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Rapid prototyping of waveguide and horn antennas

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Abstract— In this paper we review how fused deposition modelling (FDM) can be deployed for the rapid prototyping of microwave waveguide componentry and antennas. Additive manufacture of such objects allows new, novel and complex structures to be fabricated with lower impact on the environment relative to current manufacturing processes, plus the fast turnaround of design to manufacture and test. Additionally while the resulting physical antenna properties may not be perfect compared to the design or what can be machined, their RF/microwave performance can be quite forgiving thereby allowing the antenna design engineer to fully exploit the rapid prototyping concept.

Index Terms—antenna, additive manufacture, test.

I. FUSED DEPOSITION MODELLING

Recently the additive manufacturing process Fused Deposition Modelling (FDM) has been used as a platform for investigating the potential for microwave circuits and componentry. FDM is a manufacturing technique that is becoming increasingly common both for industrial applications and consumer goods, with a growing range of desktop units available from companies such as Ultimaker® and Makerbot®. 3D structures are designed digitally and then processed with software whereby the design is sliced into layers. The printers then translate these software layers into physically deposited layers extruding thermoplastic polymer filaments through a nozzle onto a platform. Using this fabrication process facilitates the rapid prototyping of designs and here we present how this can be done for microwave antennas in a cost effective manner.

II. CURRENT USE OF FDM IN MICROWAVE APPLICATIONS

Use of FDM has been to create substrates [1] or Luneberg lenses [2], while here we look at using it to create a supporting structure with the aim that the dielectric properties of the polymer has a minimal effect upon the microwave performance.

III. RAPID PROTOTYPING

A simple X-band waveguide structure was produced using an Ultimaker 2 Fused Deposition Modelling machine with PLA filament with an arbitrary length of 40mm chosen. The waveguide was produced in one single piece but with

additional flanges for alignment clamped around the waveguide as shown in Fig. 1.

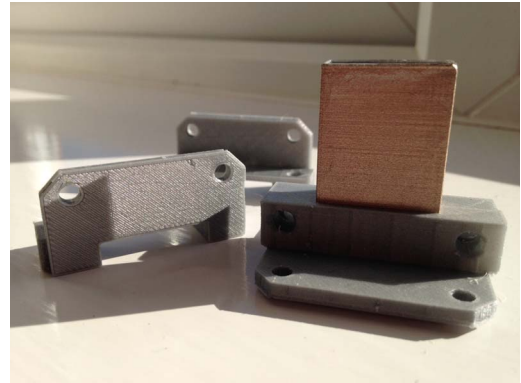


Fig. 1. FDM waveguide clamps and waveguide coated in conductive copper paint from an aerosol can.

The PLA waveguide's X-band frequency response was then measured. Then the outer walls of the PLA waveguide were sprayed using Copper (Cu) conductive paint in aerosol form.

IV. X-BAND WAVEGUIDE RESULTS

With a single coat of the conductive Cu paint from the aerosol, the RF transmission properties of the waveguide are seen to be relatively good. This assessment is based on the understanding that the conductivity of the paint will be significantly less than that of solid Cu. The transmission coefficient (S_{21} or S_{12}) is shown in Fig. 2 for a 40mm air gap between the waveguide calibrated reference planes, the 40 mm length of uncoated PLA waveguide, and the 40 mm length of Cu coated PLA waveguide. The S_{21} for the 40 mm air gap and 40 mm PLA waveguide display values <-10 dB. The addition of the thin Cu coating shows an improved S_{21} over the full 8-12GHz band with a transmission of better than -2.5dB, as shown in Fig 2.

V. CONICAL HORN ANTENNA

The above concept was further explored to investigate its potential with antennas. Here we present a simple FDM conical horn antenna coated in Cu conductive paint applied as an aerosol and shown in Fig. 3.

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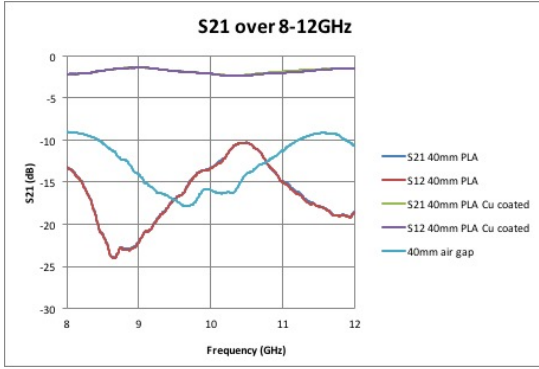


Fig. 2. Results of FDM Cu coated waveguide.



Fig. 3. Conical Horn Antenna.

The antenna was assessed over the 12 to 20 GHz frequency range displaying a gain of 8.99dB at 16.39GHz as shown in Fig. 4.



Fig. 4. Cu conductive aerosol coated antenna gain measurement over 12 to 20 GHz

VI. CONCLUSIONS

While further characterization is required for this as a cost effective rapid prototyping method for waveguide antennas, these early results indicate that there is potential using 'off the shelf' Cu conductive aerosol versus other metallization technologies, and antenna manufacturing methods.