TM_{110}-MODE RESONATORS — SIMPLE CONFIGURATIONS FOR HIGHLY FLEXIBLE WAVEGUIDE FILTER DESIGNS

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SUMMARY

Rectangular waveguide filters find widespread application in front-end communication systems operating anywhere between the lower GHz frequency range and the millimeter-wave regime. Their theory and design in directly coupled resonator/cavity arrangements are well known and understood. In order to more efficiently utilize an already densely populated frequency spectrum, recent requirements demand that many filter components be equipped with mechanisms to produce transmission zeros in the vicinity of their passbands. This can be achieved by two principal methods:

First, the use of frequency-dependent (dispersive) inverters makes it possible to produce a number of transmission zeros on either side of the passband and maintains an in-line filter topology which is easily manufactured by standard E-plane or H-plane fabrication techniques. (Note that this approach is often confused with the extracted-pole synthesis technique, which extracts series or shunt resonators at each end of the filter.) However, although dispersive inverters are capable of generating a multitude of transmission zeros, their locations are difficult to control, especially if the number of attenuation poles is close or equal to the number of electrical resonators.
Secondly, transmission zeros can be generated by elliptic or quasi-elliptic filter configurations. Traditionally implemented in dual/multi-mode circular waveguide cavities with tuning screws to compensate for mechanical tolerances, a number of rectangular filter components have been presented over the past years, which achieve similar operation without post-assembly tuning. However, many of these components require a complicated topology, which makes them unsuitable for current design and assembly lines. Simpler rectangular filter configurations often lack flexibility as to the number and locations of transmission zeros to be implemented.

This paper presents a novel kind of waveguide filter, which attempts to eliminate most of the drawbacks addressed above. Some of the salient features of such a design include:

- Resonances are based on TM_{110}-mode cavities allowing lower-order modes to generate cross/by-pass coupling.
- The maximum number of transmission zeros equals the number of TM_{110}-mode cavities.
- The locations of these transmission zeros are arbitrary, and simple design guidelines dictate their position with respect to the passpand.
- Each transmission zero is independently controlled as each resonance is capable of creating its own transmission zero.
- The filter topology is in-line and, therefore, ideally suited to fit standard waveguide

manufacturing technologies.

- Due to the TM_{110}-mode operation, the cavities are short. Therefore, an N-pole TM_{110}-mode filter usually requires less space than a comparable dual-mode filter based on $TE_{101/011}$ modes.

The only disadvantage can be seen in the fact that despite their elliptic or quasi-elliptic performance, these filters cannot be designed by standard coupling matrices because the standard inter-resonator coupling matrix formulation fails to capture the physical interactions of fields and modes involved. Therefore, a new coupling scheme based on so-called non-resonant nodes is developed and validated.

The presentation will start with a short description of the basic operational principle of a TM_{110}-mode cavity including guidelines to position individual transmission zeros. Based on these guidelines, a large number of individual designs will be presented. Specific features of the designs will be highlighted and their performances verified by measurements or results obtained with other/commercial software codes. The interactions of TM_{110}-mode cavities with other resonators in filter designs will be discussed. Finally, a new coupling scheme involving a triple-mode cavity will be presented and verified by measurements.

In conclusion, we believe that these new configurations present a viable alternative to current waveguide filter design and that they will soon find their way into waveguide-based communications equipment.