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# *Low-loss magnetodielectric spinel-ferrite based ceramic with constant permeability and permittivity in the UHF range*

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# Overview

- Context of our research
- Synthesis process
- Structural characterization
- Microwave properties
- Conclusion & Prospects

# Context for our research

- Realization of miniaturized antennas for UHF band applications (hundreds of MHz) using the microstrip technology.

⇨ The characteristic size of substrate of antenna is given by:

$$L = \frac{\lambda}{2\sqrt{\varepsilon'\mu'}} = \frac{\lambda}{2n}$$

How to decrease the size of the antenna for broad-band telecommunication applications :

⇨ by using low loss dielectric and magnetic materials

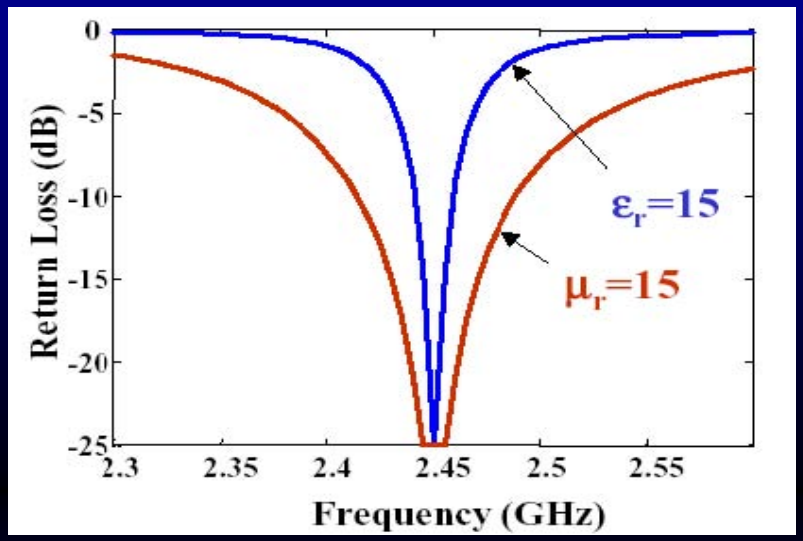
At a fixed frequency :

⇨ Increasing permittivity or permeability or both ?

⇨ Another important parameter is the targeted characteristic impedance of the antenna:

$$\frac{Z}{Z_0} = \sqrt{\frac{\mu'}{\varepsilon'}} = 1$$

- Influence of $Z_c$ on the transmission band :

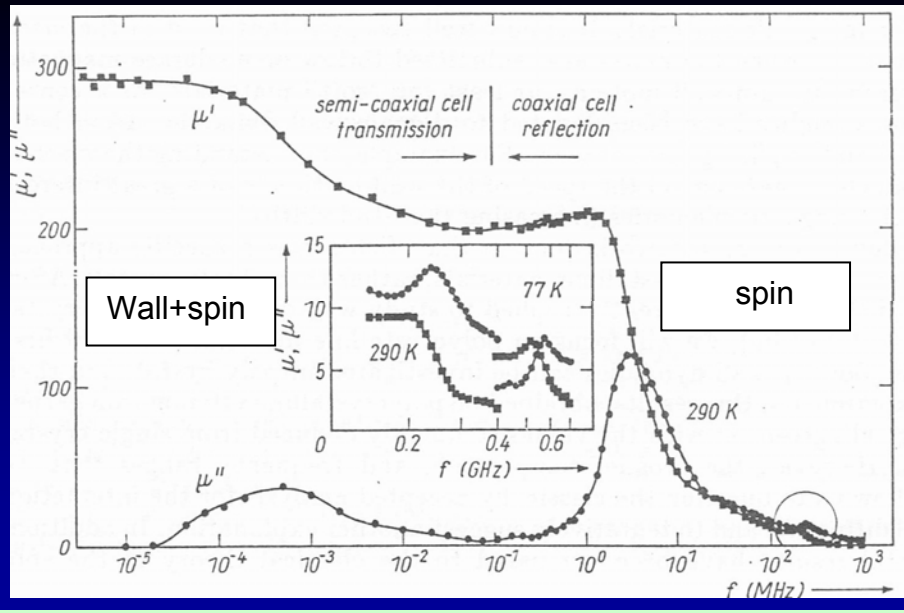



⇨ Increasing the permeability of the substrate

Ref:J.T. Aberle at.el. IEE Africon conference digest 1001-1004 sep 1999

⇨ For conventionnal ferrites : high losses due to the domain walls movement in the MHz frequency range.

