A novel approach on photonic band gap filter and its advantages in optical communication & rf engineering

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Abstract:
Microwave photonics combines the worlds of optoelectronics and radiofrequency engineering, has attracted great concentrated on both the research community and the commercial sector over the past 37 years. The technology makes it possible to have functions in microwave systems that are complex or even not directly possible in the radiofrequency domain and also creates new opportunities for telecommunication networks. Here we introduce the technology to the photonics community and summarize recent research and important properties.

Introduction
Photonic band-gap (PBG) structures are periodic structures in which the propagation of energy in certain bands of frequencies is unaltered. In the microwave region, PBG structures have been used to improve the radiation pattern of antennas, and increase the output power and efficiency of power amplifiers, along with the design of reflectors, broadband absorbers, and frequency-selective surfaces. PBG structures, studied in the optical region originally, have been applied in microwave and millimeter wave circuits recently, due to their scalable and applicable properties in a wide range of frequencies. PBG structures can be achieved by using metallic, dielectric, ferromagnetic, or ferroelectric implants. Dielectric PBG structures have been used for microstrip circuits.

A number of studies have been carried out in EBG for microwave application, for example, by drilling a periodic pattern in the dielectric substrate, etching the periodic pattern in the ground plane or using sinusoidal variation of the characteristic impedance. The ratio of the two permittivity, lattice spacing, and relative volume fraction of the two dielectric materials are the independent design variables determining the band gap characteristics. The use of PBG allows for a wide stop band filter to be integrated into the filtering is one of the most important parts of microwave systems.

In 2003 Microwave photonic filters with negative coefficients based on phase inversion in an electro-optic modulator has been designed by José Capmany et al. A novel technical approach to the implementation of photonic rf filters that is based on the π phase inversion that a rf modulating signal suffers in an electro-optic Mach–Zehnder modulator, which depends on whether the positive or the negative linear slope of the signal’s modulation transfer function is employed. Mach–Zehnder modulator that depends on whether the positive or the negative linear slope of the signal’s modulation transfer function is employed. An electro-optic Mach–Zehnder modulator as a function of applied bias voltage V_{BIAS}; a Mach–Zehnder modulator (MZM) biased at either V_{BIAS} and V_{BIAS}^{'}, depending on whether the wavelengths are employed to implement positive or negative filter samples. The output from the two modulators is combined and sent to a dispersive element that implements the constant differential time delay between the filter samples^2; as shown below.
Fig 1- Typical modulation curve of a MZM

Fig 2- Experimental layout of a six-tap filter with three negative coefficients achieved with a tunable laser array. Linearly chirped fiber Bragg grating.

Fig 3- Measured and computed moduli(solid curve) of the transfer function for the filter with Gaussian apodization and negative coefficients.
IN 2007 JOSÉ CAPMANY1 AND DALMA NOVAK2 provide information regarding the fundamental elements of a microwave photonic link is devices that offer signal modulation, or control, or detection at very high frequencies. To increasing the laser modulation bandwidth is to enhance the frequency response resonantly, using external cavity lasers or monolithic multisection lasers. Using such techniques, narrow transmission windows at millimetre-wave frequencies have been achieved.

Fig 4- Schematic highlighting the fundamental concept of an analog microwave photonic link. One or more microwave signals are converted into the optical domain before transmission through a photonic or optical fiber link. At the other end of the photonic link, the signal is converted back into the electrical domain.

