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Asymmetric Coplanar Strip Fed Monopole

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Abstract

Modern wireless devices are becoming more compact day by day. This trend is forcing designers to miniaturize each and every component of the device. Antennas which are one of the major components cannot remain as standalone devices. Hence its design too is crucial in deciding the overall performance of the device. This paper highlights the more detailed study of the asymmetric coplanar strip fed monopole

Keywords: Monopole Antennas, Asymmetric Coplanar, Strip Fed Monopole.

1. Introduction

Monopole antennas are attractive in modern wireless applications owing to simple structure, broad bandwidth and nearly omnidirectional radiation characteristics. The monopoles are usually placed vertically to a large ground plane which increases the system complexity, size and volume. Printed monopoles on the other hand, are conformal for modular design and can be fabricated along with the printed circuit board of the system, making fabrication easier.

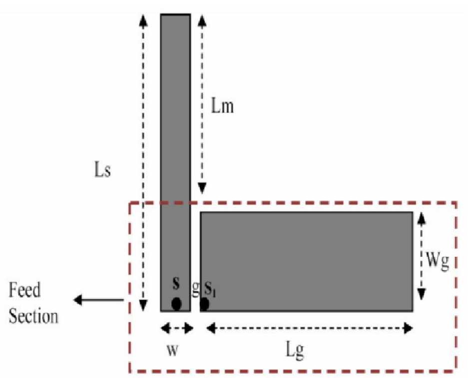

Figure 1: The Asymmetric Coplanar Strip fed Monopole Antenna.

A CPW fed monopole is an ideal example for an uniplanar monopole antenna. Therefore it is used to compare the properties of the Asymmetric Coplanar Strip (ACS) fed monopole[2].

The length of the monopole, Lm is taken to be equal to a quarter of the dielectric wavelength corresponding to 2.75 GHz in the substrate. For the substrate of dielectric constant 4.4 and height 1.6 mm, the dimensions are chosen as Lm = 17 mm, Ls = 25 mm. The other dimensions are w = 5 mm, Lg= 21 mm, Wg= 8 mm and g = 0.3 mm. The experimental and simulated return loss characteristic of the above antenna is shown in Figure 2.

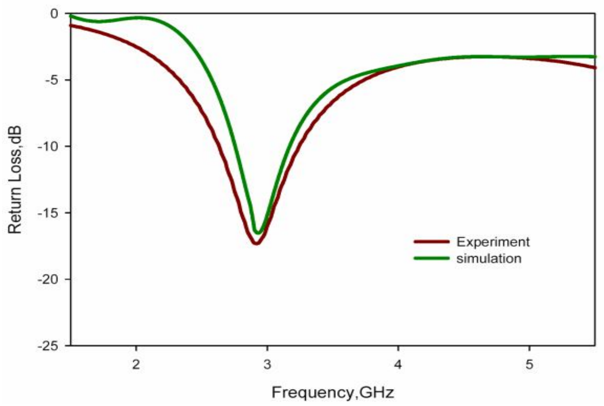

Figure 2: Return loss curve of the ACS fed monopole antenna.
Lm = 17 mm, Ls = 25 mm, w = 5 mm, Lg = 21 mm,
Wg= 8 mm, g = 0.3 mm, εr =4.4 ,h= 1.6 mm

From the return loss curves it can be seen that the antenna resonates at 3 GHz with good impedance matching. But the expected resonance was at 2.75 GHz (due to the quarter wave variation in the length of the signal strip L_m). To find out the possible cause of the shift in the resonance, a detailed parametric study is conducted by varying the different parameters of the antenna. This is outlined in the following sections[2].

2. Effect of Signal strip width (‘w’) on return loss of the antenna

The influence of the width of the signal strip on the resonant frequency of the antenna is shown in Figure 3.It can be seen that the matching deteriorates when the strip width is increased or decreased beyond an optimum value as shown in figure. It is because, as mentioned earlier, the width of the signal strip too affects the impedance of the Asymmetric coplanar strip[3].

