SUBSTRATE INTEGRATED WAVEGUIDE DUALBAND BAND PASS FILTER DESIGN USING CSRR

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Abstract -Now a days most of the technologies are looking to reduce the size and cost of component to make it easy to integrate with components and use them in real time applications. In order to archive these advantages we are designing the substrate integrated waveguide (SIW). SIW technology is the most promising candidate for the implementation of millimeter - wave (mm-wave) integrated circuits and systems for the next decade. Based on planar dielectric substrates with top and bottom metal layers perforated with metalized holes, SIW structures offer a compact, low loss, flexible, and cost-effective solution for integrating active circuits, passive components and radiating elements on the same substrate.

In this project we are designing an SIW bandpass filter using Complementary Split Ring Resonators (CSRRs). Bandpass filter is used to receive the desired band of frequency and to reject the frequency which is outside the band.

A Microwave system is generally designed by using fundamental components such as filters, couplers, dividers etc... Microstrip based devices can be used up to certain frequencies. The conventional microwave components which are heavy, bulky in size, high cost. In order to overcome these drawbacks we have chosen substrate integrated waveguide as an approach. The results will be obtained from the CST software.

Index Terms- Rectangular Waveguide, Substrate Integrated Waveguide, Microwave filters, Transition, SIW-Microstrip Technology, CSRR.

I. INTRODUCTION

Filters are electronic circuits that remove any unwanted components or features from a signal. In simple words, you can understood it as the circuit rejects certain band of frequencies and allows others to pass through. They are widely used in instrumentation, Electronics and communication Systems. These are essential building blocks of any Electronic and Communication Systems that alter the amplitude and/or phase characteristics of a signal with respect to frequency. Filter is basically linear circuit that helps to remove unwanted components such as noise, Interference and Distortion from the input signal. Ideally Filter alters the relative amplitudes of the various frequency components and the phase characteristics and its Gain depends entirely on the frequency.

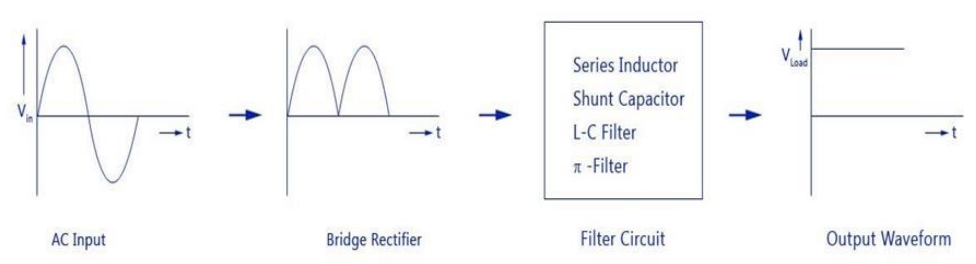

Fig.1 Block diagram of filter

TYPES OF FILTERS:

Filter is mainly classified into two types such as Active filter and Passive filters. The major difference between active and passive filter is the components those are used for construction of filters.

Active filters:

An active filter is a type of analog circuit implementing an electronic filter using active components, typically an amplifier. Amplifiers included in a filter design can be used to improve the cost, performance and predictability of a filter. Filter circuit which consists of active components like Transistors and Op amps in addition to resistors and capacitors is called Active filter. Active filters are capable of dealing with very low frequencies (approaching 0 Hz), and they can provide voltage gain (passive filters cannot). Active filters can be used to design high-order filters without the use of inductors this is important because inductors are problematic in the context of integrated-circuit manufacturing techniques .

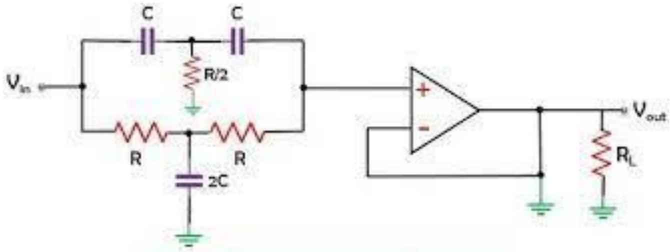

Fig.2 Circuit of Active Filter

Passive filter:

Filter circuit which consists of passive components such as Resistors, capacitor and inductors is called passive filters. Filter circuit which consists of passive components such as Resistors, capacitors and inductors is called passive filters. Passive filters are most responsive to a frequency range from roughly 100 Hz to 300 MHz .

