A Survey on Narrowband filtering Design using Microstrip filters

Akhilesh J Malse¹, Dr Reena Kulshreshtha²,

¹ME Student, ²Professor, Department of electronics, AISSMS COE, Kennedy Road, Pune-1, Maharashtra, India.

Abstract The increase in wireless communication applications in the Radio frequency range has led to an increase in the demand for compact microstrip circuits. With high performance circuits becoming a trend, more components need to be placed into per square inch area on the circuit, leading to compact structures such as filters finding high utility in these circuits. This paper reviews the basic structures and modes of microstrip filters. Four modes of filtering have been introduced with an attempt to give a novice a general understanding of microstrip resonators. Also, a single mode high-Q narrowband filter along with its generic coupled microstrip lines is presented in the paper.

Keywords — High-Q, resonators, microstrip, filter.

I. INTRODUCTION

Previously all microwave equipments utilized waveguides, coaxial or parallel strip line circuits. Recently, monolithic microwave integrated circuits (MMICs) have been introduced which facilitates the use of micro-strip lines and coplanar strip lines. An advantage of using micro-strips is that they provide accessible surface on which solid state devices can be mounted. Conventionally, two conductors are used for transmitting microwave energy.

The efficiency of a conductor can be made maximum if its characteristic impedance is matched at each of its terminals. All impedance elements are assumed to be lumped constants. However, this varies for long transmission lines spreading over a wide range of frequencies. The frequency of operation is high; as a result the inductances and capacitances of short lengths of conductors are taken into consideration.

Many applications in telecommunication and wireless technology require compact radio frequency (RF) and microwave bandpass filters. Compact microstrip resonators with superior performance are continuously developed to meet various demands. These microstrip resonators can be classified into single mode and multimode. The single-mode resonators can be classified into six sub classes. They are, half wavelength resonators, quarter wavelength resonators, stepped impedance resonators, quarter-wavelength stepped impedance resonators, patch resonators and ring resonators. Each varying in shape and performance The single mode resonator is the basic structure for the design of a low pass, high pass, band pass and band stop filters. N-number of single mode resonators is required for an N-th order filter. One way of reducing the filter size is to use multimode resonators. If each multimode resonator has N-modes, the number of resonators in the filter design is reduced by a factor of N. Thus, if dual mode resonators (N=2) are used, the filter size is halved, which can be interpolated with other designs as well. Multimode resonators can also be categorized according to the number of resonant modes. They include the dual-mode, triple-mode and quadruple mode resonators.

II. WORKING PRINCIPLE OF MICROSTRIP RESONATORS

To understand the working of microstrip filters, they have to be considered as coupled transmission lines of ideal topology. For obtaining the desired frequency variable, the shorted stubs take on the appearance of an inductor and an open circuited stub, that of a capacitor. The structure so formed consists of assemblages of shorted stubs and open stubs and cascaded transmission lines all having the same phase length. This gives a transmission line equivalent of lumped element components for a filter. The filter characteristics are then obtained by equating the impedances of the transmission lines to the impedances of lumped elements of a previously designed filter. A resonator is characterized by a resonant frequency $\omega_0$. This frequency gives a rate of periodic exchange of electric and magnetic energy. Every resonator has a quality factor $Q$, given by

$$ Q = \frac{\omega_0 \text{(time-average energy stored in system)}}{\text{energy loss per second in system}} $$

This is, the ratio of average energy stored in the resonator to energy lost per second in the resonator system multiplied by the resonating frequency. This is also a measure of the circuit losses in the resonator system.
III. CLASSIFICATION OF RESONATORS

There are different types of resonators, and as discussed above, depending upon the shape and performance characteristic of the resonator, it can be classified as:

i) Single mode
ii) Dual mode
iii) Triple mode
iv) Quadruple mode

Even though, there are more types of resonators and even more modes of operation of a resonator, this paper will limit the discussion up to quadruple mode resonators.

1) Single mode resonators: Filters that provide only a single pass band/stop band are known as single mode resonators. Different types and stages of microstrip sections can be provided to improve the filter characteristics. For eg a trisection filter shown in Figure 1 can provide better filter characteristics than a single or a dual section filter. Each section can be interpreted as one filter stage, which performs cumulatively as the sections increase, thereby giving better filter characteristics. A hairpin, c-shaped, E-shaped are the common filter shapes that can be interpolated to give multiple stages.

