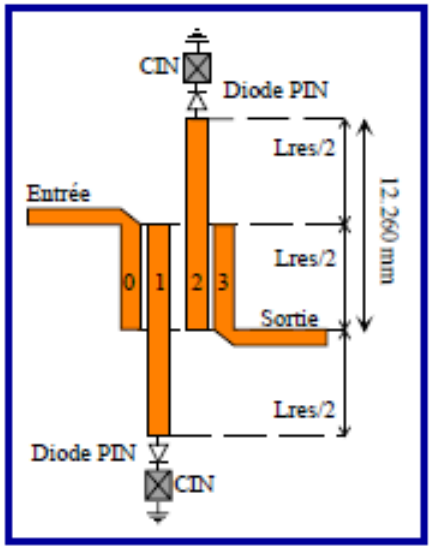
**bande Rx UMTS ($f_0$ : 1.95 GHz)**
Taille : 7 * 9.8 mm
Pertes : 2 dB
Bande passante à -10 dB : 3 %
Réjection : >40 dB de 2.1 à 2.4 GHz

# Filtre Accordable

## Variation Fréquence centrale

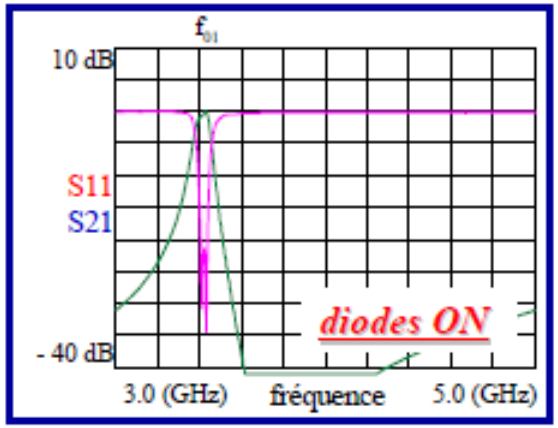
**Agilité à base de diodes + MMIC (R<0)**

### Topologie du filtre



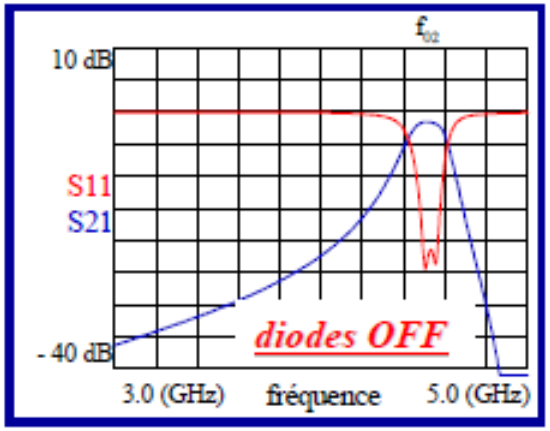

(Travaux LEST – XLIM)