II. EXISTING METHOD:

Conventional wave guide

A microwave circuit (or a system) is, in general, an interconnection of many fundamental microwave devices such as filters, couplers, power divider/combiners, etc. However, an essential requirement in all these devices is the ability to transfer signal power from one point to another as efficient as possible (i.e., with minimum amount of loss)[1]. This requires the transport of electromagnetic energy in the form of a propagating wave. Therefore, all the aforementioned fundamental microwave devices are designed and manufactured in the form of a guiding structure so that electromagnetic waves can be guided from one point to another without much loss.

Microstrip lines are among the most widely used guiding structures at relatively lower microwave frequencies because of their simple construction, low cost. and high integrability with surface mount components.

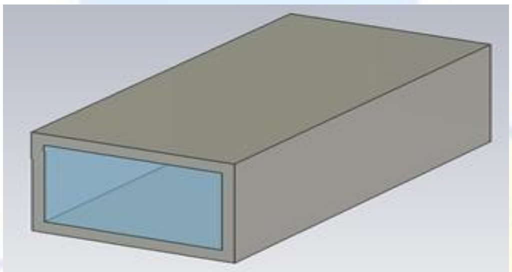

Fig.3 Rectangular waveguide

A typical microstrip line is formed using a conductor on one side of a dielectric layer substrate with a single ground plane forming the other side and air above. The top conductor is basically a conducting material (generally preferred copper) shaped in the form of a narrow line. The width of this line, the thickness, the relative dielectric constant and the dielectric loss tangent of the substrate are important parameters.

Moreover, the thickness (i.e., the metallization thickness) and the conductivity of the conductors can also be critical at higher frequencies. By carefully considering these parameters and using microstrip lines as building blocks, many printed microwave devices and components such as filters, couplers, power divider/combiners, mixers, etc. can be designed. However, as the frequency increases (when moved to relatively higher microwave frequencies), transmission loss increases and radiation emerges[2]. Therefore, hollow-pipe waveguides such as a rectangular waveguide, shown in Fig. 3 are preferred because of less loss at higher frequencies (no radiation). Inside of a waveguide is usually air. However, if desired, it can be filled with a dielectric material resulting a smaller cross-section compared to the air-filled waveguide. Unfortunately, hollow-pipe waveguides are usually bulky, can be heavy especially at lower frequencies, their productions can be difficult and costly, and they are not integrable with printed structures.

Recently, a hybrid guiding architecture between microstrip structures and waveguides called substrate integrated waveguide (SIW) has been proposed . SIWs are integrated waveguide like structures fabricated on a dielectric material with top and bottom sides are conductors, and two linear arrays of metallic vias form the side walls .

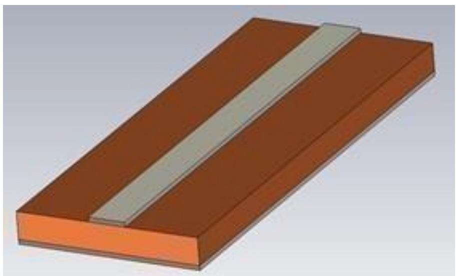

Fig. 4 Microstrip line

When compared to waveguide structures, a SIW has the characteristics of both, namely, cost effective, relatively easy fabrication process, integrable with planar devices. Besides, itis claimed to perform better than microstrip structures at high frequencies and has the waveguide dispersion characteristics. Consequently, a significant number of SIW based microwave components such as filters, couplers, power divider/combiners has been reported so that they can replace their microstrip and/or waveguide counter part appropriate frequencies.

As mentioned before, a microwave circuit (or a system) is usually an interconnection of many basic microwave components such as filters, couplers, power divider/combiners, amplifiers, attenuators, etc. Among them, filters play a vital role in the design of radio frequency (RF) and microwave systems. A microwave filter is a two-port network. It is used to control the frequency response at a certain point in a microwave system by allowing transmission at frequencies within the pass band of the filter, and rejecting (by significantly attenuating) the signal flow within the stop band of the filter. Based on their frequency responses, filters can be grouped as follows[3].

