5.1 INTRODUCTION

The enclosed single and edge coupled conductor-backed CPW (CBCPW) structures shown in Fig. 5.1a&b, support the dominant and higher order modes of single and edge coupled CBCPW along with the various waveguide modes of the structure. The waveguide modes mainly affect the circuit properties as defined by the fundamental even and odd modes in two ways: first is discontinuity coupling and the second one is synchronous coupling [128].

The discontinuity coupling is generated at any discontinuity in the circuit, between the modes of dielectric filled metal waveguide and empty waveguide sections to the dominant (edge coupled CBCPW in this case) modes and increases in intensity with frequency.

The second one, synchronous coupling, occurs between the dominant modes (of edge coupled CBCPW) and the various waveguide modes of the structure above a specific frequency, where the two modes have the same phase velocity $V_p$. Above this frequency, energy exchange between the dominant and parasitic waveguide modes becomes excessive and the circuit is unusable. Also, the synchronous coupling affects the high frequency spectral part of a narrow pulse causing power leakage. Some times, the leakage attenuation rate for higher frequencies becomes so large that such a structure exhibits low-pass-like filtering characteristics [128].

In practice, the synchronous coupling has greater significance. To avoid the synchronous coupling in conductor-backed CPW, dielectric line compensation has been proposed [73]. Basically, the dielectric line compensation increases the phase shift constant of dominant modes relative to that of the waveguide modes. This increases the difference between phase velocities of dominant and waveguide modes and hence leads to a reduction in synchronous coupling.

It is shown clearly in Section 3.4 with the help of dispersion characteristics and the corresponding frequency dependent field configurations that the various modes of the structures
Figure 5.1
(a) Conductor backed coplanar waveguide (CBCPW);
(b) Edge coupled conductor backed coplanar waveguide;
(c) Dielectric loaded edge coupled conductor backed coplanar waveguide.
shown in Fig. 5.1a and b undergo synchronous coupling. The main objective of this chapter is to avoid the synchronous coupling in edge coupled CBCPW structure with the help of dielectric loading (Fig. 5.1c). The other important parameters of a coupled section are isolation, coupling factor and band-width. Here we study for the first time the characteristics of various dielectric-loaded edge coupled CBCPW structures with respect to mode coupling and the above parameters. Next, for the optimum type of dielectric loading (with respect to synchronous coupling, isolation, coupling factor and bandwidths), the effect of variation of enclosure and other parameters such as slot and conductor widths, has been carried out.

This chapter is divided into five sections as described below. Section 5.2 gives the derivation of system equation using the method of lines for the dielectric-loaded CBCPW shown in Fig. 5.1c. Next, Section 5.3 gives the dispersion characteristics including first two higher order modes and characteristic impedance for various types of dielectric loading, viz. centre slot (Section 5.3.1), outer slots (Section 5.3.2), and partial and complete overlay (Section 5.3.3). Section 5.4 presents a detailed study on the effect of enclosure on cut-off frequency of the first higher order mode which affects the bandwidth of the structure. Also, the dispersion characteristics and characteristic impedance of dominant even and odd modes are given. Finally, Section 5.5 deals with the effect of variation in strip and slot widths on dispersion and characteristic impedance to serve as an aid in designing the coupled section.

5.2 DERIVATION OF SYSTEM EQUATION

Figure 5.1c shows the cross section of the enclosed dielectric-loaded edge coupled CBCPW structure with layer I, II & III. The layer II of dielectric-loaded edge coupled CBCPW may contain various regions with different dielectric constants. To characterize such structures one follows the analysis given in section 2.2. To obtain the system equation one considers equation (2.3.5), which gives the relation between tangential electric and magnetic fields in the transformed domain. Repeating equation 2.35.

