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Bandpass Filter using Optimum Short Circuited Stub Technique

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ABSTRACT
Filters are the key components in communication system. In this paper, the description of Ultra Wide Band filter design techniques and to show the different aspects of the design technique used. The optimum short circuited technique is one the technique used to design the Ultra Wide band filter. The word optimum refers to connecting lines between short circuited stubs. These designs have no cross coupling between I/O aliment lines. The input/output excitation is analyzed by this technique to obtain tough wide band coupling. By formulating the resonance conditions of the resonators we get the desired Ultra Wide Band.

Keywords
Ultra Wide Band, Band Pass Filter, Short Circuited Stub, Resonators.

1. INTRODUCTION
ULTRA-WIDEBAND (UWB) technology is a very promising solution for high-resolution radar, high data-rate communication, and power-efficient RF tracking and situating systems. It offers a number of captivating features such as low intricacy and low cost, carrier-free transmission, and vigorous resistance to astringent multipath and jamming, as well as passive interferences. Since the Federal Communications Commission (FCC) first sanctioned the utilization of the unlicensed operation band from 3.1 to 10.6 GHz for commercial applications [1], UWB systems have several advantages: They have a bandwidth of 7.5 GHz, which can fortify a high transmission data rate (up to 500 Mb/s); they have low energy density over a wideband spectrum engendered by short pulse excitation, which not only makes the UWB system arduous to intercept but additionally minimizes interference by other radio systems; and they have astronomically low transmission energy (less than 1.0 mW), which is auspicious for hand-held radio systems. Scholarly researchers and industry engineers have been passionate in the intend of UWB filters.

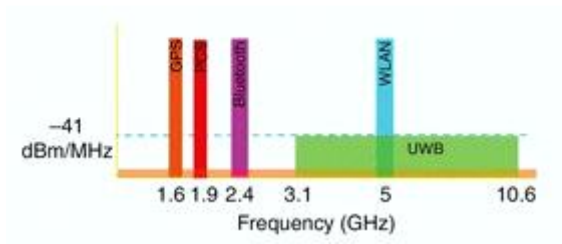

Fig 1: Ultra wideband system spectrum distribution

The technical requisites for UWB filters are low insertion loss, flat in-band group delay, and high out-of-band selectivity.

There are different design techniques for designing the Ultra Wideband (UWB) Band pass filter. These techniques can be classified as multiple-mode-resonator (MMR) techniques, hybrid microstrip/coplanar-waveguide (CPW) techniques, optimum short-circuited stubs techniques ,electronic-band-gap (EBG) structure loaded techniques ,cascaded high-/low-pass filters techniques and multilayer broadside-coupled techniques in association with packaging materials such as liquid crystal polymers (LCP) and low-temperature cofired ceramics (LTCC)[2]. The MMR technique aims to arrange multiple resonant modes in a fused resonating arrangement to design a UWB filter. The pristine design utilizes a homogeneous physical topology as the stepped-impedance resonator (SIR) structure.[2] Compact UWB bandpass filters can be designed by utilizing hybrid microstrip and CPW techniques, where the microstrip–to-CPW transitions and CPW shorted stubs were adopted as quasilumped-circuit elements for realizing a high-pass filter. By introducing a cross-coupled capacitance between I/O ports of this high-pass filter, and by congruously designing the coupled open circuited stubs, a compact UWB bandpass filter can be designed with two transmission zeros located proximate to the passband edges[2]. EBG-loaded structures can be used to propose UWB bandpass filters with improved upper stopband performance. The EBG structure is implemented using capacitive-loaded transmission lines[2]. In the Cascaded high-/low-pass filters techniques UWB filter developed by cascading a broadband bandpass filter and a broadband bandstop filter[2]. The FCC-defined UWB indoor limit covers some frequency bands utilized by subsisting radio communication systems, such as the 5 GHz wireless local access network band and 8 GHz satellite communications systems. As a result, some notching bands are desired in the design of UWB bandpass filters to reduce interference from those radio communication systems[2]