The Waveguide was invented by George C south worth. It played an important role in Radar Systems during World War II. Honor to his work in Waveguide, he was bestowed with the Morris N. Liebmann award of the IRE in 1938 and the Stuart Ballantine Medal of the Franklin Institute for his work on Microwave radiation from the sun. His contributions to the field of radio Physics were commendable.

Waveguides are used to direct and propagate Electromagnetic waves from one point to another. They are generally used to transmit high frequency waves such as Microwaves, Radio Waves, Infrared waves etc. For low frequency waves which are less than 1 MHZ, parallel transmission lines or coaxial cables are used.

It is represented by its dispersion characteristics that has a certain cut-off frequency. The signals having frequencies above this cut-off frequency are allowed to propagate through the Wave-guide and the signals having the frequencies below this frequencies below this frequency will face a high reflection. A Waveguide acts like a high pass filter due to this characteristics. The dispersion characteristics can be altered by loading the Wave-guide with metal or di-electric medium.

The most common type of waveguide is a hollow conductive metal pipe which carries high frequency Radio Waves. They also exist in the form of Wires, Coaxial cables, parallel plates, or optical filters. Its stands for a unique distribution of transverse and longitudinal components of the electric and magnetic fields. There are two types of waveguide modes that can propagate in the waveguides: TE (Transverse electric) and TM (Transverse Magnetic). There are several types of waveguides like circular waveguide, rectangular waveguide. Basically, waveguides are two types such as Rectangular waveguide and Dielectric waveguides. Metal Waveguides consists of an enclosed conducting metal pipe and the wave guiding principle works on the total internal reflection from the conducting walls. They are two types such as

I) Rectangular waveguide

II) Circular Waveguide

Microstrip Antenna

Microstrip or patch antennas are becoming increasingly useful because they can be printed directly onto a circuit board. Microstrip antennas are becoming very widespread within the mobile phone market. Patch antennas are low cost, have a low profile and are easily fabricated.

Consider the microstrip antenna shown in Figure 2.6, fed by a microstrip transmission line. The patch antenna, microstrip transmission line and ground plane are made of high conductivity metal (typically copper)[7]. The patch is of length L, width W, and sitting on top of a substrate (some dielectric circuit board) of thickness h with permittivity ε_r . The thickness of the ground plane or of the microstrip is not critically important. Typically the height h is much smaller than the wavelength of operation, but should not be much smaller than 0.025 of a wavelength (1/40th of a wavelength) or the antenna efficiency will be degraded.

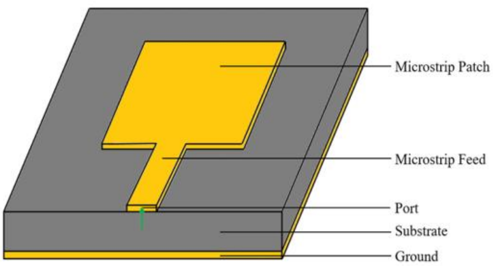

Fig 5: Top view of patch antenna

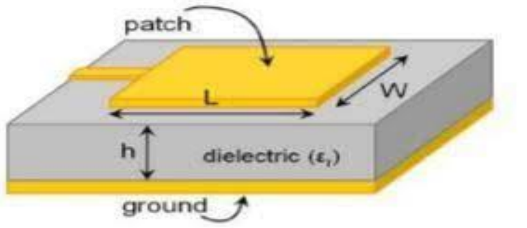

Fig 6: Bottom View of Patch Antenna

The frequency of operation of the patch antenna of Figure 1 is determined by the length L. The center frequency will be approximately given by[4]

$$f_c \approx \frac{C}{2L\sqrt{\varepsilon_r}} = \frac{1}{2L\sqrt{\varepsilon_0\varepsilon_r\mu_0}}$$

The above equation says that the microstrip antenna should have a length equal to one half of a wavelength within the dielectric (substrate) medium.

