Proc. 2010 IEEE Antennas and Propagation Symposium, July 2010.

Investigation of Varactor Tuned Stacked Patch Antennas

Rodney B. Waterhouse and Dalma Novak
Pharad LLC, Glen Burnie, MD, 21061, USA
E-mail: rwaterhouse@pharad.com

Introduction

Electrically small antennas are an enabling technology for a variety of communication applications including cellular systems, body wearable systems and biomedical devices. Of course there are well established shortcomings using this class of radiator; the instantaneous bandwidth is a fraction of the conventionally sized antenna and the overall efficiency is typically reduced. The narrow bandwidth further complicates things as it makes the performance of this radiator very dependent on the surrounding environment.

One approach to overcome the deficiencies associated with an electrically small antenna is to make the radiator adaptive by incorporating a tuning element within the radiating structure. Doing so can effectively compensate for the surrounding environment of the antenna and also increase the effective operational bandwidth of the radiator. Varactor diodes are typically considered for enabling the antenna to be tuned over a frequency range, thereby increasing its usefulness. This approach has been applied to a variety of printed antennas, including conventional microstrip patches [1]. Although the results presented to date compensate for some of the issues described above, the overall solutions are typically not truly 'cognitive'; in that the effective bandwidth is really limited to one wireless system (say IEEE.802.11b). If we could increase the effective bandwidth of a compact antenna to levels approaching an octave, we could then not only adaptively compensate for the environment in which the antenna is mounted, but also enable the remote terminal to communicate with different communication systems based on the information rate required as well as the state of the propagation conditions.

In this paper we present an adaptive antenna based on a stacked patch radiator incorporating varactor diodes that enable the antenna to be tuned from 3 GHz to 6 GHz; an effective bandwidth of an octave. As the fundamental radiator is designed for operation at the upper frequency limit, the antenna is an electrically small radiator. The general configuration is presented as well as the design methodology is presented herein. A proof-of-concept version of the antenna was designed and developed and the measured results are also presented.

Configuration, Design Methodology and Predicted Performance

Figure 1 shows a schematic of the proposed adaptable antenna. The antenna is a probe-fed stacked patch antenna and a via connects the driven radiator to the microstrip feed transmission line located below the ground-plane of the antenna. The varactor diode for the lower (or driven patch) is connected by a via to a bias circuit that is located below the ground-plane. This can be considered as 'parallel' loading. There is another way we can load a patch antenna with a varactor diode to provide frequency tuning. This can be classified as 'series' loading and Figure 1 shows this approach for the loading of the top patch, where we use two varactor diodes. We have shown previously that using diodes gives the designer greater flexibility [1]. 'Series' loading the top patch significantly simplifies the overall design of the radiator. To supply bias to these varactor diodes on the top patch, a via (isolated from the lower patch) is connected at the center of the upper patch (not shown in the schematic). To enable a return path for the series loading diodes, we used a combination of EM design strategies. Firstly, we used very thin traces connected to the patch antenna. Thin traces are highly inductive and therefore minimize the amount of RF energy that propagates along these lines. We also connected these traces along the non-radiating edges of the patches, once again to minimize RF power flowing through these conductors. Finally, we located the vias that connect these traces to the ground-plane of the antenna a reasonable distance away from the patch conductor.