Also the band width is slightly effected for larger values of ‘w’. Good matching is noted when the strip width is kept as 7 mm. But in this study the lesser matched dimension (w = 3 mm) is taken as a compromise between the matching and compactness. In all the cases resonant frequency is independent of ‘w’. But there is an increase in bandwidth with increase in width of the signal strip as evident from the figure.

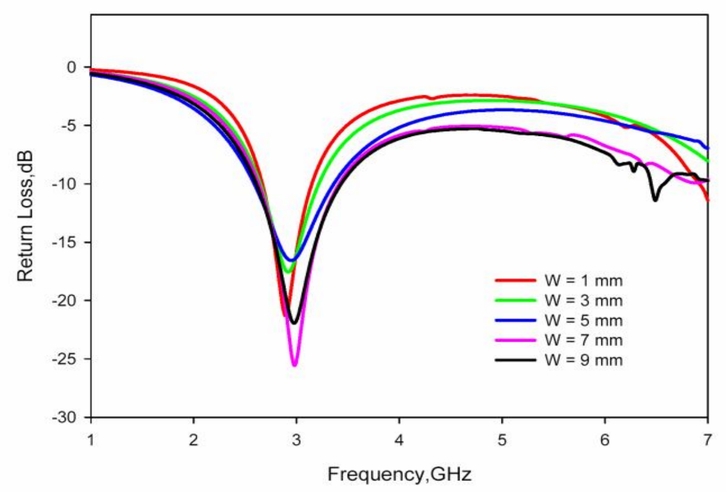

Figure 3.3: Effect of varying the signal strip width, 'w'.
L_m = 17 mm, L_s = 25mm, L_g = 21 mm, W_g= 8 mm and g = 0.3, ε_r =4.4 ,h= 1.6 mm

3. Gap width (g) variation studies

The gap width 'g' is varied and its effect in the return loss characteristic of the antenna is given in Figure 4. The characteristic impedance depends on the gap width and remains nearly constant for higher gap widths. The optimum value is taken as 0.5 mm on a substrate of dielectric constant 4.4 and height 1.6 mm when the signal strip width is 3 mm.

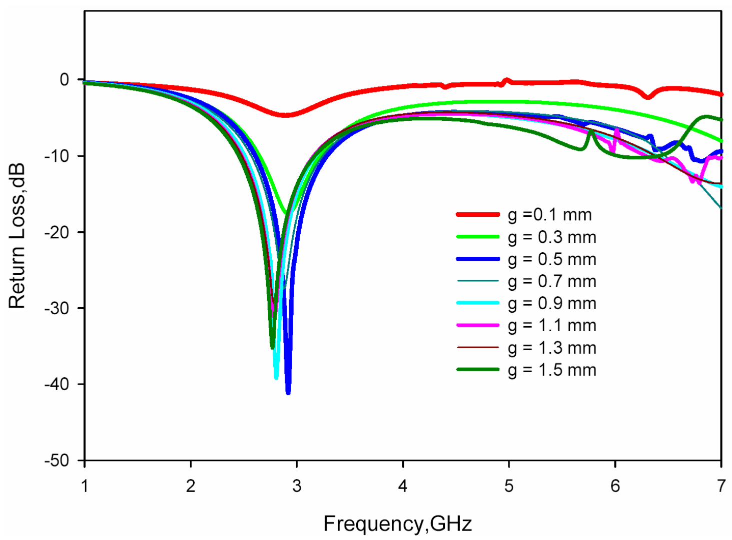

Figure 4: Gap width 'g' variation studies.
Lm = 17 mm, Ls = 25 mm, w = 3 mm, Lg = 21 mm, Wg= 8 mm, ε_r =4.4 ,h= 1.6 mm

4. Signal Strip Length ('LS') Variation Studies

The resonant frequency of the antenna highly depends on the length of the strip as evident from the graph (Figure 5). The resonant frequency decreases with increase in length of L_S as expected. It has to be noted that for small values of L_S ($L_S \leq W_g$) the system is not acting as an antenna. It moreover acts like a transmission line terminated by an open circuit. As L_S is increased beyond W_g, the resonant frequency decreases with increase in L_S. Thus this study proves that the length of the signal strip is primarily deciding the resonant frequency[4].

