# A Switched Beamforming of Fully Shielded Six Parasitic Planar Array for IoT Network


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***Abstract*— An optimized switched parasitic smart antenna (SPSA) 915 MHz that consists of 6 monopole parasitic wires encircled a single feeding monopole wire and configured on top of a 328 mm circular ground plane was manufactured and evaluated. SPSA prototype is initially designed to support the practical operation of a particular IoT based surveillance network within the university campus environment. In practical, the constructed antenna installed at a server station will continuously detect the particular active sensor node and maintain the connection and the data transfer between sensor node and the server. A slightly different switched beamforming technique deployed on the fully shielded cover seven monopole wires planar array by electronically setting-up 3 parasitic wires to be grounded and three other floating at the same time in order to point the power beam into a certain direction. Through the sequential variations of those wires set-up then the main lobe directions would be pointed to 6 different directions, i.e. 0°/360°, 60°, 120°, 180°, 240°, and 300°.**



***Keywords—915-MHz SPSA, Switched Beamforming, IoT Network, Environmental Surveillance, RF-Switching and Planar Array***


## I. INTRODUCTION

The fast development and deployment of IoT technology have recently allowed the various connections of valuable things through the wide internet infrastructure. A large varieties of IoT applications has emerged as the main breakthrough tools to strengthen some other technology solutions such as smart city, smart farming, smart building, environmental surveillance, road traffic management and control and so on and so forth. The powerful performance of the IoT network operation relies on the wireless sensor network qualities to perform the data sensing and transferring from one sensor node to the main central station [1-2] via a gateway. There are several numbers of critical natural phenomena existed throughout a particular IoT network during the data propagation. These are including shadowing, interference, network connectivity, and power consumption efficiency. All the factors might be limiting the number of the IoT sensor nodes could be deployed [3].

The solution to overcome the issues related to the IoT-based system mentioned above is to integrate an adaptive reconfigurable antenna on the RF front-end [4]. This type of antenna has the ability to change one or more parameters such as the resonant frequency and radiation pattern in real-time without changing the antenna structure. Radiation pattern reconfigurable antenna is a smart antenna system that can mitigate the phenomenon of propagation because of its ability to direct the beam in the desired direction while pressing the beam in an unwanted direction, thus increasing antenna functionality and making it more flexible.

Reconfiguration of the antenna radiation pattern can conventionally be achieved with a phased array antenna [5]. But this antenna system is more complicated because it requires an antenna array and phase shifters, and requires more costs [6]. However, as reported in some literature, it provides an alternative solution to reduce the complexity of the antenna beam steering. Antenna reconfiguration can be done with optical switch [7], PIN diode [8], varactor diode [9], RF-MEM [10], and FET transistor [11]. Of these, the simplest way to set the antenna beam is with a PIN diode. PIN diodes have the advantage of being cheaper, easy to



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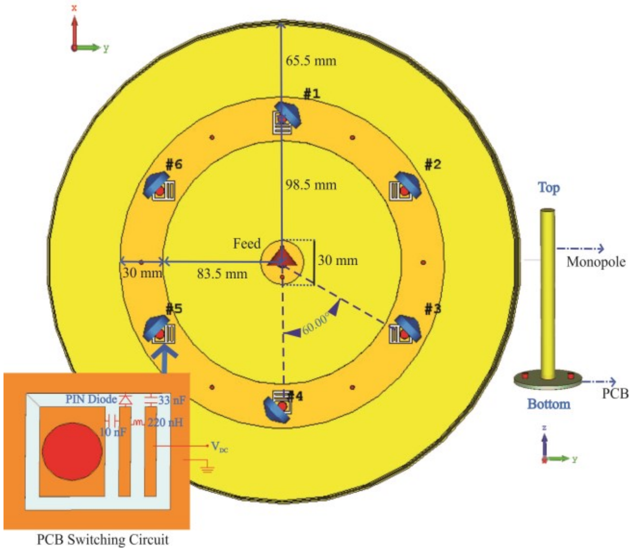
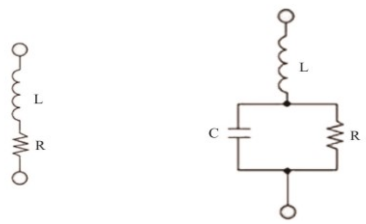



Fig. 2. Bottom view of switch parasitic array antenna. The inset is the close up view of switching circuit.