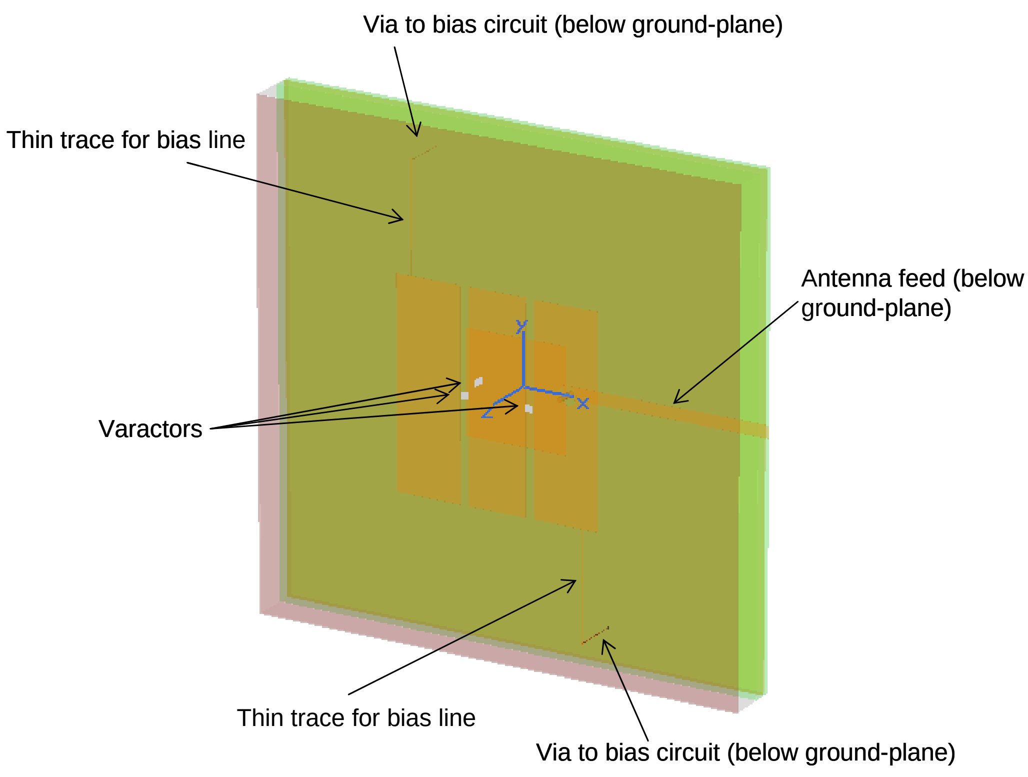

Figure 1 Schematic of proposed varactor tuned stacked patch antenna

We simulated the antenna using CST^{TM} for a variety of bias levels/capacitor values. When the varactors are biased for minimum capacitance, the antenna has a -10dB return loss from 5 – 6 GHz and the antenna gain is approximately 8 dBi. When the varactors on the upper patch are biased to 3 pF with the varactor on the lower patch biased to 2.0 pF, the return loss at 3 GHz is approximately -13 dB and the -10 dB bandwidth is approximately 100 MHz. The gain of the antenna at 3 GHz is 5 dBi. The range of capacitances can be readily realized using common varactor diodes such as the MV31014-35 GaAs varactor diode from MDT [2]. From these results, the new antenna has an effective operational bandwidth of greater than an octave, with good radiation efficiency in the selected band.

Measured Results and Discussion

We developed a proof-of-concept version of the adaptive antenna. The antenna has dimensions of approximately 2.4″ × 2.4″ × 0.4″ and is made from a combination of dielectric laminates: Arlon 450™ and Rohacell foam™. The feed for the antenna resides below the ground-plane, as highlighted in Figure 1. An SMA connector is used to connect the antennas to our RF measurement equipment. We measured the return loss of the new proof-of-concept tunable antenna prototype under different tuning load conditions: 0.2 pF, 0.5 pF, 1 pF, 2.4 pF and 3 pF for all the equivalent capacitors. Figure 2 summarizes the return loss performance of the radiator. As can be seen from this plot, the 'resonant' frequency of the antenna (where the antenna should radiate most efficiently) can be modified by simply changing the load. As expected the bandwidth dimensions as the amount of loading increases. The overall effective bandwidth of the antenna is greater than an octave; which is consistent with theory.