### Simulations




***Fréquence basse***

$f_{01} = 3.42\ GHz$




***Fréquence haute***

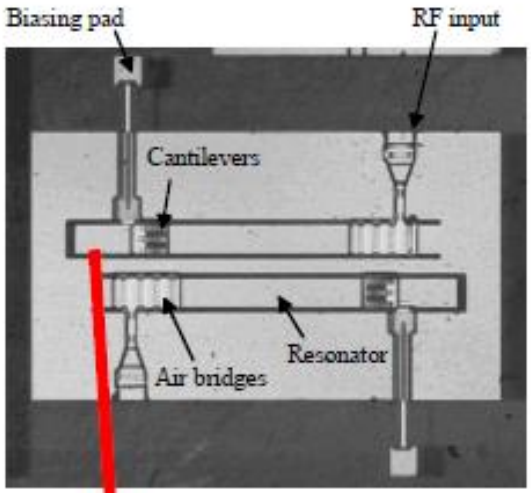
$f_{02} = 4.53\ GHz$

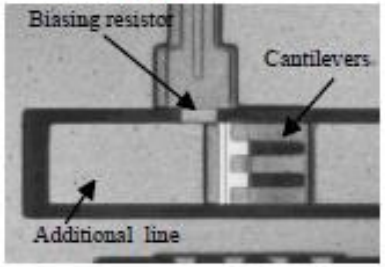
$\Delta f = 1.11\ GHz$

# Filtre Accordable

## Variation Fréquence centrale

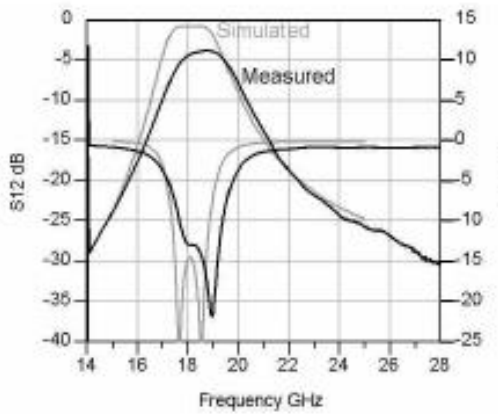
## Agilité à base de MEMS



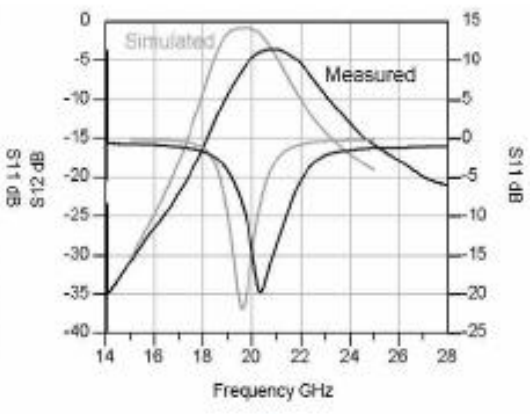




## Mesures

*Etat bas*




*Etat Haut*

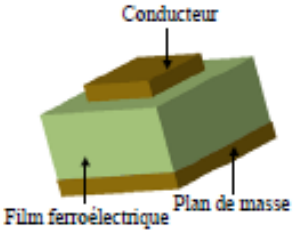



# Filtre Accordable

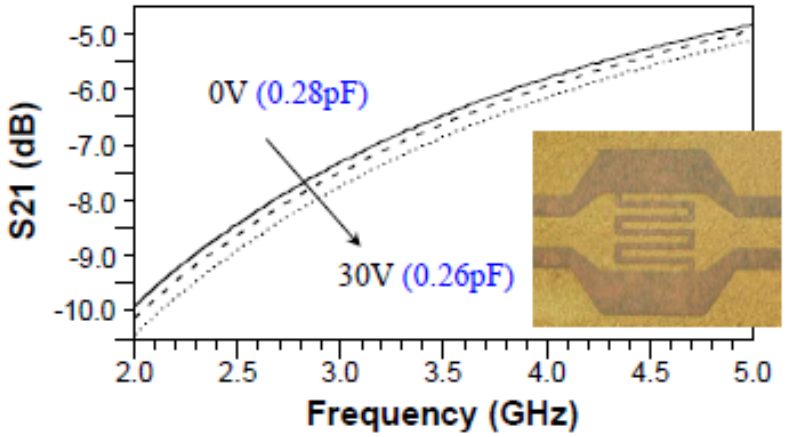
**Variation Fréquence centrale**

**Agilité à base de Matériaux**

## - Ferroélectriques -

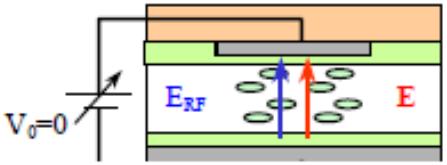



$$\varepsilon_r = f(\vec{E})$$




IDC sur $KTa_{0.6}Nb_{0.4}O_3$/Saphir

## - Cristaux liquides -



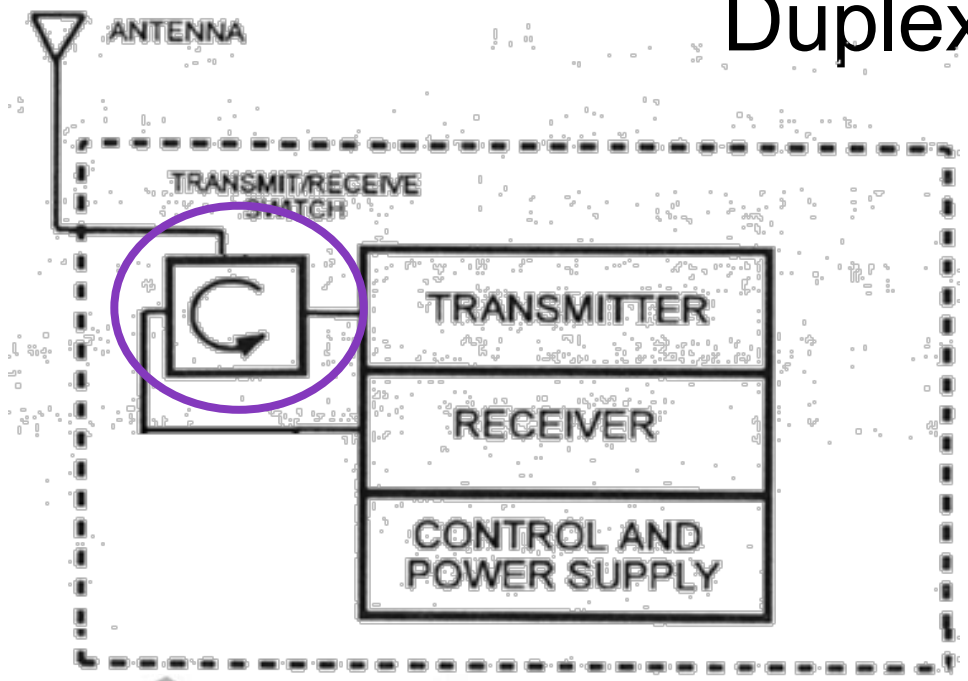

*Exemple de réponse - Filtre DBR*


**Changement d'anisotropie de CL**

# Duplexer

- A duplexer is the network that permits a transmitter and receiver to use the same antenna, at or very near the same frequency.
  - Low loss between transmitter and antenna in transmit (less than 1 dB is desirable)
  - High isolation from transmitter to receive in transmit (as much as 80 dB for megawatt systems)
  - Low loss between antenna and receiver in receive (less than 1 dB is desirable)
  - Fast switching between the transmit and receive state, sometimes "automatically switched by the transmit signal, sometimes by command signal.