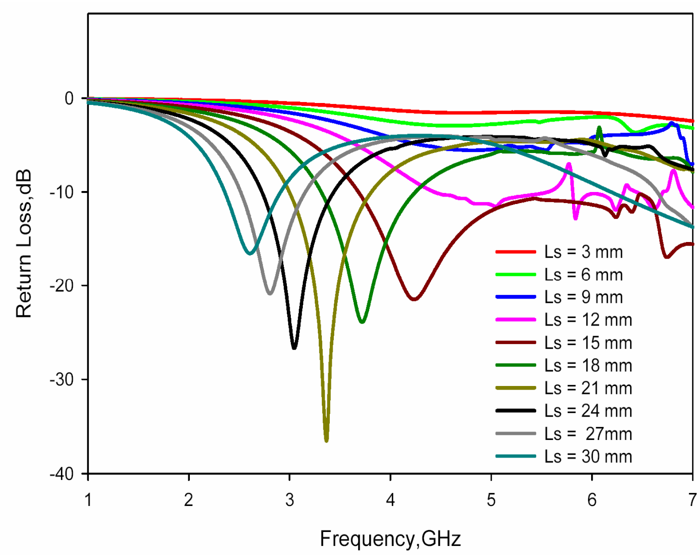

Figure 5: Effect of varying the length of the signal strip, Ls w = 3 mm, L_g = 21 mm, W_g= 8 mm and g = 0.5 mm, ε_r =4.4 ,h= 1.6 mm.

5. Ground plane width (WG) variation studies

As mentioned earlier the ground plane dimension is an important factor while the design of compact antenna is concerned. The Asymmetric Coplanar Strip uses only a single lateral ground strip compared to the twin lateral ground strips in the Coplanar Wave Guide feed. Hence the dimension of this single ground plane is expected to have far more effect on the performance of the antenna. The variation of return loss with the ground plane width is shown in Figure 6. The band width of the antenna varies with the ground plane width, W_g but the resonant frequency remains more or less the same even after large variations[5].

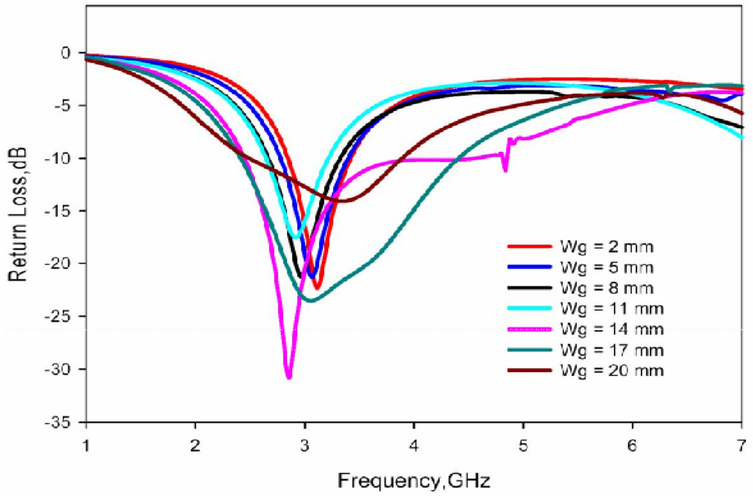

Figure 6: Ground width , WG variation studies.
Lm = 17 mm, Ls = 25 mm, w = 3 mm, LG = 21 mm,
and g = 0.5 mm, ER =4.4 ,h= 1.6 mm.

Since bandwidth enhancement is not the intension of our study, the optimum dimension is taken as Wg ≈ 0.3 Lg keeping in mind the compactness and impedance matching of the antenna.