⇨ Study & Fabrication of nano-ferrites with high level of rotational permeability and low-losses in the operating frequency band.



# Selection of composition

We wanted to check potentiality of spinel ferrites above 500MHz

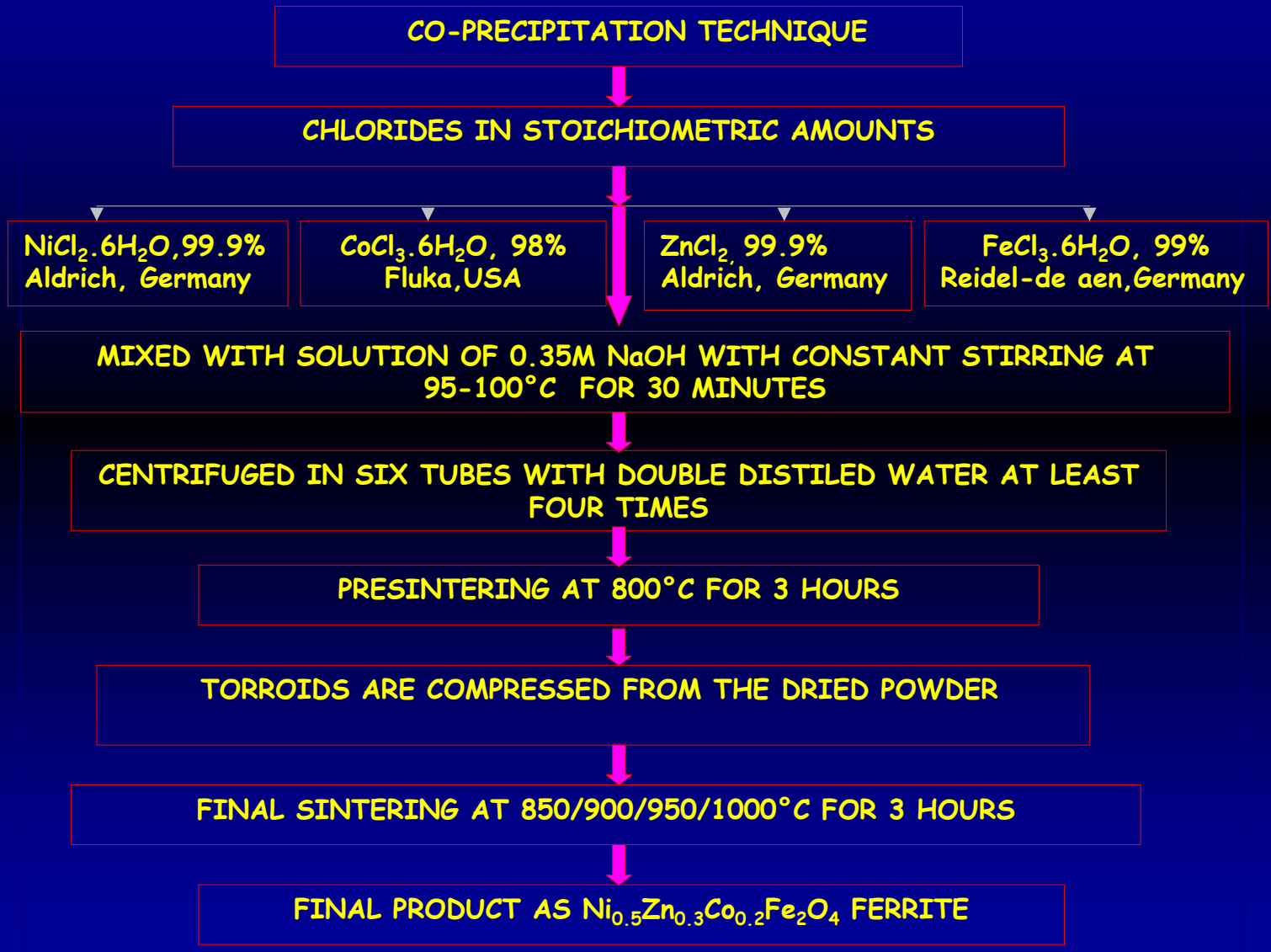
Ni-Zn ferrites series $Ni_xZn_{1-x}Fe_2O_4$ was selected because of its relative high permeability, and low magnetic loss tangent.

