Editor's Comment on "Wideband Matching of an Electrically Small Antenna Using a Negative Impedance Converter Technique" by WenXing Li, Ruilong Chen, Ning Zhai, Si Li, and Raj Mittra

These PPT Slides are from an APS symposium presentation and are fairly self-explanatory. The paper presents the results of a theoretical and experimental study of wideband matching of a small antenna by using NICs (Negative Index Converters). For additional information on author's work on this topic, the reader is referred to:

Wenxing Li, Ning Zhai, Ruilong Chen, and Wenhua Yu, "Non-Foster Impedance Wideband Matching Technique for Electrically Small Active Antenna," International Journal of Antennas and Propagation, Hindawi Publishing Corporation, Volume 2013, Article ID 531419, 7 pages.

APS 2012 Presentation

Wideband Matching of an Electrically Small Antenna Using a Negative Impedance Converter Technique

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Outline of Presentation

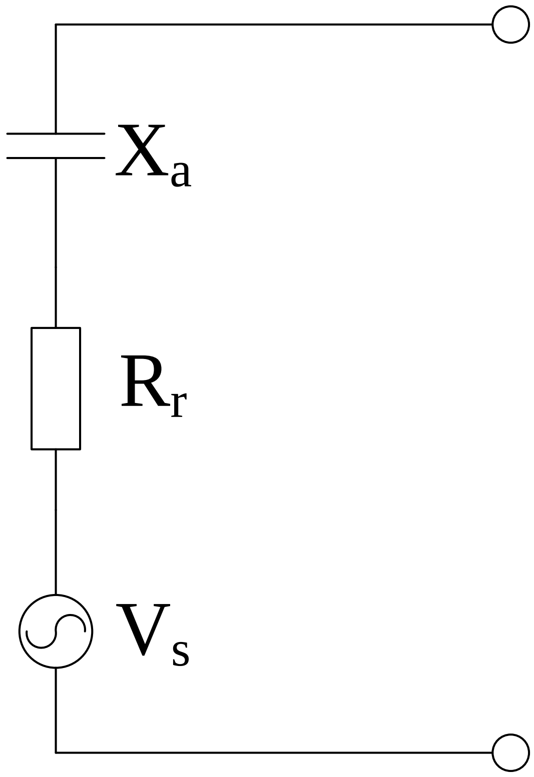
- Introduction
- NIC Analysis
- Stability Analysis
- Design of Active Receiving Antenna
- Testing of Active Receiving Antenna
- Conclusion

Introduction

- Active antennas for miniaturization and wideband performance are of considerable interest to both military and commercial communities.
- Combination of a passive antenna and an active device are to be treated as a single entity.
- Electrically-small monopoles have a high-Q characteristics, owing to their large reactance and small radiation resistance.

Introduction

Equivalent circuit of Electrically Small Antennas (ESA)



