Analysis of Different Matching Technique for realization of Effective RF Energy Harvesting Circuit

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ABSTRACT
In this paper the analysis of the different types of input impedance matching network for realization of efficient RF energy harvesting circuit. In mobile application like wireless sensors there is issue of long term power backup and charging of batteries. In this paper, there is design to matching circuit compatible for RF energy harvesting by using L-section to proposed for obtaining the signal bandwidth 900MHz with a noise figure of 4.8 dB. L network is working as resonating frequency(900MHz) as well as matching network at resonant frequency.

General Terms
S11, NF

Keywords
Energy harvester, Low Pass Filter, rectifier circuit

1. INTRODUCTION
Voltage multiplier converts incident RF power into DC power. The matching network, composed of inductive and capacitive elements, It delivers maximum power from antenna to voltage multiplier. The stored energy ensures smooth power delivery to the load and reserve it for when no external energy is available.

If number of voltage multiplier is increases then it also increases the voltage at load, and yet reduces the current through the final load branch. It may results in unacceptable delay in charging for the energy storage capacitor. Conversely, fewer stages of the multiplier will ensure quick charging of the capacitor.

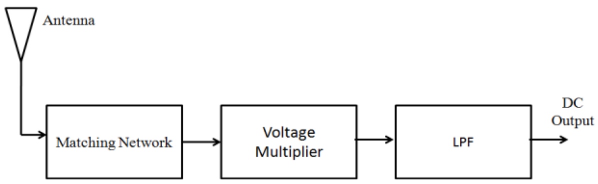

Fig.1. Block Diagram of Energy Harvesting Circuit

Resonator circuit is also a promising approach to strengthen the weak RF signals. A resonator circuit comprises of discrete inductor and capacitor. It exhibits resonant behavior for particular frequencies of interest and the frequency at which maximum amplification is achieved, called its resonant frequency. A separate resonator connected with two stage voltage multiplier circuit is described, a slight improvement in the power conversion
efficiency (60%) was observed but at the cost of increased circuit size.

It propose a resonator circuit based approach to raise the amplitude of RF signal as well as efficiency. It works as matching network and gives resonant behavior between RF input power source of internal resistance 50Ω and the rectifier circuit. One of crucial requirement of the energy harvesting circuit is to transfer the total received power by antenna to the rectifier circuit. Due to nonlinear behavior of diode, the rectifier impedance is going to vary with received RF power and its frequency that affects the circuit performance. In this situation the circuit performance can be controlled by the introduction of matching network between rectifier and the antenna.

If RF power source is not matched then some amount of power gets reflected, this reflected power builds standing waves on the transmission line between the source and load that results in reduction in output voltage. Appropriate matching is possible by selection of proper matching topology and its components values. A slight change in the matching circuit parameter alters drastically the frequency range in which the efficiency of the energy conversion is maximum matching networks can be designed either with lumped elements (resistor, inductor and capacitor). It can be designed by a single resistor for impedance matching, but it is not a desirable solution because most of the power will be lost in the resistor. Another disadvantage of resistive matching is that, it match only the real part of the impedance. In this situation, L type matching is a promising approach. It comprises of series capacitor with shunt inductor or series inductor with shunt capacitor, but the bandwidth obtained by L type network is not sufficient. It can be increased by adding another section that forms π matching network. Introduction of extra element provides an extra degree of freedom to control the value of quality factor in addition to perform impedance matching. It can be seen that harvesting circuit with π type matching circuit attains wider bandwidth than L type matching network.

2. IMPEDANCE MATCHING
It should be careful design which produces a device with well−controlled input and output impedance's at which the various essential performance characteristics are come close to coinciding. While approaching the task of input matching several important consideration is come out. If limiting the number of elements in between the antenna and the voltage multiplier input, then noise figure can be degraded. Because of minimal loss, high−Q input matching network provides an optimal noise figure and gain performance, but these networks are often quite sensitive to variations in process, voltage, temperature, and component value. There are number of performance parameters which show that at what extent the impedances are matched. Firstly, the Reflection Coefficient that is the ratio of the reflected wave to the incident wave (Equation 1.), but can also be expressed in terms of

impedance also. It describes the magnitude of reflection as well as phase shift because it is complex entity.

$$\Gamma_L = \frac{\text{Reflected wave}}{\text{Incident wave}} = \frac{Z_L - Z_S}{Z_L + Z_S} \quad (1)$$

This is the load reflection coefficient with respect to the source impedance. It is also expressed as the characteristic impedance (ZL). When load is short circuited, then maximum negative reflection occurs and reflection coefficient tends to minus unity and when the load is open circuited, then maximum positive reflection occurs and the reflection coefficient tends to plus unity. In the ideal case, when ZL is perfectly matched to , there is no reflection and the reflection coefficient is consequently zero.

