LITERATURE REVIEW

UWB Bandpass Filter with Wide Stopband Using Lumped Coupling Capacitors

This paper [1] introduces an improved performance ultra-wideband bandpass filter by using lumped capacitors as an external coupling to stepped impedance DGS low pass filter structure. The filter has a passband from 3.1 to 10.6 GHz and a wide stopband up to more than 20 GHz. The insertion loss is less than 0.6 dB. The filter has a length of just 13 mm. The experimental results agree well with the predicted ones. This filter has been designed by coupling a DGS low pass filter to the I/O ports using surface mounted capacitors, to minimize the size of the filter. The coupling capacitor value affects the performance of the filter and controls the lower cutoff frequency. A wide stop-band with a rejection higher than 20 dB up to 20 GHz has been achieved.

Small Size Defected Ground Structure (DGS) Coupled Resonator Band Pass Filters with Capacitor Loaded Slot Using FDTD Method

This paper [2] presents a design of a small size second and third order band pass coupled resonator filters by using finite difference time domain method (FDTD). Two of the proposed filters consist of compact folded DGS resonators, the other consists of compact rectangular DGS resonators and a lumped capacitor is combined within the slot of each filter. The insertion of lumped capacitor within resonators increases the effective capacitance, and reduces the resonant frequency, so the dimensions of the filter will reduce and the performance of the filter will be improved by enhancing the energy stored in the resonator. The resonance bandwidth is decreased leading to increasing the resonator quality factor.

Design of a new band-pass filter with sharp transition band using multilayer-technique and U-defected ground structure

In this paper, [3] a novel compact microstrip bandpass filter with sharp rejection bands is proposed in the given paper. The proposed filter structure is composed of U-shape microstrip resonators, ‘U-strip’, backed by similarly shaped U-slots ‘U-defected ground structure’ (U-DGS). By controlling the electrical coupling between the U-strip and the U-DGS, the bandpass filter’s stopband is optimised for better rejection. The proposed filter has low insertion loss and compact size because of the slow-wave effect. Meanwhile, sharp rejection bands induced by the presence of two transmission zeros on both sides of its passband are achieved. The measured centre frequency, bandwidth and pass band insertion loss are 3.6 GHz, 40% and 0.5 dB, respectively
An Improvement of Defected Ground Structure Low-pass /Band-pass Filters Using H-Slot Resonators and Coupling Matrix Method

In the referred paper [4], a novel compact wideband high-rejection low-pass filter (LPF) using H-DGS is presented. The proposed filter has neither open stub nor cascaded high-low impedance elements. It consists of two coupled H-slots in the ground plane along with a compensated line. The effect of the new slot on the filter performance is examined. The comparison with the conventional filters shows that the proposed filter guarantees a large rejection-band of 20dB from 2.5 to 16 GHz. This lowpass filter is not only of compact size, but also offers control of the cutoff frequency and transmission zero by means of the H-arm structure. The LPF has a low insertion loss in the passband and a very high rejection in the stopband from 2.4 to 14GHz.

A Novel Band stop Filter using Octagonal shaped patterned ground structures along with Inter digital and compensated Capacitors

In the referred paper [5] a new octagonal DGS band stop filter is investigated which shows that the proposed filter has a good sharp cut off frequency response and a good performance in both the pass band and the stop band. The use of interdigital capacitors improves the pass bands of the filter as compared to the filter without IDS and also helps in control of the resonant frequency. The structure is also very compact.

A Compact Narrow band Micro strip Band-Pass Filter with Defected Ground Structure

In the referred paper [6] a compact narrow band, band pass filter is proposed with hexagonal dumbbell shaped defected ground structure in ground plane of a 50 ohm micro strip line and a closed loop resonator in the conducting strip. This arrangement provides better coupling in pass band. Using DGS structure, forward transmission loss is -0.5 dB and return loss is -26.7 dB at the centre frequency 5.4 GHz with narrow bandwidth of 500 MHz. A conventional parallel coupled line band pass filter has also been implemented with exactly same design goals for the sake of comparison. The proposed band pass filter with DGS is quite promising with 60% size reduction and reduced harmonics in the pass band.
Design studies of Ultra Wideband Microstrip band Pass Filter with T- shaped Defected Ground Structure Controlled by Inter Digital Capacitance