## B. *DC Biasing Circuit for RF PIN Diode*

The PIN diode to act as an RF switch requires a DC bias circuit to work. The PIN diode used as a switch is HSMP 3824 device. This RF electronic part is easily modeled using a lumped element equivalent circuit consisting of an inductor (L), capacitor (C) and resistor (R) on the numerical computing process applying CST software. The equivalent circuit diagram of the PIN diode is shown in Figure 3. The ON condition of the diode is represented as a series RL circuit and when the switch is OFF it is represented as a parallel RLC circuit. The optional values for setting-up the intended PIN diode configuration are listed in Table 2.




(a) (b)

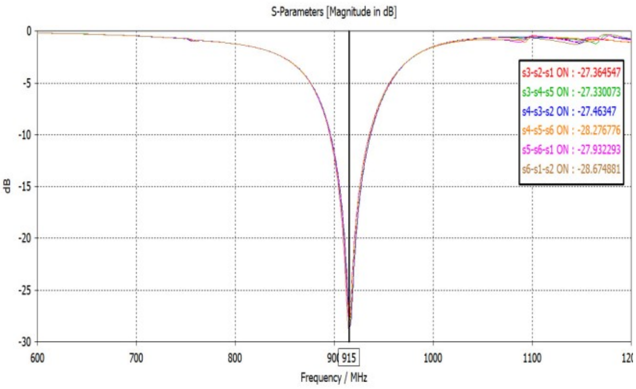
Fig. 3. Equivalent circuit of PIN diode switch: (a) ON and (b) OFF

TABLE II. PARAMETER VALUE OF EQUIVALENT RLC CIRCUIT

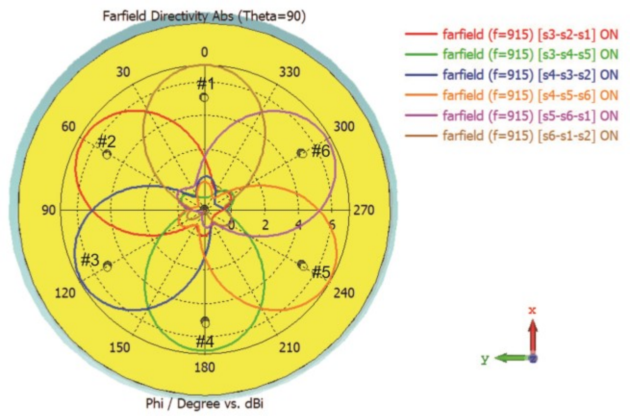
| State | Parameters | | |
|---|---|---|---|
| | R(Ω) | L(nH) | C(nF) |
| ON | 1 | 220 | - |
| OFF | 1M | 220 | 10 |

## III. RESULT AND DISCUSSIONS

The 3D-numerical computing activities described in Figure 1 and 2, respectively, have successfully produced several number of interesting results including the reflection coefficient (S11), bandwidth, the resonance frequency and the beam pattern direction variability as the effect of the different RF-switch configuration alterations. The computing results are depicted in Figs 4 (a) and (b), respectively.




(a)




(b)

Fig. 4. The 3D-numerical computing results of the designed SPSA employing the sequential tracking algorithm for maintaining the communication link between IoT sensor node and server node: (a) reflection coefficient $S_{11}$ (dB) and (b) radiation pattern for six RF-switch configurations.

It is obviously that the accurate placement of each monopole wire element in the planar geometrical area of 3D-numerical computing SPSA is highly influencing the matching impedance of whole antenna prototype. The reflection coefficients recorded from all RF-Switch configurations exhibit the same values and identical graphical profiles both in the lower frequency operation and the higher frequency operation. The operational bandwidth is approximately 50 MHz could be achieved (see Fig. 4 (a)). The return loss value at the center frequency is pretty good and it is achieving almost -30 dB. This is equal to 1.2 VSWR. Varying the RF-switch operation status as listed in Table 1 then the exact similar beam pattern direction will be generated through the 3D-computing. SPSA beam direction might be varied to 0°/360°, 60°, 120°, 180°, 240°, and 300°. These are illustrated in Fig. 4 (b).

Another interesting computing result regarding the beam steering technique applied for SPSA is illustrated in Fig.5. The maximum gain could be provide is in the direction 0° and the values is about 7 dBi.

