60 GHz Planar Antenna Array on Glass Substrate for WiGig Communications

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Abstract

A planar antenna array on the RF substrate increases the level of system integration and lowers the manufacturing cost for such systems. In this paper, the authors present the design and fabrication of a planar 2×2 antenna array for a 60 GHz Radio-over-Fiber (RoF) wireless system. The antenna is radiating at broadside and excited by microstrip line. For the measurement with RF probes on a wafer prober, a microstrip-to-coplanar waveguide transition is added. The measured gain of the antenna is 6 dBi and the matching is better than -20 dB at 60 GHz. The measurement and simulation results of gain and input return loss match very well at the resonance frequency.

1. Introduction

RoF systems integrate wireless and fiber optic networks, in order to utilize the immense bandwidth inherent with fiber optics. It is an affordable solution in environments such as conference centers, airports, hotels, shopping malls, and ultimately homes and small offices [1]. The RoF architecture consists of a central station (CS) where mm-wave signals are generated and transmitted over fiber to a base station (BS). At the BS, the transmitted signal is detected, preprocessed, amplified and wirelessly transmitted to the mobile station. Integrated planar antennas are essential components in mm-wave RoF systems. This is because for their small foot print, light weight, low cost and compatibility with integrated active radio frequency (RF) components, therefore representing the best choice for compact RoF systems. The 2×2 antenna array is designed on fused silica substrate, lightweight, and with excellent low loss ($\varepsilon_\mathrm{r} = 3.75, \tan\delta = 0.0004$) characteristics up to 110 GHz [2]. It is fabricated on fused silica of 300 µm thickness with on top immersion silver/immersion gold (ISIG) surface plating of 5 µm thick excluding vias. In the following, we present the validation of the simulation as compared to the measurement results of the 2×2 antenna array.

2. Design, Fabrication and Measurements

The antenna should cover the 60 GHz ISM band in order to support IEEE 802.11ad signals. The RoF system design requires a realized gain of greater than 6 dBi and an input matching of lower than -10 dB at 60 GHz. The fabricated 2×2 antenna array on glass is shown in Fig. 1 with CPW-to-MS feed network.

Figure 1: A 2×2 60 GHz antenna array on glass substrate with CPW to MS transition feeding element.

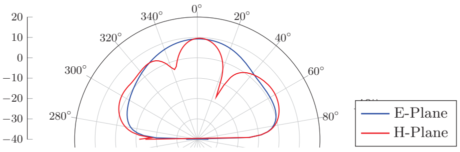

Figure 2: Simulation of the total radiation power pattern in E-Plane and H-Plane at 60 GHz of the 2×2 antenna array.

The simulated gain (EM full-wave simulation) of the microstrip antenna array at 60 GHz is 9.4 dBi, as shown in Fig. 2. The authors decided to use wafer-probes with the 400 µm pitch for the wafer prober measurements. Correspondingly, the microstrip antenna array requires a CPW transition to microstrip (MS). The CPW-to-MS transition feed network to the microstrip antenna array introduces loss of about 1 dB. As a result, the antenna array gain of 8.4 dBi is achieved. This gain meets the design criterion of 6 dBi gain and leaving some margin for implementation.

In this paper far field antenna measurements are carried out on a wafer prober using GGB Pico Probes Model 67A (ground-signal-ground (GSG) configuration, pitch of 400 µm) and a Network Analyzer up to 67 GHz connected to a receiving horn antenna with 20 dBi gain, see Fig. 3. The probe calibration was performed using thru-reflect-line (TRL) calibration structures fabricated on the fused silica substrate. The far-field region for the measurement setup can be determined by

$$R > \frac{2D^2}{\lambda} = 10.24\,\mathrm{cm} \tag{1}$$

taking into account the apარture $D = 16\,\mathrm{mm}$ of the Rx horn antenna and the wavelength $\lambda = 5\,\mathrm{mm}$. Using the x-z-plane in a distance of 11 cm optimizes the measurable angle to $\pm 24^\circ$ with the given scanning range of $10\,\mathrm{cm} \times 10\,\mathrm{cm}$. Thus, the gain can be calculated from the measured data after polarization alignment of the Rx horn antenna and antenna array using the gain comparison method given by equation (2):

$$G_{\mathrm{AUT}}|_{\mathrm{dBi}} = S_{21,\mathrm{AUT}}|_{\mathrm{dB}} - S_{21,\mathrm{horn}}|_{\mathrm{dB}} + G_{\mathrm{horn}}|_{\mathrm{dBi}} \quad (2)$$