# Duplexer


ANTENNA
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TRANSMITTER
RECEIVER
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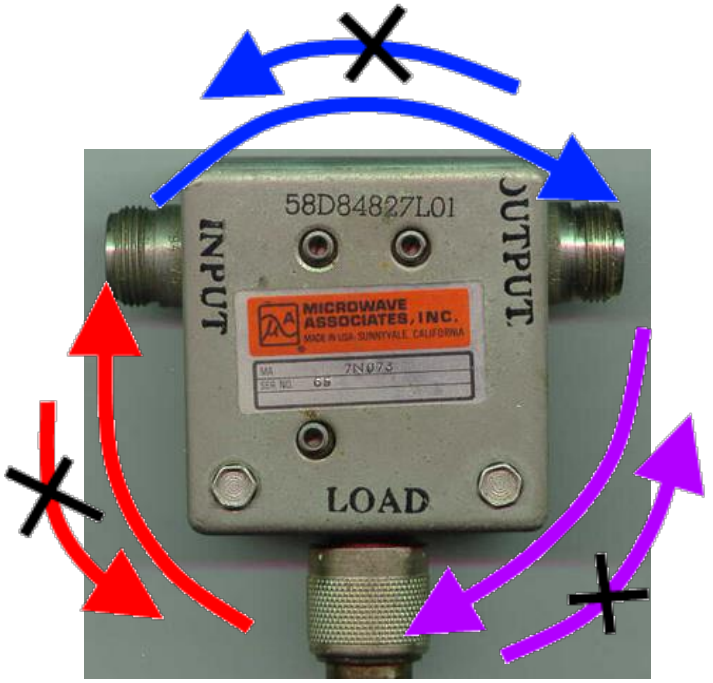
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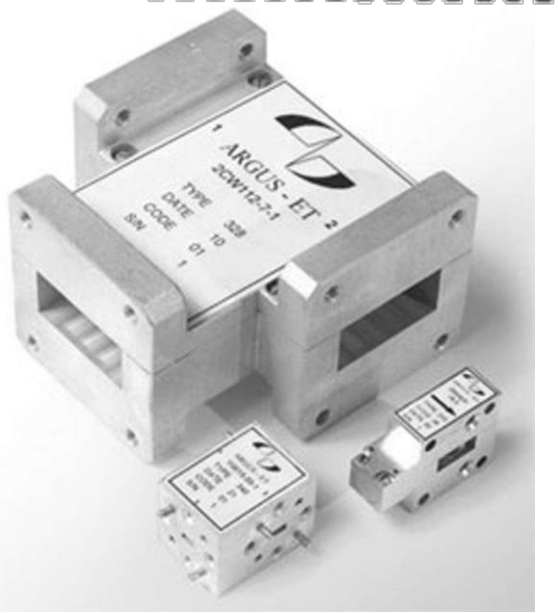
INPUT
OUTPUT
MICROWAVE ASSOCIATES, INC.
LOAD


