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A REVIEW OF TECHNIQUE TO CONVERT LOW PASS FILTER INTO MICROSTRIP LINE CIRCUIT

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ABSTRACT

The purpose of this paper is briefly describes review of techniques design a lumped element low pass filter prototype into microstrip line circuits that is normalized in terms of impedance and frequency range. There are several methods have been consequential or developed and used to provide as well as improve the conversion into microstrip line circuit by researchers to interpret the lumped element into a microstrip filter with simple and efficient techniques and which accomplish the design specification. There are some main features of the frequency at microstrip low pass filters to improve frequency responses, to obtain the sharp cutoff frequency response and low ripple corresponding to low return loss in the passband. This paper will investigates different techniques undergoes by some of the research that has been performed in the area of transforming lumped element LPF into microstrip line circuits and the future objectives that must be accomplished for achieved more efficiently devices into the RF wireless communication system to find their way into everyday use.

Keywords: low pass filter, microstrip line circuit, lumped element, RF communication systems.

INTRODUCTION

Microstrip filters are gaining popularity among researchers due to constraint design improvements and their need in many microwave systems including wireless communication (Swanson and Macchiarella, 2007; Hong and Lancaster, 2001). In filters design, there are a few parts that need to be improved or upgraded in order to produce a more efficient and better product. Lumped element filters, i.e., filters constructed with discrete components such as capacitors and inductors are not suitable for filter construction above 500 MHz, due to the wavelength becoming comparable with the physical filter element dimensions, resulting in the various losses severely degrading the circuit performance (Rajasekaran *et al.* 2013). Thus to arrive at practical filters, the lumped component filters must be converted into distributed element realizations.

In higher frequency filters, lumped element filters can be modeled and converted to distributed structures. A PCB transmission line segment is an example of a distributed structure element. The length of such a segment will be proportional to the filter midband wavelength. Beyond this range, components deviate significantly from the ideal.

The microwave filters are based on distributed parameters rather than lumped inductors and capacitors (Hong and Lancaster, 2001). In improving the current technique, a low pass filter circuit in microstrip line form can be reduced in size. This improves the performance of the characteristics microstrip low pass filter response especially on the passband insertion loss, stopband performance, and return loss. The exact value of the distributed components can be implemented instead of a lumped component. .

This paper will emphasize on the procedures or methods of involved into conversion of lumped element into microstrip line circuit of various types low pass filters operating at UHF which is commonly suitable to be used as Wireless Local Area Network (WLAN) and Worldwide Interoperability for Microwave Access (WiMAX) applications, especially in any RF communication systems.

Overview Techniques transforming microstrip line circuits of low pass filters

Filters can be realized in lumped type or microstrip line type. The lumped element filter design generally works well at low frequencies, but two problems arise at microwave frequencies. First, lumped elements such as inductors and capacitors are generally available only for a limited range of values and are difficult to be implemented at microwave frequencies, but must be approximated with distributed components. Secondly, the normal lumped inductors and capacitor components introduce stray capacitance and inductance from leads. In low frequency applications large inductors and capacitors are needed to cause a bulky system, which is often discouraged. Moreover, the lumped element circuit can work efficiency at lower frequency range because the wavelength will decrease to short on higher frequency and while for distributed elements suitable operate at higher frequency and wavelength will become too larger when into lower frequency range (Gowthami *et al.* 2014).

LITERATURE REVIEW

Various alternative methods have been developed by a number of researchers to ease simulation effort when converting prototype low pass filter into microstrip (Rajasekaran *et al.* 2013; Pravan *et al.* 2012). The insertion loss method of filter design provides lumped element circuit but for microwave applications, such design must be modified to use distributed elements consisting of transmission line sections which can be achieved by Richard's Transformation and Kuroda's Identities (Pozar, 2012; Hong and Lancaster, 2001).

Conversion of Microstrip Line by Using ABCD Network Parameters Method

Abdullah *et al.* (2011) had proposed a design of a practical broadband microstrip filter operating within cutoff at 1.5 GHz using ABCD network parameters. This conversion had simplified the analysis significantly. The analytical analysis, simulation and implementation of the filter was performed on a planar electromagnetic simulator, Sonnet V12.56 for 5th order, 0.2 ripple Chebyshev filter topology using an alumina substrate with a dielectric constant of 9 and thickness of 600 µm.

The ABCD network parameter technique has important implications for impedance matching and frequency selectivity as shown in Figure-1. Figure-1 which represents two port networks with two of four variables, while the other two can be always derived (Abdullah *et al.* 2011).

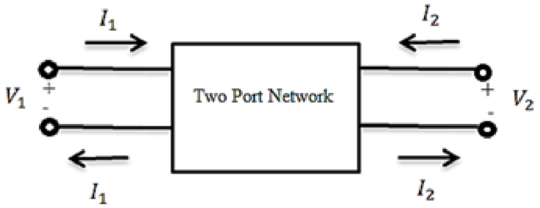

Figure-1. Two-port network representation (Abdullah *et al.* 2011).

$$\begin{Bmatrix} v_1 \\ i_1 \end{Bmatrix} = \left(\begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \cdots\cdots\cdots \begin{bmatrix} A_n & B_n \\ C_n & D_n \end{bmatrix} \right) \begin{Bmatrix} v_2 \\ -i_2 \end{Bmatrix}$$

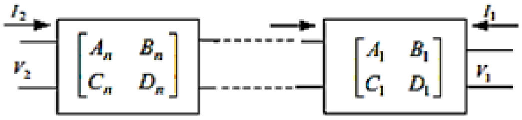

Figure-2. Cascaded network representation with ABCD parameters (Abdullah *et al.* 2011).

The proposed conversion methods obtain insertion and return losses of the filter using the ABCD parameters of the overall network. When the condition exists, the overall ABCD parameter of the network is found by simple multiplication of individual ABCD parameters of cascade components, as shown in Figure-2.