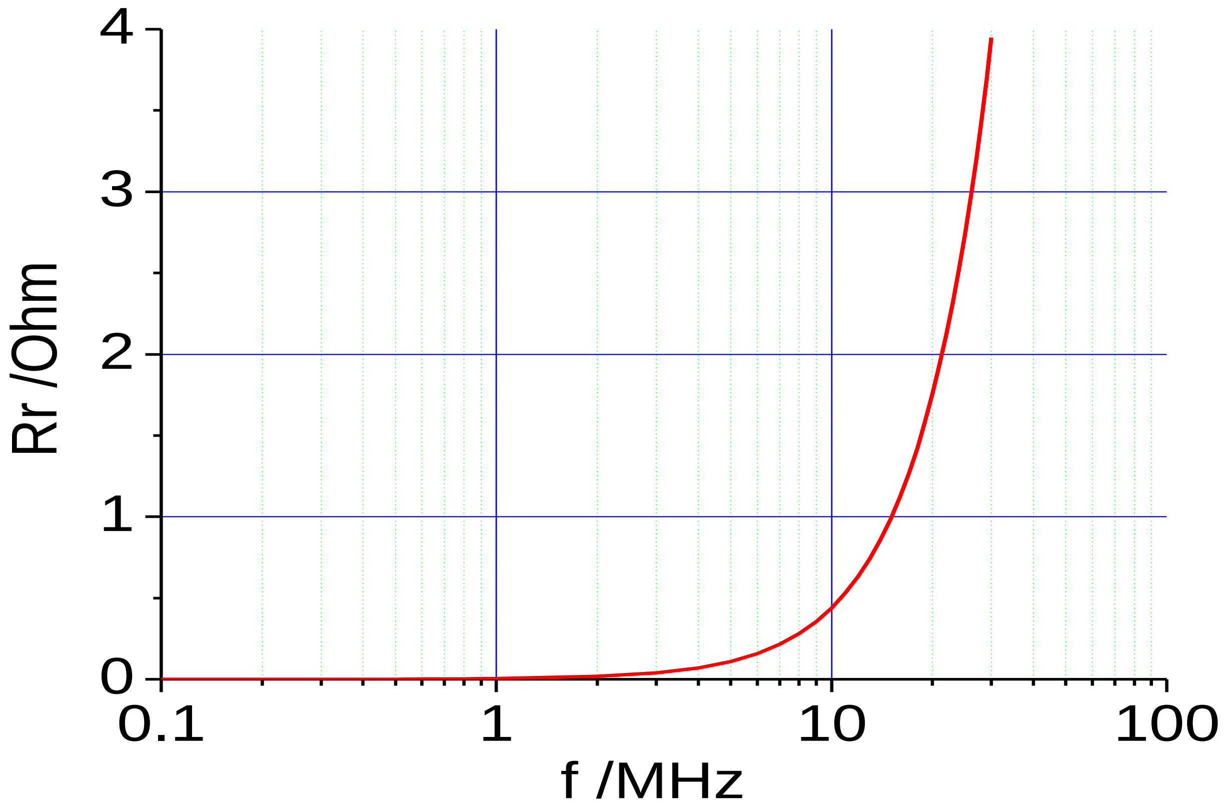
$$Q = \frac{1}{k^3 a^3} + \frac{1}{ka}$$

$$R_r = 40\pi^2 (\frac{h}{\lambda})^2$$

$$X_a = -60(\ln\frac{h}{a} - 1) \cdot \cot(2\pi\frac{h}{\lambda})$$

Introduction

ESA Example



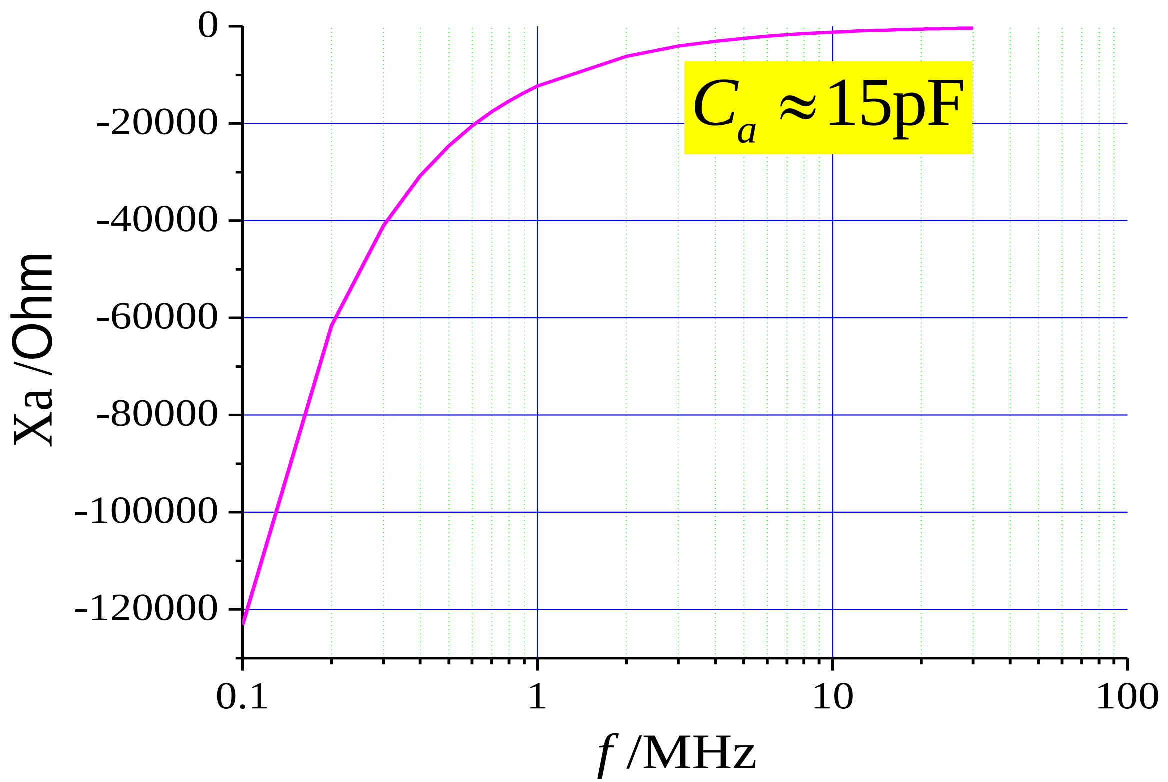
monopole:

