Reduced Size Folded Slot Antennas with Capacitive Loading

Maximilian C. Scardelletti[(1)*], George E. Ponchak[(1)], Jennifer L. Jordan[(1)]
and Shane J. Merritt[(2)]
(1) NASA Glenn Research Center, Cleveland, Ohio, 44135
(2) University of Iowa, Iowa City, Iowa, 52240
Maximilian.C.Scardelletti@nasa.gov

Introduction

Antennas for handheld portable communication systems such as mobile, medical diagnostic and sensing applications are becoming more complex and generally are required to be physically smaller then their predecessors. The ability to physically reduce the size of the antenna so that it is electrically small and satisfies the state-of-the-art hand held communication link requirements is becoming increasingly complicated and is fundamentally limited [1]. When reducing the size of the antenna, many design trade-offs must be considered so that antenna parameters such as radiation pattern, bandwidth, gain and impedance matching are not degraded to the point that the antenna no longer meets the system specifications. These characteristics are all affected when the antenna is manipulated so that it is electrically smaller than its original layout.

Several antennas have been developed using various methods to achieve size reduction. A microstrip fed slot antenna with inductive and capacitive loading has been reported with 59% size reduction [2], but gain was not reported. Another method used distributed inductive elements to reduce the size of a slot antenna [3]. The authors previously demonstrated the ability to reduce the resonant frequency of a folded slot antenna with capacitive loading [4]. In this paper the physical size of planar folded slot antennas is decreased by adding chip capacitors to the radiating slots of the antenna. Two set of antennas are designed at 3 and 5 GHz. The antennas illustrate a size reduction of 33 and 44% at 3 and 5 GHz, respectively.

Antenna Design and Fabrication

A schematic of a CPW fed folded slot antenna is shown in Figure 1a, and a photograph of it and the location of the chip capacitors is shown in Fig. 1b. The antenna is comprised of a two radiating slots that are folded so that they meet along the center line of the CPW. A virtual open circuit exists on the antenna where the slots meet at the y axis at the resonant frequency. The antennas are fabricated on Rogers RT Duriod^{TM} 6006 with a dielectric constant of 6.15, a substrate thickness of 0.635 mm and a 34 µm-thick (0.5 oz.) copper laminate on its top side (no ground plane). Although the folded slot length is approximately one wavelength without capacitor loading, the antenna designs (slot length, slot width, and capacitor value) were optimized with Ansoft's High Frequency Structure Simulator (HFSS) [5]. The CPW feed dimensions and the distance between the slot antenna and the ground plane edges were kept constant. The simulations reveal that as the antenna size is reduced, the capacitor values increase and the impedance of the radiating slots decreases. Consequently, the widths of the radiating slots decreases as well, which is a serious problem if fabrication tolerances are not accurately controlled. Therefore, in this paper, it was decided to limit the slot width to 0.1 mm which is approximately 70 ohms. The dimensions of the 3 and 5 GHz antennas are given in Tables

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1 and 2, respectively. American Technical Ceramics multilayer chip capacitors (Series ATC 500S) were used to load the antennas. An SMA connector was soldered to the CPW to facilitate the measurement process and can be seen in Figure 1b.

Antenna Characterization

The return loss of the antennas was measured on an Agilent E8364B Precision Network Analyzer (PNA). To place the reference plan at the SMA connector, a short-open-load calibration was performed using the HP 85052B calibration kit. The far-field radiation patterns are measured in an anechoic chamber and the gain is calculated using the substitution method. The gain horn used for the substitution method has a gain error of ± 0.8 dB, which is the minimum error in the reported gain measurements. The input return loss for the 3 GHz antenna is shown in Fig. 2. It is seen that there is good agreement between the simulated and measured resonant frequency. The simulated and measured radiation patterns for the 3 GHz antenna without capacitor loading and with 3 pF capacitor loading are shown in Figs. 3a and 3b, respectively. Due to brevity, the return loss for the 5 Ghz antenna and the radiation pattern for the rest of the antennas cannot be shown. However all of the results are summarized in Tables 1 and 2. The simulated and measured data agree well thus indicating that the design approach is valid. The data shows that as the antenna size is reduced due to capacitor loading the 10 dB bandwidth (BW) and gain decrease, but a reasonable amount of gain is still achievable.

Conclusion

Folded slot antennas utilizing capacitive loading to reduce the physical size of the antenna while maintaining the original resonant frequency have been presented. Simulations illustrate that to decrease the size of the antenna the width of the radiating slot must also decrease, which limits the ability to fabricate this type of antenna. Also, as the size of the antenna decreases, the value of capacitor needed increases. Size reductions of 33 and 44% at 3 and 5 GHz, respectively, are demonstrated. The 10 dB BW and gain decrease as the size of the antennas increase.