ARGUS - ET

# Microruban

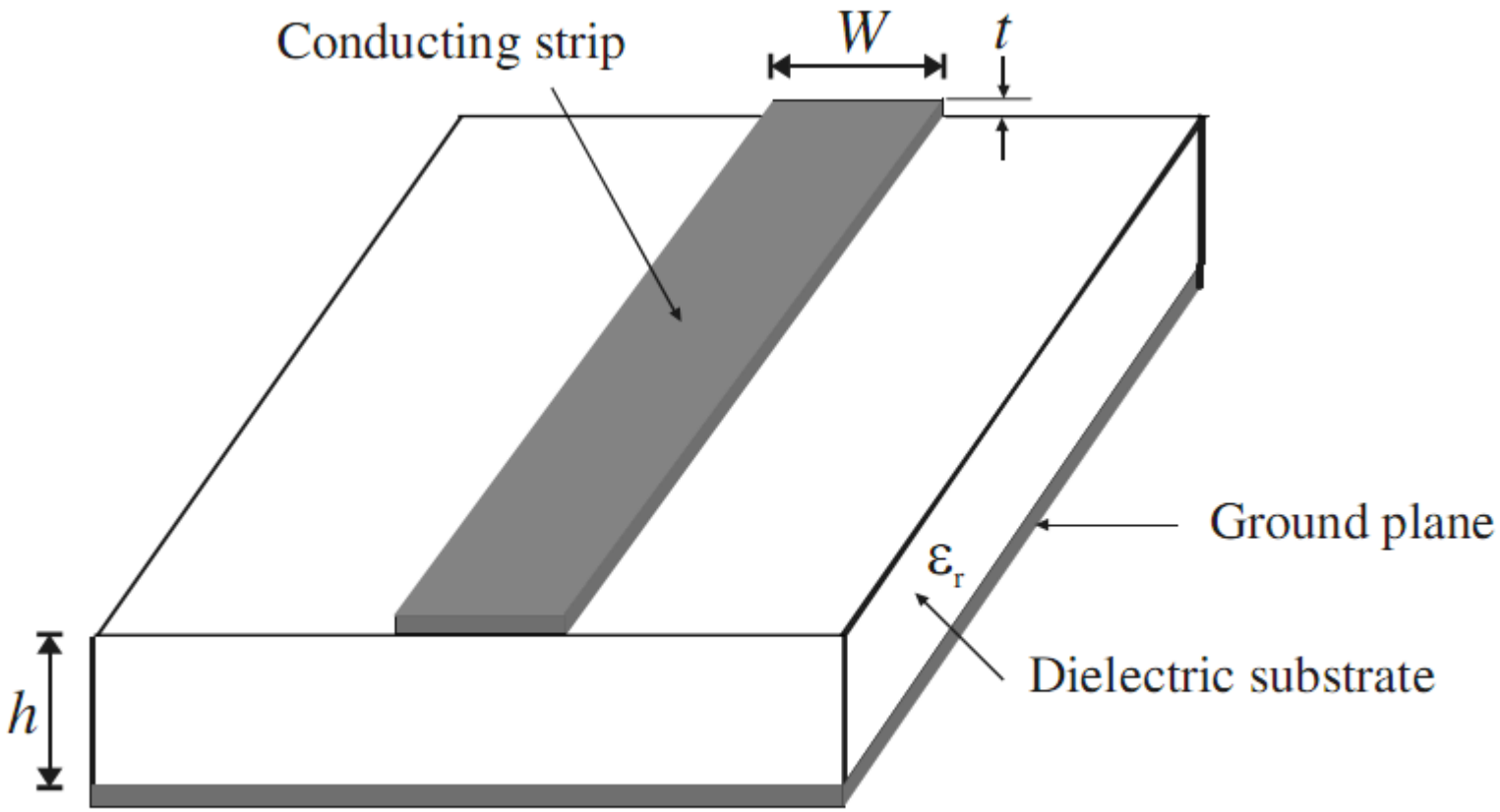
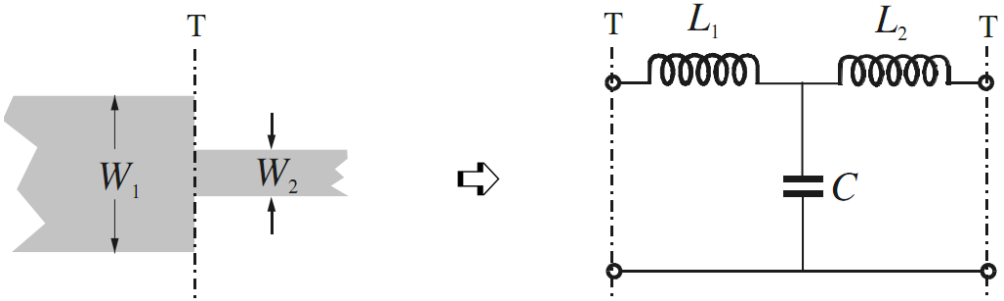
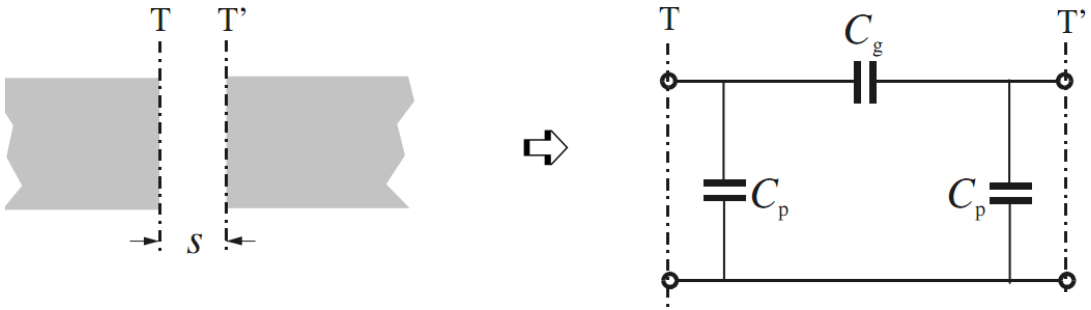
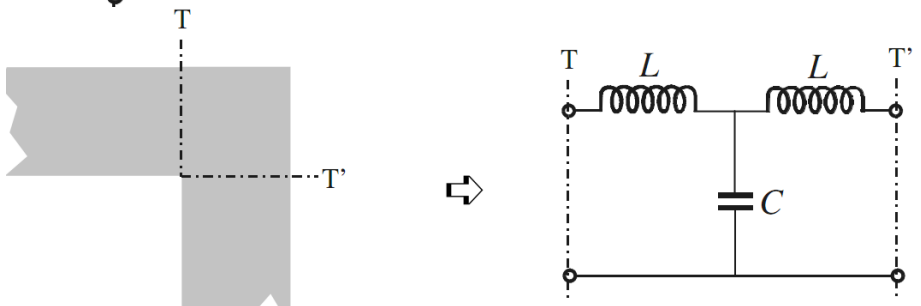