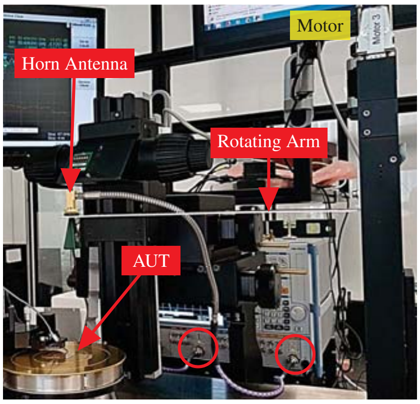

Figure 3: Overview of the AUT gain measurement at the middle of the chuck on wafer probing station with receiving horn antenna positioned on top.

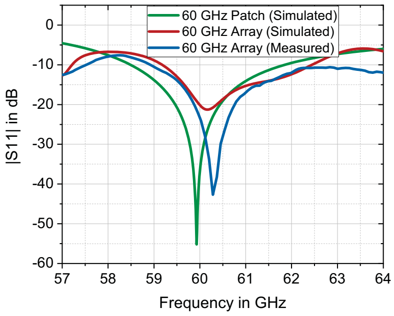

Figure 4: Simulated S11 of the 60 GHz patch element (green) compared with measured (blue) and simulated (red) S11 of the 60 GHz antenna array with CPW to MS feeding element.

The measurement and simulation results of gain and input return loss match well, as shown in Fig. 4 and Fig. 5. However, the measured gain is reduced by around 2 dB compared to the simulation. One of the reasons is the insertion loss of the CPW-to-MS transition that introduces about 1 dB loss. At these frequencies, fabrication tolerances and deviations in substrate material parameters have a huge influence [3]. Moreover, the reflections from the metal chuck induce interference effects in antenna measurements, especially around the axis perpendicular to the chuck which can be seen in the measurement curve in Fig. 5. It could be noted that the location of the minima and maxima on the measured gain is very sensitive to the probe position relative to the x-z-plane of the Rx horn antenna movements. Reducing the reflectivity of either the Rx horn antenna or the antenna array on the chuck would drastically lower that influence. One improvement could be to use a plastic chuck. The measured gain of the antenna array at 60 GHz is $G_{\mathrm{AUT}} = 6\,\mathrm{dBi}$ whereas the measured input return loss is below -20 dB. This makes the antenna suitable for usage in aforementioned RoF system.

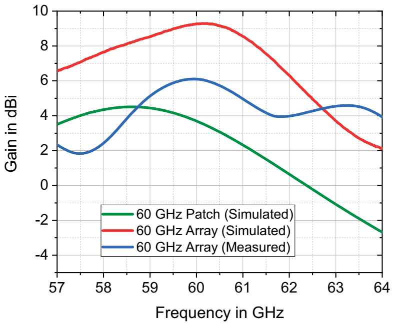

Figure 5: 60 GHz antenna array gain including losses (simulated, red) compared with measured (blue) and the patch element (simulated, green).

3. Conclusions

A 2×2 patch antenna array that can be manufactured on a simple two-layer process without vias has been successfully realized on a fused silica glass substrat that offers low-loss implementation. The characterization of matching and antenna gain shows that the antenna array covers the 60 GHz ISM band and has a gain of 6 dBi at 60 GHz. This allows the antenna to be used in a highly integrated BS for a RoF system. Further steps include the integration of the realized antenna into the RoF BS frontend design and system experiments.

References

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