\[
\begin{bmatrix}
\hat{H}_A \\
\hat{H}_B
\end{bmatrix} =
\begin{bmatrix}
\tilde{y}_1 & \tilde{y}_2 \\
\tilde{y}_2 & \tilde{y}_1
\end{bmatrix}
\begin{bmatrix}
\tilde{E}_A \\
-\tilde{E}_B
\end{bmatrix}
\]

(5.1)

where various symbols have been described in Section 2.2. At the metallization interface, the
tangential magnetic field and current density are related by

\[ \hat{H}_m - \hat{H}_m = -\tilde{J}_m \]  \hspace{1cm} (5.2)

where \( \hat{H}_m \) and \( \hat{H}_m \) are the transformed tangential magnetic fields above and below the metallization interface. Next, \( \hat{H}_m \) can be obtained in a similar way as described in Chapter IV, section 4.2. Reproducing equation (4.8)

\[ \hat{H}_A = \hat{H}_m = \left[ \tilde{y}_1 - \tilde{y}_2 (\tilde{y}_1 + \tilde{y}_2)^{-1} \tilde{y}_2 \right] \tilde{E}_A \]  \hspace{1cm} (5.3)

To obtain \( \hat{H}_m \), one has to apply eqn. (5.1) to layers III with \( \tilde{E}_A = 0 \) (because of the bottom conducting wall)

\[ \hat{H}_B = \hat{H}_m = -\tilde{y}_1 \tilde{E}_B \]  \hspace{1cm} (5.4)

Application of the continuity condition for the tangential electric field at the metallization interface \( \left( \tilde{E}_A = \tilde{E}_B = \tilde{E} \right) \) and substitution of equations (5.3) and (5.4) in equation (5.2) yields

\[ \left[ \tilde{y}_1 - \tilde{y}_2 (\tilde{y}_1 + \tilde{y}_2)^{-1} \tilde{y}_2 \right] \tilde{E} = \tilde{Y} \tilde{E} = -\tilde{J}_m \]  \hspace{1cm} (5.5)

Finally, transforming the eqns. (5.5) into the spatial domain and equating to zero the current on the lines which are in slots, one gets the required Eigen value equation:

\[ [Y]_{\text{red}} E_k = 0 \]  \hspace{1cm} (5.6)

Once again, for the symmetric structure considered here, the characteristic impedance of the dominant even and odd modes are defined as
\[ Z_0 = \frac{V}{I} \] 

(5.12)

where \( V \) is the voltage across the strip conductor and ground plane, and \( I \) is the total current on the one of the strips.

5.3 DISPERSION CHARACTERISTICS AND CHARACTERISTIC IMPEDANCE FOR DIFFERENT TYPES OF DIELECTRIC LOADING

The dispersion characteristics and characteristic impedance of edged coupled CBCPW structure without dielectric loading (\( h_2 = 0 \) in Fig. 5.1c) are given in Fig. 5.2. The various dimensions are \( h_1 = 2.5 \text{ mm}, h_2 = 2.117 \text{ mm}, w = 0.5 \text{ mm}, s_1 = s_2 = 0.3 \text{ mm}, \ a = 6 \text{ mm}, \ \varepsilon_{r5} = 2.22 \). Mode 1, the dominant even mode, with magnetic wall at the symmetry plane \( x = a/2 \), suffers rapid dispersion after 20 GHz. It is due to the synchronous coupling with mode 4, which is TE\(_{10}\) mode of the dielectric filled metal waveguide. Because of this mode coupling the characteristic impedance for mode 1 also has a rapid fall. Beyond 20 GHz, mode 1 converts into TE\(_{10}\) mode of the dielectric filled metal waveguide and the slot voltage used for calculating the characteristic impedance equation (5.12) reduces rapidly. The dotted curves in Fig. 5.2 are the approximated curves which would have been obtained in the absence of synchronous coupling. The dominant odd mode (mode 2) propagates without such dispersion up to 50 GHz. Then it couples to mode 3, which is a finline like mode. The sharp drop in the characteristic impedance value for this mode also corresponds to the same frequency. The sharp drop in the characteristic impedance value for this mode also corresponds to the same frequency. Also, at 80 GHz this mode apparently couples to another higher order mode causing further dispersion at that frequency.