6. Ground plane Length (LG) variation studies

The length of the ground plane is also found to be an important parameter affecting the resonant frequency and compactness of the antenna. It can be noted from Figure 7 that the ground plane length significantly affects the resonant frequencies and matching conditions of the antenna.

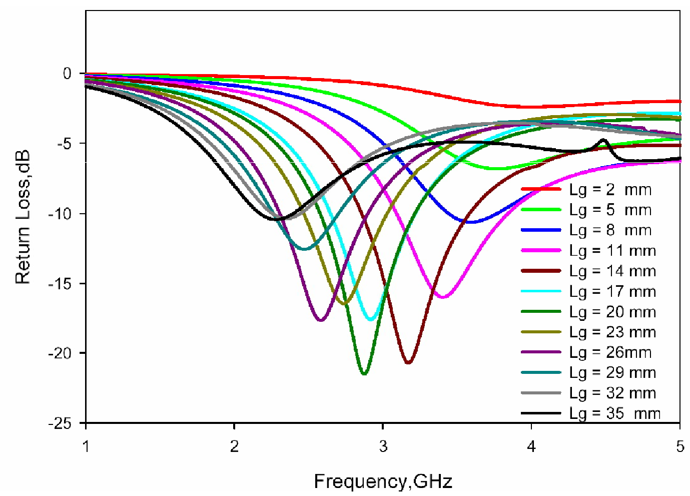

Figure 7: Ground plane length Lg variation studies.

As mentioned earlier when Lg is very much larger than ‘w’, the width of the signal strip, its effect on the characteristic impedance is less. Also the resonant frequency decreases with increase in the length of the ground plane and vice versa.

This study also explains the cause for the shift in the resonant frequency of the antenna (Figure 1) even when the length of the strip above the ground plane, Lm was taken equal to a quarter of the dielectric wavelength corresponding to the resonant frequency at 2.75 GHz. In this case the ground plane length, Lg is taken as 21 mm and not 25 mm as in the previous case .This causes the shift in the resonant frequency from 2.75 GHz to 3 GHz.

Lm = 17 mm, Ls = 25 mm, w = 3 mm, WG= 7 mm and g = 0.5, εr =4.4, h= 1.6 mm.

From the above studies It can be assumed that the total length of the antenna (monopole length Lm plus ground plane length Lg) may be determining the resonant frequency of the antenna. Thus the resonant frequency of the antenna is not simply due to the vertical strip Lm alone, but due to the combined effect of the ground plane and the signal strip.

To ascertain the above assumptions the current distribution in the antenna is pictured in Figure 8.

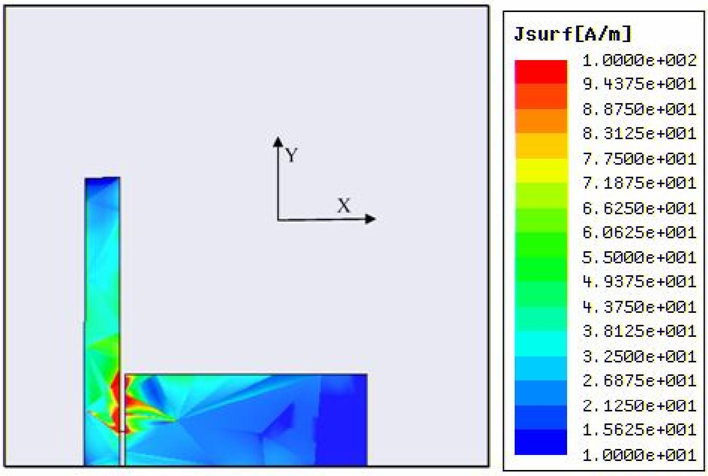

Figure 8: Current distribution in the antenna at the resonant frequency Lm = 17 mm, Ls = 25 mm, Lg = 21 mm, w = 3 mm, Wg= 7 mm and g = 0.5, εr =4.4 ,h= 1.6 mm.

