3-D-Printed Dual-Mode Filter Using an Ellipsoidal Cavity with Asymmetric Responses

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Outline

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• Motivation / Challenge
• Doublet implementation
• Higher order filters
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Introduction

Filters for aerospace applications:

- Low losses
- Cost
- Little Weight
- High selectivity
- Inline configuration

Telecommunication satellite: Broadcasting “Bent Pipe”
Introduction

- Oversized cavities to realize selective filter responses.
- **Dual-mode filters** are extensively used in **modern communication equipment**.
- **Dual-mode resonators** can implement sophisticated and selective filter transfer functions.
- Use of **tuning element** to adjust the frequency of **dual-mode filters** and to couple the modes.

Length each cavity (@ 12 GHz) ~ 54 mm

Comparative cavities @ 10 GHz

Rectangular
- Q-factor ~ 8000
- Length ~ 19.9 mm

Circular
- Q-factor ~ 11200
- Radius ~ 10 mm
- Length ~ 31.5 mm

Spherical
- Q-factor ~ 14500
- Radius ~ 13.1 mm
Spherical dual-mode filter

1. Coupling screws

2. Tuning screws

- Need of tuning (not only for mechanical considerations) and coupling screws
- Odd number of cavities: input/output with 90 degrees difference. No TZs
- Even number of cavities: input/output symmetric
- Only symmetric TZs. Not controllable

Introduction

Tuning elements:

- Screws are extensively employed in filter networks.
- The use of tuning screw reduces the need for high mechanical accuracy.
- For dual-mode filters, coupling screws are essential to provide coupling between orthogonal modes.
- Screws are not desirable for high-volume production.
- Screws can degrade the Q value by a large amount.
- Tuning elements can introduce spurious modes that cause degradation in the out-of-band rejection response.
Motivation / Challenge

**Filters for aerospace applications**

- Little weight
- Cost
- High selectivity
- Low losses
- Inline configuration

A filter that is easy to design, low weight and cheap (AM), with controllable TZ, no tuning element and high Q-factor

In this presentation an ellipsoidal filter with **asymmetric** TZs that be controlled in an inline configuration using AM is shown
Additive manufacturing

- **Stereolithography (SLA)** is an additive manufacturing process that focuses an ultraviolet (UV) laser on to a vat of photopolymer resin.

- Objective: fabricate and test prototype of waveguide filters.
- Postprocessing is required: **plating**.
Ellipsoidal cavity

• Controlling the frequency using the scaling parameters $R_y$, $R_x$

Electric field distribution (Fundamental mode) = Sphere

\[
\frac{x^2}{R_x^2} + \frac{y^2}{R_y^2} + \frac{z^2}{R_z^2} = 1
\]
Ellipsoidal cavity

• Controlling the frequency using the scaling parameters $R_y$, $R_x$

$$\frac{x^2}{R_x^2} + \frac{y^2}{R_y^2} + \frac{z^2}{R_z^2} = 1$$

$R_x = R_z = 12.8\, \text{mm}$

$R_y/R_x > 1$
Doublet implementation

• The doublet realizes two poles and one TZ.
Doublet Implementation

• Starting point at 45 degrees (No TZ).
Doublet Implementation

- Controlling the bandwidth using the ratio $R_y/R_x$.

$$\theta = 57$$
Doublet Implementation

- Rotation controls the ratio $\frac{M_s1}{M_s2}$

![Diagram showing the relationship between rotation angle and normalized coupling, with labels for $M_s1$, $M_s2$, and their normalized values. The diagram illustrates the lower and upper regions of normalized coupling as a function of rotation angle.]
Doublet Implementation

- When the rotation is 0 and 90 degrees the topology behaves as a singlet

\[ \theta = 0 \text{ degree} \]

\[ \theta = 90 \text{ degree} \]
Higher order filters

- Cascading doublets with or without NRNs

Length (@ 12 GHz – 4 pole filter) = 110 mm (conventional circular)


Length (@ 11 GHz – 4 pole filter) = 59 mm (conventional rectangular)

Experimental results

- CAD design
- ~ 7 hours
- ~ 30 min
- Silver conductivity + electroplating

Graph showing:
- S-parameters (dB) vs. Frequency (GHz)
- 0.47 dB
- 25 dB
Conclusions

- A new class of filters using ellipsoidal cavities has been presented in an inline configuration.
- The ellipsoidal cavity provides the highest Q-factor.
- The ellipsoid allows the control of the frequency of the fundamental mode and its degenerate.
- No use of tuning elements are needed.
- The rotation of input/output allows the control of the generated TZ: either in the upper or lower stopband.
- Higher order filter are possible by cascading more doublets.
- Additive manufacturing techniques (SLA) have been employed to manufacture a 2-pole filter.
Contact Information for Further Questions

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