Clearly, synchronous coupling is quite prominent in the edge-coupled CBCPW structures. To avoid the synchronous coupling in conductor-backed edge coupled CPW structures, the dielectric loading, as described in section 5.1, is adopted. In the following sub sections, we give a detailed study of the various types of dielectric loading which are shown in Figs. 5.3a-d.
Figure 5.2  Dispersion characteristics and characteristic impedance of dominant and first two higher order modes for edge coupled CBCPW (Fig. 5.1b) with $h_1 = 2.5$ mm, $h_2 = 2.117$ mm, $w = 0.5$ mm, $s_1 = s_2 = 0.3$ mm, $a = 6.0$ mm, $e_r = 2.22$. 
Figure 5.3  Dielectric loaded edge coupled CBCPW structures:
(a) Dielectric loading of centre slot;
(b) Dielectric loading of outer slot;
(c) Partial dielectric overlay;
(d) Complete dielectric overlay.
5.3.1 Dielectric Loading of Centre Slot

The enclosed edge coupled CBCPW with dielectric loading of the centre is slot shown in Fig. 5.3a.

![Graph showing dispersion characteristics and characteristic impedance for enclosed edge coupled CBCPW with dielectric loading of centre slot.](image)

**Figure 5.4 (a)** Dispersion characteristics and characteristic impedance for enclosed edge coupled CBCPW with dielectric loading of centre slot (Fig. 5.3a) with \( h_1 = 2.5 \text{ mm} \), \( h_2 = 0.254 \text{ mm} \), \( h_3 = 2.117 \text{ mm} \), \( w = 0.5 \text{ mm} \), \( s_1 = s_2 = 0.3 \text{ mm} \), \( a = 6.0 \text{ mm} \), \( b = 0.32 \text{ mm} \), \( \epsilon_{r2} = \epsilon_{r3} = 2.22 \).
The dispersion characteristics up to 100 GHz are presented in Figs. 5.4a and b for $\varepsilon_{r2} = 2.22$ and 10.2, respectively. The other dimensions are $h_1 = 2.5$ mm, $h_2 = 0.254$ mm, $h_3 = 2.117$ mm, $w = 0.5$ mm, $s_1 = s_2 = 0.3$ mm, $a = 6$ mm, $b = 0.32$ mm, $\varepsilon_{r3} = 2.22$. The dispersion characteristics given in Fig. 5.4a, show considerably reduced mode coupling for the dominant odd mode (mode 2). For this mode, the field has significant concentration over the centre slot because of an
electric wall at symmetry plane x = a/2. The dielectric loading of this slot, therefore, increases the phase shift constant of this mode. Due to the dielectric loading, the sharp minima in characteristic impedance also shift from 50 GHz to 72 GHz, indicating that the frequency of synchronous coupling has shifted to 72 GHz. On the other hand, the dominant even mode (mode 1) has little change in dispersion and characteristic impedance behaviour. This is expected since there is very little field concentration over the centre slot for the even mode.

Fig. 5.4b presents the results for $\varepsilon_{r2} = 10.2$. The phase constant of dominant odd mode increases substantially, due to the high $\varepsilon_{r2}$, thus avoiding the synchronous coupling. The characteristic impedance has no sharp minimum as in Figs. 5.2 and 5.4a because of no mode coupling. The characteristic impedance reduces because of high $\varepsilon_{r2}$ at the centre slot. The characteristics of the dominant even mode (mode 1) show no change because of the same reason as given above for $\varepsilon_{r2} = 2.22$. To improve the characteristics for the dominant even mode, the dielectric loading of outer slots is studied next.