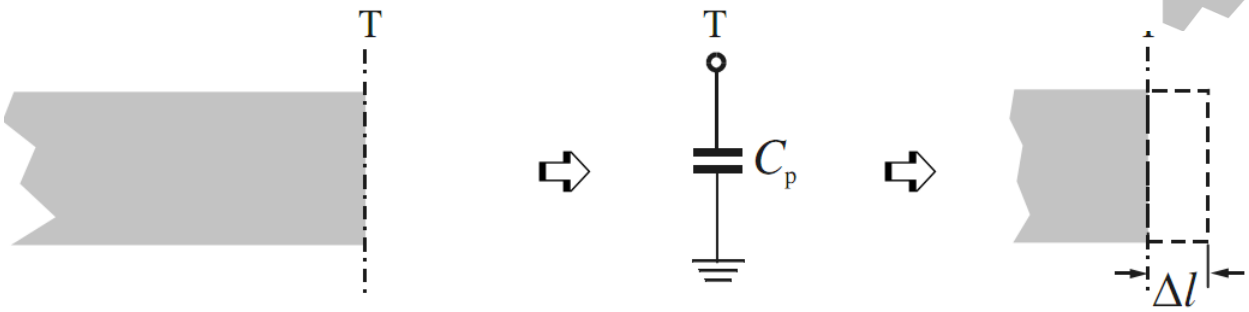

***FIGURE 4.1*** General microstrip structure.

# Microruban

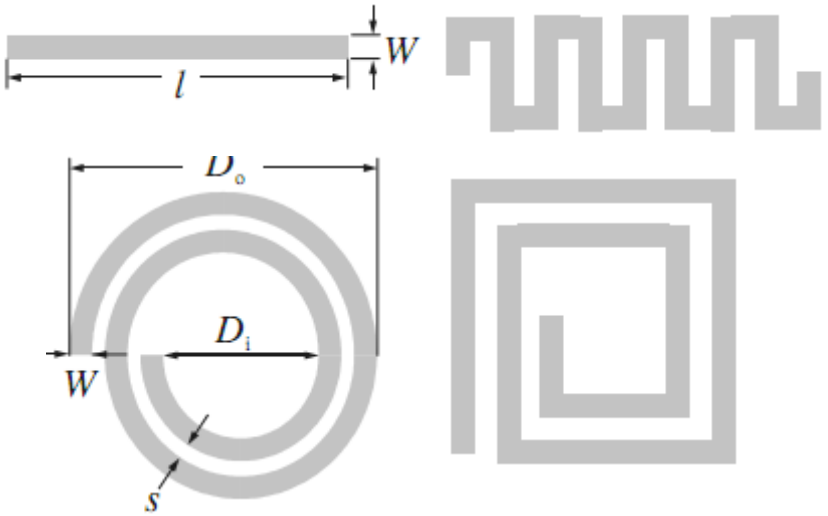


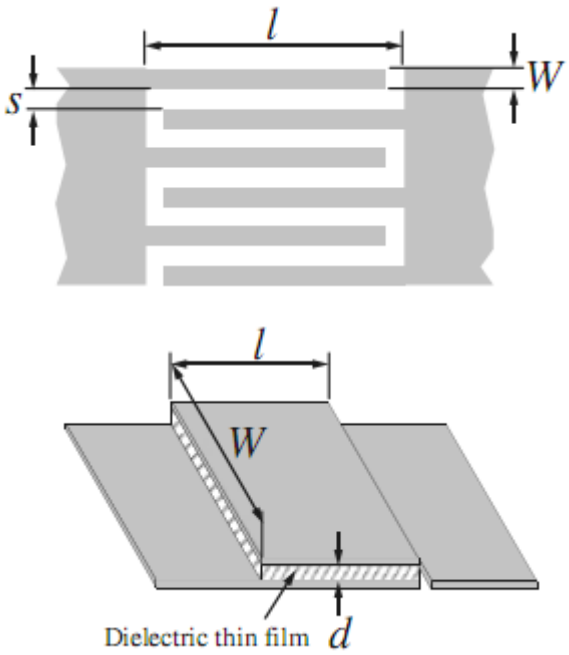



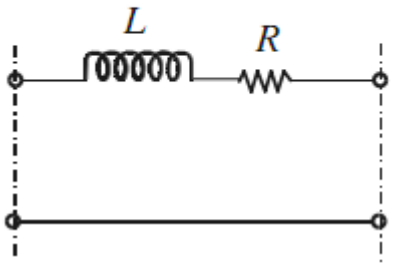



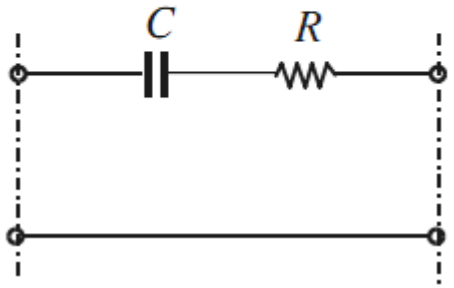



# Microruban

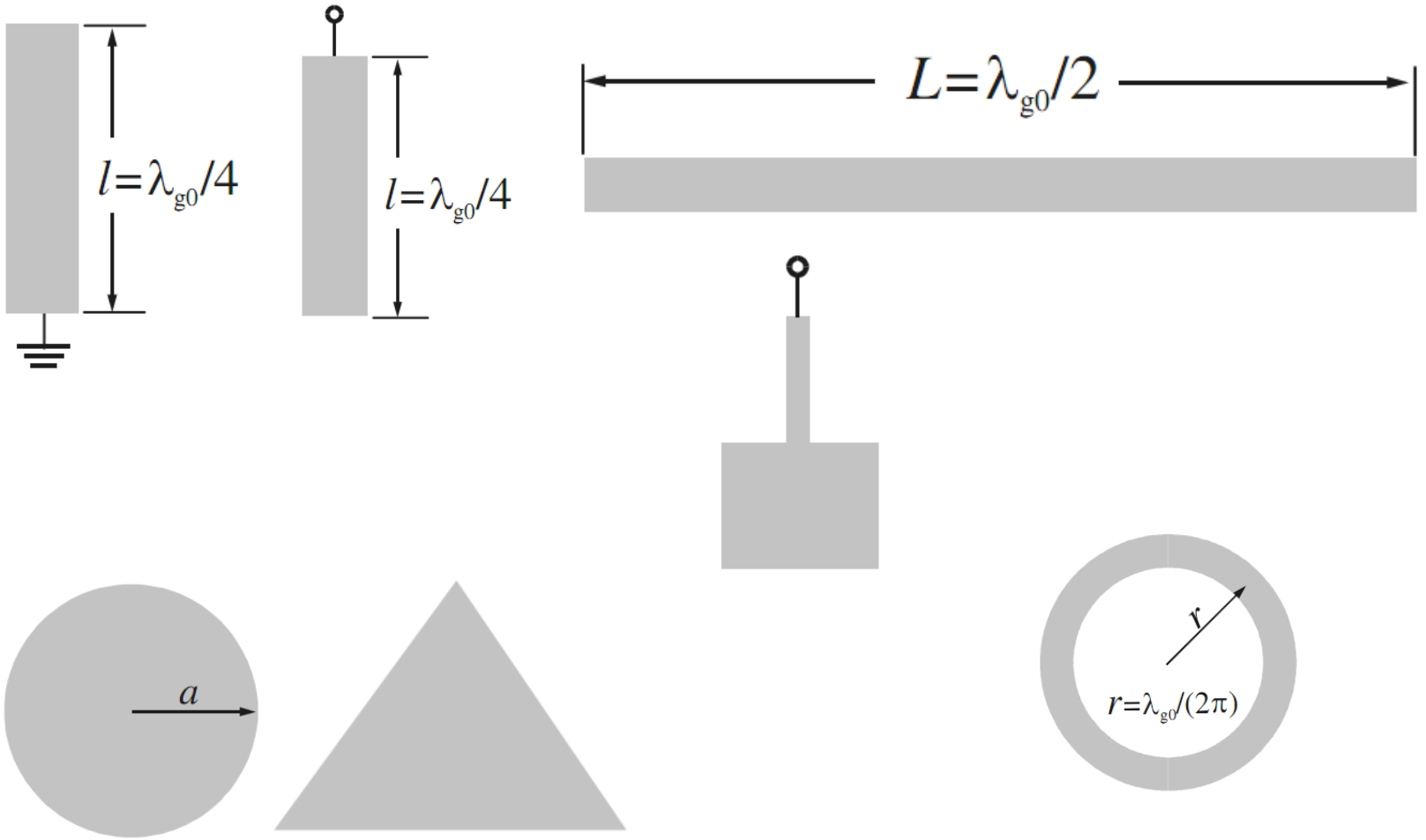