All the voltages and currents are complex variables and represented by phasors containing both magnitude and phase. This technique presented by Abdullah *et al.* (2011) is recommended suitable used for design low cost, and broadband microstrip filters with high accuracy. The advantage of ABCD network parameter is that a cascade network of two or more ports can be easily analyzed by multiplying the individual transmission matrices (David, 1999). The ABCD matrix is intuitive, it describes all ports with voltages and currents and is easy to relate to common circuit topologies (Heck, 2008).

This can be very useful in microwave circuit consisting of cascaded connections of both active and passive elements. However, the disadvantages of ABCD network parameter technique is that, they are more difficult to be understood and to be interpreted in matrix notation and iterative steps are required into calculations or implementation into microstrip line form (Heck, 2008). The 5th order, 0.2 dB ripple, Chebyshev filter topology of low pass prototype circuit is obtained as illustrated in Figure-3. The layout of five cascaded filter components, using the calculated values is shown in Figure-4 (Abdullah *et al.* 2011).

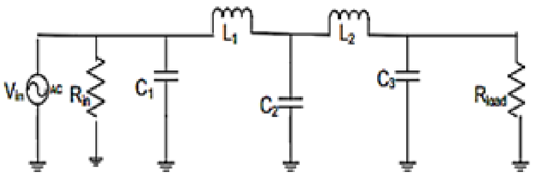

Figure-3. Low pass prototype for 5th order, 0.2dB ripple, Chebyshev filter (Abdullah *et al.* 2011).

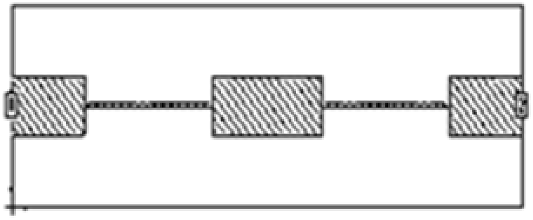

Figure-4. Layout of the filter (Abdullah *et al.* 2011).

Conversion of Microstrip Line Circuit by Using Shunt Short/Open Circuited Series Stubs

Wang *et al.* (2011) developed a microstrip line circuit filter using a shunt open stubs technique. Their Chebyshev microstrip line filter with a ripple of 0.1 dB has been simulated and measured using ADS and implemented using commercial TLX-0 dielectric substrate with relative dielectric constant of 2.45 and thickness of 0.79 mm to fabricate the filter. Applying the shunt open stubs, the passband is shifted downwards to 550 MHz from 2.45 GHz; the second passband is realized at 5.8 GHz with bandwidth of 0.1 GHz and insertion loss of less than 3 dB.

The proposed shunt stubs into microstrip circuit were introduced to produce a first passband that can be shifted toward lower frequencies, and the second passband can be obtained by shunt open stubs (Wang *et al.* 2011; Li and Wang, 2012; Makki *et al.* 2013). The shunt open stubs can also be used to suppress harmonics especially on transforming microstrip dual-band filter by adding shunt open stubs to the resonators. The conversion of Chebyshev microstrip filter circuit by using shunt open stubs technique, involves the analysis methods of ABCD matrix, configurations of asymmetric half wavelength resonators filter and equivalent circuit of the asymmetric half-wavelength resonators coupling structure (Li and Wang, 2012).

Based on the shunt open stubs structure, the center frequency of microstrip bandpass filter can be shifted to lower frequencies compared to conventional microstrip bandpass filter without using shunt open stubs (Li and Wang, 2012; Wei and Jan, 2010). The shunt open stubs technique can be also applied to multi-band filter circuits. The conversion of microstrip line filter with a number of shunt open stubs increases the performance of the second passband. Figure-5 shows the configurations of asymmetric half-wavelength resonators filters with shunt open stubs. The shunt open stubs technique is also able to produce a small size microstrip circuit by adjusting the length of ABCD matrix on equivalent circuit as shown in Figure-6. The disadvantage of this technique is that it requires an iterative method to improved performance of insertion loss and return loss.

The usefulness of the proposed practical microstrip filter with shunt open stubs is proved and fabricated as shown in Figure-7. Figure-7(a) shows the asymmetric half- wavelength resonators filter without shunt open stubs. Figure-7(b) and Figure-7(c) show the transforming microstrip filter pattern with four and eight shunt open stubs.

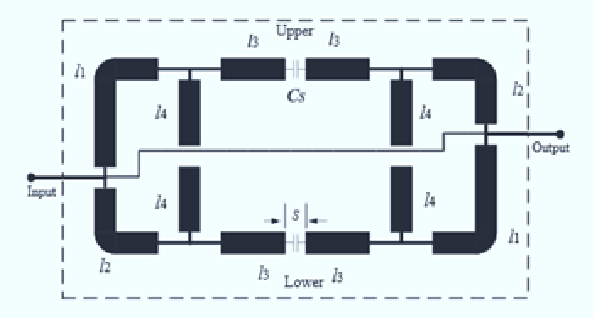

Figure-5. Configurations of asymmetric half wavelength resonators filter with shunt open stubs ($l_1 \geq l_2$) (Wang *et al.* 2011).

Jack *et al.* (1996) described about the conversion of microstrip low pass filters by using a series stubs to achieve low loss and dispersion. There are 2 sets of Chebyshev 5th order microstrip filter constructed, which work at 4, 8, 16 and 32 GHz with substrates of dielectric constant value of 3.38 value and thickness of 0.813 mm.

The microstrip low pass filter had a passband ripple of 0.2 dB. The series stubs in this work were used as a high performance alternative to stepped impedance sections, with low pass filters fabricated using short circuited series stubs (Subodh *et al.* 2009) as inductive elements and low impedance sections used as shunt capacitance.