$Ni_{0.5}Zn_{0.5}Fe_2O_4$ was optimized from $Ni_xZn_{1-x}Fe_2O_4$ series for its better electromagnetic properties - satisfactory upto 300MHz

Substitution of Co in Ni-Zn ferrite as $Ni_{0.5}Zn_{0.5-y}Co_yFe_2O_4$, since cobalt is effective to shift resonance at higher frequency region by increasing the magnetic anisotropy

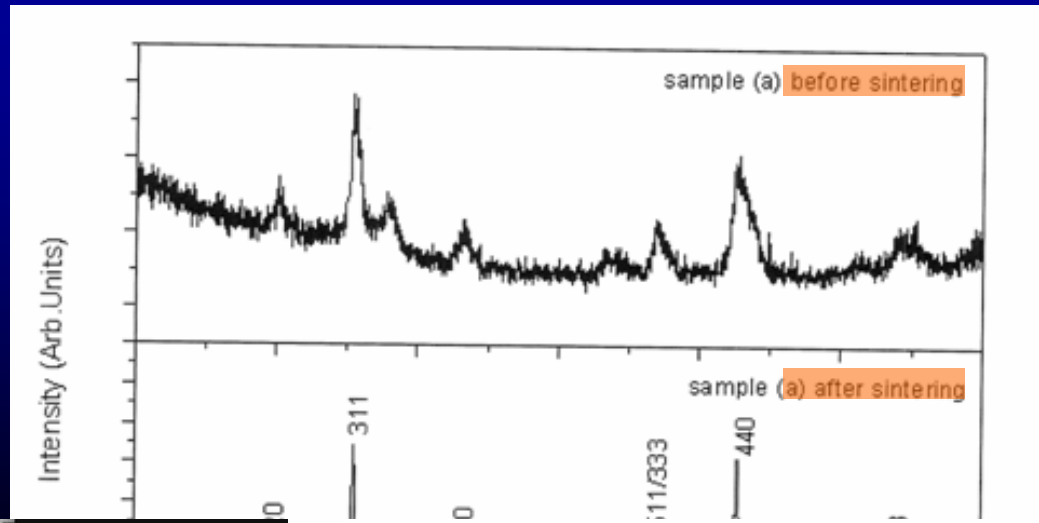
Finally $Ni_{0.5}Zn_{0.3}Co_{0.2}Fe_2O_4$ was optimized for better electromagnetic properties upto 1GHz frequency range

