

Wirelessly Reconfigurable Antenna

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Abstract— In this paper, we describe a reconfigurable antenna with switches on the antenna elements that are powered wirelessly, by the antenna itself. Control signals for individual switches are part of the antenna transmission. We describe the theory of operation and provide simulation results for a three-element parasitic dipole antenna array with two switches.

I. INTRODUCTION

Smart and reconfigurable antennas have long been known in antenna literature [1, 2] and have been used in many applications, including RFID [3]. By conventional definition, smart antennas use external variable power and phase distribution network which feeds antenna elements, allowing, for example, to steer the beam of a phased array. However, such network is costly and complicated. Reconfigurable antennas typically have the elements of the antenna itself which can be electronically switched (for example, with PIN diodes or MEMS switches [4-8]). Both smart and reconfigurable antennas need DC bias lines [5], fiber optic lines [9], DC biased RF feeds [10], or other complex circuitry [11] which complicates antenna design and construction.

We propose a different approach - a reconfigurable antenna with switches that are powered by the antenna itself. Control signals for switches are part of the antenna transmission, preceding the main data. This concept opens many possibilities for antennas with reconfigurable properties such as patterns, polarizations, and frequency bands, all without adding any wires or cables to operate switches on the antenna.

II. CONCEPT

The concept of a wirelessly reconfigurable antenna is illustrated in Figure 1. The antenna has several elements (e.g. dipoles or slots) loaded with RF switches. Current low power RF technology already allows one to create RF powered switches that can be turned on and off individually by the control signal. Good examples of such switches are UHF RFID tag ICs which have passive RF sensitivity better than -20 dBm [12, 13], unique IDs, and can modulate their input impedance between two values, staying in low impedance state for as long as 25 μ s (this duration is currently dictated by the RFID protocol details and on-chip capacitance). We envision that RF switches on the wirelessly reconfigurable antenna can be similar in structure to RFID ICs, i.e. have internal power harvester, capacitor, demodulator, ID logic, and modulator, allowing them to go to low impedance state for a certain duration of time (defined by the capacitor value). Such switches can be realized as custom ICs or as discrete circuits with low power microcontrollers, similar to discrete UHF RFID tags described in [14, 15].

The constant wavelength carrier powers all switches. Then comes a command addressing and activating specific switches (instructing them to switch to low impedance state). The main data transmission follows. Depending on which switches are activated, the antenna properties, such as radiation pattern, can be changed.

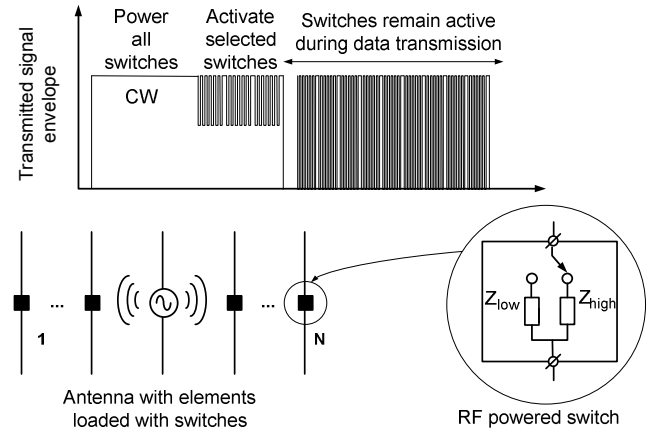


Fig. 1. Wirelessly reconfigurable antenna

III. EXAMPLE

Consider a symmetric three-element dipole antenna array consisting of half wavelength dipole antennas, shown in Figure 2. The center dipole is connected to 50 Ohm transmitter and the end dipoles are loaded with RF powered switches, switch 1 and switch 2, each of them addressable individually. The elements of the array are printed copper traces, 3 mm wide and 127 mm long, spaced 75 mm apart on 60 mil FR4 substrate (permittivity 4.4). The antenna is designed to operate at 915 MHz.