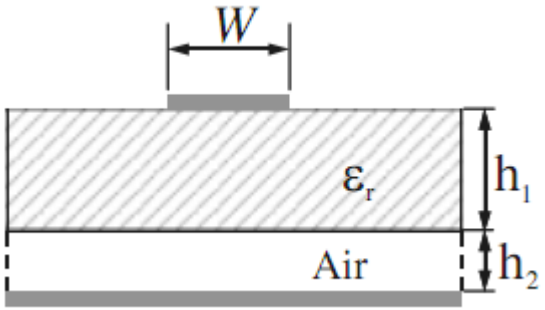



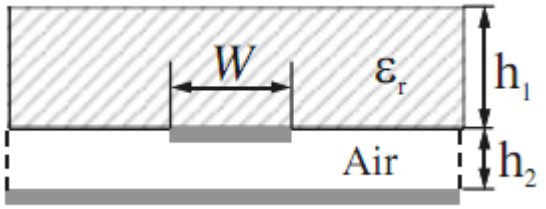
# Résonateur Microruban



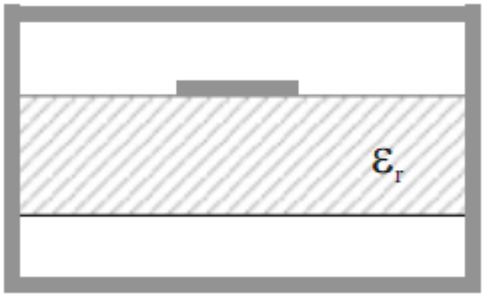
# Substrat Microruban




suspended microstrip line

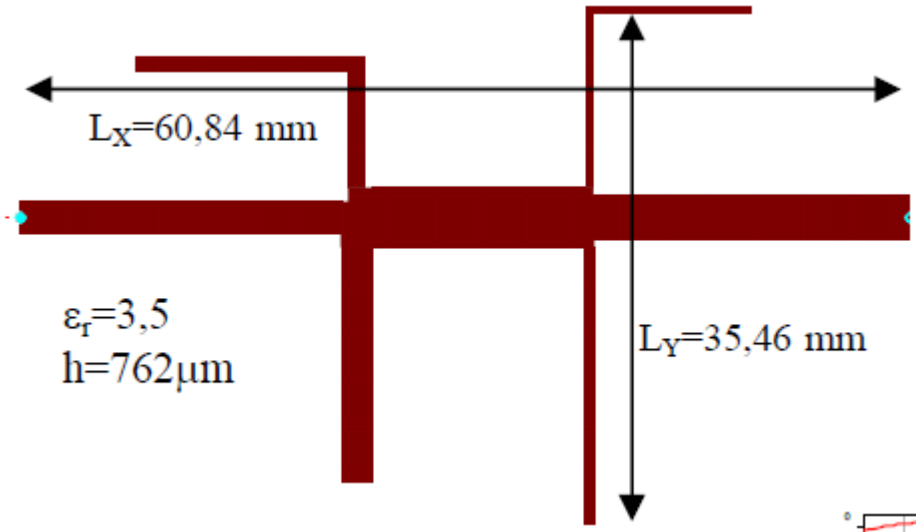


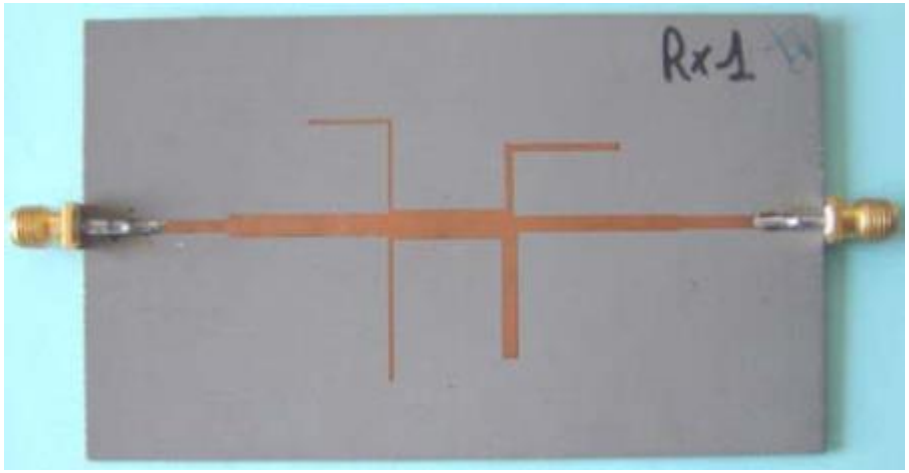