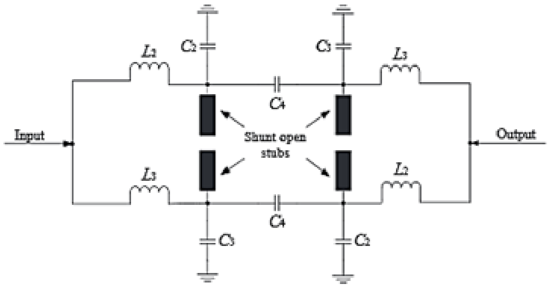

Figure-6. Equivalent circuit of the asymmetric half-wavelength resonators coupling structure with shunt open stubs (Wang *et al.* 2011).

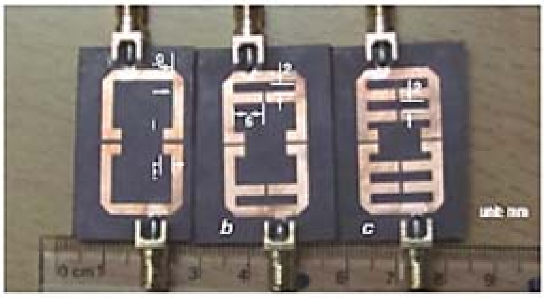

Figure-7. Photograph and size of filter, (a) filter without shunt open stubs, (b) filter with four shunt open stubs and (c) filter with eight shunt open stubs (Wang *et al.* 2011).

The advantage of series stubs technique bringing capacitors are realized as a series open circuited stubs incorporated in the parallel line array. A line drawing of a practical distributed realization of the low pass filters as simple and easy to obtain. However, the disadvantage of series stubs, it is difficult to convert into microstrip circuit form, because series connections are unable to be made to other microstrip lines, thus using Kuroda's Identity to convert microstrip line circuit with shunt stubs connections is more practical.

Two sets of filters were constructed, each set with cutoff frequencies at 4, 8, 16 and 32 GHz, both sets were based on 5th orders T-Chebyshev prototypes. The results were predicted for ideal filters of both types, with the series stub filters had improved roll-off and wider stopbands (Jack *et al.* 1996). These results were obtained using impedance data from HFSS for the stepped impedance sections and measurements for the series stubs which were then used in conjunction with super compact without modeling the discontinuity parasitic involved. The cutoff frequencies for the microstrip stepped impedance filters were not accurately predicted. It appeared that the cutoff frequencies are agreeable with theory while at stopband some unexpected spiky behavior exists.

The Cheyshev microstrip low pass filter using series stubs causes spikes due to a coupling effect when the stubs are at quarter wave resonance. They demonstrated far better performance than stepping impedance filter designed for the T-Cheyshev prototype, except for an undesirable spike in the stopband. The medium chosen for this work is a soft substrate microshield line with the dimensions given in Figure-8.

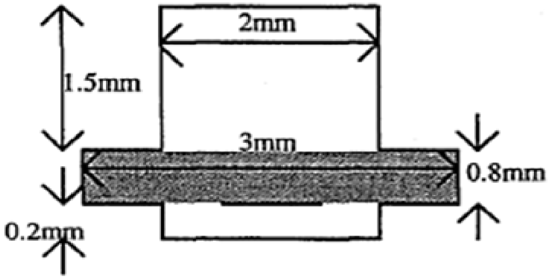

Figure-8. Dimensions of soft substrate microshield line (Jack *et al.* 1996).

The microstrip filter with no centre stub had no passband spike around 8.3 GHz (Figure-9a) and the microstrip filter with only a centre stub exhibited this spike (Figure-9b). Any spikes due to the outer stubs would fall nearer the second passband so their effects would be less visible.

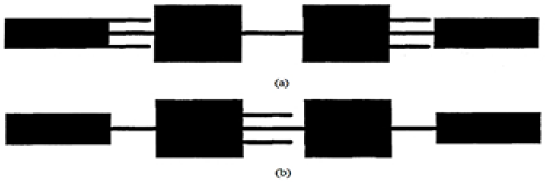

Figure-9. The microstrip filter had no passband spike around 8.3GHz, (a) with no centre stub and (b) with only a centre stub (Jack *et al.* 1996).

Li *et al.* (2009) discussed the conversion of a microstrip line low /high pass filter by using short/open circuited series stubs. In the transforming techniques, a Cheyshev low pass filter prototype with n=2 and 3 under ripple of 0.1 dB and 1.0 dB are selected respectively. Both conversion prototype low/high pass filters were fabricated on a substrate with relative dielectric constant of 10.8 and thickness of 0.635 mm. The microstrip low/high pass filter dimensions of filter layout are optimally designed by full wave ADS and HFSS simulators.

The low/high pass prototypes were interpreted as transmission line by using ABCD matrices of several individual sections in sequence. A low pass prototype can be established to synthesis the filters by short-circuiting these series stubs with both predictable in band and the out-of-band behaviors. After transfer function is introduced, the elements values in the prototype are normalized with characteristics impedance of the series stubs and connecting lines. The proposed prototype consists of a cascade of series stubs of electrical length θ_c, alternating with uniform transmission lines of electrical length 2θ_c (Li *et al.* 2009; Li *et al.* 2010).

Li *et al.* (2009) had also performed conversion of two prototypes microstrip five-pole planar filters based on the low and high-pass topologies implemented using hybrid slotline and coplanar-waveguide structures. The advantages of using stubs are produce good group delay, analytical scattering parameters, low insertion loss, high suppression level, avoiding any lumped elements and easy implementation into microstrip lines form. While, the disadvantage of conversion of microstrip line low /high pass filters using short shunt stubs compared to open circuited series stubs suffer from drilling via-holes in a practical implementation.

Figure-10 shows the transmission line models obtained by multiplying the ABCD matrices of several individual sections in sequence.

