A Multiband/Scalable Reconfigurable Antenna for Cognitive Radio Base Stations

T. Wu, R.L. Li, S. Y. Eom, K. Lim, S. I. Jeon, J. Laskar, and M. M. Tentzeris
Georgia Electronic Design Center
School of Electrical and Computer Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0250, U.S.A.
E-mail: gtg562b@mail.gatech.edu

I. Introduction

Cognitive radio aims to offer higher data rates to the end users through frequency sensing and effective bandwidth usage of the existing allocated spectrum. [1] With the various bands dedicated to existing standards, such as Cellular, PCS, WCDMA, WiFi and recently growing WiMax worldwide, it is advantageous to provide service at those frequencies using a single base station radio. In this paper, a high broadside gain, MEMS-based, reconfigurable base station antenna was designed to support four widely used frequency bands: 800-900 MHz(B1), 1.7- 2.5GHz(B2), 3.3-3.6GHz (B3)and 5.1-5.9 GHz(B4). The antenna is based on a symmetric repeatable topology making it highly scalable to incorporate additional frequency bands in the future.

II. Antenna Element Design and Performance

The overall reconfigurable antenna design is shown in Figure 1. Microstripes was used to simulate its overall performance. The antenna was designed on Taconic RF35 with ε_r=3.5 and dielectric loss tangent of 0.0018. The substrate thickness of 30 mils was used for the dipole arms to provide better structural support while the feeding network was designed on 20 mils to support narrower transmission lines. The antenna is intended to be fed by a 4 output MEMS switch. MEMS switch was chosen because it provides low loss, high isolation and high linearity desired by the RF front-end[2]. The antenna array consists of four broad band dipole with integrated baluns [3] of different sizes to support the four bands of operation.

Figure 2 shows the basic topology of each antenna elements. For B1, $L_d|_{B1}$= 170mm, $H_d|_{B1}$= 61mm, $W_d|_{B1}$= 34mm and $W_g|_{B1}$= 68mm while dimensions for B2, B3, and B4 dipoles are further described in the Figure 2 heading. Each dipole was matched to an input impedance of 50 Ω. The simulated return loss for B3 and a 3D radiation pattern at 3.5 GHz are shown as an example in Figure 3 (a) and (b). The overall individual performance obtained by Microstripes is summarized in Table1. Each of the printed dipoles satisfies a 10 dB return loss over the designed bandwidth of operation while achieving 8dBi of directivity in simulations.

978-1-4244-2042-1/08/$25.00 ©2008 IEEE

Table 1. Summary of Individual Dipole Element Performance

Band of interest	B1	B2	B3	B4
Frequencies covered (GHz)	0.8-0.9	1.7-2.5	3.3-3.6	5.1-5.9
Worst case S11 (dB)	-16	-10	-16	-14
Directivity @ center freq	8.3 dBi	8.8 dBi	8.6 dBi	8.6 dBi

III. Antenna Element Design and Performance

After optimizing the individual dipole elements, the antenna elements for B1, B2 and B3 have their symmetric counterparts placed approximately 0.5λ apart as shown in Figure 1. This ensures frequency-independent, broadside radiation at all frequencies. The replicating nature of this topology makes the design highly scalable to cover additional frequency bands. Since the each antenna element was matched to 50Ω, feeding networks with quarter wave transformers were used to feed these 3 symmetrical elements and guarantee a 50 Ω input match to each port.

The fabricated antenna is shown in Figure 4. Figure 5 shows the simulated and measured return loss performance for the four frequency bands. The return loss in higher frequency bands (B3) were greatly affected by the second harmonic coupling from the lower frequency dipole elements (B2) , that effectively boost the gain of the higher band antenna. The effect is prevalent in Figure 5 (a) and (b) where the main S11 resonance appears to be centered at 4GHz (2^{nd} harmonic of B2) for B3 and 7GHz (2^{nd} harmonic of B3). The simulated radiation pattern shown in Figure 6 for B2 and B4 further demonstrates the effect of the harmonic resonances. The performance is further summarized in Table 2 below.

Table 2. Summary of Reconfigurable Antenna Performance

Band of interest	B1	B2	B3	B4
Frequencies covered (GHz)	0.8-0.9	1.7-2.5	3.3-3.6	5.1-5.9
Measured S11 (dB)	-13	-9	-7.7	-3.6
Measure Center Freq Gain	8.21 dB	7.96 dB	9.6 dB	8.4 dB

IV. Conclusion

A four-band MEMS-based reconfigurable antenna is designed and tested. Future work would focus on the reduction of the effect of second harmonic resonances. Due to the highly scalable nature of the design, this topology can be a good basis for building future cognitive base stations that could provide higher bandwidth, large number of bands and multi-standard support for end users and the communication backbone.