In the referred paper [7] a compact wide band band pass microstrip filter with T shaped DGS with interdigital capacitance in 50 ohm conducting line is proposed. Use of DGS leads to a forward transmission coefficient of -0.08 dB and a reflection coefficient of -22 dB at the center frequency 5.4GHz with a wide bandwidth of 2GHz. Such type of filter can be used for WLAN and other applications. Thus in this filter at the center frequency of 5.4 GHz a minimum attenuation of signal -0.08 dB is achieved, that is more than 95% of the signal will be transmitted.

Microstrip Low Pass Filter With Wideband Rejection Using Opened Circuit Stubs And Z-Slots Defected Ground Structures

In this paper, [8] a new microstrip low pass filter (LPF) with defected ground structure (DGS) is proposed. The DGSs consists of reshaped rectangular dumbbell slot and four groups of Z-shape slots. The microstrip line with DGS gave good rejection band extend from 3.0 to 9 GHz with acceptable pass band. The microstrip line with open circuit stubs (without DGS) gave good rejection band at the high frequency from 9 to 14 GHz. Using both structures results in LPF with wideband rejection from 3.37 to 14 GHz with attenuation less than (26.0dB) and good passband less than (25 dB).

Compact Low Pass Bessel Filter Using Microstrip DGS Structure

In the referred paper, [9] the design and performance of 5th order DGS based Bessel type LPF with 3 dB cut-off frequency at 2.5 GHz has been proposed. It significantly improves the cut-off performance of the lumped element based Bessel type LPF. The sharpness of pass cut-off of the DGS based Bessel filter is comparable to that of the sharpness of the Butterworth kind LPF. The frequency range of 10 dB return loss of the DGS based Bessel LPF is 1.91 GHz as against 0.8 GHz for the lumped element based Bessel LPF. The variation in group delay of the DGS based Bessel LPF in passband is 42.8 ps; whereas the DGS based Chebyshev and Butterworth LPF have group delays of 277 ps and 120 ps respectively. The lumped element based Bessel type LPF provides maximally flat group delay response in the pass-band. However, its sharpness of cut-off is poor and impedance matching in the pass-band is also not satisfactory. Due to these limitations this filter is not popular in RF/Microwave bands. However, useful compact Bessel type LPF can be designed with help of the DGS structure in the microstrip environment. This filter has sharpness of cut-off frequency comparable to the response of a Butterworth type LPF. Its group delay response is much superior to the group delay response of the DGS based Chebyshev and Butterworth type LPF. The DGS based Bessel type LPF has
acceptable impedance matching in the pass-band. The Bessel filter can be designed in the higher microwave frequency bands also.

**Design of A Wide Stopband Harmonic Suppressed Microstrip Low Pass Planar Filter Using Defected Ground Structure**

In this paper, [10] an analysis is made of the filter characteristics of the low pass planar filter originally designed by J.S Hong and M.J Lancaster. It is noticed that a spurious harmonic at 2.9 GHz appear in the filter characteristics. This paper presents a novel design of a wide stop band low pass planar filter using defected ground structure, which eliminates the 2.9 GHz harmonic from the filter output. The simulation and analysis of the low pass planar filter is performed using the Ansoft HFSS v11 simulator. Snapshots of the simulation and the graphical results obtained after suppression are shown in the paper, to establish the suitability of using defected ground structure for this low pass planar filter. The simulation firmly establishes the fact that when a single defect is introduced there is reduction of 20 dB in the power level at 2.9 GHz, the spurious frequency in the pass band and when two defects are introduced there is a reduction of 30 dB in the power level at 2.9 GHz which is better than when a single defect is introduced.

