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A Superdirective Electrically Small Rectenna

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RF energy harvesting and wireless power transmission enable the wireless powering of ultra low power sensors and RFIDs [1]. Electrically small rectennas are particularly suitable for miniature sensors [2, 3]. They typically have omnidirectional radiation patterns and directivity values of approximately 1.7 dB. Superdirective electrically small antennas appear interesting in order to obtain increased operating range and are also suitable for applications that require directive rather than omnidirectional transmission for example for security reasons. Superdirective electrically small antennas comprising a fed element and a closely spaced parasitic element are considered [4]. A wire antenna element is simulated using the Numerical Electromagnetics Code (NEC). The antenna comprises a directly fed dipole and a parasitic dipole with reactive loading (Fig. 1). Furthermore, a single shunt diode rectifier is considered based on an Skyworks SMS7630 diode and simulated using harmonic balance in Agilent ADS. An electrically small dipole has a small radiation resistance and a large capacitive reactance. Due to the fact that the rectifier circuit also presents a complex input impedance, a self-resonant antenna is not designed in order to implement conjugate matching to the rectifier impedance. The dipole arms are folded in order to tune the input impedance reactance. The dipole length excluding the folded sections is equal to the parasitic dipole length and is 0.127 λ at 915 MHz. The wire radius of both dipoles is 1 mm. The parasitic dipole has a reactive load in its center to optimize the directivity of the antenna. The fed dipole had a input impedance of $5.1 - j199$, a directivity of 1.7 dB and radiation efficiency of 99% assuming copper wire. The maximum theoretical superdirective directivity value for the two element array is 7.7 dB ($N^2 = 4$ or 6 dB above the single element gain), compared to 4.7 dB for a broadside array with 0.5 λ spacing [4]. A directivity of 6.97 dB at 915 MHz and an input impedance of $1.6 - j195$ were simulated for a parasitic element distance of 0.12 λ and a reactive load $Z_p = j607$ corresponding to an inductance $L = 105$ nH. An increase in the input impedance $4.7 - j193$ is obtained by changing the operating frequency to 919 MHz and allowing a smaller directivity 5.07 dB and 99.2 % radiation efficiency. A shunt diode rectifier circuit was selected with a series inductor to a parallel RC load at its output in order to filter the dc voltage. An inductive rectifier input impedance was obtained by tuning the value of the inductor $L_1 = 26$ nH, while load and source pull simulation determined the optimum input $5 + j218$ impedance and load 12.2 KOhm impedance for optimum RF-dc conversion efficiency 55.9 % at -20 dBm input power. An ideal inductor model was used in simulation. The obtained RF-dc efficiency and antenna gain will be reduced once realistic inductor models are considered. These preliminary results demonstrate that it is possible to obtain a conjugate impedance match between the superdirective dipole antenna with a reactively loaded parasitic element and a shunt diode rectifier for optimum RF-dc conversion efficiency. Further challenges need to be addressed, such as increasing the real part of the antenna input impedance (see e.g. [4]), addressing the sensitivity of the design to component and fabrication tolerances, implementing a printed prototype and considering different circuit topologies.

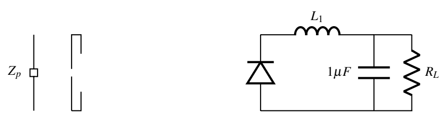

Figure 1. Superdirective rectenna: electrically small antenna layout (left) and rectifier circuit (right).

References

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