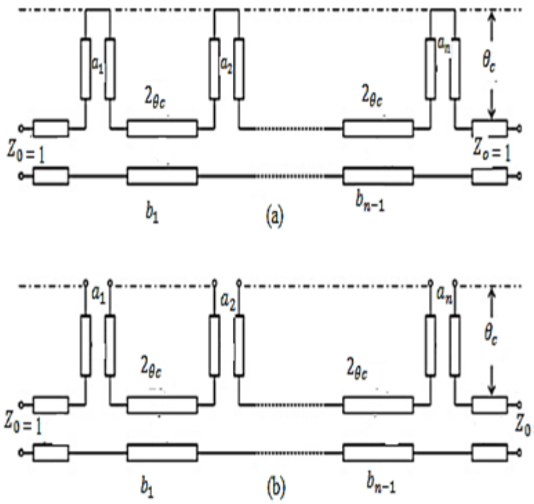

Figure-10. Transmission line models of the proposed filter prototype based on series stubs, (a) low pass filter prototype with short-circuited series stubs and (b) high pass filter (HPF) prototype with open-circuited series stubs (Li *et al.* 2009).

Figure-11 depicts the proposed final schematic layouts where Figure-11(a) is a low pass and, Figure-11(b) is a high pass filters generated by full wave ADS and HFSS of these two filters with all the dimensions labeled.

Quendo *et al.* (2000) suggested that the out-of-band performance response of conversion microstrip line circuit can be improved by using open stubs techniques. The 3rd order Cheyshev low pass filter prototypes with passband ripple 0.1 dB is implemented in microstrip technology on a classical AR1000 substrate, with a dielectric constant of 10 and thickness of 635 µm.

The conversion of a microstrip filter using open circuited stubs is simulated using an EM simulator. The experiment mentioned that two syntheses characteristically have been carried out into the design of low pass microwave filters. Next, these two filter circuits are fabricated and their relevant photographs are illustrated in Figure-12 and Figure-13.

The first one is accomplished with semi-lumped element using a cascade of inductive and capacitive lines (Figure-14) (Matthaei *et al.* 1980), whereas the second one constructed with open stubs and admittance inverters (Figure-14) (Pozar, 2012).

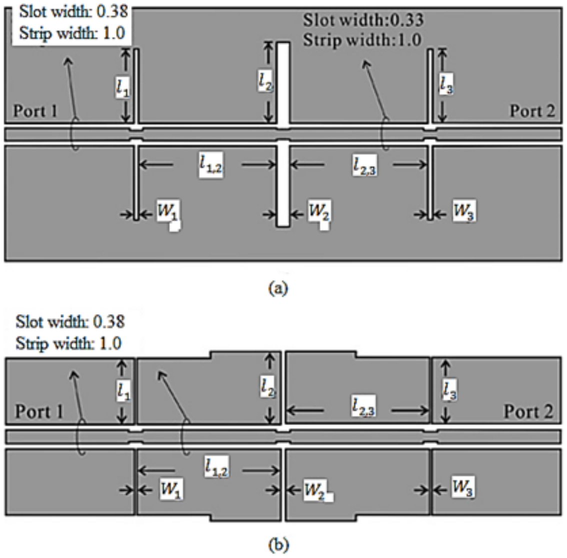

Figure-11: Schematic layouts of two prototype filters (n=3), (a) Low pass filter dimensions, (b) high pass filter dimensions (Li *et al.* 2009).

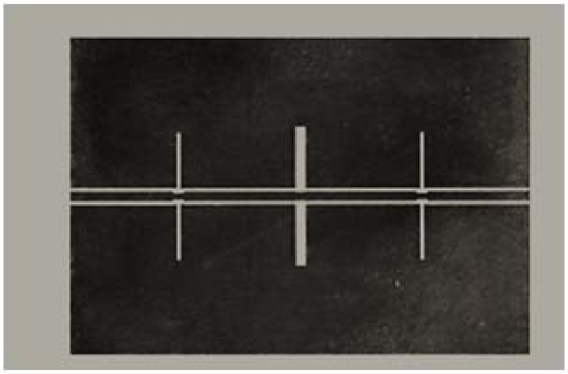

Figure-12. Low pass filter (n-3) using hybrid slotline and coplanar waveguide (CPW) structures (Li *et al.* 2009).

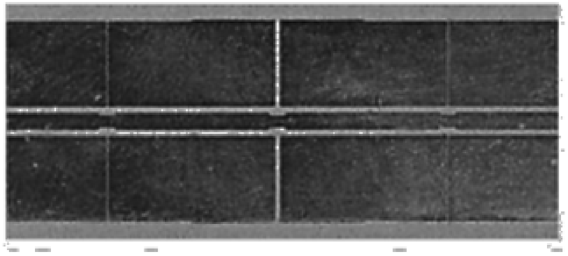

Figure-13. High pass filter (n-3) using hybrid slotline and coplanar –waveguide structures (Li *et al.* 2009).

Quendo *et al.* (2000) proposed that a comparison is made between these two techniques. Conversion of microstrip low pass filter can utilize open stubs for displaying the parallel capacitances into circuit, while admittance inverters are interchanged by inductive lines. However, it should be realized that for the case of semi-lumped synthesis, the electrical response can be improved in the attenuated band by using self-filtering resonators which a technique able to control spurious resonances with a wider range of characteristic impedance (Quendo *et al.* 2000). But, its implementation is more complex and difficult.

It must be stressed that, its implementation is more difficult. Moreover, for second synthesis case of conversion of microstrip filters based on open stub structures, (Pozar, 2012) was unable to optimize since the lengths are imposed (λ/4), and the circuit size was larger due to the use of series of admittance inverters. The advantages of the above proposed new synthesis transformation provided an optimal arrangement of semi-lumped, distributed elements and the electrical response is quite similar to the one usually obtained with an ideal L-C lumped circuit. Thus, the out-of-band attenuation is significantly improved with respect to the two previous cases.

Besides that, the open stubs method presents fabrication problems due to relatively narrow width connecting lines between parallel stubs. The disadvantages are that the methods take more space, are more complex and create a larger physical impedance matching network.