Acknowledgement

The authors would like to thank Georgia Electronic Design Center and ETRI for supporting this research. The authors would also like to acknowledge Ms. Kim Rutkowski of SATIMO for providing the antenna pattern measurements.

References

[1] J. Mitola III, “Cognitive Radio for Flexible Mobile Multimedia Communication”, Proc. IEEE International Workshop on Mobile Multimedia Communications (MoMuC) 1999, November 1999, pp. 3–10.
[2] E.R. Brown, “RF-MEMS switches for reconfigurable integrated circuits,” IEEE Transactions on Microwave Theory and Techniques, vol. 46, no.11, pp. 1868-1880, Nov.1998
[3] B. Edward and D. Rees, “A broadband printed dipole with integrated balun,” Microwave. J., pp.339-344, May 1987.

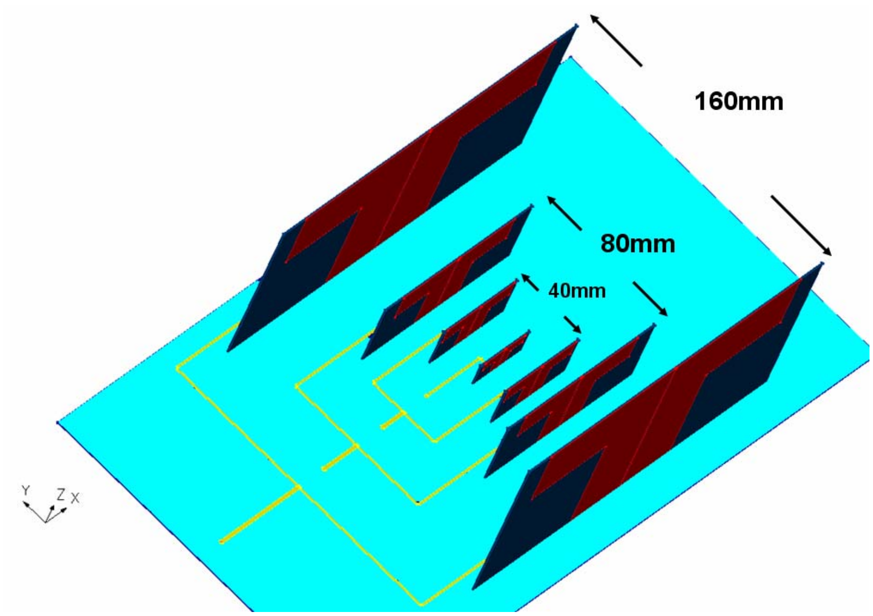

Figure 1. Reconfigurable antenna element.

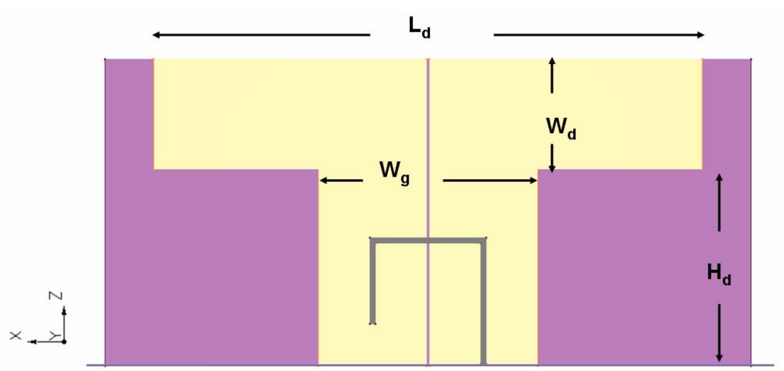

Figure 2. Single dipole design: $L_d|_{B2}$= 76mm, $H_d|_{B2}$= 25mm, $W_d|_{B2}$= 15mm, $W_g|_{B2}$= 30mm, $L_d|_{B3}$= 45.6mm, $H_d|_{B3}$= 16.2mm, $W_d|_{B3}$= 9mm, $W_g|_{B3}$= 18mm, $L_d|_{B4}$= 27mm, $H_d|_{B4}$= 9.5mm, $W_d|_{B4}$= 5.5mm and $W_g|_{B4}$= 11mm.