2. ULTRAWIDE BAND BANDPASS FILTER
The given filter is utilized using the stub loaded resonator.[4] stub-loaded resonator is composed of the fingers of a wire-bonded interdigital capacitor loaded with one open stub and one short stub and it is able to create supplemental resonances to the conventional multimode resonator.[my paper]. A wire-bonded interdigital capacitor (WBIDC) [5], [6], [7], rather than a conventional three-line interdigital capacitor, as in stub loaded resonator as given in [4] is used in this study as an input/output coupling arrangement. This is having two advantages. Firstly, very strong input and output pairing can be achieved with four interdigital fingers using a single-layer circuitry, while the width of line and the width of gap uses the lowest amount of manufacture requirements of usually accessible printed circuit board (PCB) process. Secondly, the specious resonances of the straight multifinger interdigital capacitor can be censored by wire bond links.

The paper is starting with the design of stub loaded resonator and the effects of the cross junction between interdigital fingers, short bonding wires and stubs are ignored. The parametric study of the stub loaded resonator can be done using the Full wave simulation in turn to include the parasitic effect as mention above and also to examine the coupling between different resonant modes. The equivalent circuit is then design and fabricate by using the 1.27mm thick and RT/Duroid 6010.2LM substrate.

3. ANALYSIS OF STUB-LOADED RESONATOR

3.1 Simplified Equivalent-Circuit Model of the Stub-Loaded Resonator

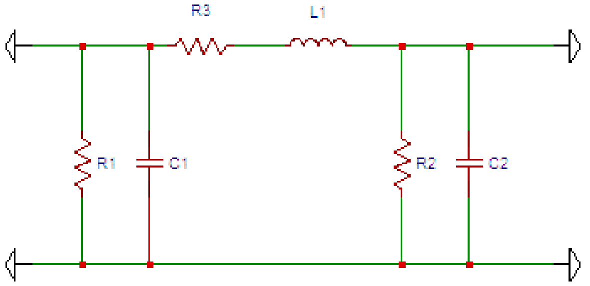

Fig 2: **Equivalent-circuit model**

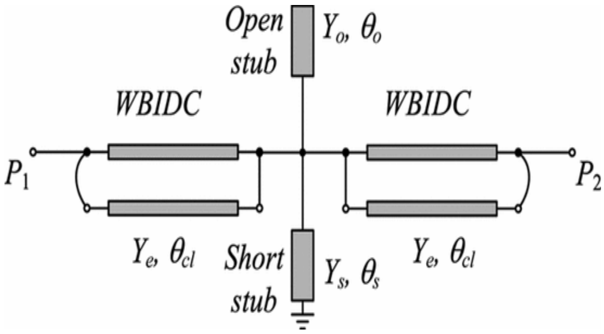

Fig 3: **Equivalent-circuit model of stub-loaded resonator**

The equivalent circuit is shown in Figure 3 in which the shunt stubs are used they are shown as short stub and open stub. Here the WBIDC is the Wire Bond Interdigital Capacitor. The P_1 and P_2 are the ports. Y_e is the characteristic admittance of the coupling lines and Y_o and Y_s is the characteristics admittance of the open stub and short stub respectively. Using the equivalent circuit, the input impedance of the equivalent circuit is calculated.

The transmission parameters or the ABCD parameters for the two port network is given by

$$[A]=[A_{wbidc}]\times[A_{ss}]\times[A_{wbidc}] \qquad (1)$$

Where the A_{wbidc} is the ABCD parameter of the Wire Bond Interdigital Capacitor and the A_{ss} is the ABCD parameter of the shunt stubs used in the circuit. The impedance matrix of the two port network for the series circuit elements is given as

$$T=\begin{bmatrix}1 & Z\\ 0 & 1\end{bmatrix} \qquad (2)$$

For the Shunt circuit element the matrix is given by

$$T=\begin{bmatrix}1 & 0\\ Y & 1\end{bmatrix} \qquad (3)$$

The ABCD parameters of the Wire Bond Interdigital capacitor are given by connecting the input and output of the connecting lines.

$$[A_{wbidc}]=\begin{bmatrix}\cos(\theta_{cl}) & \dfrac{j\sin(\theta_{cl})}{2y_e}\\ j2Y_e\sin(\theta_{cl}) & \cos(\theta_{cl})\end{bmatrix} \qquad (4)$$

Where the θ_{cl} is the electrical length of the connecting lines.