Acknowledgments

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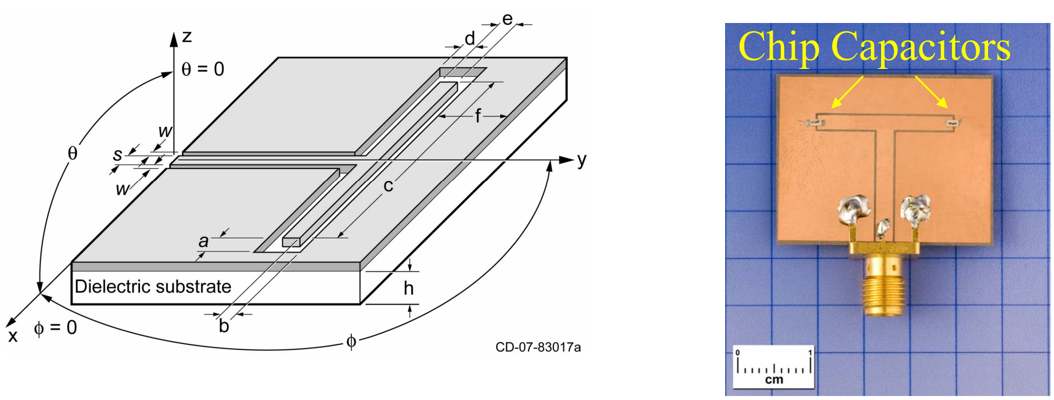
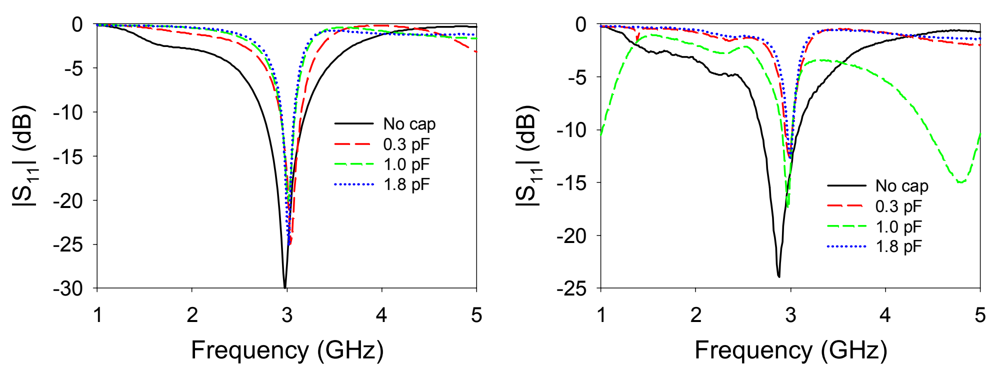


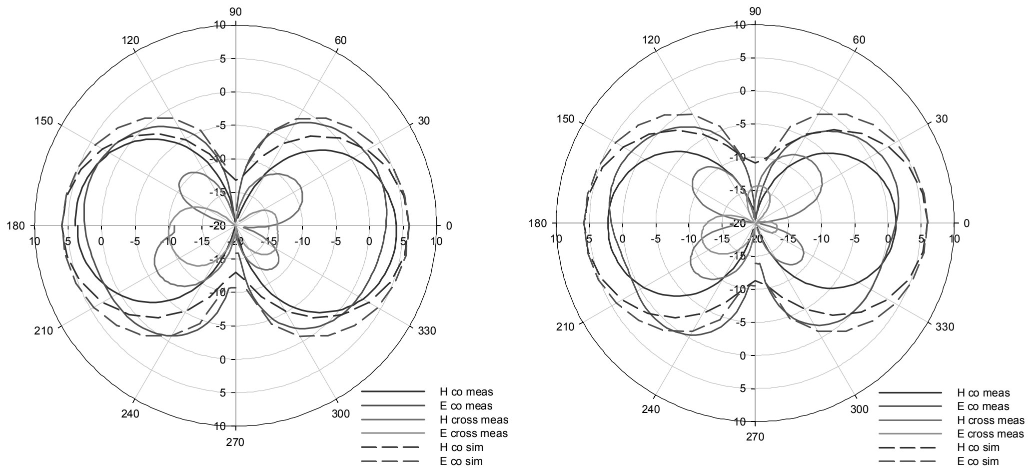
(a) (b)

Figure 1. (a) Schematic of CPW fed folded slot antenna and (b) microphotograph of folded slot antenna with capacitive loading.



(a) (b)

Figure 2. Return loss for 3 GHz folded slot antennas (a) Simulated (b) Measured.



(a) (b)

Figure 3. Radiation patterns for 3 GHz folded slot antennas (a) with no capacitors and (b) with 0.3 pF capacitors.

Tables 1 and 2: Antenna parameters and characteristics

c (mm)	e (mm)	e+2d (mm)	Mean Path Length (mm)	C (pF)	f_o (GHz) (meas/sim)	10 dB BW (%) (meas/sim)	Gain (dBi) (meas/sim)	Size Reduction (%)
40	**2**	**10**	**50**	**N/A**	**2.88/2.98**	**14/17**	**4.0/3.9**	**N/A**
38	**2**	**4**	**42**	**0.3**	**2.94/3.05**	**3/8**	**2.2/3.9**	**17**
33.5	**2**	**2.5**	**36**	**1.0**	**2.97/3.02**	**3/6**	**2.1/3.4**	**29**
32	**2**	**2.02**	**34.02**	**1.8**	**2.99/3.02**	**2/5**	**0.8/2.8**	**33**

c (mm)	e (mm)	e+2d (mm)	Mean Path Length (mm)	C (pF)	f_o (GHz) (meas/sim)	10 dB BW (%) (meas/sim)	Gain (dBi) (meas/sim)	Size Reduction (%)
23	**2**	**6**	**29**	**N/A**	**4.7/5**	**8/18**	**2.9/5.3**	**N/A**
19.5	**2**	**4**	**23.5**	**0.2**	**4.9/5**	**2/9**	**2.3/4.97**	**19**
17	**2**	**2.5**	**19.5**	**0.9**	**4.9/5**	**2/4**	**0.2/3.4**	**32**
14	**2**	**2.02**	**16.02**	**1.8**	**5/5.18**	**1/3**	**-0.5/2.8**	**44**