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Additively Manufactured K-Band Septum Polarizers: A Comparative Study

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***Abstract*—A septum waveguide polarizer with integrated circular to square waveguide transition has been manufactured using three different additive manufacturing (AM) processes. Polymer and AlSi10Mg printing processes from a specialized RF manufacturer and a selective laser melting (SLM) process from a university research group are evaluated. Measurements confirm the polarizer design is well suited for AM.**

I. Introduction

Radio frequency (RF) and microwave components heavily depend on accurate manufacturing to ensure optimum performance. Traditional manufacturing of these devices, better described as subtractive manufacturing, has become a limiting factor in the innovation and design of new RF components. Complex structures with intricate designs are difficult to accurately manufacture with subtractive techniques. Within the past decade, additive manufacturing (AM) has provided engineers with techniques to fabricate these new and complex structures, relaxing design constraints.

There are many different AM processes, some that are suitable for manufacture of three-dimensional metallized components. Two techniques that have been successfully used are stereolithography (SLA) and selective laser melting (SLM).

SLA was the first patented AM process and involves a resin that is selectively cured to build a part layer by layer [1]. SLA can be used to print planar structures where selective metallization can be applied post-print, as shown in [2], or a skeleton or preliminary surface can be printed then coated or plated with a metal, as described in [3]. SLA is used for RF components due to its smooth final surface and accuracy of complex structures [4].

SLM utilizes a laser to melt metallic powders to form layers of a homogenous component [1, 5]. Although SLM prints metals directly, for RF components, an additional coating or plating on the printed part may improve surface roughness, as discussed in [6]. SLM's appeal stems from its ability to accurately print conductive, monolithic components.

Therefore, this paper presents a waveguide polarizer with a design enhancement for reduced length that necessitates AM and the results of commercial manufacture as well as university laboratory manufacture.

II. Polarizer Design and Manufacture

A K-band septum polarizer with integrated circular to square waveguide transition has been designed for manufacture using AM. This enabled the length of the polarizer to be reduced to 60 mm, as shown in Fig. 1. The polarizer has a 10 mm diameter circular waveguide port, and two WR42 rectangular waveguide ports. It is a shortened version of the polarizer discussed in [7] that was manufactured using an electroplating process confirmed with measurements. This design was well suited for AM and was chosen to investigate AM processes.

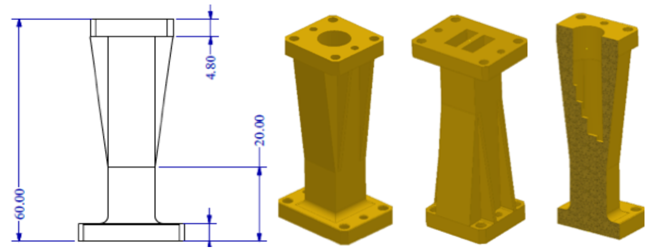

Figure 1. 60 mm septum polarizer design, with a circular waveguide port, two rectangular waveguide ports, and an internal view of the stepped septum.

The polarizer in Fig. 1 was manufactured by Swissto12 using both their patented polymer and AlSi10Mg processes. These processes include chemical surface treatment post printing to improve surface finish plus a double plating process of copper and silver. The polarizer was also printed using SLM in copper at the University of South Australia Industry 4.0 Testlab. The copper polarizer was not plated however was sintered in a furnace and the flanges were machined post printing. All three polarizers are shown in Fig. 2.

Figure 2. Polymer polarizer (left), AlSi10Mg polarizer (middle), and copper polarizer (right).

III. Polarizer Measurements

An Agilent E8364B precision network analyzer (PNA) with WR42 to coaxial adapters and a custom TRL calibration kit was used to measure the S-parameters. An adapter printed with the polymer polarizer was used to separate the two rectangular waveguides of each polarizer so each rectangular port could be connected to a PNA port.

S-parameters were measured for two scenarios: the first with the circular waveguide port open and an RF absorber placed in front; the second with the circular waveguide port shorted using a short from a WR42 calibration kit. Fig. 3 displays the measured S_{11}, S_{12}, S_{21} and S_{22} results for all three polarizers with the circular waveguide port open, as well as the simulated results from CST [8]. Fig. 4 similarly displays the measured and simulated S_{11}, S_{12}, S_{21} and S_{22} results with the circular waveguide port shorted.