It can be seen from the current distribution in the antenna that there is a quarter wave variation in the signal strip. In addition to this, there is a similar variation along the length of the ground plane also. But it is worth noting that the current variation in the ground plane is only along the edge, which therefore doesn’t perturb the asymmetric coplanar strip line characteristics. The antenna acts moreover like a dipole. This is a modification to the earlier assumption that the antenna acts like a quarter wavelength monopole.

From exhaustive studies it is found that the resonant frequency corresponds to nearly half of the dielectric wavelength corresponding to the total length of Lm + Lg of the antenna as shown in Figure 9.

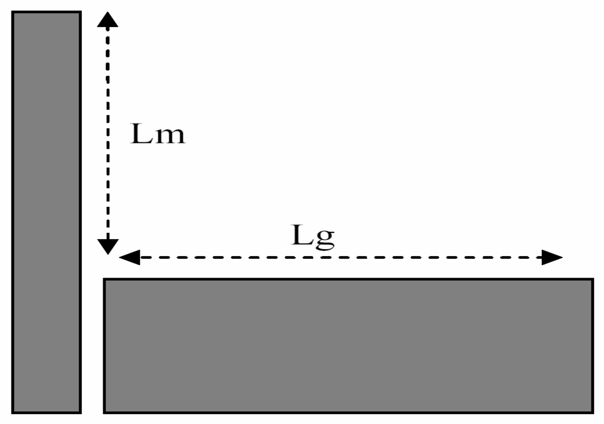

Figure 9: Current path in the antenna.

The observations may be mathematically given as

$$F = 0.55 \times \frac{30}{L \times \sqrt{\varepsilon eff}}$$

where $L = L_m + L_g$ and $\varepsilon_{eff} = (\varepsilon_r + 1 + 1)/3$ is the relative dielectric constant. where ε_r and 1 are the relative dielectric constant of the substrate and air and F is the resonant frequency. The antenna is fabricated on a substrate of dielectric constant 4.4 and height 1.6 mm.

It is also found that different combinations of the signal strip length and the ground plane length can give the same resonant frequency. To find out the optimum relation between L_m and L_g, a set of variation studies have been performed keeping the total length constant and is given in Figure 9.

7. Effect of various combinations of L_m and L_g on antenna performance

In this study the total current path ($L_1 + L_g$) is kept constant and the matching conditions are studied for various values of L_g and L_m. It is noted that the best matching is obtained when the ground plane length Lg is made equal to Lm + Wg/2 .i.e, when the mean length of both the arms are equal. When the ground plane length is far different from the vertical strip length the matching gets distorted. The optimized width of the ground plane is nearly taken as one third of its length.

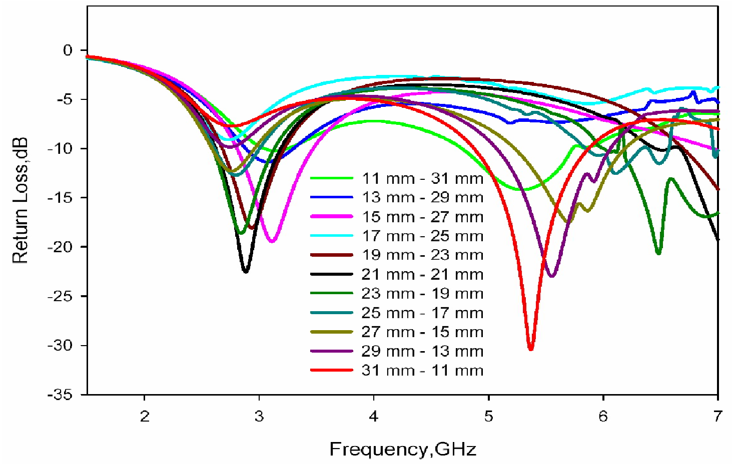

Figure 10: Ground plane variation studies keeping Lm + Wg/2 + Lg a constant ((Lm + Wg/2) – Lg variations are shown).

w = 3 mm, Wg= 8 mm and g = 0.5 mm, ε_r =4.4 ,h= 1.6 mm

The following conclusions can be derived from the above studies.