The width W of the microstrip antenna controls the input impedance. Larger widths also can increase the bandwidth. For a square patch antenna fed in the manner above, the input impedance will be on the order of 300 Ohms. By increasing the width, the impedance can be reduced. However, to decrease the input impedance to 50 Ohms often requires a very wide patch antenna, which takes up a lot of valuable space. The width further controls the radiation pattern. The normalized radiation pattern is approximately given by:

$$E_\theta = \frac{\sin(\frac{KW\ sin\theta \sin\emptyset}{2})}{\frac{KW\ sin\theta \sin\emptyset}{2}} \cos(\frac{KL}{2} sin\theta \cos\emptyset) \cos\emptyset$$

$$E_\varphi = -\frac{\sin(\frac{KW\ sin\theta \sin\emptyset}{2})}{\frac{KW\ sin\theta \sin\emptyset}{2}} \cos(\frac{KL}{2} sin\theta \cos\emptyset) \cos\theta \sin\emptyset$$

In the above, k is the free-space wavenumber, given by $^{2\pi}/_{\lambda}$. The magnitude of the fields, given by:s

$$f(\theta,\emptyset) = \sqrt{E_\theta^2 + E_\emptyset^2}$$

III. PROPOSED METHOD:

A substrate-integrated waveguide (SIW) also known as post wall waveguide or laminated waveguide is a synthetic rectangular electromagnetic waveguide formed in a dielectric substrate by densely arraying metallized posts or via holes that connect the upper and lower metal plates of the substrate. The waveguide can be easily fabricated with low-cost mass-production using through-hole techniques, where the post walls consists of via fences. SIW is known to have similar guided wave and mode characteristics to conventional rectangular waveguide with equivalent guide wavelength.

Since the emergence of new communication technologies in the 1990s, there has been an increasing need for high-performance millimeter - wave systems. These need to be reliable, low-cost, compact, and compatible with high-frequencies. Unfortunately, above 10 GHz, the well known microstrip and coplanar lines technologies cannot be used because they have high insertion and radiation losses at these frequencies[5]. The rectangular waveguide topology can overcome these issues, as it offers an excellent immunity against radiation losses and presents low insertion losses. But in their classical form, rectangular waveguide is not compatible with the miniaturization required by modern applications.

The concept of SIW was developed in the early 2000s by Ke Wu to reconcile those requirements. The authors presented a platform for integrating all the components of a microwave circuit inside a single substrate, with a rectangular cross-section. Using a single substrate guarantees a limited volume and a simplicity of manufacture, while the rectangular cross-section of the line provides the advantages of the waveguide topology in terms of losses.

To compare the field distribution of SIW vs conventional waveguide, X band simulations were done. Figure 1 compares the field distribution of SIW and conventional waveguide. We can see striking similarities between the two in particular the electromagnetic field distribution is TE_{10} like[6].

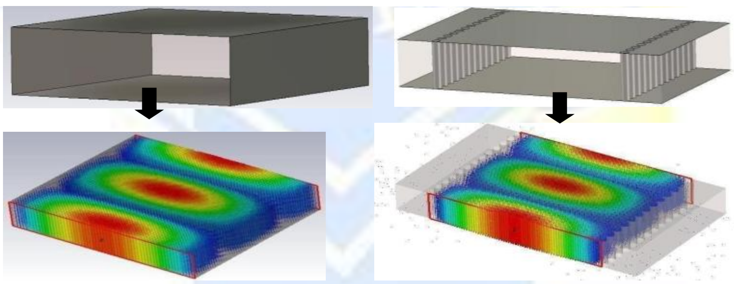

Fig 7 Field Distribution of a waveguide structure (left) and SIW structure (right)

Complementary Split Ring Resonator (CSRR)

A complementary split-ring resonator (CSRR) is a type of resonant structure that is commonly used in microwave and radio frequency (RF) applications[8]. It consists of a pair of split-ring resonators (SRRs) that are placed on either side of a dielectric substrate. The CSRR is designed to exhibit a resonant frequency that is complementary to the resonant frequency of the SRR. This means that while the SRR exhibits a resonance at a certain frequency, the CSRR exhibits a resonance at a different frequency.

The CSRR is often used as a building block in the design of various RF and microwave components such as filters, antennas, and couplers[9]. Its unique properties allow it to selectively attenuate or enhance certain frequencies, making it useful for applications such as frequency selective surfaces (FSS) and meta materials.