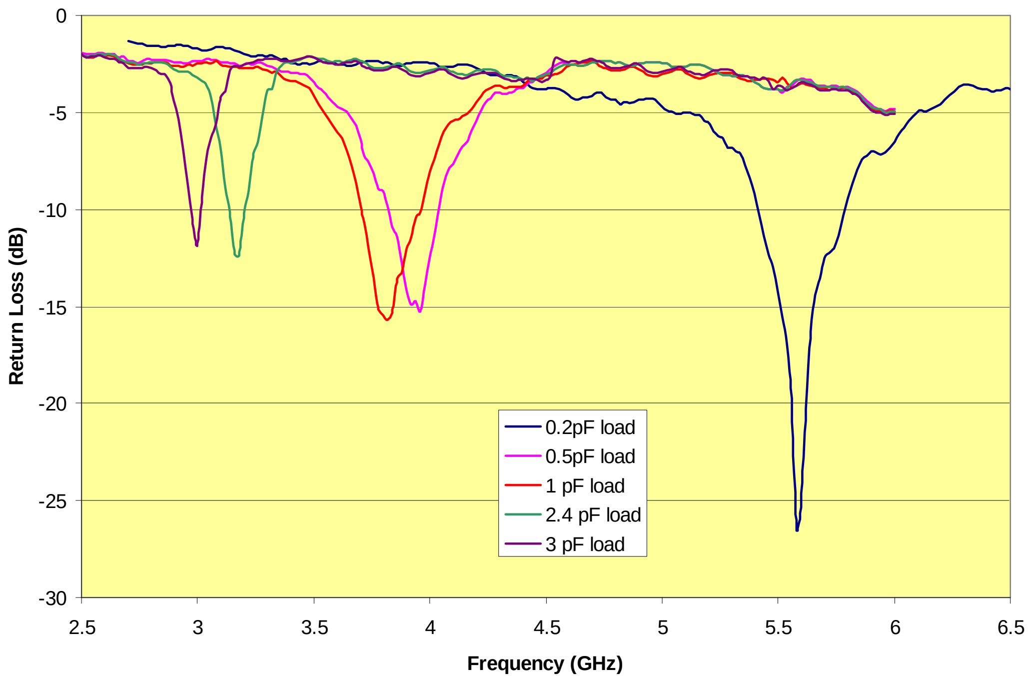

Figure 2 Measured return loss of the fabricated proof-of-concept antenna under different tuning load conditions

We measured the radiation performance of the proof-of-concept antenna and Figure 3 highlights the results. In Figure 3 we show the measured H-plane co-polar radiation pattern of the antenna at 3.1 GHz and 5.8 GHz when we load the stacked patch antenna with capacitors of 3 pF and 0.2 pF, respectively. The measured results presented here are in very good agreement with the theory. To lower the resonance of the low profile antenna to 2.4 GHz, a capacitance of 5 pF is needed.

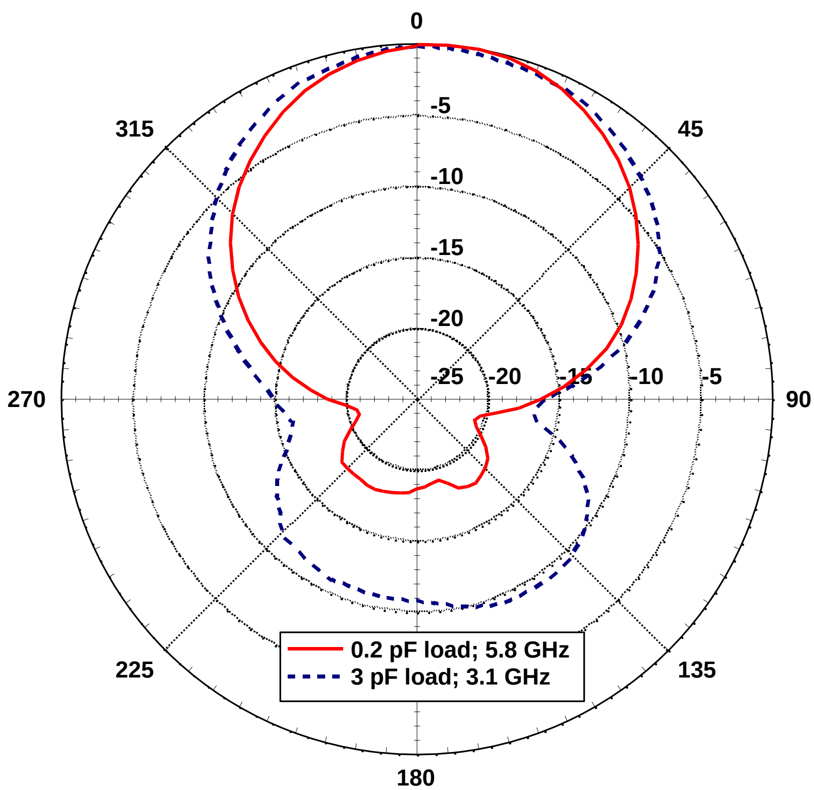

Figure 3 Measured H-plane co-polar radiation patterns of the proof-of-concept antenna at different frequencies for different loads

Conclusions

In this paper we presented a wideband adaptive compact radiator based on a stacked patch antenna loaded with varactor diodes. We investigated the performance of the antenna through simulation, developed a proof-of-concept version of the antenna and experimentally verified its characteristics.

References

[1] R. B. Waterhouse and N. V. Shuley, "Full characterization of varactor-loaded probe-fed rectangular microstrip patch antennas", *IEE Proceedings Part-H*, vol. 141, pp. 367 – 373, Oct. 1994.
[2] www.mdtcorp.com