The resonance is due to the combined length of the signal strip (L_m) and the ground plane (Lg).

Good performance is noted when the length of the ground plane (Lg) is kept nearly equal to the strip length ($L_m + W_g/2$).

The above design offers more freedom for an antenna designer. For instance, once can design an antenna with a smaller radiating strip by increasing Lg . Also the resonance of the antenna is independent of Wg. So an optimum feed length can be selected based on the communication system space allocation.

8. Effect of the substrate height on antenna performance

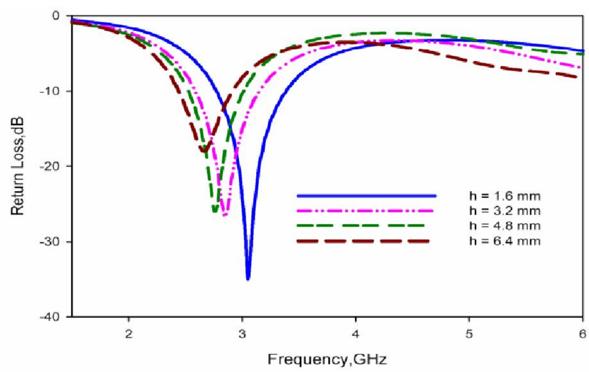

Figure 11: Effect of varying the height 'h' of the substrate.
Lm = 17 mm, Ls = 25 mm, w = 3 mm, Wg= 8 mm,
Lg = 25 mm and g = 0.5 mm, ε_r =4.4.

The effect of the height of the substrate on the performance of the antenna is depicted in Figure 12. The frequency decreases with increase in substrate thickness. The resonance at 3 GHz (for h =1.6 mm shifts to 2.7 GHz when the height is increased to 6.4 mm. Thus there is nearly 10 % frequency variation when the thickness is increased eight times.

9. Effect of varying the dielectric constant of the substrate

The return loss characteristic of antenna for different substrates is shown in Figure 12. When ε_r=2.2 the antenna is resonating at 3.3 GHz. The resonant frequency is found to be decrease with increase of dielectric constant as expected.

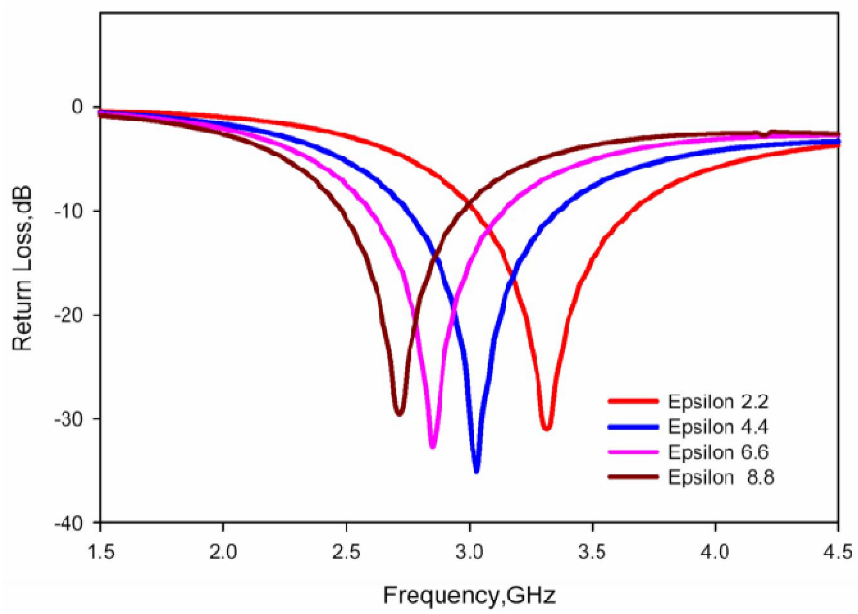

Figure 12: Variation of the resonant frequency
with the dielectric constant of the substrate.
Lm = 17 mm, Ls = 25 mm, Lg = 25 mm w = 3 mm, Wg= 8 mm,
Lg = 25 mm and g = 0.5 mm, h= 1.6 mm.

