Mr.Bhushan R. Vidhale, Dr. M.M.Khanapurkar / International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com
Vol. 2, Issue4, July-August 2012, pp.2340-2345

Design of Low Cost and Efficient Strip Line Band Pass Filter for Bluetooth Application.

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Abstract—

In this paper, low cost and efficient strip line band pass filter is implemented. The new structure does not only reduce the size of the filters, but also provides good gain for pass band and better attenuation for the stop band characteristics. A designed filter provides bandwidth which is needed for Bluetooth transmission. It can be mounted on Bluetooth transceiver system which has broad application area. The designed band pass filter has 2.4 Ghz of frequency band and has about 150 MHz of bandwidth. The design of filter has been done on simulation software and successfully tested on spectrum analyzer.

Keywords— **Band pass filter, Strip line, Bluetooth.**

I. INTRODUCTION

Filters of some sort are essential to the operation of most electronic circuits. It is therefore in the interest of anyone involved in electronic circuit design to have the ability to develop filter circuits capable of meeting a given set of specifications.

In circuit theory, a filter is an electrical network that alters the amplitude and/or phase characteristics of a signal with respect to frequency. Ideally, a filter will not add new frequencies to the input signal, nor will it change the component frequencies of that signal, but it will change the relative amplitudes of the various frequency components and/or their phase relationships. Filters are often used in electronic systems to emphasize signals in certain frequency ranges and reject signals in other frequency ranges. Such a filter has a gain which is dependent on signal frequency.

A band-pass filter is a device that passes frequencies within a certain range and rejects (attenuates) frequencies outside that range.

An example of an analogue electronic band-pass filter is an RLC circuit (a resistor–inductor–capacitor circuit). These filters can also be created by combining a low-pass filter with a high-pass filter.

Bandpass is an adjective that describes a type of filter or filtering process; it is frequently confused with passband, which refers to the actual portion of affected spectrum. Hence, one might say "A dual bandpass filter has two passbands." A bandpass signal is a signal containing a band of frequencies away from zero frequency, such as a signal that comes out of a band pass filter.

An ideal bandpass filter would have a completely flat passband (e.g. with no gain/attenuation throughout) and would completely attenuate all frequencies outside the passband. Additionally, the transition out of the passband would be instantaneous in frequency. In practice, no bandpass filter is ideal. The filter does not attenuate all frequencies outside the desired frequency range completely; in particular, there is a region just outside the intended passband where frequencies are attenuated, but not rejected. This is known as the filter roll-off, and it is usually expressed in dB of attenuation per octave or decade of frequency. Generally, the design of a filter seeks to make the roll-off as narrow as possible, thus allowing the filter to perform as close as possible to its intended design. Often, this is achieved at the expense of pass-band or stop-band ripple.

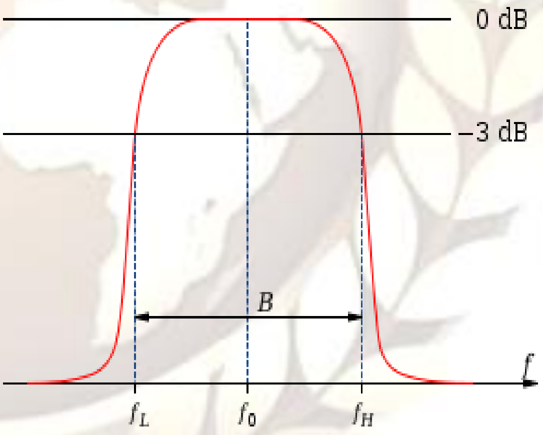

Fig.1 A diagram showing magnitude transfer function versus frequency for a band-pass filter

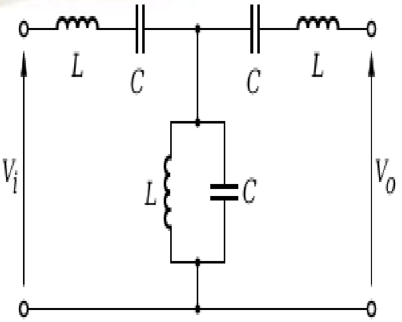

Fig.2 A medium-complexityexample of a Band Pass Filter band-pass filter

a) Stripline

Stripline is a transverse electromagnetic (TEM) transmission line medium, that was invented by Robert M. Barrett of the Air Force Cambridge Research Centre in the 1950s.

