

Miniaturization of Microwave Devices: It's Effect in Improving Electronic Circuits

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Abstract- Major Microwave devices are very large in dimension, hence the need to reduce their size and weight to enable their efficient use in many applications. Modern communication systems require microwave components of high performance and in small size. Once these miniaturized components (e.g. filters and oscillators) become available, the fundamental bases upon which communication systems are developed may also evolve, giving rise to new system architectures with, possible power and bandwidth efficiency advantages. This paper tends to examine the effects of miniaturization of microwave devices in improving electronic circuits.

Keywords: Miniaturization, Microwave Devices, Effects and Circuits.

1 INTRODUCTION

Miniaturization is the trend to manufacture ever smaller mechanical, optical and electronic products and devices. The revolution of electronics miniaturization begun during World War II and is continuing to change the world and has spawned a revolution in miniaturized microwave devices [1]. The design of complex microwave circuits and systems is mandatory in several important areas for civil and military telecommunication systems, industrial and medical equipments. The conventional microwave design techniques are quite effective for the design of basic microwave active as well as passive devices. The discrete microwave components have large dimension, hence the need to reduce their size and weight which enable their efficient use in many electronics circuit applications.

Different techniques have been adopted in to miniaturize these devices which allowed for both lateral and thickness control for the miniaturizing structures. These processes also enable mass production of these devices. It could also be observed that the miniaturizations of some microwave device dimensions are such that the voltage and phase over the length of the device can vary significantly. By modifying the lengths and dimensions of the device, the line voltage (and current) amplitude and phase can be effectively controlled in a manner to obtain a specifically desired response of the device [2].

Miniaturization of these devices has create new markets by enabling new applications, more especially in rapid development in modern communication technology, where there has been a growing interest in miniaturizing microwave devices for communication applications. The microstrip filter is an example of a microwave device which is widely used in modern communication systems. The advantages, among them are lower cost, greater density higher and speed. Smaller electronics devices are generally faster because the signals do not have to travel as far within the device.

This technique has several challenging factors among which are discussed below.

II. CHALLENGES

A. Packaging and assembly:

Packaging miniaturized microwave device products faces major problem especially in the mechanical, optical, chemical and biomedical applications. Due to the sheer minute size of these products, complete sets of new tools and fixtures need to be designed and [3] developed for the packaging and assembly of these delicate components.

B. Thermal management:

Thermal management also has been identified as an obstacle to miniaturization; especially as heats loading outpace established cooling techniques. Heat transmission in substances smaller than one micrometer needs to be treated differently than the conventional analyses [4]. Consequently a modification in the heat conduction is necessary to accommodate the heat transient.

C. Capital intensive:

Substantial capital investment is required for new equipment, tools and fixtures, and the production environment such as clean rooms and a strictly controlled manufacturing environment. Miniaturized microwave devices become more expensive as sizes are reduced. A part of the increased cost results from facilities and placement/bonding machines that can attain higher precision.

III. MATERIALS AND METHOD

We begin this section by considering a conventional bandstop filter, a complementary split ring resonator (CSRR) based on 50Ω lines shown in the figure 1. This filter is considered as reference of comparison with the realized miniaturized filters. It has a dual electromagnetic behavior; the incident electric field needs to be polarized in the axial direction of the resonator. Thus, CSRRs are etched on center line of the microstrip technology [5].

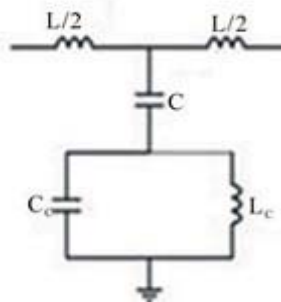


Figure 1: A Typical Discrete Bandstop Filter

To reduce the bandstop filter size in figure 1, we would use two techniques of metamaterial miniaturization. The first technique is on the dimensions optimization and the second is based on the increasing of the equivalent distributed capacitance.

The first technique consists of reducing the physical size of the resonator, bearing in mind that the complementary split ring resonators (CSRR) [6] frequency depends on their dimensions and the second may be based on the increasing of the equivalent distributed capacitance as desired.

