NON-FOSTER ACTIVE IMPEDANCE MATCHING OF SHORT DIPOLE ANTENNA FOR A LIGHTNING INSTRUMENT:

S. Jitarwal[1]*, T. Upadhyaya[2], J. P. Pabari[1], S. Nambiar[1], D. Kumar[3], Rashmi[1] and K. Acharyya[1], [1]Physical Research Laboratory, Ahmedabad-380009, INDIA. *Email: sonam@prl.res.in, [2]CHARUSAT, Changa, INDIA, [3]BITS Hyderabad, INDIA.

Introduction: Electrically small antenna (ESA) suffers from high Q impedance such as narrow bandwidth and poor gain [1, 2]. To improve them, passive impedance is often used but it is restricted to the Bode-Fano limit [3] Active matching network incorporating non-foster circuits could overcome the shortcoming of passive impedance matching. We have proposed an instrument called Lightning Instrument for VEnus (LIVE) to detect Venusian lightning using future mission [4]. In this work, we have proposed an active impedance matching network to transfer the maximum power from an electrically small antenna to the load. Without the proper impedance matching, signal reflections can exist along the path from the source to the load. Matching the impedances throughout the circuit yields a desired Voltage Standing Wave Ratio (VSWR). Low VSWR circuits transfer the maximum amount of power from the source to the load. Impedance Matching can eliminate or minimize the reactance in a wide frequency range.

In the present work, matching of short dipole antenna to the load by using Non-Foster Active Impedance matching network is realized using negative Impedance Converter. The simulation results of the Active matching network prototype are presented and discussed.

Passive vs. Active Impedance Matching for ESA: In passive matching circuits, every component contributes to the total loss, hence the power transferred to the antenna and the overall circuit efficiency decreases. The conventional matching can be done by passive circuits that cancels out the negative reactance (capacitive impedance) of an antenna with an inductive component and transform the overall impedance into a purely resistive value. Although this approach can provide good match at a single frequency, it is not an ideal solution LIVE, which covers a wide frequency range from Hz to kHz. To overcome the deficiencies in passive matching, it is feasible to match the antennas with the circuit of Non-Foster elements. One of the fundamental characteristics that makes a non-Foster element so novel is its negative reactance slope. Using negative impedance converter, in active impedance matching circuits we can cancel out the effect of capacitive reactance part over a wide frequency range.

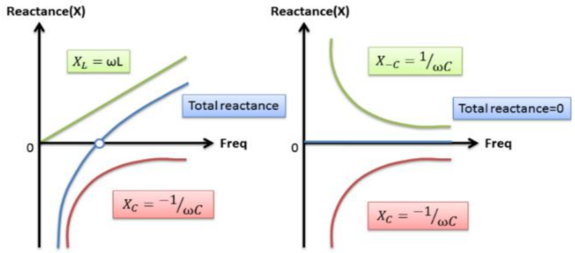

Figure 1: (a) Passive Impedance matching (b) Active Non-foster impedance matching

Negative Impedance Converter (NIC): Linvill proposed that the NIC circuit is used to generate non-Foster impedance. It works on the basic principle of inverting the current through a load while maintaining the voltage across it, or of inverting the voltage across a load and maintaining the current through it, leading to a negated load impedance [5]. Non-Foster circuits can not only cancel reactance, but can also transform resistance to any required value with specifically designed non-Foster matching networks [6]. An ideal negative impedance converter is usually assumed as an active two-port device in which the impedance at one pair of the terminal is the negative of the impedance connected to the other terminal pair as shown in fig. 2.

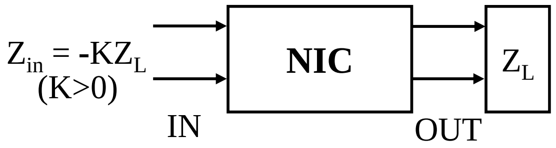

Figure 2: An Ideal NIC Scheme

The NIC uses active elements such as op-amps or transistors to obtain the negative of the load impedance at the input. The matching operates at a very large frequency range which implies wider bandwidth and improves the overall power efficiency. NICs can be realized via a combination of active devices (amplifiers) and lumped loads (capacitors and inductors). Several configurations of NICs can be found in [6], with simple one presented in Figure 3.

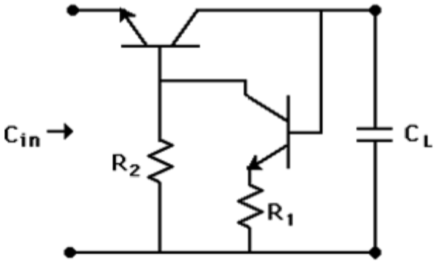

Figure 3: Equivalent circuit of NIC [6]

Implementation of Active Impedance Matching Circuit: The ESA is typically capacitive in nature. The resistive component of the antenna shall be quite small, which is taken to ~4 Ω, and capacitance of ~10.6 pF is taken from the physical measurement. Load impedance is ~50 Ω. The active impedance matching network is designed using the NIC circuit as discussed earlier.

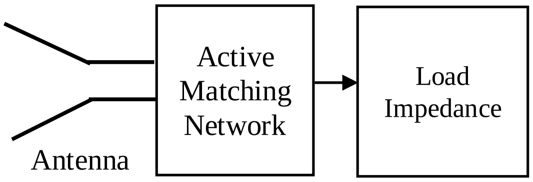

Figure 4: Block diagram of the overall circuit

The typical equivalent circuit is shown in Figure 5, where R_A and C_A represent ESA and Z_L represents the load termination.

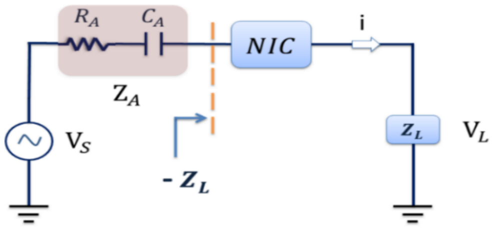

Figure 5: Antenna Equivalent circuit loaded by NIC

Simulation Results: All the necessary simulations of the overall equivalent circuit were performed in ADS software. The VSWR at these levels is well below 1.2, which is suitable for wide bandwidth from Hz to kHz.

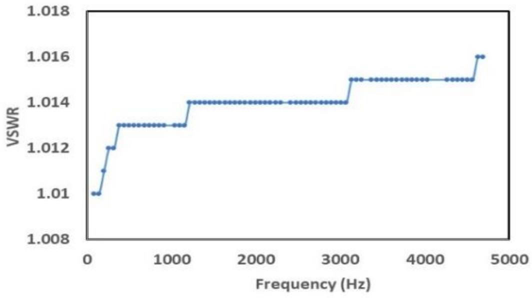

Figure 6: VSWR vs. frequency for the Non-Foster active matching network

Conclusion: This study has presented the design of active impedance matching using negative impedance converters (NICs) and a comparative study of passive vs. active impedance matching is also discussed. We have shown the non-foster impedance matching concept by reducing a large portion of the reactance of an electrically small antenna. Further, we will optimize the active impedance matching network as per the required input and load impedance values.

References: [1] Best et al., (2010) *IEEE Antennas Propagation Magazine* (2010), 52, 47-70. [2] Harrington et al. (1960), *J. Res. Nat. Bur. Stand*, 64, 1-12. [3] R.M. Fano et al. (1950), *J. Franklin Inst.*, 249,139-154. [4] Pabari et al. (2018), *LPSC*, 19-23. [5] S. Canik et al. (2014), *PhD thesis, Bilkent University*, 1-49. [6] S.E. Sussman-Fort et al. (2009), *IEEE*, 57, 8.