The measured results show the characteristics of microstrip low pass filter improved especially at the attenuated band, stopband and return loss. In introducing open stubs, it is also appropriate to apply it for higher order filters with different impedance values of capacitances and inductances of lumped elements prototype. The conversion configurations can be represented by highest capacitance and highest inductance denoted by symbols ‘a’ and ‘b’ respectively. And other elements are assumed as lower and upper attainable of characteristic impedances. The main technique is minimizing the length of the first resonator and such effect consists of adjustment of the connected characteristic impedances.

The new approach of open stubs into microstrip low pass filter transformation had shown improvement in the performance of the electrical response and enhancement of the attenuation band. Based on the two combinations of open stub filter and semi-lumped topologies and syntheses, this allows the incorporation of technological parameters, selected via advanced technological possibilities.

Figure-14(a) shows that the technique determines semi-lumped elements using a cascade of inductive and capacitive lines (Mathaei, 1980), whereas the second one in Figure-14(b) employs open stubs and admittance inverters.

Figure-15(a) and Figure-15(b) shows the separate categorizing of the chain matrices of the open stubs (impedance, Z_C) with capacitances C and the chain matrices of the inductive line (impedance, Z_L) with the inductance. Figure-15(a) presents topology used for 3rd filter and Figure-15(b) equivalent of lumped prototype (Quendo *et al.* 2000). This filter is also developed in microstrip technology on the substrate (Z_{min}= 25 Ω and Z_{max}= 95 Ω) (Figure-16a). The proposed synthesis is generalized for a higher order filter (Figure-16b), by selecting different values for 'a' and 'b' referring to the different values of the capacitances and inductances of the lumped elements model.

Kim *et al.* (2004) stated a conversion of Chebyshev 3rd order microstrip low pass filter, by using shunt open stubs and coupled slots on the ground plane with prominent cutoff sharpness and very wide stopband. The microstrip low pass filter is composed of a transmission line with shunt open stubs on the topside of the microstrip structures and coupled slots on the ground plane.

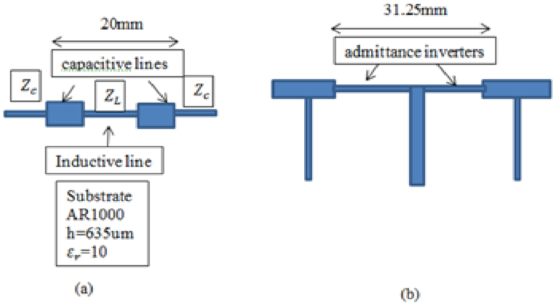

Figure-14. Layout of the 3rd low pass filters, (a) semi – lumped filter and, (b) open stub filter (Quendo *et al.* 2000).

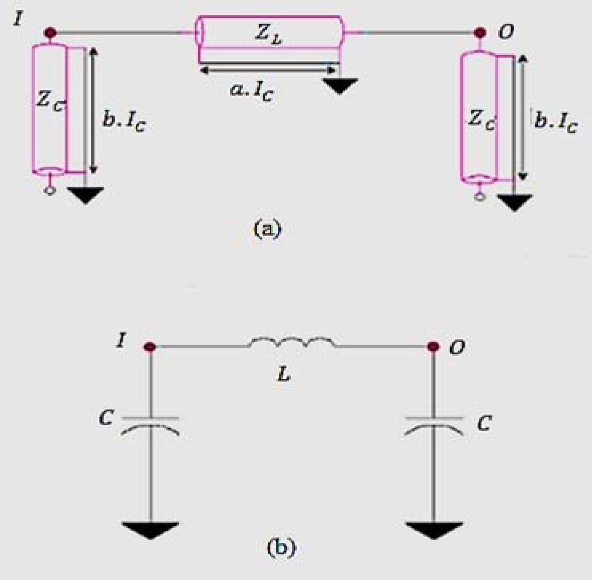

Figure-15. The method illustrated in third-order filter, (a) topology used for 3rd filter and, (b) equivalent of lumped prototype (Quendo *et al.* 2000).

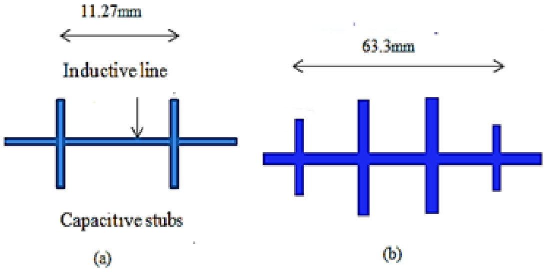

Figure-16. Layout of the new open stubs filters, (a) third - order and, (b) seven-order (Quendo *et al.* 2000).

The shunt open stubs microstrip filter with slots on the ground plane has a wide stopband at high frequencies, and the coupled slot on the ground plane has a sharp cutoff response at low frequencies. The combined characteristics of these structures form an excellent low pass filter. Accordingly, a very wide stopband can be created by arranging these stopbands alternately with a judicious choice of the design parameter such as length and width of shunt open stubs and slots.

Improper selection of this transforming procedure may produce spurious resonator modes inside the stopband. Hence, an indentation on the slots to suppress unwanted resonators modes has been made to avoid resonances. In the case of the cutoff response, it is mainly associated with the roll off rate of the first stopband by the slots. Thus, sharp cutoff response can be achieved by using the coupling effect through the narrow coupling gap between the wide rectangular slots located adjacent to each other. The converted microstrip filter was fabricated on an RT/ duroid 6010 substrate with relative dielectric constant of 10.2 and a thickness of 0.635 mm.

Simulation of prototype microstrip filters were accomplished using Ensemble, which is an electromagnetic wave simulator based on the method of moment (MoM), and a filter cutoff frequency of 1.36 GHz. The converted microstrip line circuits using shunt open stubs method are easier to fabricate when it comes to printing a circuit layout. If a short stub cannot be traded with an open one, then a via (or vias) must be drilled through the PCB all the way down to the ground layer. It is easier to achieve a good short to ground than a good open (fringe effect on the end of the open). In order to improve the high performance microstrip low pass filter with a passband ripple of 0.2 dB, shunt open stubs and coupled slots on the ground plane was used. A short-circuited stub is preferred over an open-circuited stub because of greater ease in construction and inability of the open stubs to maintain high enough insulation resistance at the open circuit point in order to ensure the stub is really open- circuited.