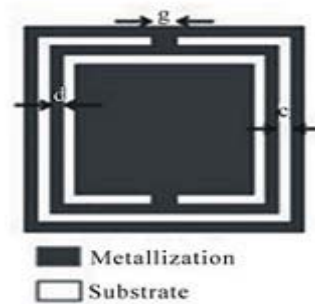


Figure 2: Miniaturized Bandstop Filter of figure 1.

The equivalent circuit model of figure 1 is illustrated in Figure 2. RT/Duroid substrate is used which has the following characteristics (relative permittivity $\epsilon_r = 2.2$, loss tangent $\tan(\phi) = 0.0001$ and thickness $h = 0.8$ mm). The CSRR unit cell was designed to operate around 5.70 GHz. The geometry of the cell is as follows: $c = d = 0.3$ mm, $g = 0.6$ mm and the global size is $7.4 \text{ mm} \times 3 \text{ mm}$.

IV. RESULT AND DISCUSSION

The overall area for the conventional bandstop filter is higher, than the miniaturized metamaterial filter consumes which consumed a less area [7].

The CSRR itself can be described as an L_C resonant; the resonant frequency is described by the following expression:

$$f = \frac{1}{2\pi\sqrt{L_C C_C}}$$

The Figure 3 shows the optimized CSRR [S] simulated parameters. It presents a rejected frequency band around the designed frequency of the CSRR resonator explained by a transmission of about -25 dB.

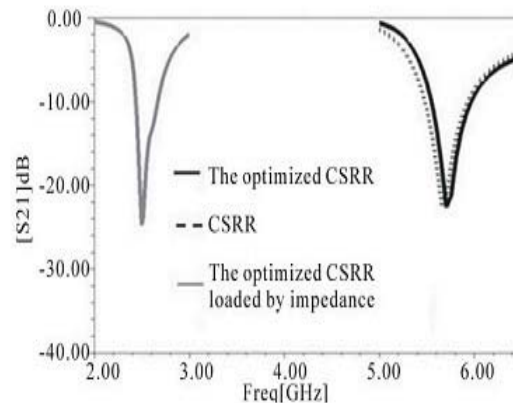


Figure 3: Optimized S-parameter of a typical miniaturized Bandstop Filter.

V. EFFECT ON ELECTRONIC CIRCUITS

A. Small Size

The size of a typical microwave device is much smaller than an equivalent discrete circuit, which makes it ideal for use in places where space is limited. Modern powerful mobile communication devices can be built just because such

miniaturized microwave devices are available. The micro antenna of a mobile phone is an integrated circuit, and if it was made with discrete components, it would take up thousands of times more space. It would be fair to say that this miniaturization of electronic circuits has greatly helped us make rapid developments in technology.

B. Speed

The time taken for signal to move to the neighboring component in an electronic circuit will be reduced. Hence, miniaturization has inherent advantages, among them higher speed.

C. Low Power Consumption

Miniaturizing microwave devices holds some answers for how we might increase the capabilities of electronics devices while we reduce their weight and power consumption. The power consumed by a miniaturized microwave device of milliwatts range is much lower than its equivalent discrete circuit.

D. Temperature Tolerance

Microwave devices circuits have high temperature tolerance than discrete circuits. The reason for this is that they are housed in protective material resistant to heat. Also, due to their smaller size, they absorb less heat than all discrete components combined. This makes them ideal for use in places such as computer motherboards, [8] where temperature can get as high as 70 degrees Celsius. Also, in rugged industrial applications it is desired that the electronics remains intact if the temperature increases to high values. Therefore, in such environments, it is preferred that the electronic circuitry mostly consist of miniaturized microwave device.

E. Improving performance.

Various researchers have proven that miniaturization is used for improving microwave performances. Most circuit designers understand that by using material with higher dielectric constant value, it is possible to miniaturize the dimensions of a microwave circuit for a given frequency. The size of a circuit for a particular [9] wavelength/frequency decreases as the dielectric constant value of the material increases. Circuit materials with high dielectric constant values can affect electromagnetic (EM) wave properties by operating with smaller circuits and shorter wavelengths and by slowing the phase velocities of the EM waves. Electric fields are also more condensed on higher-dielectric constant circuit materials.

VI. CONCLUSION

The materials and the strategy that are combined to achieve miniaturization enhance the device functions and reduce manufacturing cost.

There is no doubt that the manufacturing industry is faced with an enormous challenge in producing the miniaturized devices but their economic benefits have created new markets.

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