A related parameter is the Voltage Standing Wave Ratio (VSWR). It is defined as the ratio of the maximum voltage to the adjacent minimum voltage of that standing wave (Equation 2.). Knowing the domain of the reflection coefficient, it follows that when there is no reflection as in a perfectly matched system; VSWR assumes its minimum and ideal value of 1.

$$\text{VSWR} = \frac{|V|_{max}}{|V|_{min}} = \frac{1 + |\Gamma_L|}{1 - |\Gamma_L|} \quad (2)$$

The source and load impedance's are designed, the objective is to design the input matching network so that ZS matches Z1 and the output matching network so that ZL matches Z2. In other words Z1 and Z2 respectively, are transformed to perceptually match the input and output impedance's. According to the Maximum Power Theorem,the maximum power transfer will occur when the reactive components of the impedance's cancel each other, that is when they are complex conjugates. This is suitably called conjugate matching.

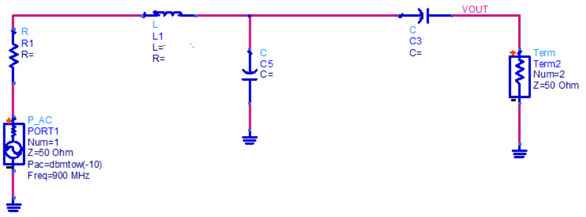

Fig.2. L-match network.

To get the conversion with an impedance matching network there are basically three options. Firstly, there is the L-match. L-match has an advantage of the simplicity, but it has simultaneously its downside as well because it has only two degrees of freedom. Since there are only two component values to set, the L-match is restricted to determining only two out of the three associated parameters:impedance transformation ratio, centre frequency and Q. For getting a third degree of freedom, it is therefore necessary to cascade another L-match stage. By doing this, another impedance transformation are encountered: the π-match, the T-match and L-match.

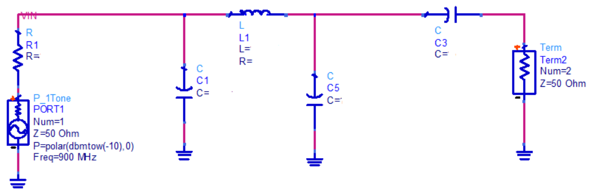

Fig.3. Π-match network.

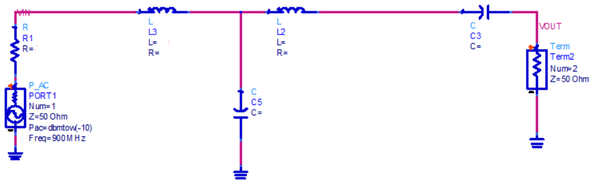

Fig.4. T-match network

The advantages with the T-match and π-match configurations do not end with an additional degree of freedom. But because of their topology they can absorb parasitic reactance present in source or load. Specifically parasitic inductance is absorb by T-match whereas the parasitic capacitance is absorb by π-match. In addition it is also possible to achieve significantly higher Q compared to an L-match configuration. To match the source impedance with rectifier impedance, matching circuit that consists of L (15.8nH) and C (1pF) is used. This circuit also works as a resonator. It amplifies the weak RF input signal which is coming from the antenna side.

3. SIMULATION RESULT

We have simulated those entire impedance matching networks using Agilent's ADS 2009 tool. It is the most powerful IC design tool at RF frequencies. S-Parameters or Scattering parameters are complex numbers that exhibit how voltage waves propagate in the radio-frequency (RF) environment. The characteristics of the 2-port is represented by S-parameter: S11 which correspond to input reflection coefficient respectively. S-parameters, on the other hand, are measured under matched and mismatched conditions. Another factor is noise figure. Under such circumstances, it becomes necessary to measure the parameter. These measurements are carried out by measuring wave ratios while systematically altering the termination to cancel either forward gain or reverse gain.

Following simulation results shows the input reflection coefficient and noise figure for each of the matching network techniques.

