λ/16 Spaced ESPAR Antenna Using Analog RF Switches for Single RF Chain

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Abstract - Electronically steerable parasitic array radiator (ESPAR) antenna using analog RF switches for single RF chain is presented. A switch simplifies the design and implementation of reactance loads, does not require complex additional antenna matching circuits. The measured impedance bandwidth of the proposed ESPAR antenna is 650 MHz (2.35 – 3 GHz). The proposed antenna has a beam pattern is reconfigurable in the 2.45 GHz due to a change in the reactance value, the measured peak antenna gain is 4.5 dBi.

***Index Terms* — ESPAR antenna, single RF chain, analog RF switch, reactance load.**

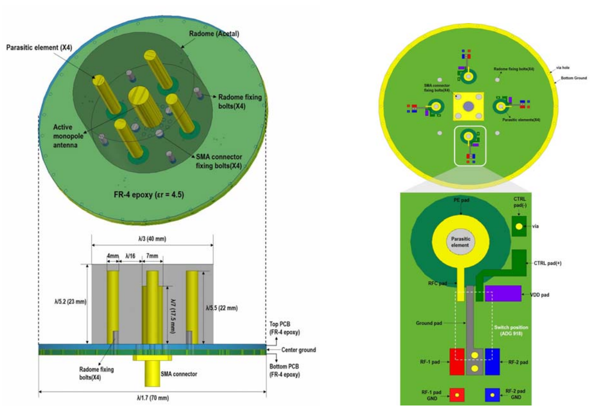
1. Introduction

An electronically steerable parasitic array radiator (ESPAR) antenna is a typical implementation form of a single RF chain MIMO system. An active antenna is fed from the RF single, while the passive parasitic elements are terminated with reactance loads. A conventional ESPAR antenna [1-2] use λ/4 elements spacing, λ/4 elements length and ground plane of λ. For this reason, there is a disadvantage that the whole size of the antenna increases. To reconfigurable antenna beam pattern, the loads may be typically implemented with either varactor or PIN diode with DC voltage controlled reactance. Reactance load circuit implemented using the varactor or PIN diode requires additional voltage driving circuit. Also, in order to realize the reactance load value for a reconfigurable beam pattern, one or more lumped elements are required in series or parallel.

In this paper, we present a small ESPAR antenna using analog RF switch for single RF chain. The proposed antenna elements are spaced of λ/16 and the antenna size is miniaturized using a dielectric radome. The reactance loads are optimized for a constant impedance matching at the single active monopole antenna. The ESPAR antenna has a beam pattern is reconfigurable in the WLAN band (2.45 GHz) due to a change in the reactance value. The measured peak gain and efficiency are 4.5 dBi and 90 %, respectively.

2. Design of the ESPAR Antenna

We have designed and implemented an ESPAR antenna using analog RF switches. Figure 1 shows a λ/16 spaced 5-element monopole type ESPAR antenna. The ESPAR antenna is composed of one active monopole antenna, four passive parasitic monopole elements, top PCB, bottom PCB with reactance load circuit, and radome.



a b

Fig. 1. The proposed ESPAR antenna: (a) Top plane, and (b) Bottom plane

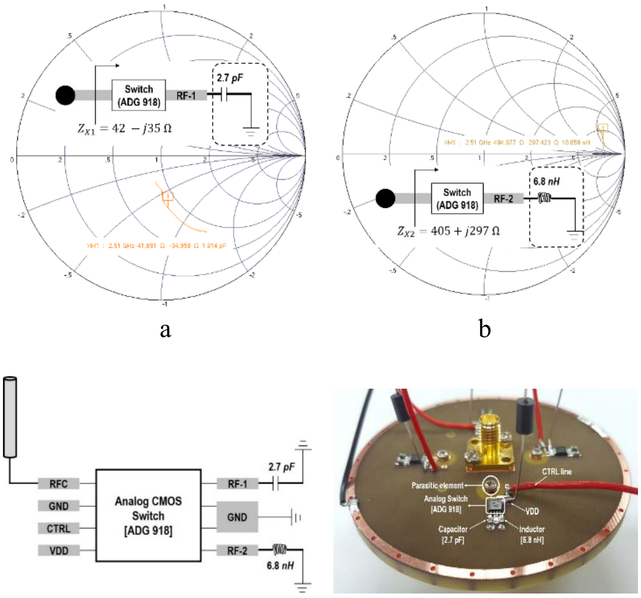
An active monopole antenna is encircled by four, equally spaced (λ/16 at 2.45 GHz), passive parasitic monopoles and is printed on a 70 mm (λ/1.7) x 3.2 mm FR-4 epoxy substrate (εr = 4.5, Loss tangent = 0.025).