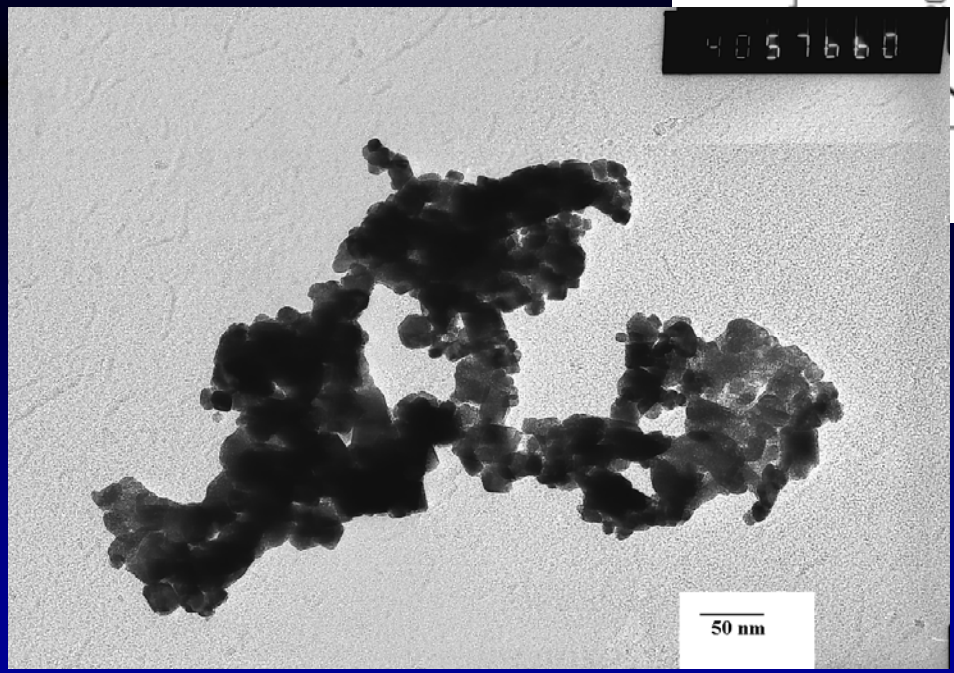
# Synthesis Process

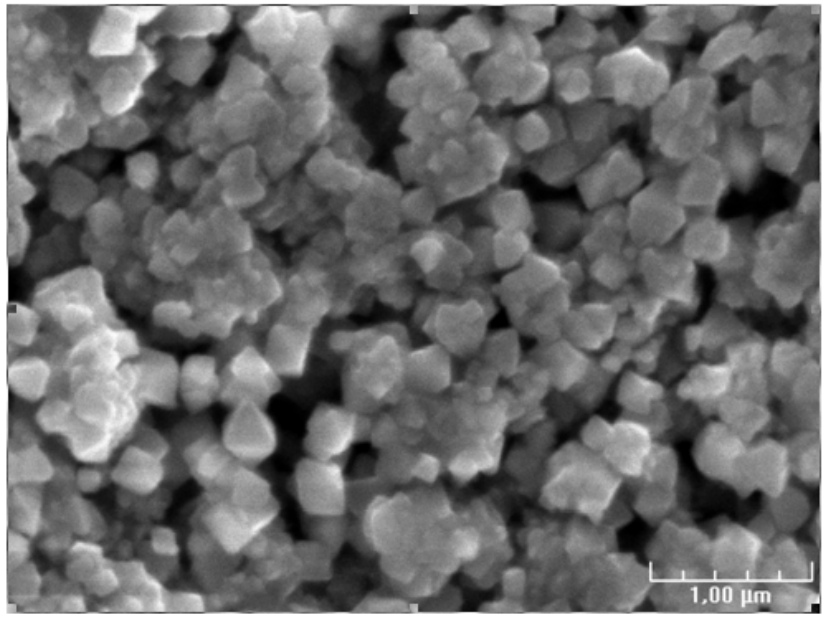


# Microstructural properties

| Sample label | Tps (°C) | Ts (°C) |
|---|---|---|
| (a) | 800 | 850 |
| (b) | 800 | 900 |
| (c) | 800 | 950 |
| (d) | 800 | 1000 |