**Study And Realization Of Defected Ground Structures In The Perspective Of Microstrip Filters And Optimization Through ANN**

In this paper, [11] Micro-strip low pass filter with Dumbbell Shaped Slot Defected Ground Structure (DGS) is designed. The response of the filter is analyzed with respect to variation in dimension of the DGS unit. The variation of dimensions of defects studied with their corresponding change in capacitance, inductance as well as frequency response. The defects dimensions are modeled with respect to frequency using the artificial neural network. Optimizing the convergence of Artificial Neural Network (ANN) classifiers is an important task to increase the speed and accuracy in the decision-making. The frequency response of the micro strip filter is modeled with respect to the variation in dimension of DGS using CST microwave studio. The dimensions are further optimized in order to achieve minimum error in frequency response. Incremental and online back propagation learning approach is followed in the training of neural network because of its learning mechanism based upon the calculated error and its ability to keep track of previous learning iteratively. The simulation results are compared with the results obtained through ANN and the designs are further optimized.
A Design of the Low-Pass Filter Using the Novel Microstrip Defected Ground Structure

In this paper, [12] a new defected ground structure (DGS) for the microstrip line is proposed in this paper. The proposed DGS unit structure can provide the bandgap characteristic in some frequency bands with only one or more unit lattices. The equivalent circuit for the proposed defected ground unit structure is derived by means of three-dimensional field analysis method. The equivalent-circuit parameters are extracted by using a simple circuit analysis method. By employing the extracted parameters and circuit analysis theory, the bandgap effect for the provided defected ground unit structure can be explained. By using the derived and extracted equivalent circuit and parameter, the low-pass filters are designed and implemented. The experimental results show excellent agreements with theoretical results and the validity of the modeling method for the proposed defected ground unit structure. The proposed DGS sections can realize small element values for implementation of a low-pass filter. Furthermore, the fabricated low-pass filter with the proposed DGS sections is expected to provide improved power-handling capability because that DGS section can implement the high impedance inductance line with broader conductor width than that of a conventional microstrip.

Performance of Low Pass filter Using Defected Ground Structure

In this paper, [13] a new DGS (Defected Ground Structure) technique to design a low pass filter is proposed, ground is defected or cut in a desired shape which improves its performance. The size of filter is also reduced. The method to calculate the cutoff frequency of the LPF has been developed based on the modelled equivalent inductance and capacitance, which depends on the dimension of the DGS pattern. In addition, the method to determine the size of the DGS pattern, which exactly realizes the required transformed inductance, has been proposed by curve fitting with excellent accuracy.

Ultra Wideband Band-Pass Filter with Improved Upper Stop-Band performance Using Defected Ground Structure

In the referred paper [14], a novel ultra-wideband (UWB) band pass filter (BPF) with improved upper stop band performance using a defected ground structure (DGS) is presented. The proposed BPF is composed of seven DGSs that are positioned under the input and output micro strip line and coupled double step impedance resonator (CDSIR). By using CDSIR and open loop defected ground structure (OLDGS), UWB BPF characteristics can be achieved, and by using the conventional CDGSs under the input and output micro strip line, the upper stop band performance can be improved. Simulated and measured results are found in good agreement with each other, showing a wide pass band from 3.4 to 10.9 GHz, minimum insertion loss of 0.61 dB at 7.02 GHz, a group delay variation
of less than 0.4 ns in the operating band, and a wide upper stop band with more than 30 dB attenuation up to 20 GHz.

**Compact Microstrip Lowpass Filter Based on Defected Ground Structure and Compensated Microstrip**

In this paper, [15] an improved defected ground structure (DGS) with compensated microstrip line is investigated for lowpass filter (LPF) applications. With this structure, the basic resonant element exhibits the elliptic-function lowpass responses. The use of introduced resonant elements allows sharp cutoff frequency response and high harmonic suppressions together with small size to be obtained with less number of periodic structures. An equivalent lumped \( L-C \) circuit model is presented and its corresponding \( L-C \) parameters are also extracted by using parametric relationships. Based on the equivalent circuit model, a 3-pole LPF, using 3 DGS units cascaded, is optimally designed and implemented; measurements show good consistency with calculations. The compact size, sharp cutoff frequency response and high harmonic suppressions would make the introduced DGS pattern to meet the requirements of modern wireless communication systems.