The ABCD parameters of the shunt stubs are given by

$$[A_{SS}]=\begin{bmatrix}1 & 0\\ j(Y_o\tan(\theta_o)-Y_S\cot(\theta_S)) & 1\end{bmatrix} \qquad (5)$$

Where θ_o is the electrical length of the open stub. The open stub and short stub has the same width so Y_o= Y_s. from this

$$Y_{SS}=jY_s(\tan(\theta_o-\cot(\theta_S)) \qquad (6)$$

The total admittance Y_{in} at port1 is given by port 2 left open

$$Y_{in}=\frac{jY_e\tan\theta_{cl}+jY_S(\tan(\theta_o)-\cot(\theta_S))}{1-\tan^2\theta_{cl}+\dfrac{jY_S(\tan(\theta_o)-\cot(\theta_S))\tan\theta_{cl}}{2Y_S}} \qquad (7)$$

The resonance conditions can be obtain by keeping Y_{in} = 0.

$$\begin{cases}\tan\theta_{cl}=\infty\\ 4Y_e\tan\theta_{cl}+jY_S(\tan(\theta_o)-\cot(\theta_S))=0\end{cases} \qquad (8)$$

The cases for the resonance conditions are as follows.

<u>**Case 1:-**</u> At Low edge of the passband frequency, calculate the electrical length of the short stub. here the electrical length of the open stub is quarter wavelength at transmission zero.

$$\theta_S=\tan^{-1}\left(\frac{Y_S}{4Y_e\tan\theta_{cl}}\right),\left(\theta_{cl}=\frac{\pi}{2}\right) \qquad (9)$$

<u>**Case 2:-**</u> At the center frequency of the passband, the electrical length of coupled line is one quarter wavelength.

<u>**Case 3:-**</u> At the high edge of the passband frequency, calculate the electrical length of the open stub.

$$\theta_O=\tan^{-1}\left(\frac{4Y_e\tan(\pi-\theta_{cl})}{Y_S}\right),\left(\frac{\pi}{2}\prec\theta_{cl}\prec\pi\right) \qquad (10)$$

3.2 Analysis Wire Bonded Interdigital Capacitor

Several methods have been used to characterize interdigital capacitors, including approximate analysis, J-inverter network equivalent representation, full-wave methods, and measurement-based models. [12]

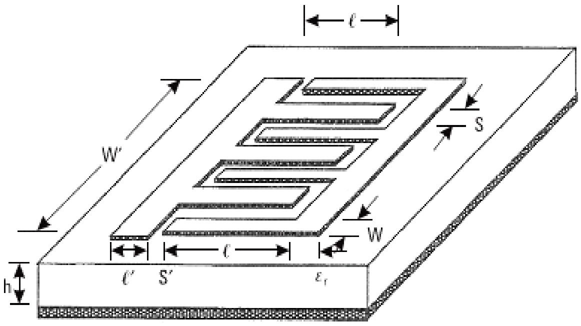

Fig 4: An interdigital capacitor configuration

An expression for the interdigital capacitance is given by

$$C = \frac{\varepsilon_r + 1}{W'} l[(N-3)A_1 + A_2] \quad (11)$$

Where C is the capacitance per unit length along width, A1is the interior capacitance and A2 is the exterior capacitance are the capacitances per unit length of the fingers of the interdigital capacitor, N is the number of fingers of the interdigital capacitor, and the dimensions width W′ are shown in Figure 4 and expressed in microns. The A_1 and A_2 is given by the $A_1 = 4.409\times10^{-6}$ pF/mm and $A_2 = 9.92\times10^{-6}$ pF/mm. The capacitance of length l of an interdigital structure is given as

$$C = (\varepsilon_r + 1) l[(N-3)A_1 + A_2] \quad (12)$$

Where, A_1 and A_2 are the approximate expressions and are obtained by following expressions and the effect of the height h is included in the values of A_1 and A_2 for the finite substrate.