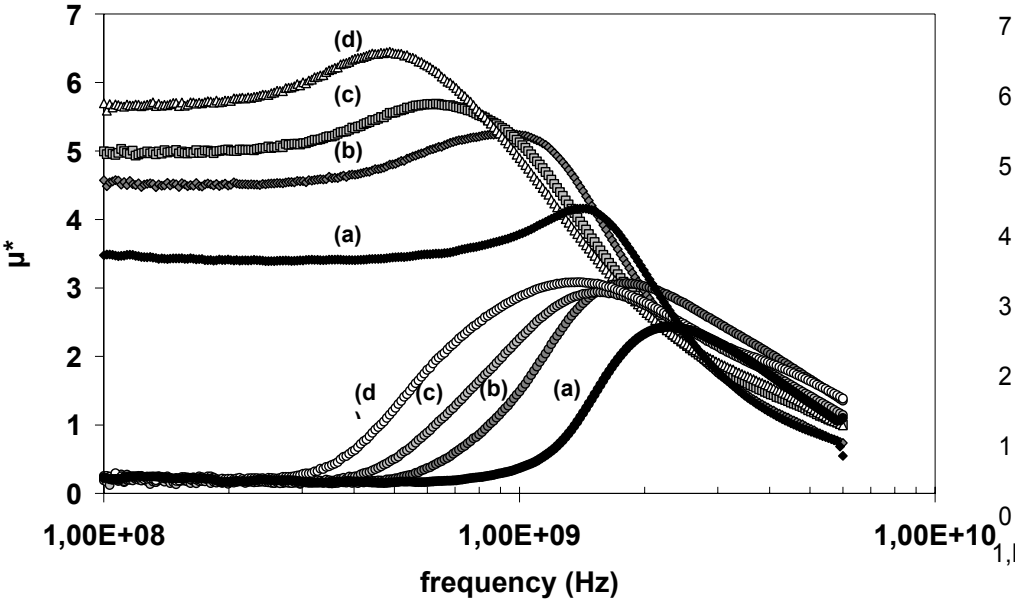


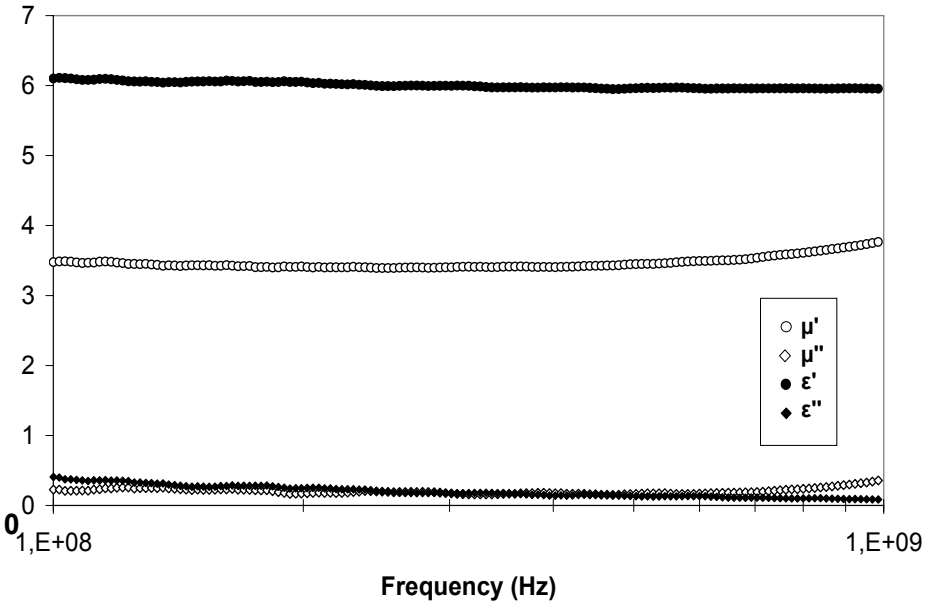



# Microwave properties

Microwave properties were studied by using transmission/ reflexion co-axial method

