Presented at the 2013 IEEE International Symposium on Antennas and Propagation, Orlando, FL, USA, 7-13 July 2013 DOI: 10.1109/APS.2013.6710876

A Wideband, 5-50+ GHz Tapered-Slot Antenna For Use in Handheld Test Equipment

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***Abstract*—A lightweight, wideband tapered-slot antenna that uses an antipodal Vivaldi design and provides useable gain from ~5 GHz to in excess of 50 GHz is described. Simulations and measurements are presented that show excellent agreement. This antenna design is currently deployed in handheld test equipment.**

I. INTRODUCTION

Numerous designs exist for wideband (multi-octave) antennas that also have good directivity. However, the selection pool reduces if the antenna is to be employed within handheld test and/or monitoring equipment. For example, the relative bulk and weight of standard gain or double-ridged waveguide horns is undesirable, as is their cost. Microstrip antennas are attractive because they are, by comparison, lightweight and cheap. While a patch array is simple, its feed structure is more complicated and incurs losses, particularly at higher microwave frequencies. For desired operation from below ~20 GHz to above ~40 GHz, a tapered-slot or Vivaldi antenna was considered suitable [1]. Furthermore, an antipodal Vivaldi design was selected because it offers a simple microstrip-coax interface and provides good gain over a wide bandwidth [2]. Inevitably, some engineering design trade-offs are required.

II. DESIGN METHODOLOGY

The Vivaldi (exponential) taper is defined by the opening rate R and two points P1(x_1,y_1) and P2(x_2,y_2) [3]:

$$y(x) = c_1 e^{Rx} + c_2 \tag{1}$$

$$c_1 = \frac{y_2 - y_1}{e^{Rx_2} - e^{Rx_1}} \tag{2}$$

$$c_2 = \frac{y_1 e^{Rx_2} - y_2 e^{Rx_1}}{e^{Rx_2} - e^{Rx_1}} \tag{3}$$

SEMCAD X was used for the 3D electromagnetic simulation and optimization of the return loss and radiation pattern for the tapered-slot antenna [4].

Rogers RT/duroid 5880 was selected as the substrate material because of its low loss at microwave and mm-wave frequencies ($\varepsilon_r = 2.20$, tan δ ~0.0009 @ 10 GHz). A substrate thickness of 0.020” (0.508 mm) was used for reasons of strength. However, some performance compromises are likely when the effective dielectric thickness is > ~0.01 [5].

To ensure that no higher-order modes below 50 GHz were supported in the coaxial cable, a 2.40 mm end launch connector was used for the coax-to-microstrip transition [6]. The end launch connector was included in the SEMCAD X model. Additionally, the microstrip line was tapered towards the connector to achieve a low VSWR over a broad bandwidth [7].

Following optimization, the tapered-slot antenna design occupied an area of 80 x 30 mm. The final manufactured PCB incorporated an additional dielectric-only border each side for mounting purposes inside the handheld test equipment (overall PCB dimensions were 80 x 50 mm). The bottom layer of the PCB is shown in Figure 1. For more generic applications, the antenna could be packaged in a low-loss, low-permittivity foam to create a lightweight and rigid structure [8].

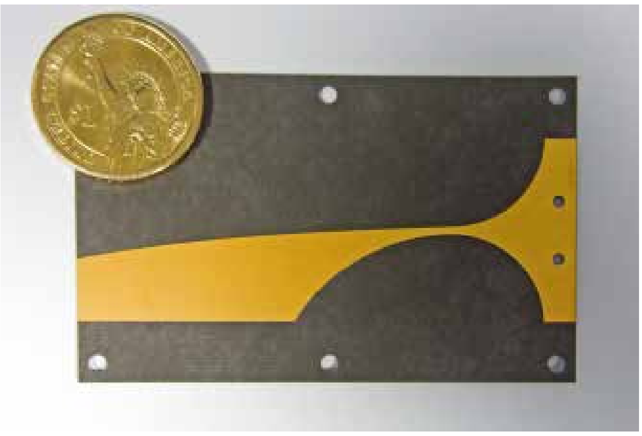

Figure 1. Bottom layer of the final tapered-slot antenna design

III. SIMULATION AND MEASUREMENT RESULTS

Figure 2 compares the simulated and measured reflection coefficient of the tapered-slot antenna. Very good agreement is seen almost up to 50 GHz. Note that 50 GHz was the upper frequency limit of the antenna measurement equipment. Both simulation and measurements indicate that the return loss remains better than 10 dB to frequencies above 50 GHz.

