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Miniaturized Multi Band pass Filter with Single Finline and Split Ring Resonators

V.Madhusudana Rao[1], Dr. B.Prabhakara Rao(Senior member IEEE) [2]
[1]Department of ECE, JNTU, Kakinada, AP India
[2]Rector of JNTU, Kakinada, AP India
Email: vepakayala@gmail.com, drbpr@rediffmail.co

Abstract— This paper presents a systematic procedure for designing a multi bandpass filters with single finline and Split Ring Resonator (SRR) i.e. metamaterials. A bandpass filter of order 3 having center frequency of 12 GHz with fractional bandwidth of 30 % is designed. This wide bandpass filter is converted into multi band pass filters by using metamaterials on the other side of the finline structure is simulated with High Frequency Structure Simulator(HFSS).

Keywords— Unilateral Single finline, Band pass filter, Metamaterials, Split Ring Resonators (SRR), and Multi band pass.

I. INTRODUCTION

Modern communication systems require high performance, low loss and miniature size band pass filters are essentially required to enhance the system performance and to reduce the fabrication cost. Now a days device needs multitasking, for example, say speaking to someone over the phone and surfing the internet simultaneously which operate in a different band of frequencies demands for the system to be reconfigurable. If this band pass filter can be designed to shift its center frequency based on the type of signal that comes in, then it would be very inexpensive way to address this challenge. Development in multi-band/multi-service wireless communication systems has created more potential, such as the combination of wireless local area networks (WLANs) at 2.4/5.2GHz and global system for mobile communications (GSM) at 0.9/1.8GHz, or WLANs and global position system (GPS) at 1.575 GHz, or WLANs and automotive radar system at 8.2GHz. Multi-passband filters become key components in the front-end of these portable wireless communication devices.

In the frequency range 3-30GHz, microstrip is the most extensively used planar transmission line although its use can be extended to millimeter band. It starts facing various problems in this band. These problems include radiation loss, spurious coupling, dispersion and higher order mode propagation. Also as the frequency increases, dimensional tolerances become more critical due to very small dimensions at higher frequencies, reproducibility decreases hence the cost increases. Though some other variations of microstrip which are less lossy and have guided wavelengths much greater than that in microstrip can be used at millimeter wave frequencies, there is yet another transmission structure known as finline which has special advantages in millimeter wave frequencies.

It can be viewed as slot line inserted in the E-plane of a rectangular waveguide (WG). Finline differs from slot line in that the former has a lower cutoff frequency, but does not require high permittivity substrate to avoid radiations. Since finline resembles the ridge WG, it is single mode bandwidth is relatively wide. The structure is considered quasi planar in the sense that entire circuit pattern including the active devices, is incorporated on the planar surface of a dielectric substrate, while the design takes into account the effect of the WG housing. The mode of propagation is hybrid mode consisting of a combination of TE and TM modes [1-9].

Fig.1 shows cross sectional view of unilateral single finline used in practice. With this finline we designed wide band pass filter. This wide band pass filter is converted in to multi band pass filters using metamaterials.

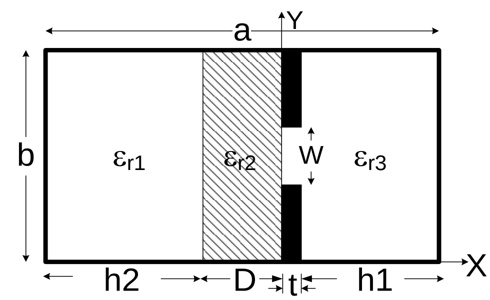

Fig.1.Cross sectional view of unilateral single finline.

Metamaterials are engineered composites tailored for specific electromagnetic properties that are not found in nature not observed in the constituent materials. The electric and magnetic properties of materials are determined by two important parameters are dielectric permittivity (ε) and magnetic permeability (μ). Together the permeability and the permittivity determine the response of the material to the electromagnetic radiation. Generally, ε and μ are both positive in ordinary materials. No natural materials with negative ε or μ are known. However, for certain structures, which are called left-handed materials (LHM), both the effective permittivity, ε_{eff} and permeability, μ_{eff} possess negative values. In such materials the index of refraction, n, is less than zero, and therefore, phase and group velocity of an electromagnetic (EM) wave can propagate in opposite directions such that the direction of propagation is reversed with respect to the direction of energy flow [10]. This phenomenon is called the negative index of refraction and was first theoretically proposed by Veselago in 1968, who also investigated various interesting optical properties of the negative index structures.