The diameter and height of active monopole antenna and passive monopoles are 8 mm, 17.5 mm and 4 mm, 22 mm, respectively. The proposed ESPAR antenna size is miniaturized using a dielectric radome (acetal, εr = 3.5, Loss tangent = 0.003). Figure 1(b) shows the bottom plane of the ESPAR antenna. The active monopole antenna is fed by a 50 Ω SMA connector while the passive parasitic monopoles are connected to the parasitic (PE) pad of the bottom PCB plane. A RF switches are connected to the switch position. We used ADG 918 from Analog Devices, which have high isolation and low insertion loss.

The load impedance value can be determined analytically based on the scattering parameters of the antenna structure. The result of the S-parameter at 2.45 GHz is given by:

$$[S] = \begin{vmatrix} -0.05-j0.15 & -0.25+j0.2 & -0.25+j0.2 & -0.25+j0.2 & -0.25+j0.2 \\ -0.25+j0.2 & 0.06-j0.17 & -0.05+j0.27 & 0.28-j0.005 & -0.05+j0.27 \\ -0.25+j0.2 & -0.05+j0.27 & 0.06-j0.17 & -0.05+j0.27 & 0.28-j0.005 \\ -0.25+j0.2 & 0.28-j0.005 & -0.05+j0.27 & 0.06-j0.17 & -0.05+j0.27 \\ -0.25+j0.2 & -0.05+j0.27 & 0.28-j0.005 & -0.05+j0.27 & 0.06-j0.17 \end{vmatrix}$$

By using equations in [3], the target reactance load value was calculated based on the S-parameter value at 2.45 GHz. The targeted reactance loads set is determined as [j_{x1}, j_{x2}] = [*-j34*, *j300*] Ω at the operating frequency of 2.45 GHz. The initial load value of the embedded RF switch (DC 3V "ON") and micro-strip transmission line are measured as *37.6 – j0.86 Ω*.



a b

c d

Fig. 2. Measured reactance loads with RF switch controls: (a) Z_{X1} matching, (b) Z_{X2} matching, (c) reactance load circuit, and (d) Photograph of the bottom plane

Figure 2 shows the measured reactance matching results. It is possible to simplify Z_{X1} and Z_{X2} load the only consists of the RF switch and lumped elements without additional matching components. With connecting a series capacitor (2.7 pF) in the RF-1 port, Z_{X1} = *-j35 Ω* can be obtained. With connecting a series inductor (6.8 nH) in the RF-2 port, Z_{X2} = *j297 Ω* can be achieved. The reactance loads of the measured impedances at 2.45 GHz are *-j35 Ω* and *j297 Ω* in ON (V_{CTRL} = 3V) and OFF (V_{CTRL} = 0V) states, respectively. These values ($[j_{X1}, j_{X2}]_{measured}$ *Ω = [-j35, j297] Ω*) are close to the target reactance loads ($[j_{X1}, j_{X2}]_{target}$ *Ω = [-j34, j300] Ω*).

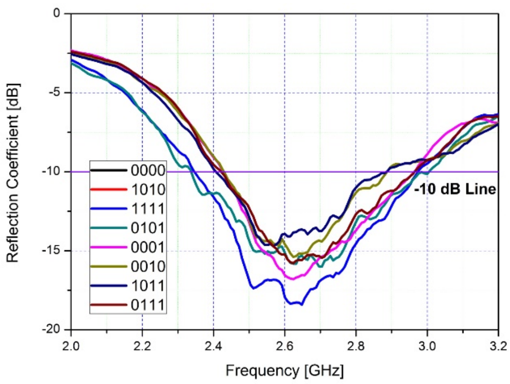


Fig. 3. Measured reflection coefficient

Figure 3 shows the measured reflection coefficient. We have the input signal of "0" and "1" to the RF switch control port. When the control signal input 0, parasitic element is connected to RF-2 port. When the control signal input 1, parasitic element is connected to RF-1 port [4]. As shown in figure, it can be seen that to satisfy the operating frequency bands in all cases.

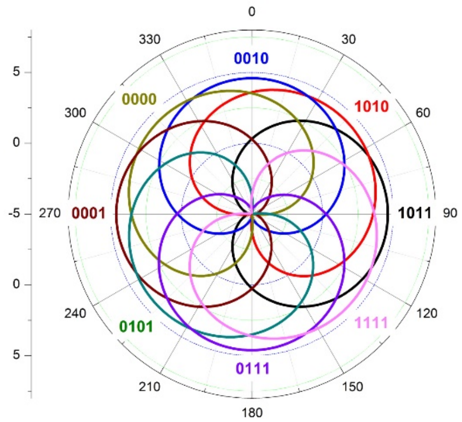


Fig. 4. Simulated radiation patterns

Figure 4 shows the simulated radiation patterns at 2.45 GHz. The combination of the four control signals, the beam patterns are made in different directions. The simulated peak gain is 4.5 dBi and beam-width is 100°.

3. Conclusion

ESPAR antenna using analog RF switches for single RF chain is presented. We provide a simple reactance matching circuit structure using the RF switch instead of the diode.

Acknowledgment

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