A stripline circuit uses a flat strip of metal which is sandwiched between two parallel ground planes. The insulating material of the substrate forms a dielectric. The width of the strip, the thickness of the substrate and the relative permittivity of the substrate determine the characteristic impedance of the strip which is a transmission line. As shown in the diagram, the central conductor need not be equally spaced between the ground planes. In the general case, the dielectric material may be different above and below the central conductor.

To prevent the propagation of unwanted modes, the two ground planes must be shorted together. This is commonly achieved by a row of vias running parallel to the strip on each side.

Like coaxial cable, stripline is non-dispersive, and has no cutoff frequency. Good isolation between adjacent traces can be achieved more easily than with microstrip. Stripline provides for enhanced noise immunity against the propagation of radiated RF emissions, at the expense of slower propagation speeds.

b) Microstripline

Microstrip is a type of electrical transmission line which can be fabricated using printed circuit board technology, and is used to convey microwave-frequency signals. It consists of a conducting strip separated from a ground plane by a dielectric layer known as the substrate. Microwave components such as antennas, couplers, filters, power dividers etc. can be formed from microstrip, the entire device existing as the pattern of metallization on the substrate. Microstrip is thus much less expensive than traditional waveguide technology, as well as being far lighter and more compact. Microstrip was developed by ITT laboratories as a competitor to stripline (first published by Grieg and Engelmann in the December 1952 IRE proceeding.).

The disadvantages of microstrip compared with waveguide are the generally lower power handling capacity, and higher losses. Also, unlike waveguide, microstrip is not enclosed, and is therefore susceptible to cross-talk and unintentional radiation.

For lowest cost, microstrip devices may be built on an ordinary FR-4 (standard PCB) substrate. However it is often found that the dielectric losses in FR4 are too high at microwave frequencies, and that the dielectric constant is not sufficiently tightly controlled. For these reasons, an alumina substrate is commonly used.

On a smaller scale, microstrip transmission lines are also built into monolithic microwave integrated circuits.Microstrip lines are also used in high-speed digital PCB designs, where signals need to be routed from one part of the assembly to another with minimal distortion, and avoiding high cross-talk and radiation.

Microstrip is very similar to stripline and coplanar waveguide and it is possible to integrate all three on the same substrate.

The electromagnetic wave carried by a microstrip line exists partly in the dielectric substrate, and partly in the air above it. In general, the dielectric constant of the substrate will be different (and greater) than that of the air, so that the wave is travelling in an inhomogeneous medium. In consequence, the propagation velocity is somewhere between the speed of radio waves in the substrate, and the speed of radio waves in air. This behaviour is commonly described by stating the effective dielectric constant (or effective relative permittivity) of the micro strip, this being the dielectric constant of an equivalent homogeneous medium (i.e. one resulting in the same propagation velocity).

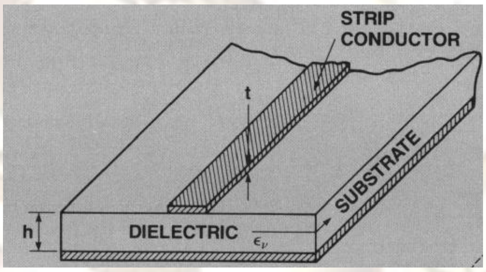

Fig.3 Micro strip separated from ground plane by a dielectric material

II. LITERATURE SURVEY

A paper on “An Interdigital Band pass Filter Embedded in LTCC for 5-GHz Wireless LAN Applications” given by Gangqiang Wang, Senior Member, IEEE, Minh Van, Fred Barlow, Member, IEEE, and Aicha Elshabini, Fellow, IEEE [1] presented a compact interdigital stripline bandpass filter embedded in low temperature cofired ceramic for 5-GHz wireless LAN applications, including design, simulation, fabrication, and measurements. The filter measures 8 mm 7 mm 1.1 mm and exhibits an insertion loss of 3.6 dB, is turn loss of 20 dB, and a 212-MHz pass band with the midband frequency at 5.28 GHz. The filter is highly reproducible with good tolerance. A low noise amplifier (LNA) built on the top of the LTCC substrate with an embedded filter has the same bandwidth and midband frequency as those of the filter. Using this filter and an integrated chip, a small RF front-end receiver has been achieved.