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Electromagnetic properties of Metamaterials:

The dielectric constant ε and the magnetic permeability μ are the fundamental characteristic quantities that determine the propagation of electromagnetic waves in matter [11-12]. This is due to the fact that they are the only material parameters appearing in the dispersion equation.

$$\left| \frac{\omega^2}{c^2} \varepsilon_{ij} \mu_{ij} - k^2 \delta_{ij} + k_i k_j \right| = 0 \qquad (1)$$

which gives the relation between the frequency ω of a monochromatic wave and its wave vector *k*. For an isotropic substance Eqn (1) takes a simpler form:

$$k^2 = \frac{\omega^2}{c^2} n^2 \qquad (2)$$

Where n^2 is given by

$$n^2 = \varepsilon\mu \qquad (3)$$

From Eqn. (1) and (2), one can say that a simultaneous change of the signs of ε and μ has no effect on these relations. But as we will see in the upcoming parts of this chapter, materials having simultaneously negative values of ε and μ have some physical properties and unique characteristics that are different from those of ordinary materials having positive ε and μ.

To understand the effect of changes in signs of ε and μ, we have to consider the initial Maxwell equations,

Primarily Maxwell equations

$$\nabla \times E = -\frac{1}{c}\frac{\partial B}{\partial t} \qquad (4)$$

$$\nabla \times H = \frac{1}{c}\frac{\partial D}{\partial t}$$

and constitutive relations are given.

$$B = \mu H \qquad (5)$$

$$D = \varepsilon E$$

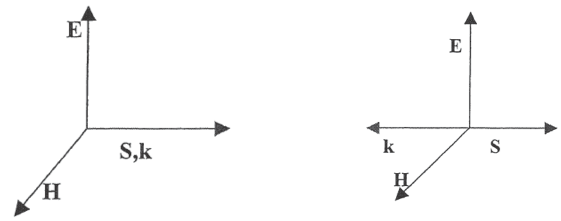
For a monochromatic plane wave, all quantities are proportional to $e^{i(kz-\omega t)}$ and therefore Eqn. (4) and (5) reduce to

$$k \times E = \frac{\omega}{c} \mu H \qquad (6)$$

$$k \times H = -\frac{\omega}{c} \varepsilon E$$

These are the key expressions to understand the problem of left-handed material. If both ε and μ are positive, it is clearly seen that **E, H** and **k** form a right handed triplet vectors as shown in Fig. 2 (a). The interesting point is that for simultaneously negative values of ε andμ, a left handed vector triplet of E, **H** and **k** is formed as shown in Fig.2 (b). At the same time the direction of energy flow determined by the Pointing vector **S** is independent of the signs and values of ε and μ.

$$S = \frac{c}{4\pi} E \times H \qquad (7)$$



(a) (b)

Fig. 2 (a) E, H, k triplet in right handed materials,
(b) E, H, k triplet in left handed materials.

Pointing vector is always directed away from the source of the radiation. But amazingly the **k** vector may be directed away from the source (for the cases where ε and μ are both positive) or towards the source (for the cases where ε and μ are both negative). This is the major difference between the case with negative ε and μ values and the case with corresponding positive values [10].

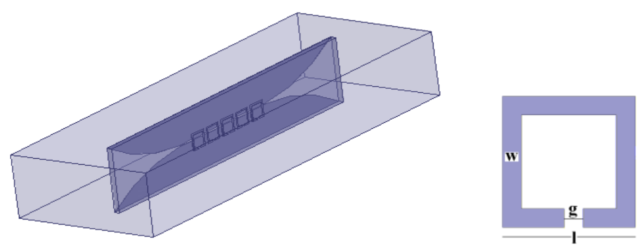
II. FILTER DESIGN

Fig.2 shows the simulated structure of the proposed multi band pass filter with Split Ring Resonator (SRR) array loaded on other side of substrate operated in X-Band regime. We conducted EM simulations to estimate a resonance frequency of the array using HFSS software. The SRR array is fixed in the x-y plane and the magnetic field (**H**) is parallel to the z direction and penetrates through the SRRs, thus exciting a magnetic resonance. H fields are perpendicular to the SRR.

