Abstract

Defected Ground Structure (DGS) is a simple microwave structure with a transmission zero or bandgap at finite frequency, inspired on the traditional photonic bandgap structure. This bandgap is widely used in rejecting the unwanted response of guided wave and radiated wave devices. Previous published work reveals that the present DGS units offer only a single bandgap implying that the suppression of the unwanted responses at different frequencies requires a number of DGS units with different sizes. Using large number of DGS units brings disadvantages as the excess of circuit size and increased losses. One possible alternative to overcome the previous drawbacks is the DGS with multiple bandgaps that is seldom used. This thesis will be specifically related with the investigation of compact multiple-bandgap DGS, as well as its implementations and applications.

Three dual-bandgap DGS elements will be developed, namely, the double *U*-shaped, the open-loop dumbbell-shaped and the *S*-shaped, moreover, several examples will be presented of these DGS elements with three, four and five bandgaps. The proposed dual-bandgap DGS units offer two controllable transmission zeros, retaining the compact etched area as the conventional single-bandgap DGS. Extra bandgaps will exhibit the obvious advantage of simultaneous suppression of unwanted responses at different frequencies. Besides that, this new class of DGS units brings additional flexibility in various aspects of microwave circuit design and synthesis. A notable guided wave circuit is the highly selective microstrip bandpass filter that will be the focus of

this thesis. This filter is always required in modern wireless communication systems to provide better signal selection and interference rejection. To realize the bandpass filter with such a stringent requirement a new dual-zero DGS bandpass unit will be developed using an end-coupled microstrip resonator pair, enabling a very compact quasi-elliptic bandpass filter realization. In addition, an integrated design method of highly selective bandpass filter with DGS elements' consideration, as an elementary component, will be mathematically formulated and implemented. Multiple-bandgap DGS technique outweighs the traditional DGS approaches as follows:

1. *Size reduction of conventional DGS lowpass filter* - In the realization of microstrip lowpass filter using DGS, the filters with 5 double *U*-shaped DGS units or open-loop dumbbell-shaped DGS units demonstrate a wider stopband up to 10 GHz with only half of the size as the conventional uniform and non-uniform DGS lowpass filters.

2. *Multiple harmonic suppression of conventional bandpass filter* - The triplex-bandgap DGS unit is applied to multi-spurious suppression of the parallel coupled-line bandpass filter resulting in a wide stopband with 30 dB attenuation up to 5-fold the center frequency value.

3. *Realization of compact quasi-elliptic bandpass filters with wide-stopband* - By etching the open-loop dumbbell-shaped slotted pattern directly under a simple end-coupled microstrip resonator pair, it results in a bandpass response with two transmission zeros near the band-edges, leading to a very compact quasi-elliptic DGS bandpass unit. Also, some of these bandpass units may be used together for a higher order quasi-elliptic

bandpass filter design. A prototype using two units is designed with center frequency at 1.5 GHz and 50% fractional bandwidth, yielding a quasi-elliptic bandpass filtering response with two transmission zeros at 0.92 GHz and 2.34 GHz; low passband insertion loss as 0.72 dB and a wide stopband of more than 20 dB attenuation up to 10 GHz. The overall circuit size is about 104 mm × 16 mm and the resonator in each end-coupled pair has a length close to 0.2 guided wavelength, resulting in a much compact circuit size.

4. *A simple synthesis of Inverse-Chebyshev bandpass filter* - An approximate design technique for inverse-Chebyshev bandpass filtering response is developed, using a cascade connection of a conventional maximally flat bandpass filter and the proposed multiple-bandgap DGS element. The *S*-shaped DGS unit offers the characteristics that are required in the synthesis. Theoretical and experimental results of the order-2 and order-4 quasi inverse-Chebyshev bandpass filters with center frequency of 2 GHz and 10% fractional bandwidth will demonstrate a good fitness with the responses of the inverse-Chebyshev mathematical models; confirming the method's usefulness.