### 5.3.2 Dielectric Loading of Outer Slots

For the shielded edge coupled CBCPW with dielectric loading of outer slots, shown in Fig. 5.3b, with $\varepsilon_{r2} = 10.2$, the dispersion characteristics and characteristic impedance are shown in Fig. 5.5. The other parameters of the structure are as in previous section. The dielectric loading of outer slots increases the phase constant of both dominant even and odd modes in comparison to the edge coupled CBCPW without dielectric loading as shown in Fig. 5.2. This is due to the existence of field for both the modes in outer slots. Fig. 5.5 also shows that, both even and odd modes are not undergoing any synchronous coupling as the effective dielectric constant of both the modes is above 2.22, which is the maximum possible effective dielectric constant of the dielectric filled metal waveguide modes.

The characteristic impedance of both even and odd modes merges at higher frequencies due to the concentration of more fields in the outer slots due to the dielectric loading. Because of this the coupling factor also reduces very much, which is the main drawback of this configuration.
Dielectric Overlay

The dispersion characteristics and characteristic impedance of edge coupled CBCPW with partial dielectric overlay (Fig. 5.3c) are given in Figs. 5.6a and b for dielectric constants $\varepsilon_{r2} = 10.2$ and 2.22, respectively; the parameters used are the same as before with $b = 2.025$ mm. The dispersion characteristics for $\varepsilon_{r2} = 10.2$, given in Fig. 5.6a, show the effective dielectric constant

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**Figure 5.5** Dispersion characteristics and characteristic impedance for enclosed edge coupled CBCPW with dielectric loading of outer slots (Fig. 5.3b) with $\varepsilon_{r2} = 10.2$ and other parameters are same as in Fig. 5.4a.

5.3.3 Dielectric Overlay

The dispersion characteristics and characteristic impedance of edge coupled CBCPW with partial dielectric overlay (Fig. 5.3c) are given in Figs. 5.6a and b for dielectric constants $\varepsilon_{r2} = 10.2$ and 2.22, respectively; the parameters used are the same as before with $b = 2.025$ mm. The dispersion characteristics for $\varepsilon_{r2} = 10.2$, given in Fig. 5.6a, show the effective dielectric constant
of both dominant even and odd modes to be higher as compared to the dielectric loading of centre and outer slots given in Sections 5.3.1 and 5.3.2 respectively. Due to the large shift in the phase constants of dominant even and odd modes, the synchronous coupling is completely avoided. Because of this there is less variation in characteristic impedance values for both even

\[
(\beta/k_0)^2 = e_{r_{eff}}
\]

Figure 5.6 (a) Dispersion characteristics and characteristic impedance for enclosed edge coupled CBCPW with partial dielectric overlay (Fig. 5.3c) with \( e_{r2} = 10.2, \ b = 2.025 \) and other parameters are as in Fig. 5.4a.
and odd modes. The characteristic impedance at low frequencies of both dominant modes is reduced compared to unloaded structure because of the increase in capacitance due to the dielectric loading of all three slots. The only disadvantage of this configuration is that the phase constants of the two modes are not equal, which results in poor isolation.

Figure 5.6 (b) Dispersion characteristics and characteristic impedance for enclosed edge coupled CBCPW with partial dielectric overlay (Fig. 5.3c) with \( \varepsilon_r = 2.22 \), \( b = 2.025 \) and other parameters are as in Fig. 5.4a.
The dispersion characteristics and characteristic impedances for $\varepsilon_{r2} = 2.22$ are shown in Fig. 5.6b. This configuration mainly improves the isolation characteristics by reducing the difference between phase constants of the dominant even and odd modes. There is no synchronous coupling in the dominant odd mode, but the dominant even mode undergoes synchronous coupling with $TE_{10}$ mode of dielectric filled metal waveguide. The mode coupling in the dominant even mode can be reduced by increasing the cut-off frequency of $TE_{10}$ dielectric filled metal waveguide mode. The low frequency characteristic impedance of dominant even and odd modes are higher compared to the case with $\varepsilon_{r2} = 10.2$ due to the reduction in capacitance. The characteristic impedance of the odd mode is almost constant with frequency, but that of the even mode changes sharply due to the mode coupling.