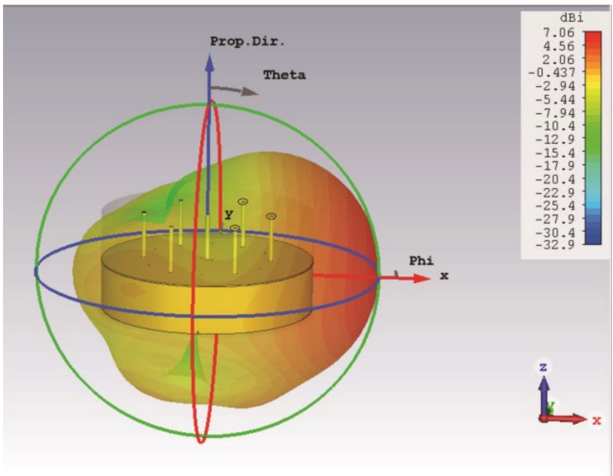
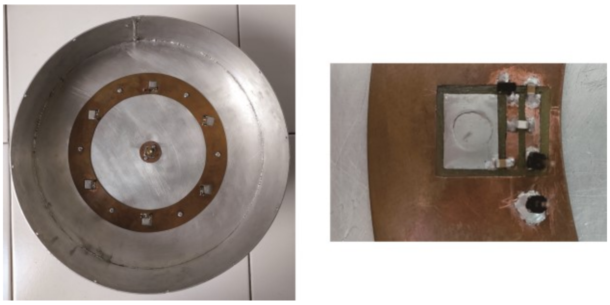



Fig. 5. Simulated 3D radiation pattern at 915 MHz for RF-switch configuration s6-s1-s2 ON with passive element shorten to the ground marked by black circle lines.

Fig. 6. The fabricated SPSA 915 MHz fully covered with the polycarbonate material.

The fabricated SPSA 915 MHz is fully covered with polycarbonate materials. The upper side shielding is transparent material and the lower side is untransparent one. This cover selection was implemented to allow the easy repairing and maintaining whole SPSA prototype in case of the technical operation problems occurred. Underneath of each parasitic wire element, RF-switching network is directly soldered. A certain terminal of the network is connected to a circular PCB track (see Figs 7 (a) and (b)). The impact of the RF-switching unit network configuration alterations to SPSA antenna operation is depicted in Fig.8. Based on Fig.8, it is apparently confirmed that the return loss values will vary about 1 to 7 dB while each switching set-up altered.



(a) (b)

Fig. 7. Bottom view of the fabricated SPSA: (a) Bottom Grounding Plane, (b) RF-switching circuit

Figure 7 (b) shows the RF switch circuit, where the PIN diode, inductor and capacitor components are soldered to the PCB. The inductor / RF choke is connected to $+V_{DC}$ and the diode anode is used to isolate the RF current from the antenna so as not to interfere with the DC bias supply. While the $-V_{DC}$ terminal is connected directly to the diode cathode to the antenna ground plane. A DC blocking capacitor is added to the circuit to pass RF current and block DC current, while a bypass capacitor is added after the RF choke to isolate the RF current from the DC bias supply. Small capacitance value was applied in order to minimize RF leakage when the diode is OFF.

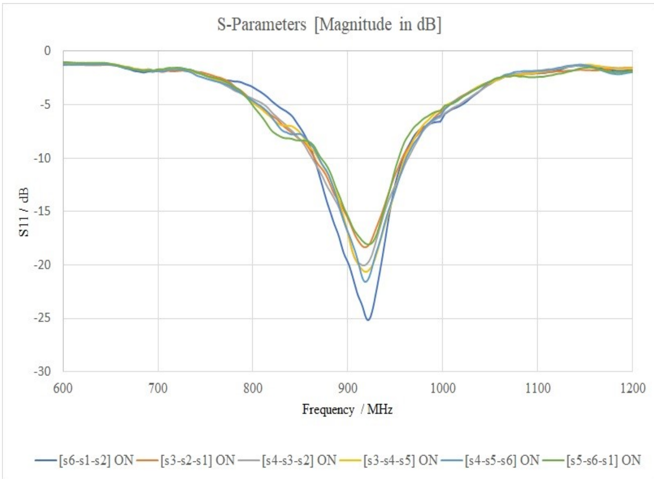



Fig. 8. Reflection coefficient variation of the proposed SPSA antenna for all switch configurations in order to steer the beam direction into the angle 0°/360°, 60°, 120°, 180°, 240°, and 300°.