In 2003 by dr. Sam Mansaori et al. designed a novel photonic Band-pass RF transversal filter, employing a comb-laser and a length of single mode fiber as the dispersive medium has been proposed and demonstrated. The experimental results compared well with the simulations and thus the concept is validated. It has been proposed that the overall bandpass filter transfer function could be tuned by using a tunable comb-laser. Reconfigurability of the filter transfer function could be achieved by using an AOTF after the comb-laser. It would be advantageous to make the demonstrated band-pass filter tunable and reconfigurable. Tuning of the filter pass-band could be achieved by using a tunable comb-laser. By varying the spacing between the longitudinal modes, hence the filter tap’s spacing, the free spectral range (FSR) could be adjusted. To reconfigure the pass-band of the filter, a tunable optical filter can be employed to shape the comb-laser spectrum and thus obtain the required filter impulse response. The Acousto-optic tunable filter (AOTF) is a suitable candidate for this purpose. The performances of the periodic surface structures of defected shapes on the ground plane for low-pass filter (LPF) co-design are studied. Simulated results with full wave electromagnetic analyses are in good agreement with those experimental data. The optimal structure of double periodic structure bringing about the perturbation electromagnetic waves will be determined. The proposed LPF has defect ground surface with the characteristics of band-gap characteristics. The periodic surface structure is like photonic band-gap (PBG). [Munet al; 2000] structures are effective in RF and microwave application that provides an effective control of electromagnetic (EM) waves along Specific direction and performance. Controlling the periodic distance of PBG that exist band reject characteristic. Periodic and defected ground structure (DGS) have some excellent performance applied microwave transmission line guide such as the microstrip PBG [Radisic et al. 1998], coplanar waveguide PBG [Fu et al; 2001], coplanar-stripline PBG [Yun et al; 2001], uniplanar compact PBG and multiplayer PBG. The perforation patterns of PBG on the ground surface with band-stop and slow wave characteristics are studied. The DGS show great promise in improving the power added efficiency and radiation pattern in high power amplifier [Y. Qian, 1998], increase the Q value of planar inductor [Wu et al; 2002] or high efficiency planar antenna application to suppress unwanted sub-harmonic compared to conventional harmonic turning techniques. Some papers also report a new tunable technique on traditional planar filter [Yang, 1999] or DR filter [Sam et al; 2003] to reject undesired resonator modes. A new type of compact microstrip line photonic band gap (PBG) structure employing T-type microstrip line for filter is presented. A miniature band rejection filter with four cells is simulated, fabricated, and measured. The filter with four proposed PBG structures exhibits band rejection characteristics. The center frequency of stop-band is at 28GHz. The period of the PBG lattice is about 0.15λe. The line length of the filter with PBG cell employing T-type microstrip line was reduced to about 10.4mm, and its size was 14% of the conventional band rejection filter. The filter is very compact and much easier for fabrication and realization in MIC and MMIC. Several PBG structures etching in the ground plane have been presented [J. S. Lim et al.]. But, disadvantage of these kinds of structure comes from the packaging problem and realization of MMIC. A sandwich structure of PBG is proposed [C. Caloz et al.]. This structure can avoid the packaging problem, but realization in MMIC is still very difficult. For this reason, Nesic has proposed a novel PBG microstrip structure without etching in the ground plane for filter [D. Nesic et al.].
In the microwave region, PBG structures have been used to improve the radiation pattern of antennas, and increase the output power and efficiency of power amplifiers, along with the design of reflectors, broadband absorbers, and frequency-selective surfaces. PBG structures, studied in the optical region originally, have been applied in microwave and millimeter wave circuits recently, due to their scalable and applicable properties in a wide range of frequencies. PBG structures can be achieved by using metallic, dielectric, ferromagnetic, or ferroelectric implants. Dielectric PBG structures have been used for microstrip circuits. A number of studies have been carried out in EBG for microwave application, for example, by drilling a periodic pattern in the dielectric substrate, etching the periodic pattern in the ground plane or using sinusoidal variation of the characteristic impedance. The ratio of the two permittivity, lattice spacing, and relative volume fraction of the two dielectric materials are the independent design variables determining the bandgap characteristics. The use of PBG allows for a wide stopband filter to be integrated into the circuit substrate, thus allowing for collocation of other microstrip-circuit elements with the filter. According to Prof. Sanjeevkumargupta, II.S.C. Bangalore, Analysis of photonic band-gap microstrip filter provides the following observations:

- The start of the bandgap is relatively constant.
- The width of the bandgap is also a constant.
- The depth of the band gap increases as the number of periods increase.
- The passband ripples decrease as number of periods increase.

Analysis of photonic band-gap microstrip resonator had provide the following observations, if we increase the length of cavity resonant peak is decreasing and passband ripple is increasing.

In summary, we have reported a novel technical approach to the implementation of photonic rf filters that is based on the π phase inversion that a rf modulating signal suffers in a Mach–Zehnder modulator, T-shapes photonic band gap filter, 1-D photonic band gap filter, optical WDM photonic filter and its advantages compared with each other approaches have been discussed.
References

1. José Capmany, Daniel Pastor, Alfonso Martinez, Beatriz Ortega, and Salvador Sales “Microwave photonic filters with negative coefficients based on phase inversion in an electro-optic modulator” August 15, 2003 / Vol. 28, No. 16 / OPTICS LETTERS.