**Design of Low-Pass Filters Using Defected Ground Structure**

In the referred paper, [16] a method to design low-pass filters (LPF) having a defected ground structure (DGS) and broadened transmission-line elements is proposed. The previously presented technique for obtaining a three-stage LPF using DGS by Lim et al. is generalized to propose a method that can be applied in design -pole LPFs for 5.

**Design Of Microstrip Hairpin Band Pass Filter Using Defected Ground Structure And Open Stubs**

In this paper, [17] five pole chebyshev microstrip band pass filter is designed using hairpin resonators. A dumbbell shaped defected ground structure and square split ring resonator DGS are presented to suppress the second and third order harmonics of bandpass filter. Dumbell and square split ring resonator defected ground structure cells are etched under feed lines for improving stop band rejection without affecting the centre frequency and insertion loss of basic filter. For effective suppression of higher order harmonics open stubs are also used at the input and output feed lines. A five pole chebyshev microstrip band pass filter is designed with 700 MHz bandwidth at the centre frequency of 2.5 GHz. Band pass filter is simulated using ADS 2009 software. The simulated results of conventional band pass filter, dumbbell DGS bandpass filter and SRR DGS bandpass filter are compared and tabulated. Compared to dumbbell DGS bandpass filter, SRR DGS bandpass filter has
improved suppression at second harmonic frequency. Here, 5 pole chebyshev hairpin BPF is designed using dumbbell shape DGS, SRR DGS and open stubs. Two pairs of DGS structures are etched under the input and output feed lines of proposed filter to reduce the spurious frequencies. In the design of B.P.F using dumbbell DGS and open stubs, second and third harmonics are suppressed by 23B and 48 dB at 5 and 7.5 GHz respectively. By including open stubs in the design of proposed filter improved suppression is achieved at the third harmonic frequency. In the design of B.P.F using SRR DGS and open stubs, second and third harmonics are suppressed by 54B and 34 dB at 5 and 7.5 GHz respectively. Compared to B.P.F designed using SSR DGS and open stubs, improved suppression is achieved at second harmonic frequency. The stop band properties of DGS and open stubs provide wide and deep stop band characteristics. The out of band suppression is no less than 34 dB until 7.5 GHz

Semicircular Microstrip Low pass Filter

In the referred paper [18] a semicircular microstrip low pass filter with the sharp rejection and wide stop band has been designed. The proposed filter design is based on the calculations of filter parameters from traditional Hi-Lo impedance method and is available in the literature of microstrip filter. To further improve the design performance, high impedance lines are magnetically coupled, resulting in an attenuation pole near -3dB cut off point of the filter. This design gives insight in designing a low pass filter with reduced size of an arbitrary geographical shape. It has been observed that the proposed design requires much less area as compared to skirt filter area and also because of the wide stop band proposed design is quite efficient for the suppression of spurious signals.

Comparative Study of Three DGS Unit Shapes and Compact Microstrip Low-Pass and Band- Pass Filters Designs

In this paper [19], three types of defected ground structure (DGS) units which are triangular-head (TH), rectangular-head (RH) and U-shape (US) are investigated and their characteristics are compared each other. Further, they are used in the design of low-pass filters (LPF) and band-pass filters (BPF) and the obtained performances are examined. The LPF employing RS-DGS geometry presents the advantages of compact size, low-insertion loss and wide stopband compared to the other filters. It provides a cutoff frequency at 2.5 GHz, a largest rejection band width of 20 dB from 2.98 to 8.76 GHz, a smallest transition region and a smallest sharpness response at the cutoff frequency. The BPF based on RS-DGS has the highest bandwidth (BW) of about 0.74 GHz and the lowest center frequency of 3.24 GHz whereas the other BPFs have BWs less than 0.7 GHz.
An Ultra-Wideband Bandpass Filter With an Embedded Open-Circuited Stub Structure to Improve In-Band Performance