3.4.9 Radiation performance of the antenna

As mentioned earlier the pattern is similar to that of a dipole, but with a 45^{o} tilt. The tilt in the pattern is due to the asymmetry in the feed structure. The current distribution (Figure 8.) shows that the nearly equal X and Y directed currents are responsible for the 45^{o} tilt in the radiation pattern. This also increases the cross polar level compared to conventional monopoles.

10. Unbalanced to balanced transformation in the Antenna –Use of Balun

From the current distribution in the antenna shown in Figure 8, it can be seen that there is equal intensity current in the signal strip as well as the ground strip and the antenna is behaving nearly as a dipole. In all the above studies the antenna is directly fed using the coaxial connector. Since the Asymmetric Coplanar Strip feed is a balanced feed and the coaxial connector an unbalanced, the problem of unbalanced to balanced transformation arises. Hence a balun has to be used to compensate for this unbalance.

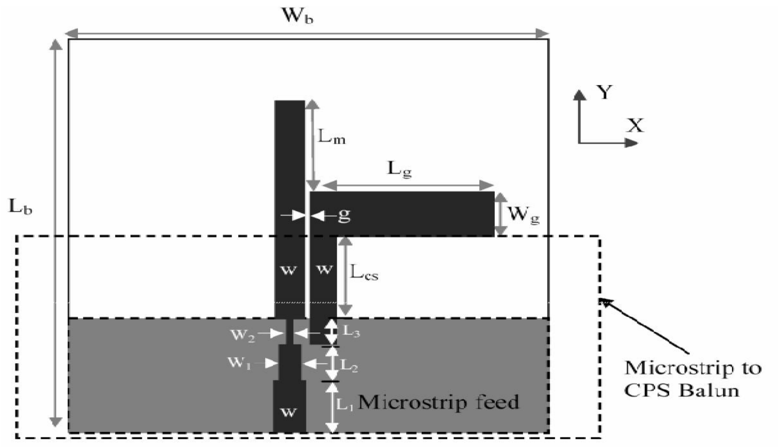

Figure 13: Geometry of the ACS fed Monopole with a Microstrip – CPS Balun
Lb= 75 mm, Wb=47mm, Lcs = 25 mm,w = 3 mm, Lg = 21 mm, Wg = 7 mm,
Lm = 17 mm,L1=5mm, L2=5mm, L3=5mm, w1=2mm,
w2=0.5mm, g = 0.3 mm, εr =4.4 ,h= 1.6 mm.