$$A_1 = 4.409 \tanh\left[0.55\left(\frac{h}{w}\right)^{0.45}\right]\times10^{-6}\ pF/\mu m \quad (13)$$

$$A_2 = 9.92 \tanh\left[0.52\left(\frac{h}{w}\right)^{0.5}\right]\times10^{-6}\ pF/\mu m \quad (14)$$

The equivalent models of the interdigital capacitor using lumped elements is as follows

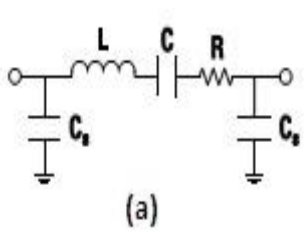

Fig 5: Lumped-element models of the interdigital capacitor for low frequency.

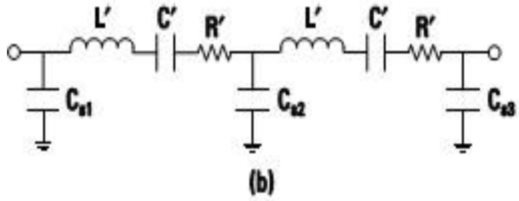

Fig 6: Lumped-element models of the interdigital capacitor for high frequency.

The series resistance, inductance and the half microstrip total shunt capacitance of the interdigital capacitor is given by following formulas

$$R = \frac{4}{3}\frac{l}{WN} R_S \quad (15)$$

$$L = \frac{Zo\sqrt{\varepsilon_{re}}}{c} l \quad (16)$$

$$C_S = \frac{1}{2}\frac{\sqrt{\varepsilon_{re}}}{Z_0 c} l \quad (17)$$

Where Z_0 and ε_{re} are calculated using W' and h microstrip parameters and $c = 3\times10^8$ m/s is the velocity of light in free space.

4. DESIGN OF SINGLE-STAGE UWB FILTER

The substrate is RT/Duroid 6010.2LM with a thickness of 1.27 mm. The values of all the parameters can be found bythe equations used above in the section 3 and 4. The open-end effect is then included after subtracting the equivalent additional line length of the ending capacitance [10]. Similarly, an equivalent additional line length is subtracted from the short stub for considering the inductance of grounding via [11]. The physical dimension is conclusively optimized for compensating the frequency-dispersive cross junction. The wire bonding ribbons are used to connect the fingers of interdigital capacitor.

The equivalent circuit of the single stage UWB filter can be shown below in the figure 7. The figure showing the Wire bond interdigital capacitor and the stub arrangement. The connections of the connecting lines with ribbons are shown in the figure.

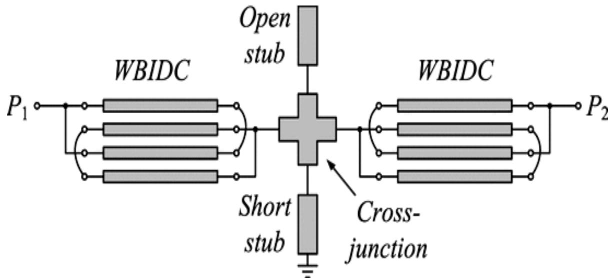

Fig 7: Equivalent Circuit model of the Single stage UWB filter

The characteristic impedance of input and output microstrip at top of substrate is 50 ohm. The substrate of RT/Duroid 6010.2LM with a thickness of 1.27 mm and the ε_r=10.2, tan δ=0.0023. The length of the fingers of the wire-bonded interdigital capacitor can be originate by establishing the second resonance of the stub-loaded resonator at the center frequency of the UWB band with an early value of stub width. According to the given resonant frequencies of the first and third modes, the early values of the lengths of short and open stubs can be considered from the equations.[3]