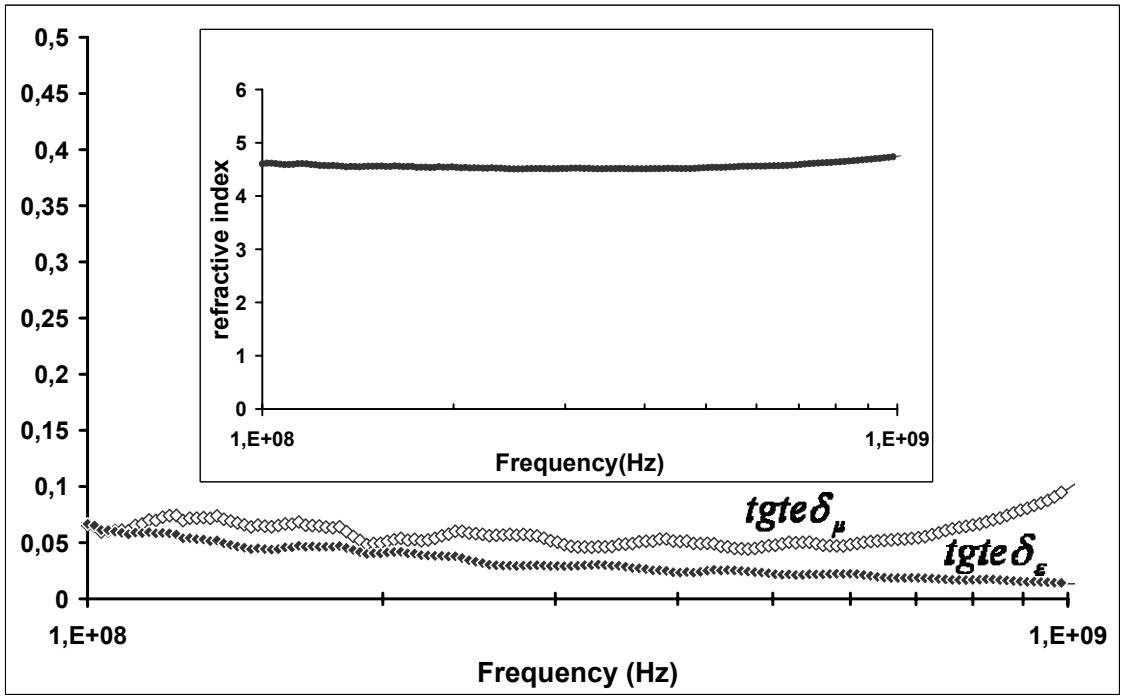



Real and imaginary parts of permeability for $Ni_{0.5}Zn_{0.3}Co_{0.2}Fe_2O_4$ ferrites.




Measured complex permeability and permittivity spectra of sample (a) between 100 MHz and 1GHz

# Loss tangents and refractive index




| Sample label | $T_c$ (°C) | $T_s$ (°C) | Density (g/cm$^3$) | porosity | ($\mu'$-1) @10$^2$Hz | ($\mu'$-1) @100MHz | $f_r$ (GHz) | ($\mu'$-1). $f_r$ |
|---|---|---|---|---|---|---|---|---|
| (a) | 800 | 850 | 4.15 | 15% | 3.9 | 2.51 | 2.41 | 6.05 |
| (b) | 800 | 900 | 4.459 | 7% | n.m. | 3.57 | 1.78 | 6.35 |
| (c) | 800 | 950 | 4.518 | 6% | n.m. | 3.95 | 1.54 | 6.08 |
| (d) | 800 | 1000 | 4.740 | 1% | 6.3 | 4.64 | 1.36 | 6.31 |

We know, $f_r = \gamma H_{eff}$ ($\gamma$ = 2.8 MHz/Oe)

For sample (a); $f_r$= 2.42 x$10^3$MHz
$\rightarrow H_{eff}$ = 69.44kA/m

$(\mu_{init} - 1).f_r = 2/3(\gamma M_s) \rightarrow M_s$= 403kA/m

$H_{eff} = \frac{4}{3}\frac{K}{\mu_o M_s}$

$H_{eff}$ = 4/3 ($K/\mu_o M_s$)$\rightarrow$ K = 2.62 x $10^4$ J/$m^3$

Whereas K = 0.42 x $10^4$ J/$m^3$ for $Ni_{0.5}Zn_{0.5}Fe_2O_4$

# *Conclusion & Prospects*

$Ni_{0.5}Zn_{0.3}Co_{0.2}Fe_2O_4$ was synthesized using co-precipitation technique, calcinated, and sintered at temperatures between 850°C to 1000°C.

For sample (a) ($T_S$=850°C) the measured magnetic and dielectric loss tangents show values close to 0.04 and 0.02 respectively in the frequency range from 100 MHz up to 1 GHz.

In the same frequency range, we get the following constant values: $\mu'$=3.5 and $\varepsilon'$=6, that is a refractive index n=4.85.

This low-temperature sintered material can be considered to be in an *intermediate state between the sintered ferrite and the composite*

This porous structure of the material- that induced gaps between the magnetic grains- can be invocated to explain the unusual-for spinel ferrites materials- high value of the relaxation phenomenon.

These *electromagnetic performances fit the requirements for the design of antennas (VHF-UHF range) with reduced size.*

We are still in process to find better and better results by taking different temperature profiles and duration for presintering and sintering as the size of nanoparticles is sensitive to these parameters.

In future, we also plan to prepare samples:

- With hot isostatic pressing technique.
- With doping Mn/In
- With hexaferrite

# Thank You