In this paper, [20] a compact ultra-wideband bandpass filter (BPF) with a notch band in the BPF is presented by using an embedded open-circuited stub structure. The filter mainly consists of conventional stepped impedance resonator (SIR) as the multiple-mode resonator and two enhanced coupled input/output lines. The bandwidth can be analyzed by using the image-parameter method to obtain the proper dimension of the coupled lines and verified by using electromagnetic (EM) simulation. The embedded open-circuited stub structure in the SIR is used to produce a narrow notched band at 5.8 GHz, which is its frequency position and bandwidth can be tuned by its physical parameters. The measured 3 dB fractional bandwidth of 113.8% and narrow notched band with 25 dB rejection is achieved. Good agreement between the EM simulation and measurement is obtained. It is also verified that the tight coupled I/O lines are necessary for introducing the UWB frequency response by using the image-parameter method and the EM simulation. With the embedded open-circuited stub structure in the MMR, the UWB response is still obtained and a desirable notched band at 5.8 GHz is achieved.

Compact Ultra Wideband Band-Pass Filter with Defected Ground Structure

In this paper, [21] a compact planar microstrip ultra-wideband (UWB) bandpass filter is presented in this paper. The proposed UWB filter is realized by cascading a high pass filter (HPF) and a lowpass filter (LPF). HPF with short-circuited stubs is used to realize the lower stopband and a lowpass filter based on a defected ground array in the ground plane employed to attenuate the upper stopband. One such bandpass filter is designed and simulated. The filter consists of a LPF and a HPF. The LPF is designed using DGS sections. Variations of the resonant frequency versus DGS parameters were investigated and the method to incorporate DGS units in designing the LPF was suggested. The HPF is realized by coupled short circuited stubs. The composite bandpass filter was simulated using EM simulators. Simulated S-parameters showed that the filter has a 3 dB bandwidth of 7.5 GHz (3.1–10.6 GHz) and the attenuation in the stop band is better than 20 dB up to 22.7 GHz.

Design, Simulation and Construction of a Low Pass Microwave Filter on the Micro Strip Transmission Line:

In this paper, [22] a low pass microwave filter has been designed. The filter has been designed by step impedance method in which the alternative part characteristic linear impedance is too high or too low
In this filter by changing every high or low impedance characteristics such as length or width desired characteristics can be reached and it has been simulated by using HFSS software, and relying on full-wave analytical methods in three dimensional work. This Filter has less complexity rather than other filters. Results of practical measure and simulation have been in fairly good agreement with each other.

**Formulation of Size Reduction Technique in Microstrip Circuits by using DGS and DMS**

In the referred [23] paper a simplified and accurate mathematical formula is derived to predict the reduced dimension of the microstrip circuit by using applicable etching geometry on plane of microstrip circuit such as DGS or DMS that will affect the resonant frequency of microstrip circuit in desired direction due to increment of slow wave effect. Here a proportional formula of defect has been developed which is verified successfully by applying to a network implemented with an open circuit and for microstrip patch antennas, phase shifter etc. From this proportional relation slow wave factor, phase velocity, change in electrical length can be directly calculated. By using this formula the graph between the phase velocity and frequency can also be plotted. Using this formula the variation of dispersion characteristics can also be done.

**Control of Band Stop Responses of Very Compact Size Microstrip Filter of Improved Q factor & Sharp Transition by Using hexagonal Transmetal DGS**

In this paper [24] a compact size microstrip filter using hexagonal with transmetal Defected Ground Structure (DGS) has been proposed. Here the response of five different types (square, circular, triangular, hexagonal & hexagonal with transmetal) of dumbbell shape DGS have been studied which are having the same resonant frequency, and the response of different shapes of DGS has been compared. It is observed that proposed DGS has more sharp cutoff frequency, quality factor as well as sharpness factor and occupying area of the proposed DGS is less as compare to others. From frequency response curve, it is clear that the proposed structure achieved 30.4dB of S21 while all other structures have S21 approaching to 21dB. Thus it has been seen that the transmitted power is 99.95% in the proposed structure, while all the other structures provide approximately -0.04 of insertion loss with transmitted power 99%. Proposed structure gives a sharp cutoff between 3 db to 30 dB. Q-factor as well as sharpness factor is more in the proposed structure as compared to all other structures. Regenerated frequency curve gives an amazing result which shows that the accuracy of the calculated value of L and C from the frequency response curve is optimum.
Ultra Wideband Seven Poles Lowpass Filter Using DGS Array