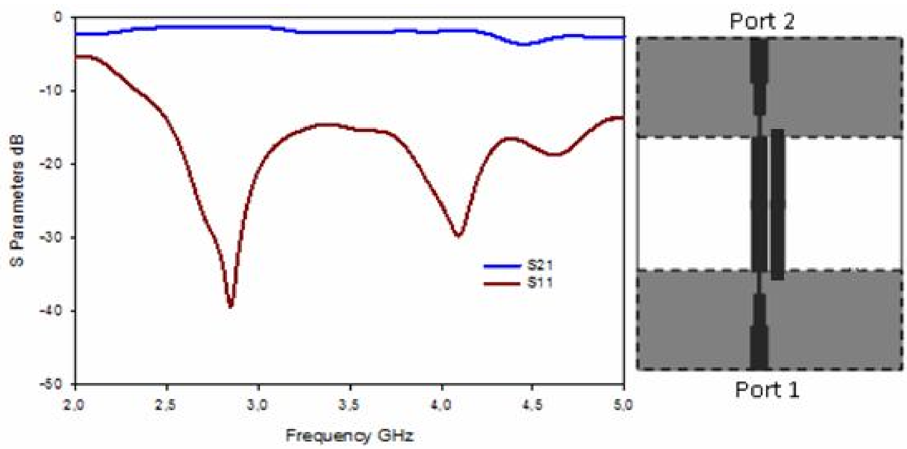

Figure 14: Back to back S parameters of the microstrip to CPS transition.
L_b= 75 mm, W_b=47mm, L_{cs} = 25 mm,w = 3 mm, Lg = 21 mm, W_g = 7 mm,
L_m = 17 mm,L_1=5mm, L_2=5mm, L_3=5mm, w_1=2mm,
w_2=0.5mm, g = 0.3 mm, ε_r =4.4, h= 1.6 mm.

But in all the previous studies even though a balun is not used, the antenna doesn’t show any degradation in performance. In order to substantiate this, the characteristics of the antenna are studied with and without a balun in this section.

Figure 3.22 shows the geometry of a ACS fed monopole with the balun mentioned in [4]. The Asymmetric coplanar strip fed monopole described in the previous section [section 3.4] is studied with and without a balun. The back to back S parameter characteristic of the microstrip to coplanar strip balun is given in Figure 14. It has to be noted that the back to back insertion loss twin balun system is -1.4 dBi at 3 GHz. Thus a single balun system has an insertion loss of -0.7 dBi.

The return loss curve of the antenna with and without the balun is shown in Figure 15. Both the antennas resonate at around 3 GHz. The use of balun excites higher order modes as shown in figure. Also a spurious resonance at 3.8 GHz is excited owing to the balun configuration. From the return loss curve it can be inferred that the antenna without the balun too exhibits nearly same impedance matching as that of the antenna using the balun.

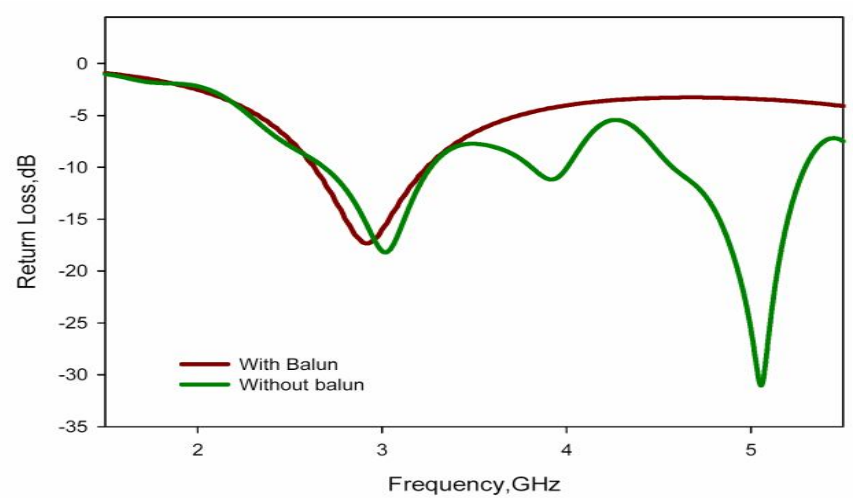

Figure 15: Return loss Curves of the antennas with and without the balun Lb= 75 mm, Wb=47mm, Lcs = 25 mm,w = 3 mm, Lg = 21 mm, Wg = 7 mm, Lm = 17 mm,L1=5mm, L2=5mm, L3=5mm, w1=2mm, w2=0.5mm, g = 0.3 mm, ε_r =4.4 ,h= 1.6 mm

Conclusion

Finally it can be concluded that the Asymmetric Coplanar Strip Fed antenna exhibits all the advantages of conventional monopoles with nearly 46 % area reduction except a tilt in the radiation pattern. Owing to the uniplanar nature many integrated devices can be embedded into these antennas. All the reflection and radiation characteristics of the Asymmetric Coplanar Strip fed antenna are similar to antennas using conventional feeding mechanisms.

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