A paper on “Cross-Coupled Suspended Stripline Trisection Bandpass Filters with Open-Loop Resonators”, given by,E.Hanna, P.Jarry, Senior Member, IEEE, E.Kerherve, Member, IEEE,[2] presented two bandpass trisection filters with asymmetrical characteristics in the suspended substrate technology. The open-loop resonators are based on a meandered half-wavelength line topology thus allowing a significant size reduction. The design of these filters follows two steps: A synthesis based on the extraction of the general cross-coupled folded network parameters and coupling matrix, then the relationship between the resonators' spacing's and coupling coefficients is obtained thanks to fullwave electromagnetic simulations. Transmission zeros on both sides of the pass band can be achieved.

A paper on "Multilayered Stripline Interdigital-Hairpin Bandpass Filters with Small-Size and Improved Stopband Characteristics", given by ,Yani Mu1, Zhewang Ma2, and Deming Xu1 [3] School of Communication and Information Engineering, Shanghai University,China presents a multilayered stripline interdigital-hairpin bandpass filters are proposed. The new structure can not only reduce the size of the filters, but also provide transmission zeros to improve the stopband characteristics. As design examples, a four-pole and an eight-pole bandpass filters using the proposed structures are provided. Moreover, the novel four-pole bandpass filter is fabricated and measured. The experimental results agree very well with the simulated data.

A paper on "Design of a Tri-Section Folded SIR Filter",given by, D. Packiaraj, M. Ramesh, and A. T. Kalghatgi, Member, IEEE, [4] presents the design of a suspended substrate stripline bandpass filter with relocatable second pass band using tri-section folded stepped impedance resonators (TFSIRs). Resonance conditions for the TFSIR in terms of impedance ratios have been derived. Location of the second pass band as a function of impedance ratios (of TFSIRs) has been studied in detail. Experimental results of a filter designed at 2.95 GHz with 31% bandwidth have been compared against the simulation results. Index Terms—Bandpass filter (BPF), suspended substrate stripline (SSS), tri-section folded stepped impedance resonator (TFSIR).

A paper on " Miniature Broadband Bandpass Filters Using Double-Layer Coupled Stripline Resonators ",given by,Yunchi Zhang, Student Member, IEEE, Kawthar A. Zaki, Fellow, IEEE, Andrew J. Piloto, and Joseph Tallo, [5] presents a double-layer coupled stripline resonator structure is introduced to realize miniature broadband bandpass filters. Filters with relative bandwidth up to 60% and size less than 8 8 (is wavelength at the midband frequency; is the substrate height, which is much smaller than 8) can be fulfilled using such resonators. Two possible filter configurations are proposed in this paper: combline and interdigital. The filter synthesis procedure follows the classical coupling matrix approach that generates very good initial responses. Optimization by the mode-matching method and fine tuning in Ansoft's High Frequency Structure Simulator are combined to improve the filter performance. Two filter design examples are given to validate the feasibility. Low temperature co-fired ceramic (LTCC) technology is employed to manufacture the filters. Experimental results of the two manufactured filters are presented. The effects of LTCC manufacturing procedure on the filter performance are also discussed.

A paper on "Quasi-Lumped—Open-Loop Suspended Stripline Bandpass Filters" ,given by, Atallah Balalem,Wolfgang Menzel, and Abbas Omar,Chair of Microwave and Communications Engineering, University of Magdeburg,Germany,[6] presents a combined quasi-lumped-openloop resonator (QL-OLR) is introduced and applied for filter design. The resonator can have single and dual-band behavior. Two bandpass filters as well as two dual-band bandpass filters have been designed, fabricated, and tested, that consist of two resonators each. The bandpass filters show the behavior of four return loss poles (fourth order filter), and by slitting these resonators a dual-band bandpass filter can be achieved (each band has two return loss poles). Transmission zeroes can be easily introduced into the filter response as well by utilizing the properties of both quasi-lumped and open-loop resonators.