inverted microstrip line

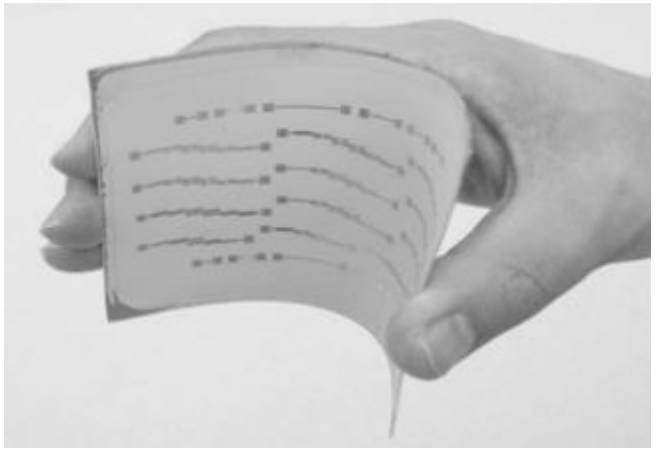


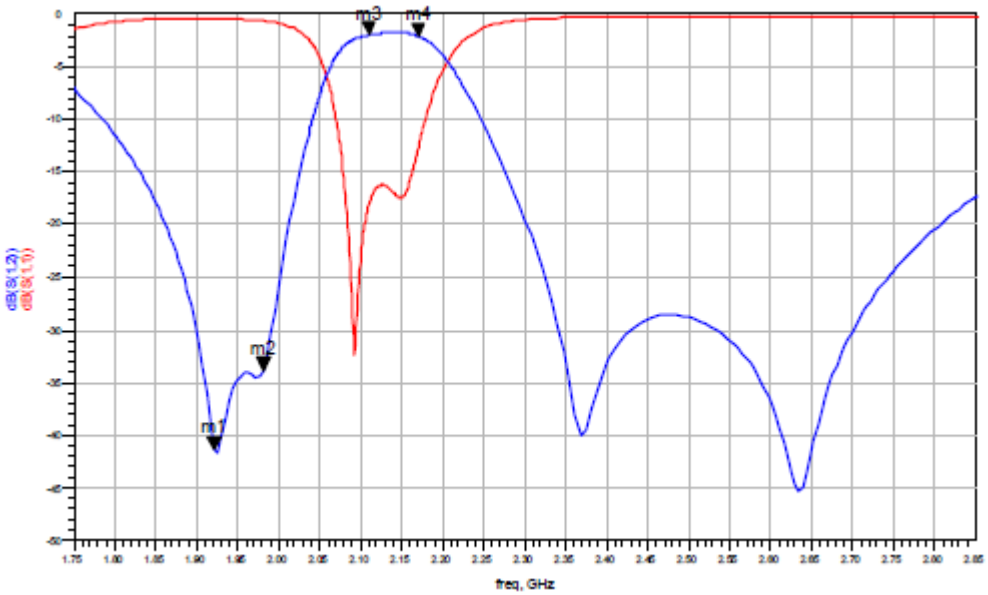

suspended or inverted microstrip line, enclosed

# Filtre Microruban

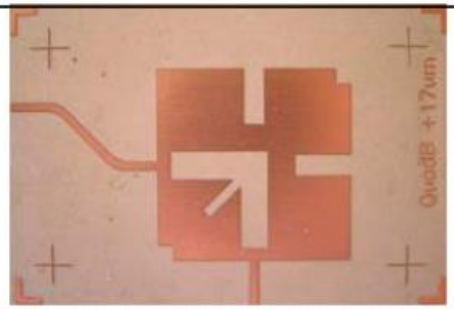


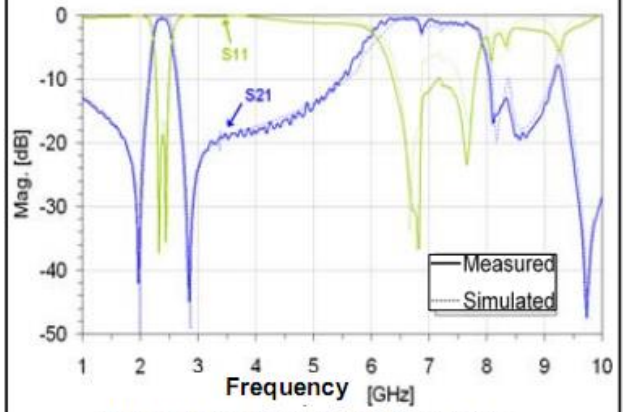





# Filtre Patch

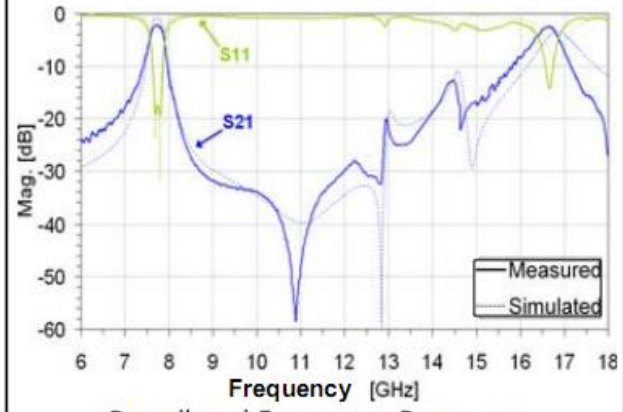