This paper presents a systematic procedure of a multi band pass filters with unilateral single finlines. Designed parameters are mentioned below.

Centre frequency 12 GHz, X band 9.5 to 19 GHz, Zo=120ohm

Wave guide dimensions: (WR62) 7.9 X 16mm, ε_r =2.2



(a) (b)

Fig.2 (a) Simulated structure of multi band pass filter with single finline and split ring resonator (SRR) back side of the substrate in X-band wave guide.

(b) Split ring resonator (SRR) dimensions: w = 0.254 mm, l = 2.54 mm, g = 0.254 mm.

Split Ring Resonator (SRR) can be seen as a corresponding LC circuit, with its resonance properties determined by the equivalent inductance and capacitance. Now deriving physical parameters of SRR for a particular frequency is required. It needs to calculate effective permeability of the SRR as shown in Fig.3. The peak value of the permeability, is an infinite in

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case of no loss, is constrained by the magnitude of the material loss in the SRR.

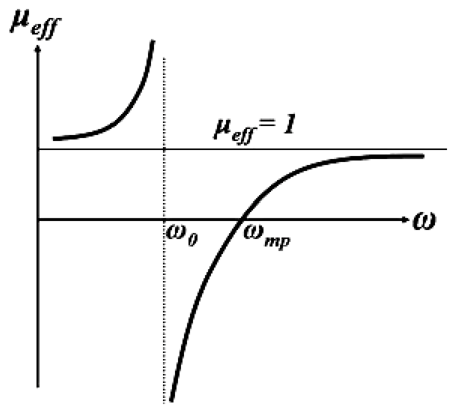

Fig.3 Resonance for effective permeability of SRR.

The detailed calculations of effective permeability of the SRR is given by

$$\mu_{\text{eff}} = 1 - \frac{F}{1 + \frac{2\sigma i}{\omega r \mu_0} - \frac{3}{\pi^2 \mu_0 \omega^2 C r^3}} \quad (8)$$

Where F is the fractional volume of the cell, and r in the radius of the outer ring

$$F = \frac{\pi r^2}{a^2} \quad (9)$$

C is the capacitance per unit area. Fig. 6 illustrates the generic form of μ_{eff} for SRRs.

ω_0 is the frequency at which μ_{eff} diverges as follows:

$$\omega_0 = \sqrt{\frac{3}{\pi^2 \mu_0 C r^3}} = \sqrt{\frac{3 d c_0^2}{\pi^2 r^3}} \quad (10)$$

the effective permeability is

$$\mu_{\text{eff}} = 1 - \frac{F\omega^2}{\omega^2 - \omega_0^2 + i\Gamma\omega} \quad (11)$$

Now SRR concept has been introduced on other side of substrate of this wide band pass filter. These SRRs creates negative effective permeability μ_{eff} (ω) at desired frequency. It creates a notch at resonance frequency. This is the useful characteristics for converting the wideband pass filter in to multiple narrow bandpass filters. The notch can be controlled by number of SRRs and placing. Fig.4 shows the S parameters of multi band pass filter.

III. CONCLUSION

In modern communication systems, high performance and small size band pass filters are essentially required to enhance the system performance and to reduce the fabrication cost. Vast advance in wireless communication systems has increased the demand of research regarding band pass filters with higher accuracy. When it comes to a specific frequency, it is all about a bandpass filter. The most important advantage of finline multi band filter presented here is that it can be widely used in microwave and millimeter wave applications.