A paper on " A Fully Integrated Scanning Receiver Array ",given by,Wolfgang Menzel, Ziqiang Tong,Microwave Techniques, University of Ulm,Germany,[7] presents, an integrated antenna receiver array is presented. The RF signal is received by open waveguide ports connected to finline mixers. A chain of suspended stripline bandpass filters is used as LO feed network where phase shifting occurs as a function of frequency. Combining the IF signal in a fixed equal-phase network, the antenna array characteristic is scanned varying the LO frequency from -35° to +35° while the RF frequency is kept constant. The overall very compact arrangement is integrated on a single substrate and placed in a compact metal mount.

III. MATERIAL USED

Material with Good Dielectric Constant (FR4)

FR-4 (or FR4) is assigned to glass-reinforced epoxy laminate sheets, tubes, rods and printed circuit boards (PCB). FR-4 is a composite material composed of woven fibreglass cloth with an epoxy resin binder that is flame resistant (self-extinguishing).

FR-4 glass epoxy is a popular and versatile high-pressure thermo set plastic laminate grade with good strength to weight ratios. With near zero water absorption, FR-4 is most commonly used as an electrical insulator possessing considerable mechanical strength. The material is known to retain its high mechanical values and electrical insulating qualities in both dry and humid conditions. These attributes, along with good fabrication characteristics, lend utility to this grade for a wide variety of electrical and mechanical applications.

NEMA is the regulating authority for FR-4 and other insulating laminate grades. Grade designations for glass epoxy laminates are: G10, G11, FR4 and FR5. Of these, FR4 is the grade most widely in use today. G-10, the predecessor to FR-4, lacks FR-4's self-extinguishing flammability characteristics. Hence, FR-4 has since replaced G-10 in most applications.

FR-4 epoxy resin systems typically employ bromine, a halogen, to facilitate flame-resistant properties in FR-4 glass epoxy laminates. Some applications where thermal destruction of the material is a desirable trait will still use G-10 non flame resistant.

Properties:-

Typical physical and electrical properties of FR-4 are as follows. LW (length wise, warp yarn direction) and CW (cross wise, fill yarn direction) refer to fiber orientations in the board that are perpendicular to one another.

TABLE I
MATERIAL SPECIFICATIONS

Parameter	**Value**	**Alternate units**
Specific Gravity/Density	1850 kg/m³	
Water Absorption	-.125" < .10 %	
Temperature Index	140 °C	284 °F
Rockwell Hardness	110 M scale	
Bond Strength	> 1000 kg	2200 lbs
Flexural Strength-LW-A-.125"	> 448 MPa	65,000 psi
Flexural Strength-CW-A-.125"	> 345 MPa	50,000 psi
Tensile Strength (.125") LW	> 310 MPa	45,000 psi
Izod Impact Strength-LW	> 54 Nm/m	
Izod Impact Strength-CW	> 44 Nm/m	8 ft-lbs/in
Compressive Strength-Flatwise	> 415 MPa	60,000 psi
Dielectric Breakdown-A	> 50 kV	
Dielectric Breakdown-D48/50	> 50 kV	
Dielectric strength	20 kV/mm	
Permittivity-A	4.8	
Permittivity-D24/23	4.8	
Dissipation Factor-A	0.017	
Dissipation Factor-D24/23	0.018	
Dielectric constant permittivity	4.70 max, 4.35 @ 500 MHz, 4.34 @ 1 GHz	
Glass Transition Temperature	Can vary, but is over 120°C	
Young's Modulus – LW	3.5x10^6 psi	
Young's Modulus – CW	3.0x10^6 psi	
CTE x-axis	14ppm/°C	
CTE y-axis	13ppm/°C	
CTE z-axis	175ppm/°C	
Poisson's Ratio – LW	0.136	
Poisson's Ratio – CW	0.118	

FR-4 is the primary insulating backbone upon which the vast majority of rigid printed circuit boards (PCBs) are produced. A thin layer of copper foil is laminated to one, or both sides of an FR-4 glass epoxy panel. These are commonly referred to as "copperclad laminates."