In this paper, [25] it was intended to build a microstrip low pass filter with a pass band till 3 GHz at 3 dB cutoff frequency. In the first stage, a conventional seven pole low pass filter using commensurate length / 8 g λ is designed by converting the value of g1 to g7 into unit elements as well as open circuit stubs. In second stage, a method to design low pass filter having a Defect ground structure (DGS) as well as defect microstrip structure is proposed. In this Section, we have studied the square shaped DGS array having the same resonant frequency as compared to conventional seven poles low pass filter and compared the response of DGS array with seven poles low pass filter. It is observed that DGS array have more sharp cutoff frequency, quality factor as well as sharpness factor and occupying area of the proposed DGS is less as compare to the seven poles low pass filter.

Improved Performance of DGS Based LPF using Anisotropic Substrate

In this paper, [26] Low pass filters (LPF) with planar defected ground structure (DGS) for microstrip line on anisotropic substrate are designed and fabricated. An improvement in the sharpness factor using anisotropic substrate for a two element DGS based LPF and a periodic 1-D five element based LPF has been reported. The use of anisotropic substrate is found to improve the sharpness characteristic of the two DGS elements and five DGS elements LPF compared to its isotropic counterpart. The sharpness of the filters has improved by up to 2.6 % by using anisotropic substrate and it can be further improved significantly by using a substrate with higher anisotropy ratio.

Improving Frequency Response of Microstrip Filters Using Defected Ground and Defected Microstrip Structures

In this work, [27] the introduction of Defected Microstrip Structures and Defected Ground Structures is presented to improve the performance of a traditional stepped-impedance microstrip lowpass filter. The attenuation in the stop-band is enhanced by more than 15 dB and selectivity is increased, without modifying the insertion loss in the pass band. A comparison of characteristics in filters is made when the combination of Defected Ground and Defected Microstrip Structures, as well as when only the first one are used.

Compact Ultra-Wideband Bandpass Filters Using Composite Microstrip–Coplanar-Waveguide Structure

In this paper, [28] a compact ultra-wideband bandpass filters are proposed based on the composite microstrip–coplanar-waveguide (CPW) structure. In this study, the microstrip–CPW transitions and the CPW shorted stubs are adopted as quasi-lumped-circuit elements for realizing a three-pole high-
pass filter prototype. By introducing a cross-coupled capacitance between input and output ports of this high-pass filter and suitably designing the transition stretch stubs, a compact three-pole ultra-wideband bandpass filter is implemented with two transmission zeros located close to the passband edges. To further improve the selectivity, two microstrip shorted stubs are added to implement a five-pole ultra-wideband bandpass filter with good out-of-band response. Being developed from the quasi-lumped elements, and not from the transmission lines, the proposed ultra-wideband filters have sizes more compact than those of the published wideband filters. The proposed ultra wideband filters have the merits of compact size, flat group delay, good insertion/return loss, and good selectivity. Agreement between simulated and measured responses of these filters is demonstrated. In the five-pole UWB bandpass filter, two microstrip shorted stubs used to realize two shunt inductances would resonate at higher frequency, thereby producing the third transmission zero at this higher frequency. With these transmission zeros, the proposed filters have good selectivity and stopband rejection. In addition, the dimensions of proposed UWB bandpass filters are much less than those of the published UWB filters. The proposed filters with good frequency performance and flat group delay are attractive for UWB radio applications.

A Novel Low Pass Filter Using Elliptic Shape Ground Defected Structure

In this paper, [29] a novel elliptic shape defected ground structure (DGS) for low pass filter (LPF) applications. An equivalent RLC circuit model is presented and its corresponding parameters are also extracted from the measured S-parameters. The filter presents the advantages of compact size, high selectivity; low insertion loss and high out-band suppression from 5.15 GHz to 10 GHz below −31 dB. Good agreement with response of equivalent circuit, electromagnetic simulation and measurement is demonstrated.