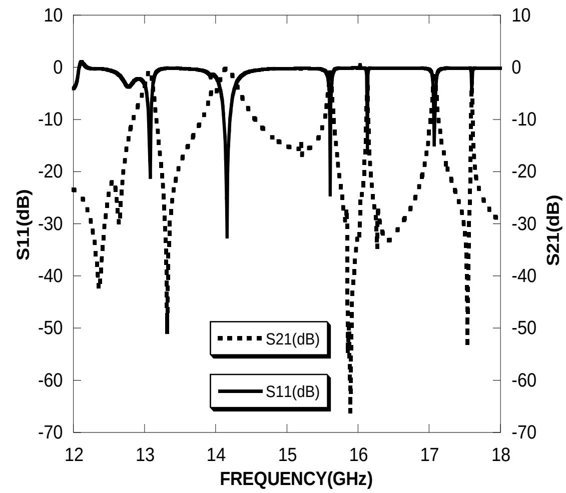

Fig.4 S parameters of multi-band pass filter.

Notch filters with the narrowest bandwidths are designed. The type of notch filters required for a particular application depends on the frequency, attenuation requirements, loss, bandwidth, and power handling requirements. The Ku-band is utilized for fixed and broadcast satellite communications services, including the specific applications of agencies like NASA's Tracking Data Relay Satellite system in the United States. The Ku-band is split or divided into different segments, which vary according to the geographical region that's covered by the ITU, or the International Telecommunication Union. A couple of frequencies of the Ku-band are also utilized for detecting vehicle speed, especially by law-enforcement officials in Europe.

REFERENCES

i. R. *Vahldieck and W. J.R. Hoefer, "Finline and Metal Insert Filters with Improved Passband Separation and Increased Stopband Attenuation," IEEE Trans. Microwave Theory & Tech., vol. MTT-33, no.12, pp. 1333-1339, Dec. 1985.*

ii. *R. Vahldieck, "Quasi planar filters for millimeter-wave applications," IEEE Trans. Microwave Theory & Tech., vol. MTT-37, no.2, pp. 324-334, Feb. 1989.*

iii. *B. Bhat and S.K. Koul, Analysis, Design and Application of Finlines. Artech House, 1987.*

iv. *P. J. Meier, "Integrated finline millimeter components," IEEE Trans. Microwave Theory & Tech., vol. MTT-22, no.12, pp. 1209-1216, Dec. 1974.*

v. *D. M. Syahkal, J. B. Davies, "An accurate, unified solution to various finline structures, of phase constant, characteristic impedance and attenuation," IEEE Trans. Microwave Theory & Tech., vol. MTT-30, no. 11, pp. 1854-1861, Nov. 1982.*

vi. *L. P. Schmidt, C. Chang, T. Itoh, "Spectral domain analysis of dominant and higher order modes in finlines," IEEE Trans. Microwave Theory & Tech., vol. MTT-28, no. 9, pp.981-985, Sept. 1980.*

vii. *S. Luo, A. Biswas and V. K. Tripathi, "Finline mutiport couplers," IEEE Trans. Microwave Theory & Tech., vol. MTT-42, no. 12, pp. 2208-2215, Dec. 1994.*

ISSN:2319-6890 (online),2347-5013(print)
1 April. 2017

viii. *A. Biswas and V. K.Tripathi, "Analysis and design of symmetric and multiple coupled finline couplers and filters," in IEEE MTT-S Int. Microwave Symp. Dig., 1990, pp. 403-406*

ix. *Jen-Tsai Kuo and Eric Shih, "Wideband band-pass filter design with three line microstrip structures", Microwave Symposium digest," in IEEE MTT-S Int. Microwave Symp .Dig.2001, pp.1593-1596*

x. *Pozar D. M. "Microwave engineering," John Wiley & sons, Inc.*

xi. *V. G. Veselago, "The electrodynamics of substances with simultaneously negative values of permittivity and permeability," Sov. Phys. USPEKHI, vol. 10, p.509, 1968.*

xii. *J. B. Pendry, A. J. Holden, D. J. Robbins, and W. J. Stewart, "Magnetism from conductors and enhanced nonlinear phenomena," IEEE Trans. Microwave Theory tech. vol. 47, p. 2075, 1999.*

xiii. *Richard W. Zoilkowski, "Design, fabrication, and testing of double negative metamaterials," IEEE Trans. Antennas propagate. Vol. 51, no. 7. July 2003.*