3.1 L-match

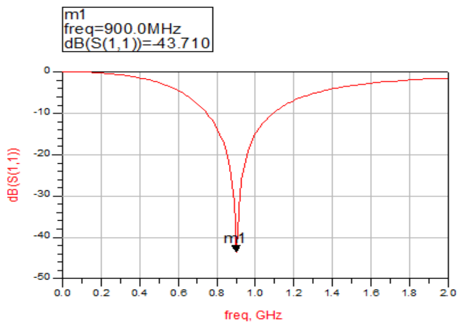

Fig.5. Input Reflection Coefficient

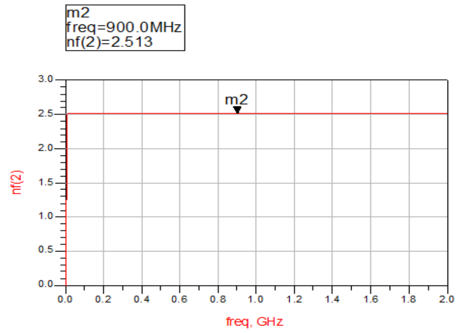

Fig.6. Noise figure

3.2 *π-match*

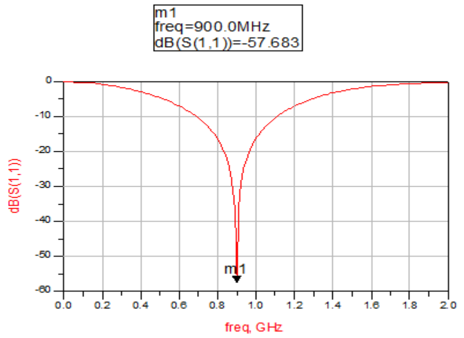

Fig.7. Input Reflection Coefficient

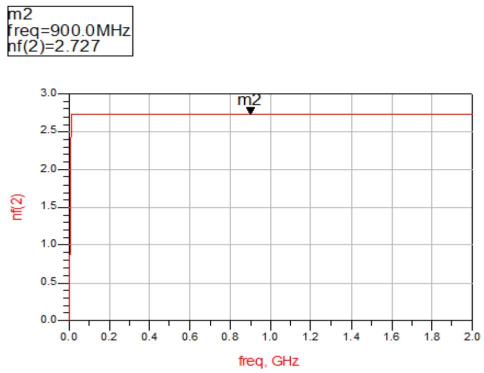

Fig.8. Noise figure

3.3 *T-match*

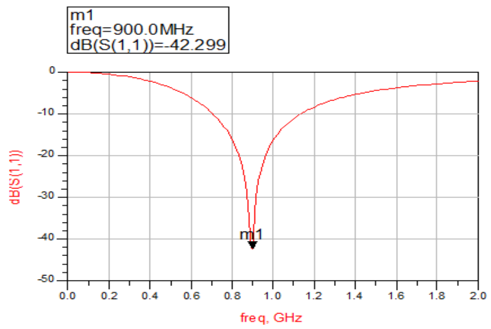

Fig.9. Input Reflection Coefficient

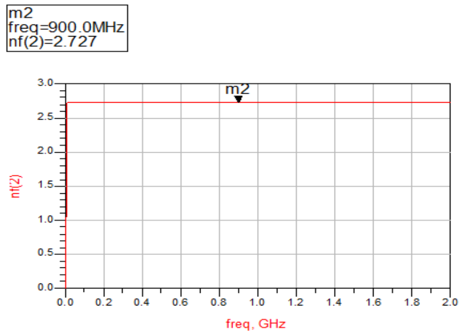

Fig.10. Noise figure

4. CONCLUSION

Thus we have simulated π-match, T-match and L-match matching network to match 50Ω impedance in Agilent ADS 2009 tool. Following table show the comparison of all three matching techniques with two approaches one is directly signal coming from antenna and another is with along with the RF signal external noise of 1μV applied. Even after applying External Noise L-section gives good input reflection coefficient of -3.5dB and noise figure of 4.8dB.

Table 1. Comparision table between impedance matching

Pac=-10 dBm	Without external noise			With external noise applied		
Freq=900 MHz	T	L	π	T	L	π
S11(dB)	-42.30	-43.71	-57.68	-4.79	-3.51	-6.22
NF(dB)	2.7	2.5	2.7	4.94	4.94	5.20

5. ACKNOWLEDGMENTS

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