This type of microstrip circuit does not give a sharp cutoff. This cutoff must be considered when a filter is required in certain applications. The combined effects of microstrip open stubs and coupled slots on the ground plane result in excellent low pass filter characteristics. The experimented result shows that conversion of microstrip filter by using shunt open stubs has low insertion loss and sharp rejection attenuation at stopband.

The combination of shunt open stubs alternating stopbands in each structure produces a very wide stopband and the coupling between slots on the ground plane makes for prominent cutoff sharpness. Figure-17 shows the proposed low pass filter where the conversion of microstrip filter using shunt open stubs with the transmission line overlap on etched slots on the ground plane.

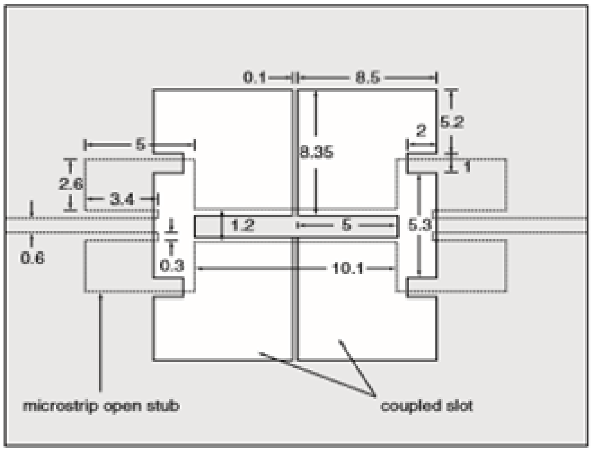

Figure-17. Layout of proposed low pass filter (units in mm) (Kim *et al.* 2004).

Conversion of Microstrip Composite Filter by Using Image Parameter Technique

Tan *et al.* (2007) presented the conversion of a Composite microstrip low pass filter by applying image parameter technique. The image parameter method involves combining of characteristics and specifications of passband and stopband to form the cascade two-port network.

The lumped element schematic and microstrip line of the filter had been implemented and optimized by ADS software. The microstrip line simulation results show the filter has a 1.5 GHz cutoff frequency, which satisfied the design requirement. The image parameter method (Tan *et al.* 2007) encompasses the combination of four filter sections and present an attenuation pole close to the cutoff frequency to ensure a sharp cutoff, which is one of method used into designed of Composite filter circuit.

Constant-k and m-derived half sections can be connected together to form a filter. Sections were chosen so that image impedances match at the junctions. The total image impedances are simply the sum of the image attenuations and the phase values of the individual sections. The resistive terminations to an image filter do not match its image impedance. Therefore, matching end sections are designed to improve the response of the filter. The m-derived half sections were used as the matching end sections. They improved the passband response of the filter and can further sharpen the cutoff characteristic of the filter. The m-derived half sections reduce the reflections at the filter ends. On the other hand, they gave no assurance as to how large the peak reflection loss values may be in the passband. The composite low-pass filter is less complex and having a sharp roll –off, with its microstrip line with T and π network are effectively with sharper cutoff and less ripples in the passband. These filters were fabricated on a FR4 substrate with dielectric constant of 4.5 and thickness of 1.5 mm are very low cost solution for RF applications.

The image parameter was introduced by defining the image impendence and voltage function for arbitrary reciprocals of a two-port network because these designed results are required for the cutoff frequency and attenuation characteristics. Cascade combinations of the constant-k, m-derived sharp cutoff, and the m-derived matching section, a filter with desired attenuation and matching properties can be realized. From a design point of view, it is important that a desired attenuation and matching properties stay constant, at least in its passband (Matthaei *et al.* 1980).

During the design of the composite, low-pass filter, two of the important factors that must be taken into consideration are the constant-k filter section and the m-derived section. Since constant-k filter section undergoes from the weakness of a relatively slow attenuation rate past cutoff and a non-constant image impedance, so the m-derived filter section is a important requirement into design modification of a Composite filter or improving the performance of the constant-k. In order to achieve and obtain a more accurate, desired result, multiple iteration is applied on this simple method.

The advantages of the image parameter method are that the filter design is simple and provides the link between an infinite periodic structure and a practical designed filter response. Though the image method is conceptually simple, it requires a great deal of trial and error if accurately defined band edges and low passband reflection loss are required. In the construction of Composite microstrip filter, inductances are connected in series and are able to be added until larger value of inductances are achieved.

During the microstrip lines design, the L-C classical lumped elements will be converted by using an equivalent short length transmission line for inductances and capacitances (Martins and Abdalla, 2001). Figure-18(a) shows the layout of a combination of four sections to become a complete Composite low pass filter. Figure-18(b) shows the classical lumped elements design converted into a microstrip line form and with its equivalent short lengths of transmission line into inductance or capacitance.

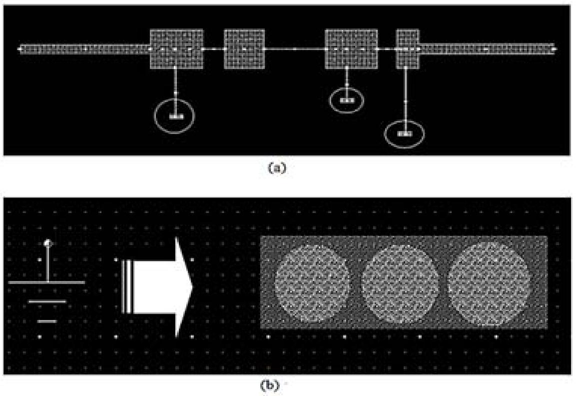

Figure-18. Composite low pass filter, (a) the layout of combinations four sections to become a complete Composite low pass filter and (b) the classical lumped elements design are converted into microstrip line form and with equivalent of short length of transmission line into inductance or capacitance (Tan *et al.* 2007).