2) Dual mode resonators: Dual mode resonators basically have the following design constraints [3]:
   1. There must be at least a 90° separation between the phases of the EM energies at the input and output ports.
   2. The resonator must have a discontinuity/perturbation to generate a reflected wave against an incident wave in the resonator, and
   3. The resonator structure must be symmetric.

   The introduction of stubs or cuts onto the symmetrical planes of the resonators makes the ring or patch to split the fundamental resonant frequency into two. Further, by making the ring structure meandered, the size of the filter can be reduced. The stop-band response of dual-mode ring resonators are improved by designing defected grounding structure and by adding a T-shaped coupling feed structure.

   The basic structure of the dual-mode centrally loaded open-loop resonator is a half-wavelength open loop resonator. The half wavelength open loop resonator is then centrally loaded with an open-circuited stub, a short-circuited stub or a grounded via as shown in Figure 2.

   3) Triple-mode resonators: Open loop resonators when centrally loaded with an open-circuited stub and a grounding via, becomes a triple-mode resonator as proposed in [5]. The open-circuited stub of a triple-mode resonator can be replaced with an open-circuited stepped impedance stub as given in [6]. Deng et al.[7][8] researched a series of work on triple-mode resonator design using a centrally loaded stub with open-circuited U-shaped resonators, T-shaped stub and two short-circuited stubs as shown in Figure 3.

   4) Quadruple-mode resonators: Classification of quadruple mode resonators is done into following categories, depending to their structures.
   (i) Coupled-ring resonators [12],[13].
   (ii) Five-section stepped impedance resonators (Figure 4(a)) [9].
   (iii) Tri-section stepped impedance resonators with embedded stubs (Figure 4(b)) [10].
   (iv) Centrally loaded quadruple-mode resonators.

   A straight line resonator is centrally loaded with an open circuited stepped impedance stub and two additional stepped impedance stubs at the symmetry plane of the resonator (Figure 4(c)) to form a quadruple-mode resonator as proposed in [11].
As discussed in [1], another method to realize a high Q narrow band bandpass filter is the ABSF (absorptive band stop filter). Such a filter can be realized using waveguide resonators. However, their size is impractically large, which hinders their applicability in mobile systems.

IV. NARROWBAND BANDPASS FILTER

Narrowband RF filters that are able to pass a band of frequencies and reject the remaining through the mechanism of impedance transfer in the pass band reflecting incident energy in the stop band have attracted significant attention due to the following remarkable advantages:

i) Theoretically infinite attenuation despite the resonators finite Q, and,

ii) Inherent input/output matching that allows their direct integration without the need for external matching networks.

These unique performance merits are obtained by cascading in parallel all-pass and bandpass microstrip networks so that signal cancellation occurs at the overall output node. A typical structure of a narrowband filter along with the generic coupled microstrip lines is as shown in Figure 1. The S-parameter frequency response of such a c-shaped microstrip filter (Figure 1) is shown in Figure 5. It can be observed that the filter stopband bandwidth (BW) and the roll-off slope are a function of the resonators Q. A narrower BW and a steeper slope are attained as higher Q values are considered. The application of such filters in an interference scenario where strong jammers are closely spaced to the receive band, narrowband filters with a manifold value of Q need to be cascaded in series with a preselect pass band in order to efficiently transmit the passband and suppress interference without affecting the receive band. As discussed in [1], another method to realize a high Q narrow band bandpass filter is the ABSF (absorptive band stop filter).

Fig 5: S-parameter frequency response of the c-shaped microstrip filter shown in figure 1.

Therefore, for a C-shaped trisection filter, as shown in figure 1, the Q factor is 14, as central frequency is 2.515 GHz and bandwidth is 0.09 GHz.

V. CONCLUSION

Modifications to the structure of microstrip resonators provide different modes of operation, thereby giving a wide frequency range for usability. Moreover, the narrowband filters, characterised by a high Q frequency response depicts the frequency selectivity of a filter, thereby resulting in lower bandwidths for filters with higher Q values. Most multistage filters start with a relatively high-Q value and exhibit a significant Q degradation over the frequency range. This problem in an ABSF can be easily overcome by employing a tuning device, to maintain the filter characteristics over the entire frequency range. A screw or a disk attached to a moving mechanism and is penetrating inside the resonator cavity to tune its resonance frequency is one of the methods to overcome Q degradation. As the resonator is tuned over a wide tuning range, the screw/disk needs to have more penetration inside the resonator, which reduces Q significantly. A similar effect takes place when using MEMS/varactors to tune resonators, such high loading capacitance can significantly reduce the resonator Q value even if the varactor is assumed loss less [1].

REFERENCES