One of the key advantages of the CSRR is its ability to exhibit a negative refractive index, which allows for the creation of metamaterials with unique optical properties such as cloaking and superlensing. Overall, the CSRR is a versatile and useful resonant structure that finds applications in a wide range of RF and microwave systems.

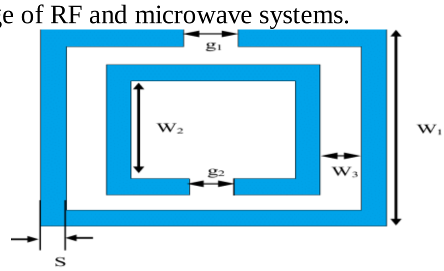

Fig 8 complementary split-ring resonator

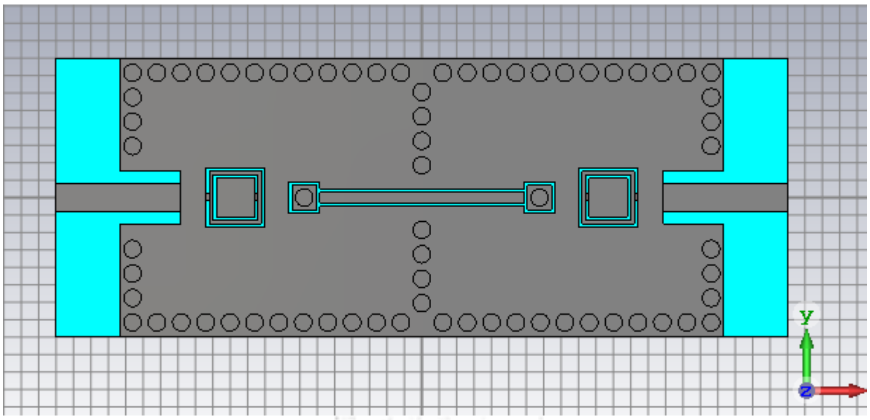

Fig 9 :- Structure of proposed dual band filter including cssr

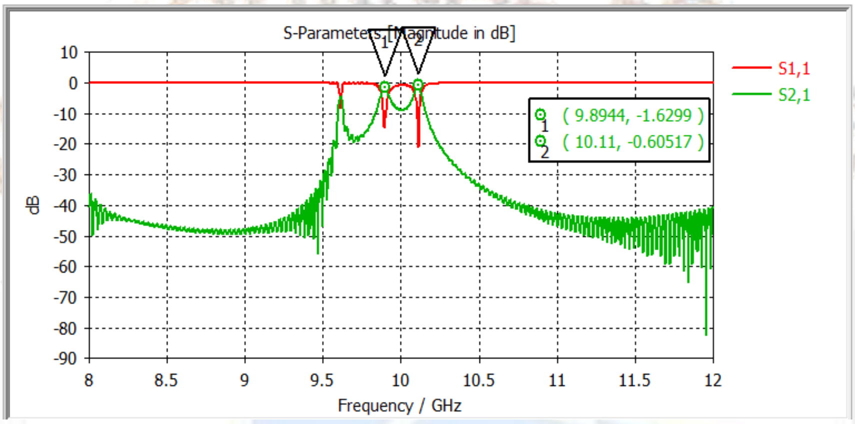

Fig:10 Simulation and measure result of proposed filter

In order to validate the proposed filter, Filter is designed and measured. The simulation and measured results of Filter is as shown in Fig 10..The measured results show that Filter having two passbands are centered at 10.11 and 9.8944 GHz .The measured minimum in-band insertion losses of the two passbands are around o.6 dB and 1.6 dB. Moreover, the simulation and measured results show a good agreement. The discrepancies in the measured results can be attributed to fabrication inaccuracy and losses due to connectors.

IV. CONCLUSION

In this letter, a new coupling structure has been presented and applied to design dual-band filter using the desired couplings of TE_{101} and TE_{102} modes of SIW cavity. The proposed filters exhibit low loss, low cost, and wide-stopband and dual-band response with a tunable second band.

V. REFERENCES

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