high=1m

radius=0.5cm

Introduction

ESA Example



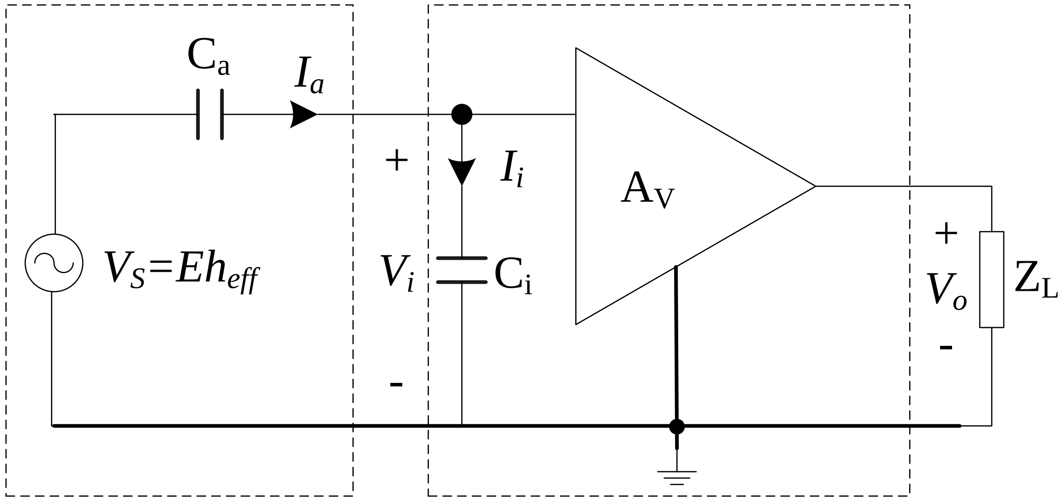
monopole:

high=1m

radius=0.5cm

Introduction

Problem with traditional active antenna design



Equivalent circuit of ESA

Active Amplifier

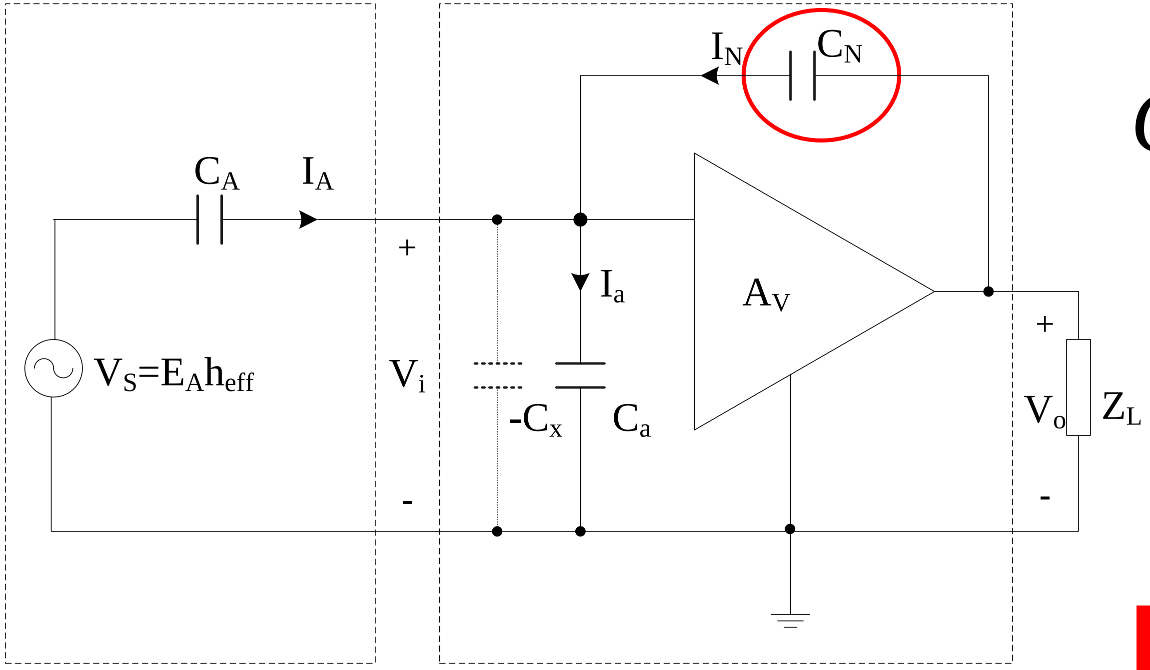
$$V_i \approx Eh_{eff} / (1 + C_a / C_A)$$