FR-4 copper-clad sheets are fabricated with circuitry etched into copper layers to produce printed circuit boards. More sophisticated and complex FR-4 printed circuit boards are produced in multiple layers, aka "multilayer circuitry".

IV. METHODOLOGY

Initially survey has been done for fine quality pcb material having high dielectric constant and high value of characteristic impedance. Higher values of dielectric constant ensure precise results and proper wavelength propagations through the band pass filter. As design consideration is for low cost so Finally, after a deep survey selected a FR4(having dielectric constant = 4) PCB material. For perfect results one can use RT Duroid pcb material having dielectric constant equal to 10.But Duroid is quite costly compared to FR4 and is rarely available in India. Hence, FR4 was the best option.

After designing the schematic of the band pass filter we fabricated the layout on double sided PCB (FR4).One side of pcb contains designed copper tracks and the other side is used as ground.

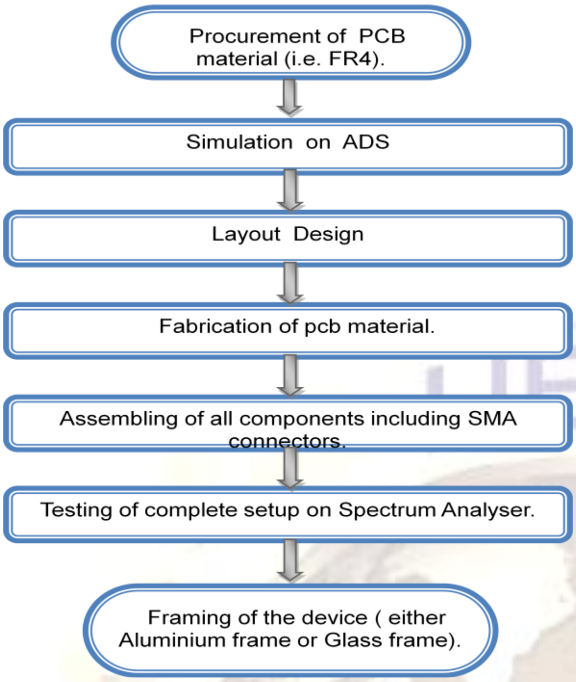

Fig 4: Design Flow

Then pcb based female SMA connector is attached to both the ends of the strip. At last, the setup was assembled that includes Spectrum analyzer, Microwave generator, male SMA connector, Detector and BNC cable.The snapshot of complete setup is shown below. Proper results were obtained from the spectrum analyzer and Band pass filter using stripline technology was prepared successfully.

V. SIMULATIONS AND TESTING RESULTS

The simulation setup and results for the bandpass filter are given below. Circuit design and simulation has been done on ADS schematic window and Layout design of filter is performed on Layout window of ADS.

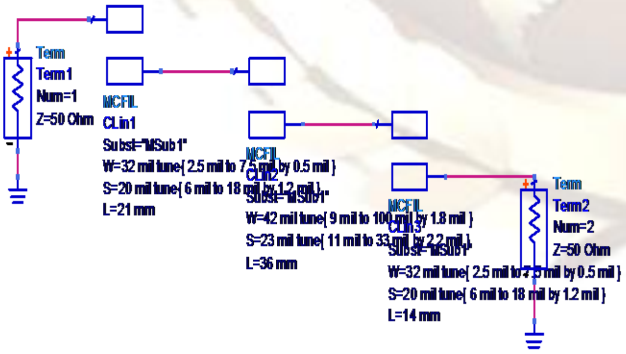

Fig 5: simulation setup on circuit window The results for simulation are as follows