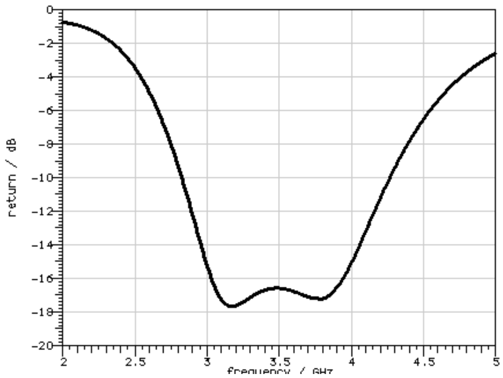

Figure 3. Return loss of single element dipole designed for B3

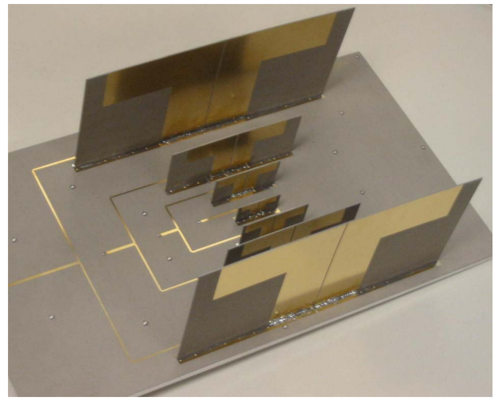

Figure 4. Fabricated Antenna Design

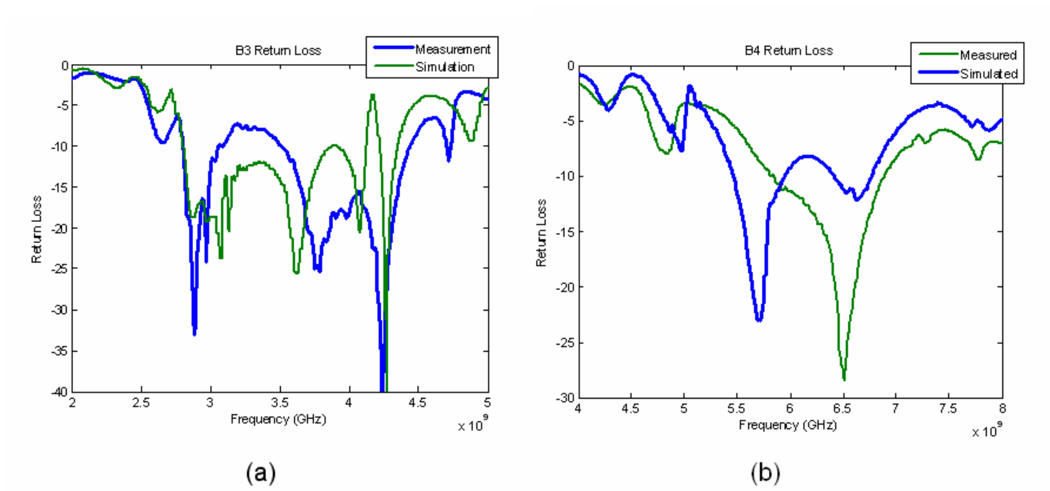

Figure 5. Antenna Return loss. (a) for B3 (b) for B4.

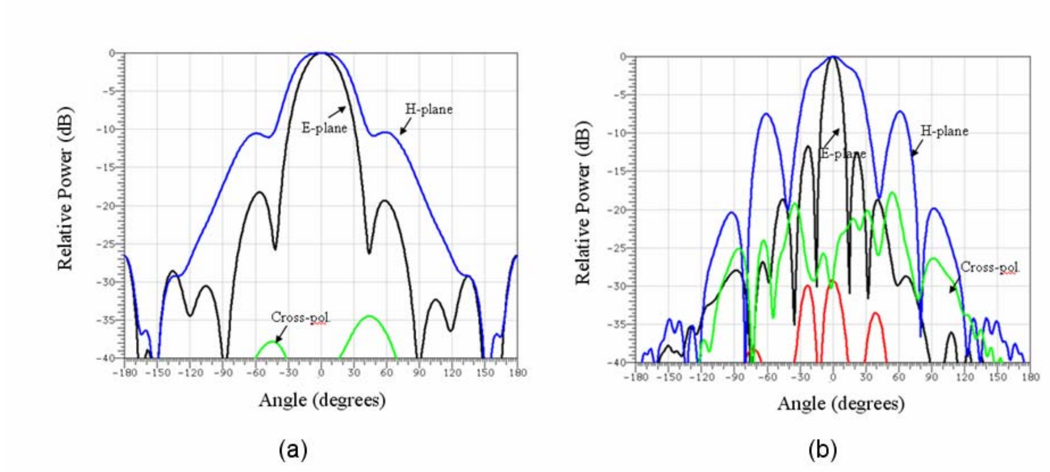

Figure 6. Antenna directivity. (a) for B2 (b) for B4