Figure 3 shows an example 3D radiation pattern for the antenna at 22 GHz, while Figure 4 shows the 2D radiation pattern in the plane of the antenna at 22 GHz and 42 GHz. A slight asymmetry exists, which indicates a current imbalance in the antenna arms and is an engineering trade-off associated with tapered-slot antennas on substrates where the effective dielectric thickness is > ~0.01 [5]. The simulated and measured forward gain are compared in Figure 5. Excellent agreement is observed except below ~8 GHz, which is due to mismatch losses not being accounted for in the simulated gain.

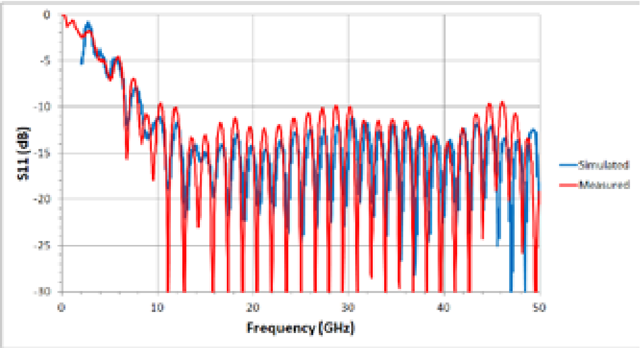

Figure 2. Simulated and measured reflection coefficient

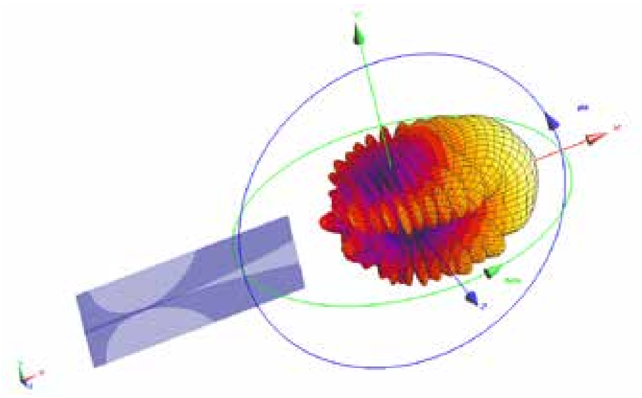

Figure 3. Simulated 3D radiation pattern at 22 GHz

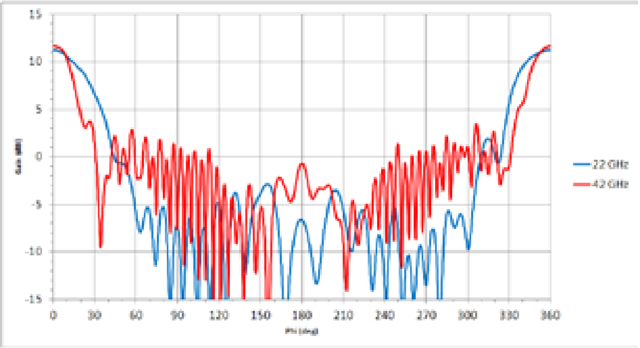

Figure 4. Simulated 2D radiation pattern at 22 and 42 GHz (xy-plane)

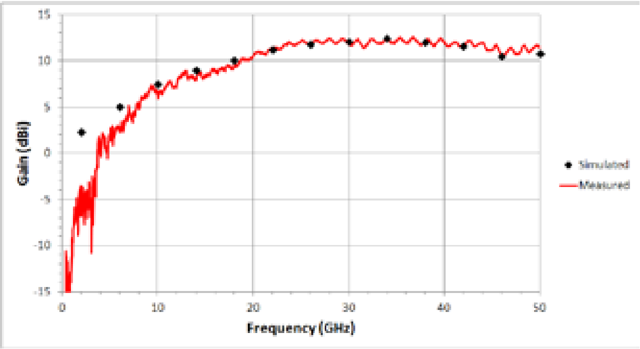

Figure 5. Simulated and measured forward gain

While the simulations and measurements indicate good return loss and gain to frequencies exceeding 50 GHz, there is a risk that other modes might be supported in the coax and the substrate. Therefore, the use of a smaller coax connector and thinner substrate might be prudent at these higher frequencies.

IV. SUMMARY

A lightweight, wideband tapered-slot antenna using an antipodal Vivaldi design has been described. The antenna is useable from ~5 GHz to in excess of 50 GHz. Simulations and measurements show excellent agreement. This antenna design is currently deployed in handheld test equipment.

ACKNOWLEDGMENT

I am grateful to Steve Greendale for technical discussions during the development of this wideband tapered-slot antenna.

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