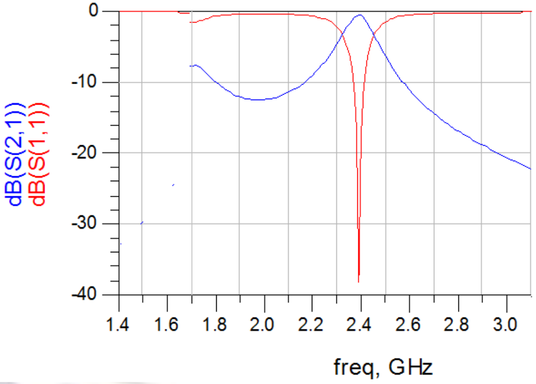

Fig 6: simulation output window

Here graph of S(1,1) represents nature of INPUT RETURN LOSS which should be less at desired frequency i.e. 2.4 GHz and S(2,1) shows nature of TRANSMISSION COEFFICIENT (i.e. FORWARD GAIN) which is maximum at the desired frequency of 2.4 GHz.

After successfully finishing of layout and fabrication of PCB testing established the testing setup includes microwave frequency generator, detector and spectrum analyzer.The setup is as given below

Fig 7: Testing Setup

The testing results are examined with the help of spectrum analyzer the results is shown in fig.8

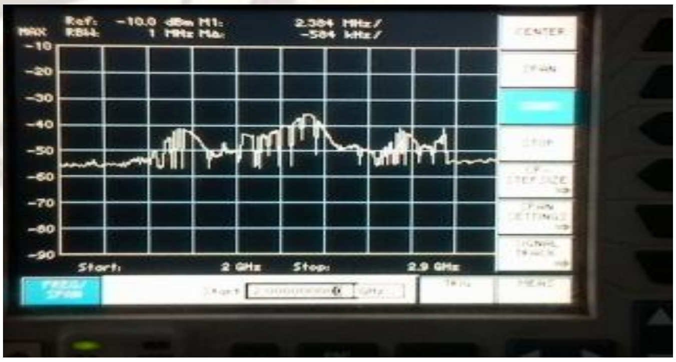

Fig 8: Result on Spectrum analyzer

Figure shows testing results of 2.4 GHz Stripline Band Pass Filter on Spectrum Analyser's seen from figure graph shows minimum attenuation of around 25 dB at desired frequency of 2.4 GHz and much more attenuation at other frequencies.This implies that it is easily allowing the centre frequency of 2.4 GHz to pass through it and restricts other frequencies.

Final view of stripline bandpass filter after completion of framing is as follows

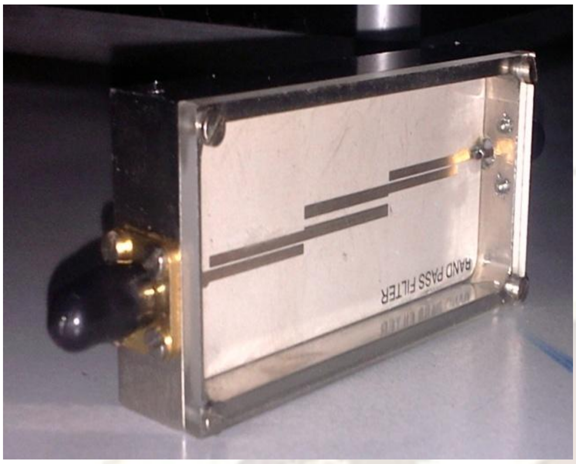

Fig 9: Filter after assembly.

VI. CONCLUSIONS

Designing of bandpass filter with Butterworth approach in combination with concentrated components, i.e. inductors and capacitors and its computational verification in form of parallelcoupled microstrip lines with the program give very good filter characteristics at the centre frequency 2.4 GHz with frequency bandwidth of about 100 MHz as required at the specification stage. At the center frequency the insertion loss and reflection factor has the values about -2 dB and better than -15 dB, respectively.

Micro strip Filters for RF/Microwave Applications is not only a valuable design resource for practitioners, but also a handy reference for students and researchers in microwave engineering. Various devices and complex circuits can be easily designed using Strip line technology.

Micro strip gives sharp response i.e. passes particular frequency bands and suppress other frequency. It is a low cost solution, easy to fabricate, gives accurate results once designed, rock solid and robust in design

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