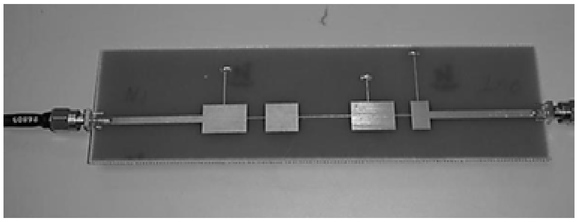

Figure-19. Design 1: the inductor representative microstrip line is placed with a ground in the other end (Tan *et al.* 2007).

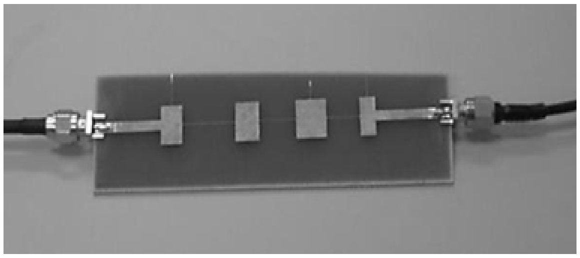

Figure-20. Design 2: inductor representative microstrip line when the ground are represented with a longer microstrip line (Tan *et al.* 2007).

Figure-19 represents Design 1, the inductor representing the microstrip line placed with a ground in the other end while in Design 2 (Figure-20) the grounds is represented with a longer microstrip line. The difference between Design 1 and Design 2 was the grounding of the microstrip line that represents the series-resonant combination in the shunt arm.

Conversion of Microstrip Line by Using Implicit Space Mapping (SM) Optimization Technique

Saeed *et al.* (2010) demonstrated an experiment using an implicit space mapping method, the conversion parameters for a microstrip low pass elliptic filter. It was shown that this technique led to decreasing the number of fine model evaluations.

Low pass elliptic filter prototypes were realized in microstrip technology on a substrate with a relative dielectric constant of 10 and, thickness of 635 μm and cutoff frequency at 7 GHz. The microstrip technology is used for simplicity and ease of fabrication. The prototypes for the converted microstrip low pass filter structure were simulated using ADS software.

The space mapping technology is both a modeling and a design optimization tool. It strategically enhances a “coarse” (ideal or low-fidelity) model (Wu *et al.* 2004) to the accuracy of a “fine” (practical or high-fidelity) model with very few fine model training points. It exploits coarse model knowledge and finds the optimal design of a fine model using very few fine model simulations (Zhong *et al.* 2012). There are a few preliminary steps that must be followed in using the implicit space mapping method. First, the coarse model must be optimized to obtain design parameters satisfying the design objective. Second, auxiliary parameter must be calibrated in the coarse model to match coarse and fine model responses. Third, the improved coarse model must be re-optimized to obtain a new set of design parameters. Finally, the resulting converted circuit is used in the fine model to evaluate its performance.

Space mapping (SM) technique addresses the issue of reducing unnecessary, time-consuming and the conversion procedure is repeated to obtain a satisfactory solution (John *et al.* 2004). Simulation results showed that only two iterations of the finest model were sufficient to obtain a satisfactory result for the given case-study application. The advantages of the implicit space mapping (ISM) optimization technique are improved optimization efficiency and less computational time. Several optimization algorithms; such as hybrid algorithms, general algorithms and optimization phase (Adil *et al.* 2013), have been successfully applied to the synthesis filters, but their disadvantage is the exhaustive simulation time and complicated, thus encouraging the scientific community to focus its research to adapt optimization algorithms consumes less in terms of computation time (Adil *et al.* 2012).

The space mapping (SM), introduced by John *et al.* (2004), is a powerful technique to optimize complex microstrip models. The structure of this filter is illustrated in Figure-21. The coarse model composed of empirical models of simple microstrip elements, as shown in Figure-22. The purpose of this implicit space mapping technique is to enable shortcuts in transforming microstrip line circuits using a cheaper but less accurate model, such as the coarse model in Figure-22, to gain information about the optimal parameter setting, compared to an expensive and more accurate model, such as the fine model.

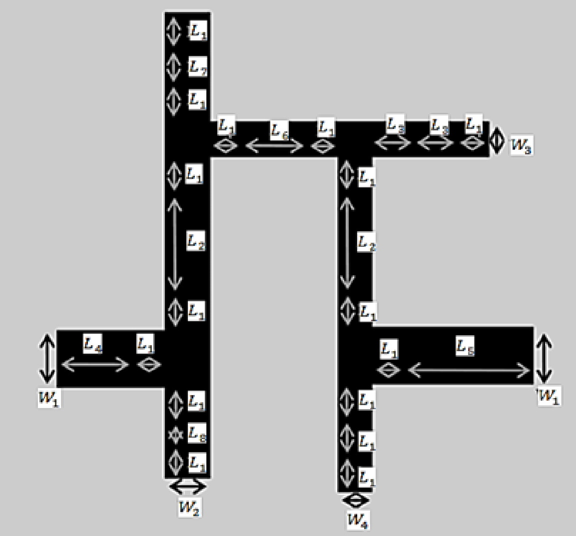

Figure-21. Microstrip low pass elliptic filter structure (Saeed *et al*. 2010).

Implicit space mapping (SM) technique has become more advanced due to popularity of computer-aided design methods. SM optimization criteria had become a technique widely recommended in design of microwave circuits. In some cases, this mapping method weakness in not explicit, and is hidden in the coarse model.