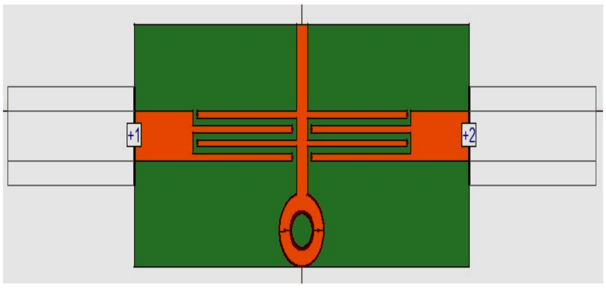

Fig 8: The design of Single stage UWB Bandpass filter

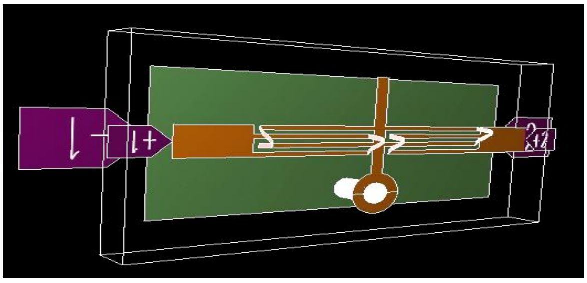

Fig 9: 3D View of the Design

5. EXPERIMENTAL VERIFICATION

The simulator used is IE3D electromagnetic simulator for designing the structure. IE3D is the full wave simulation and optimization package for 3D and planar microwave circuits. It solves Maxwell's equations in an integral form.

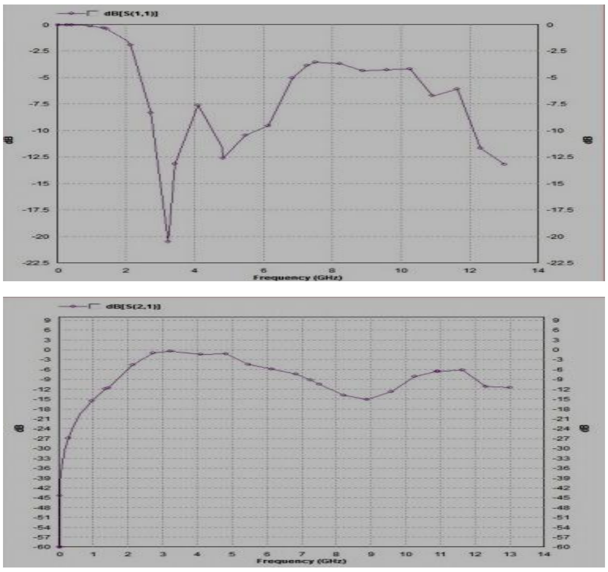

Fig 10: Simulation Results

As seen from figure the insertion loss (transmission coefficient) S_{21} is minimum in the UWB passband the S_{21} is almost equal to zero. The return loss S_{11} is less than -10 db within the band. The relationship between input port and output ports (or terminals) in an electrical system can be described by S-parameters. In the simulation, the normally used parameter in regards to filter is S_{11}. The S_{11} shows that how much power is reflected from the antenna, therefore it is known as the reflection coefficient (or return loss).

6. CONCLUSIONS

In this paper, the Single stage UWB filter using optimum short circuited stub technique predicated on stub-loaded resonators. Partial of wide bandwidth is achieved with the wire-bonded interdigital capacitor. After the categorization of the stub-loaded resonator, equipollent-circuit networks are planned to facilitate the design procedure with which a single-stage UWB filter is designed.

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