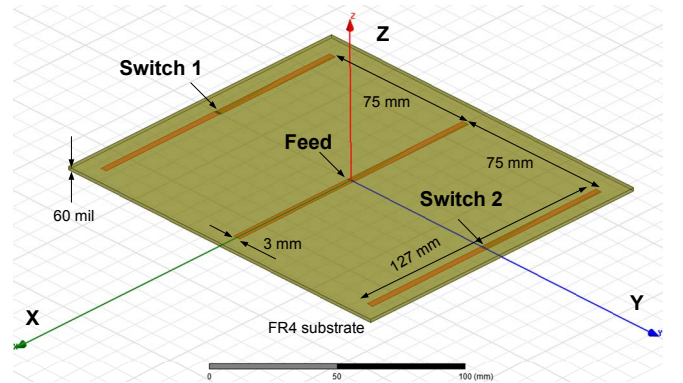


Fig. 2. Three-element antenna array with two switches.

Three-element switched parasitic antenna arrays have been investigated before [7-8], but in our case the switches are wirelessly powered by the antenna itself. As we mentioned above, a good example of such switch is RFID tag IC. The input impedance of these ICs can be represented as an equivalent parallel RC circuit [12]. For illustrative purposes, assume that the two impedance states of our RF powered switches have the values shown in Table I. These values can be considered as fairly typical for RFID ICs [12, 16-17] but in reality will depend on the details of the RF front end modulator (typically, a MOSFET transistor) as well as input power and frequency.

TABLE I. RF SWITCH IMPEDANCE STATES.

Switch state	$R_{parallel}$	$C_{parallel}$	Complex impedance at 915 MHz
A	1 KOhm	1 pF	$29 - j 169 \text{ Ohm}$
B	300 Ohm	3 pF	$11 - j 56 \text{ Ohm}$

We modeled and simulated this antenna system using Ansys HFSS [18]. Figure 3 shows the radiation pattern in the E-plane (XY-plane in Figure 2) for the two different combinations of switch states. One can see that, depending on the state, the antenna pattern can be steered by 180 degrees with more than 3 dB difference in two peak gain values. One, of course, must make sure that the RF switches receive enough power from the antenna signal to respond to the commands. Our simulation showed that with 10 dBm transmitter output, the RF switches will scavenge more than -10 dBm in either impedance state, which is enough to power even discrete circuit architectures described in [14, 15].

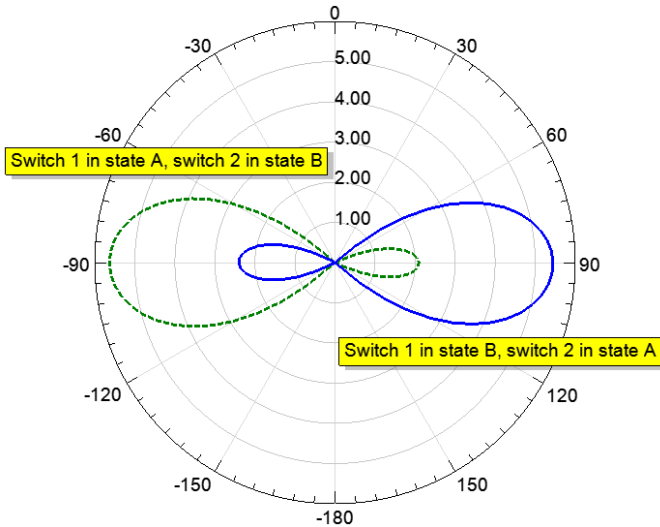


Fig. 3. Antenna radiation pattern at 915 MHz (gain, dBi) in XY-plane for two different switch state combinations.

Note that the symmetric three-element antenna array in this example was picked for illustrative purposes and can certainly be modified and optimized to obtain higher gain and better front-to-back ratio, as shown, for example in [19, 20].

CONCLUSIONS

We described a reconfigurable antenna with RF powered and activated switches and showed via simulation how this concept can be applied to three element parasitic dipole array whose radiation pattern can be steered by activating selected switch combinations. This concept can also be used for other antenna types and applications (such as RFID systems or cellular base stations) and opens many possibilities for antennas with reconfigurable properties such as patterns, polarizations, and frequency bands, all without adding bias lines to operate the switches. The idea presented in this paper has been described in patent application [21].

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