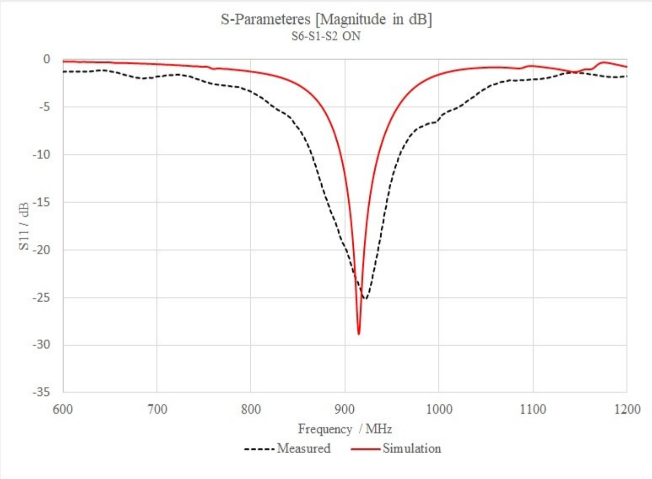
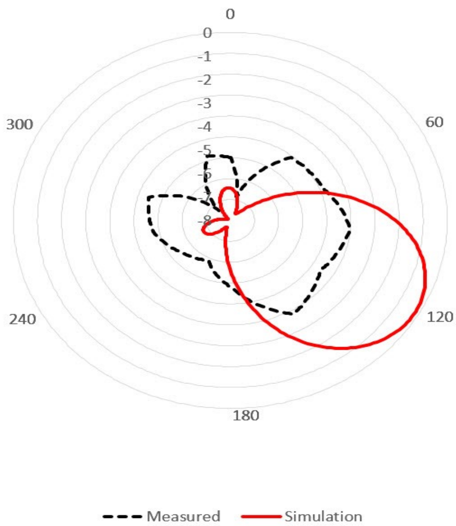


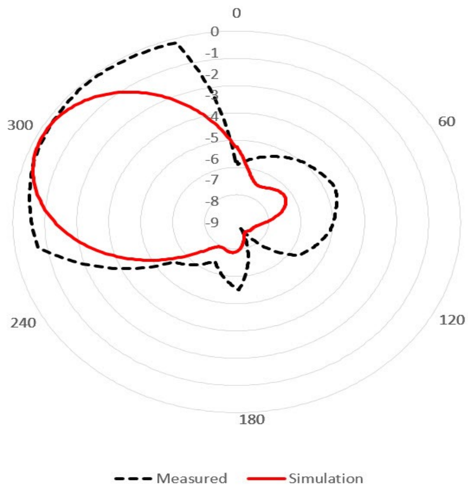

Fig. 9. The return loss values comparison between the simulated $S_{11}$ and the measured one for a particular direction 0/360 degrees by configuring the RF-switching S1-S2-S6 ON and other three RF-switching OFF.

Through the proper RF-PIN diode switching operation variation, ON and OFF, then the beam power radiation/ reception might be steered consistently to point to 6 different directions.

The measurement results are shown in Figure 9 and Figure 10, which indicate that the antenna can direct its beam to the six radiation directions by adjusting the switch configuration. The achieved reflection coefficient is less than -10 dB for all switch configurations at 915 MHz. There was a shift in the measured reflection coefficient to be 6 dB higher with lower return loss than the simulation results. Likewise, in the measured radiation pattern, it can be observed that the side lobe level is still greater than the simulation results. These changes might be occurred due to some technical problems including fabrication tolerances, material losses, SMA connectors, and DC bias circuit influence.




(a)




(b)

Fig. 10. Radiation pattern measured antenna (a) s5-s6-s1 ON, (b) s4-s3-s2 ON

## IV. Conclusion

Various technical difficulties on the development of the switched parasitic smart antenna (SPSA) 915 MHz has been analytically assessed. A number of technical issues regarding the construction difficulties to convert the SPSA numerical model into the manufactured one has been extensively presented and discussed. It is apparently confirmed that the accuracy of the monopole wires placement on the planar circular ground area, the RF-PIN diode switching consistency, and the proper configuration of intelligent transceiver part will have significant impact to the whole SPSA performance, not only in the context of S11 parameter variation but also influence the beam pattern quality generated.

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