NOVEL METAL 3-D PRINTED WAVEGUIDE COMPONENTS

IQRAM HAIDER

ABSTRACT

The research presented in the thesis focuses primarily on the design of novel waveguide filters and waveguide filtering antennas for modern satellite communications. These novel waveguide structures are developed by utilizing the manufacturing capabilities of metal 3-D printing. Hence, these waveguide components have achieved a lightweight, low manufacturing cost, and excellent RF performance.

First, a novel waveguide singlet is designed at 7 GHz using dual tri-slanted metal posts that are longitudinally placed within the waveguide. This waveguide singlet has produced a pole and a TZ in the upper stopband. Furthermore, by changing the posts' slant angle, this TZ can be placed closer to the pole frequency. Finally, this waveguide singlet's first spurious response appeared at 2.33 times the designed frequency by increasing the capacitive loading. Metal 3-D printing is preferred for waveguide singlet manufacturing because of its slanted profile. The fabricated waveguide singlet weighs only 25.7 grams, and its manufacturing cost is low. Additionally, the stopband performance of the waveguide singlet is better than that of other post-based waveguide singlets reported in the literature. This singlet can be utilized to implement highly selective waveguide filters for satellite communications.

A novel NFVC inverter using three closely spaced metallic posts that are placed within the propagating waveguide is presented. This NFVC inverter has provided three TZs that can be placed above two poles. Further, one of the TZs has been placed closer to the poles on both sides of the passband by changing the slant angle of the middle post. For the first time, the proposed structure has introduced a middle-slanted post between two closely spaced posts, making it novel in the literature. To demonstrate its usefulness, a fourth-order inline waveguide filter with an operating frequency of 7.9 GHz, a bandwidth of 1.5 GHz, and three TZs at 8.58 GHz, 9.37 GHz, and 10.9 GHz is designed, fabricated, and measured. Because there is a slanted middle post between closely spaced vertical posts, 3D printing is preferred for manufacturing the proposed waveguide filter. For the first time, 3-D printing is proposed for closely spaced, partial-height post-based configurations. This fabrication technique eliminates the requirement of a cutting process between very closely spaced, partial-height posts and reduces manufacturing costs due to less material waste. This waveguide filter is also useful for modern satellite communications due to its low weight (59.28 grams) and excellent RF performance.

A new inductive singlet based NFVC inverter is proposed to realize a compact waveguide filtering antenna with a TZ. This NFVC inverter can produce a TZ that can be placed above a pole. This inverter is utilized for the design of a compact wideband waveguide filtering antenna with a centre frequency of 9.3 GHz, a 10 dB return loss fractional bandwidth FBW of 22.22%, and a TZ positioned in the upper stopband at 11.4 GHz. A design technique based on synthesis and optimization has also been developed. Metal 3-D printing is used to achieve a low weight of 59 grams with low manufacturing costs (<25,000 INR). This waveguide filtering antenna ($0.2872\lambda o3$) has a smaller volume than other wideband waveguide filtering antennas reported in the literature. This waveguide-filtering antenna is an excellent candidate for modern satellite transponders due to its compactness, light weight, broad beamwidth, and wide bandwidth.

Finally, a novel synthesis technique is presented for the design of a slotted waveguide filtering antenna. This slotted waveguide filtering antenna is composed of transverse slots in the broad wall that are separated by suitable guide lengths. The design approach employs RLC circuit equivalents for radiating transverse slots, filter synthesis theory, and simulation-level optimization. To validate the proposed technique, a waveguide filtering antenna with a 10 dB return loss fractional bandwidth of 5.2 % at 27 GHz is designed, fabricated, and measured. The slotted waveguide filtering antenna is manufactured using the CNC milling process due to the inability to 3D print very thin transverse slots from the available metal 3-D printer, the EOS-M290. The fabricated filtering antenna provides suppression greater than 10 dB beyond 22% of the centre frequency on both sides of the gain passband without the need for an additional filtering circuit. The simulation-based optimization is used to achieve enhanced as well as fixed beam scanning compared to the small-perturbation or “leaky-wave” case. For the first time, the potential of jointly optimizing filtering performance and beam scanning is explored. This work shows the first steps for using filter synthesis theory to improve both the filtering and beam-scanning performance of a slotted waveguide-filtering antenna.