2-pole square bandpass patch filter

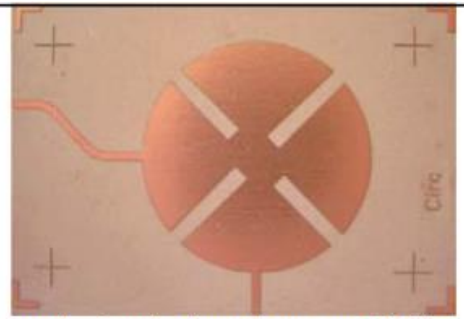



Broadband Frequency Response

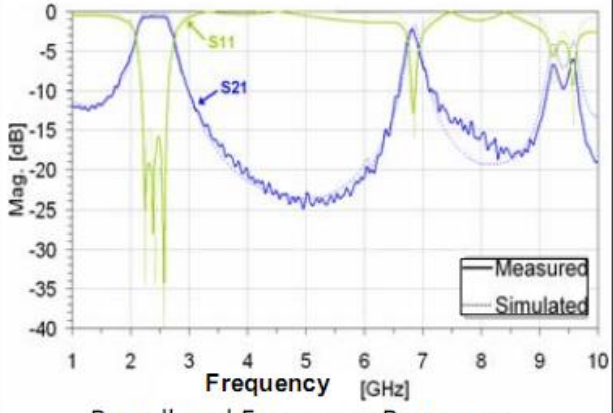
2-pole triangular bandpass patch filter




Broadband Frequency Response



3-pole circular bandpass patch filter




Broadband Frequency Response