If the polarizer is operating as designed the reflection coefficients, S_{11} and S_{22}, of the open and short circuit cases will be similar. The transmission coefficients for the open circuit case (S_{12} and S_{21}) are the isolation between the two rectangular waveguide ports. There will be a small reflection from the circular waveguide port, the largest effect of this being on the isolation. With the circular waveguide port shorted, the transmission coefficients are a measurement of the transmission from waveguide port 1 to 2 as the polarization sense swaps on reflection.

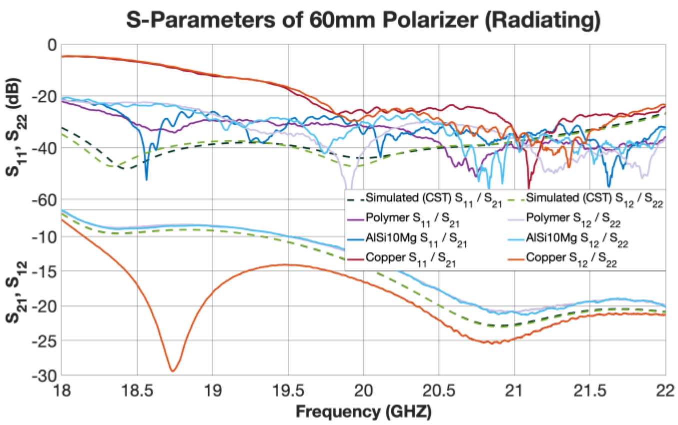

Figure 3. S_{11}, S_{21}, S_{12}, S_{22} for radiating polymer, AlSi10Mg, copper, and simulated (CST) polarizers.

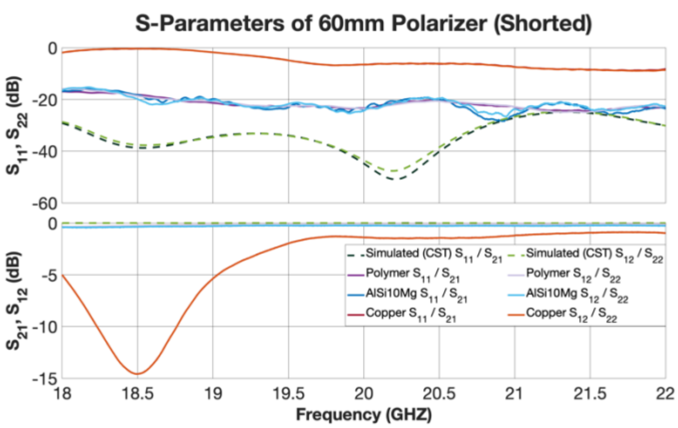

Figure 4. S_{11}, S_{21}, S_{12}, S_{22} for shorted polymer, AlSi10Mg, copper, and simulated (CST) polarizers.

The measurements in Fig. 3 and 4 show that the two Swissto12 polarizers perform very well across the frequency range of interest, and all S-parameters for the two measurement scenarios are close to the simulations. The copper polarizer does not perform as well. The reflection coefficients and isolation are close to the simulation in the top half of the band, with large differences seen in the bottom half of the band. The results suggest that the copper polarizer has a structural problem, possibly an asymmetry in the septum part of the polarizer [9, 10].

IV. Conclusion

A septum waveguide polarizer designed to be manufactured using AM by integrating the circular to square waveguide transition and the septum has been manufactured using three different AM techniques. Polymer and AlSi10Mg polarizers were manufactured by the specialized RF AM group, Swissto12, and the results were excellent. A third polarizer was manufactured in copper by an AM university research group, to compare a process that is more available in terms of both time and cost. The first polarizer was not successful with performance not matching expectations. Three more identical polarizers are being manufactured using the same process. After measuring the RF performance, one will be dissected to check for physical deformations internally, and the electrical conductivity of the copper will be measured.

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