$$V_i < V_s$$

which is undesirable

NIC Analysis

NIC active antenna



Equivalent circuit of ESA

NIC Amplifier

$$\frac{V_i}{V_s}=\frac{C_A}{C_A+C_i+(1-A_V)C_N}$$

$$C=C_i+(1-A_v)C_N$$

$$C>0,\quad V_i<V_s$$

$$C=0,\quad V_i=V_s$$

$$C<0,\quad V_i>V_s$$

NIC Analysis

$$C > 0, \quad V_i < V_s$$

- For this case, we conclude that the circuit is not functioning as an NIC.
- Instead, it is similar to a classical active antenna, for which the equivalent input gain is less than 1.

NIC Analysis

$$C = 0, \quad V_i = V_s$$

The active network input voltage and the antenna source voltage are equal. which implies that the input capacitance of the amplifier is 0. This case is similar to the Non-Foster matching examples that have been considered in the past, and its application is limited to improving the antenna gain and the SNR.

NIC Analysis

$$C < 0, \quad V_i > V_s$$

- For this case, the input amplifier capacitance is negative ($C < 0$).
- The active network input signal is larger than the received signal at the antenna.
- This case is similar to that of the Enhanced Non-Foster matching, and is useful for improving the efficiency of the antenna gain and its SNR.

Stability Analysis

Principal ingredient of an NIC is a positive feedback circuit.
Hence, we must carry out a stability analysis of the active antenna and derive the criterion that guarantees stability.

$$\left.\begin{array}{l} C_a + C_i + (1 - A_V) C_N \neq 0 \\ A_V > 1 \end{array}\right\} \Rightarrow 1 < A_V < 1 + (C_a + C_i) / C_N$$

For the active antenna to provide equivalent input gain $V_i > V_s$, and must require that $-C_a < C < 0$, should have:

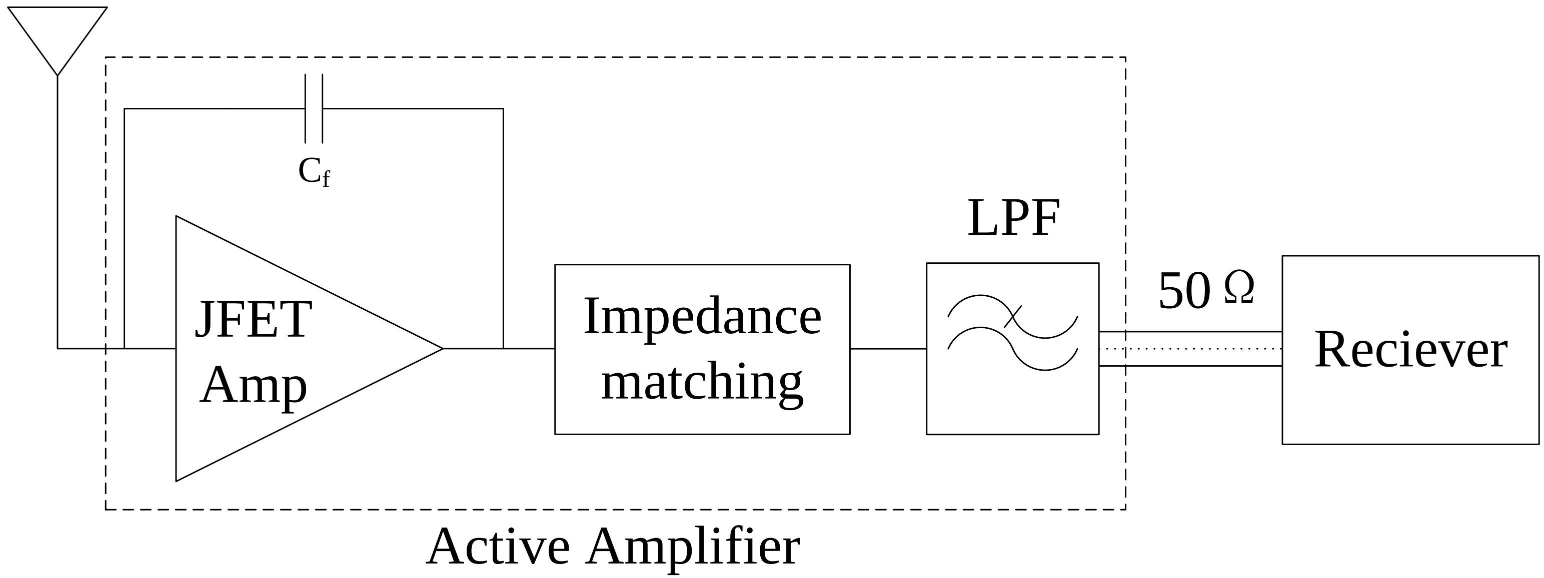
$$1 + C_i / C_N < A_V < 1 + (C_a + C_i) / C_N$$

In addition, for out-of-band frequencies, it must satisfy:

$$A_V < 1 + (C_a + C_i) / C_N$$

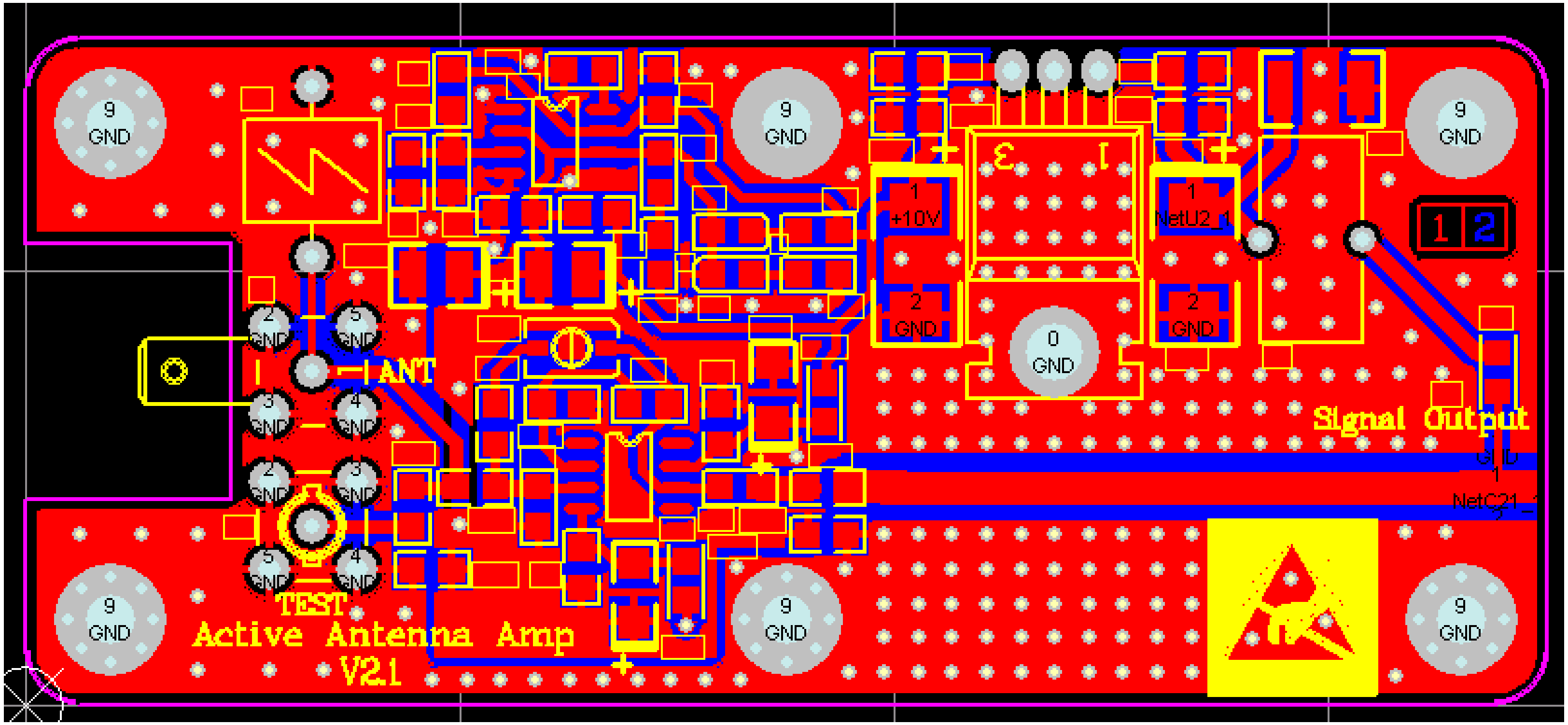
Design of Active Receiving Antenna

Structure of Active Amplifier



Design of Active Receiving Antenna

PCB of NIC Amplifier

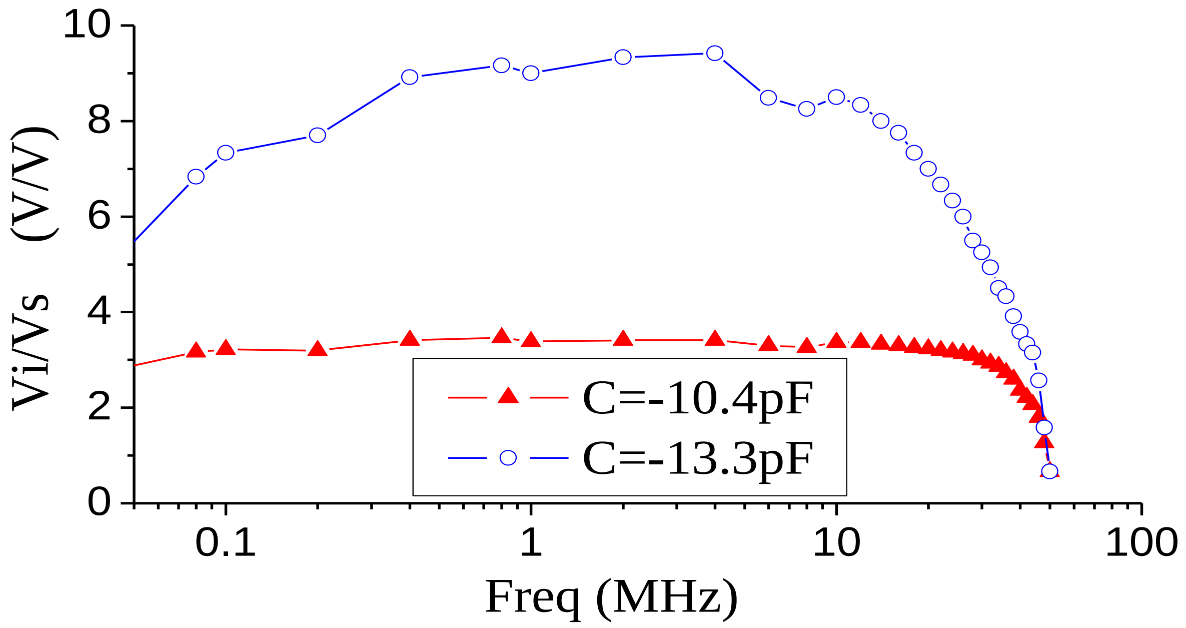


Design of Active Receiving Antenna

Photos of real antenna

Testing of Active Receiving Antenna

Equivalent input gain test results



We observe that the equivalent input gain increases with an increase $|C|$ in the active network equivalent input negative capacitance.

Conclusion

- Presented an analysis and the design of an active receiving antenna utilizing the NIC.
- Experimental results based on the design have been included.
- Circuit presented in this work is simple, and exhibits good performance.

Thank you for your attention!