Hybrid Microstrip T-Stub/Defected Ground Structure Cell for Electromagnetic Interference Bandpass Filter Design

In this paper, [30] the hybrid microstrip T-stub/defected ground structure (HMT/DGS) cell is designed, which is composed of a microstrip T-stub and an interdigital DGS with the broadside-coupled (BC) transition. Finely adjusted resonance can be achieved by the proposed cell. Meanwhile, strong slow-wave effect is employed by the structure, which leads to wide stopband responses. Based on these HMT/DGS cells, the interdigital coupled scheme is employed to implement the electromagnetic interference (EMI) bandpass filter with high performance. Specifically, the second-order bandpass filter with a fractional bandwidth (FBW) of 14.3% has a 29.1-dB stopband rejection up to 15f0 (where f0 stands for the passband center frequency). The fourth-order bandpass
filter with an FBW of 10.8% demonstrates a 30.1-dB stopband rejection up to 12.1f0. Both types of filters show compact sizes with low insertion losses less than 1.1 dB.

**Microstrip Dual-Mode Bandpass Filter Using CPW-Fed Triangular Loop Resonator with Controllable Attenuation Pole**

In this paper, [31] a novel microstrip dual-mode bandpass filter (BPF) based on the triangular loop resonator with coplanar-waveguide (CPW) feeding structure is presented. The novelty of this design is to use two forms of perturbation, the isosceles triangle shape of microstrip loop resonator and the open stub element, both of which contribute to the coupling between two degenerate modes. By making various combinations of these two parameters, it is possible to design both narrow and wide band filters and to control the attenuation pole frequency simultaneously. Moreover, the issue of harmonic suppression using dumb-bell-shaped defected ground structure (DGS) cells integrated at each input/output port is also investigated. Experimental results show a good agreement with the simulated ones, which validates the proposed design. The proposed filters exhibit a good performance including low insertion loss, compact size, novel and simple structure, high selectivity, and easy design and fabrication. This design concept can be an important addition to the dual-mode BPF designs with emphasis in simplicity and design flexibility.

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**SKEW-SYMMETRICAL DEFECTED GROUND STRUCTURE FOR PARALLEL-COUPLED LINE FILTERS**

A system and method are disclosed for improving the reliability of parallel-coupled line filters. In one embodiment, a parallel-coupled line filter system is disclosed which comprises at least one open-line resonator, at least one defected ground structure arranged on opposite sides of the line resonator having a first lattice and a second lattice in a skew-symmetrical fashion and coupled through a slim gap, wherein the first and second lattices are formed on a ground plane.

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**DEFECTED GROUND STRUCTURE WITH SHIELDING EFFECT**

A defected ground structure with shielding effect is provided. The structure includes a dielectric layer, a defected metal layer, a grounded metal layer and at least a conductive mushroom-like structure. The defected metal layer has a line-shaped opening and is disposed in the dielectric layer. The conductive mushroom-like structure is disposed between the defected metal layer and the grounded metal layer and is arranged along an extending direction of the line-shaped opening periodically. The conductive
mushroom-like structure includes a fungating part and a stipe part. The fungating part is parallel to the defected metal layer and a distance is maintained away from the defected metal layer. The projection area of the fungating part on the defected metal layer covers a length of the line-shaped opening corresponding to the fungating part. The stipe part connects the fungating part and the grounded metal layer.

**Date of Patent:** Sep. 13, 2011

**RESONATOR HAVING A THREE DIMENSIONAL DEFECTED GROUND STRUCTURE IN TRANSMISSION LINE**

A high quality resonator has a three dimensional Defected Ground Structure (DGS) in the transmission line. The resonator includes a substrate installed at the center of the resonator floating in the air through supporting members, a transmission line on the substrate, and an upper ground plane member above the substrate at a predetermined interval. A DGS pattern with a predetermined shape is on each portion of the body of the ground plane member symmetrically with respect to the transmission line. An upper cover closely contacts the upper surface of the upper ground plane member to seal the upper opening of the DGS pattern on the upper ground plane member. A lower ground plane member has the same pattern as the upper DGS, and a lower cover functions similar to the upper cover. The upper and lower members should be installed symmetrically with respect to the substrate.