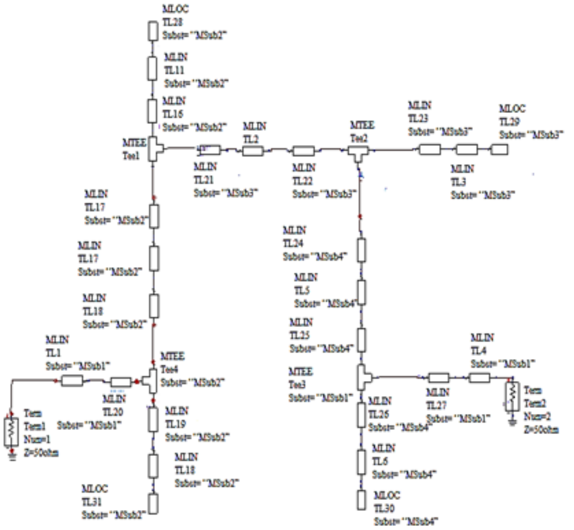

Figure-22. Coarse model simulated by ADS (Saeed *et al.* 2010).

Conversion of Microstrip Line by Using Insertion Loss Method, Richard's Transformation and Kuroda's Identity Technique

Rajasekaran *et al.* (2013) recommended that conversion of microstrip low pass filter using insertion loss method to obtain excellent harmonic suppression. The 3rd order Butterworth LPF prototypes were realized in microstrip technology on a substrate with a relative dielectric constant of 9.6, thickness, h, of 0.63 mm with a cutoff frequency at 10 GHz.

The prototype structures for the microstrip low pass filter transformation are simulated using ADS software. Richard's Transformation and Kuroda's Identity are used to convert lumped elements into microstrip lines, which enable attainment of practical filters with distributed element realizations.

The next step used was Richard's Transformation to convert series inductors to series short-circuited stubs, and shunt capacitors to shunt open-circuited stubs. The characteristic impedance of a shunt stub is 1/C, whilst that of the series stubs is L. A Kuroda's Identity was used to convert a series stub into a shunt stub. First, redundant elements were added to each end of the filter redundant, since they do not affect the filter performance as they are matched to the normalized source impedance. In addition, at microwave frequencies the distances between filter components is not negligible. Richard's Transformation was used to convert lumped elements to transmission line sections, while Kuroda's Identity can be used to separate filter elements by using transmission line sections.

In order to comprehend the conversion of lumped into distributed circuit designs; Richard's Transformation proposed a special transformation that allows open and short-circuits transmission line segments to emulate the inductive and capacitive behavior of the discrete components (Pozar, 2012). Richards's Transformation allows replacement of lumped inductors with short circuit stubs and capacitors with open circuit stubs of characteristic impedance. Whereas, Kuroda's Identity has the advantage of transforming series transmission line stubs into shunt stubs.

The advantage of insertion loss technique is complete specification of a physically realizable frequency characteristic over the entire pass and the stop bands from which the microwave filters are created. The conversion of microstrip filters had exhibited sharp rejection attenuation and superior harmonic suppression in stopband, when compared to a conventional one. These 10 GHz filters are suitable for use in a X-band electromagnetic environment.

Figure-23 shows the lumped elements schematic diagram designed using ADS. After applying Richard's Transformation and Kuroda's Identity, the width and length of each microstrip are calculated. This is illustrated as shown in Figure-24.

The layout of microstrip LPF is shown in Figure-25. Even though in addition to both design complies with the requirements, but the added advantage of Richard's Transformation and Kuroda's Identity is that the filter had a steeper roll-off and was more robust to dielectric and metal losses.

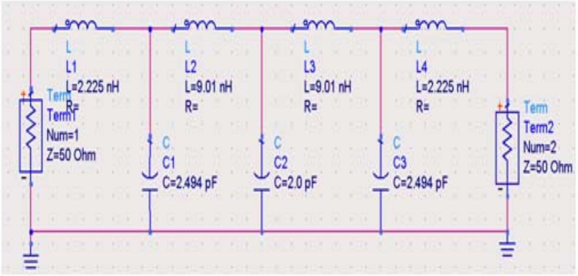

Figure-23. Schematic diagram of LPF (lumped elements) in network (Rajasekaran *et al.* 2013).

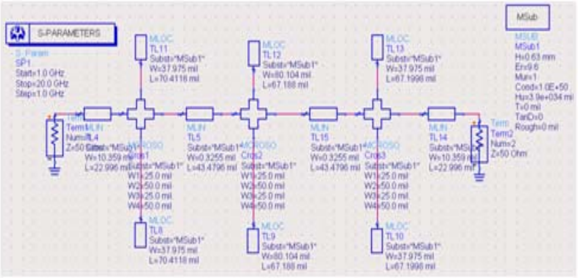

Figure-24. Schematic diagram of LPF (microstrip line) design by ADS (Rajasekaran *et al.* 2013).

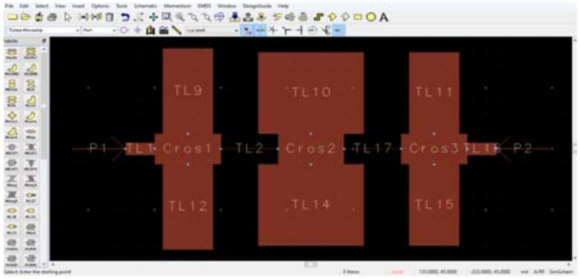

Figure-25. Layout of LPF using microstrip line (Rajasekaran *et al.* 2013).

CONCLUSIONS

A several technique for conversion of low pass filter conversion from lumped element into microstrip line circuit has been accomplished in this study. The understanding on the microstrip properties and their frequency response behaviour in the processing are necessary in order to improve the characteristics of microstrip low pass filter and its optimization process. Optimization and tuning features will be applied to all types of low pass filter prototypes, lumped (quasi-lumped) elements or microstrip line form to improve the overall frequency performance and meet the design specification. In order to produce a better performance of microstrip line circuit filters, have two requirement parameter are necessary to be taken into consideration. For example, the rejection performances seem improves when it's close to 40dB, and the more unwanted frequency can be eliminated. The return loss matching response also getting better overall achieved almost near to 20 dB.That means all the signal are able transmit to receiver. When designing any type of filter, important parameters to consider is the filter should be able to transmit signal with the lowest insertion loss at passband, have good high attenuation at stopband, low weight and minimum cost.

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