The results for the edge coupled CBCPW structure with complete dielectric overlay (Fig. 5.3d) are presented in Fig. 5.7 with $\varepsilon_{r2} = 10.2$, for the same dimensions as given above. With the complete dielectric overlay the cut-off frequency of the first higher order mode goes down leading to reduction in single mode band width. Also the complete overlay requires more dielectric material compared to the partial dielectric overlay although the difference in the remaining characteristics of the two cases is very little.

To decide the optimum type of dielectric loading, the characteristics of various dielectric loadings are summarized here. The edge coupled CBCPW without any dielectric loading offers high isolation and high coupling factors at low frequencies. The bandwidth of this structure for pulse signals is very limited because of the synchronous coupling in both dominant even and odd modes. Otherwise the single mode band-width is high in comparison with dielectric-loaded edge coupled CBCPW structures. Next, the characteristics with dielectric loading of the centre slot, as shown in Figs. 5.4a and b, exhibit reduced mode coupling only for the dominant odd mode. For dielectric loading of the outer slots, as shown by the characteristics in Fig. 5.5, there is no synchronous coupling, but the characteristic impedance varies sharply; this leads to very low coupling factors at high frequencies limiting the bandwidth of the structure. This mode coupling phenomenon is particularly restrictive for pulsed signals, because sometimes the leakage becomes so high that the CPW exhibits low-pass like filtering characteristics. This mode-
coupling phenomenon can be eliminated with the partial dielectric overlay leading to the structure which can be used for broad-band applications. The results of the edge coupled CBCPW with partial overlay as shown in Fig. 5.6a for $\varepsilon_{r_2} = 10.2$, yield good coupling factor and eliminate mode coupling but the ratio of $\varepsilon_{\text{eff}}$ for the dominant even and odd modes is 0.8, leading to poor isolation. This can be improved upon by a partial overlay with $\varepsilon_{r_2} = 2.22$ as shown by the results in Fig. 5.6b, and better isolation characteristics. This configuration suffers from mode coupling to some extent which can be reduced by increasing the cut-off frequencies.
of higher order modes with an appropriate enclosure. On the basis of the above arguments edge coupled CBCPW with partial overlay is considered to be the optimum configuration for the broad-band applications. In the next two sections the effect of the enclosure and other parameters of the edge coupled CBCPW are studied for this configuration.

5.4 **EFFECT OF ENCLOSURE**

To provide protection to the circuit from environmental factors, usually the circuits/components are kept in a metal enclosure. Sometimes, the enclosure adversely affects the circuit performance due to the parasitic modes generated by the enclosure/packaging. The dimensions of the enclosure have to be chosen appropriately to improve the performance of the circuit. Also, the parasitic modes are responsible for synchronous coupling above a certain frequency leading to excessive leakage of power from the dominant mode. Here we carry out a study on the effect of enclosure on the dispersion characteristics, characteristic impedance and the cut-off frequency of the first higher order mode.

5.4.1 **Variation of Height of the Enclosure**

The dispersion characteristics and characteristic impedance of edge coupled CBCPW with partial overlay (Fig. 5.3c), with parameters $h_2 = 0.254$ mm, $w = s_1 = s_2 = 0.3$ mm, $a = 6$ mm, $b = 1.9$ mm, $\varepsilon_{r2} = \varepsilon_{r3} = 2.22$, up to 100 GHz are shown in Fig. 5.8 for the following two sets:

(i) $h_1 = 2.5$ mm and $h_3 = 2.117$ mm

(ii) $h_1 = 1.0$ mm and $h_3 = 1.0$ mm

From Fig. 5.8, one observes that variation of $h_1$ and $h_3$ has no significant effect on the dispersion characteristics of dominant even and odd modes. The characteristic impedance of the dominant even mode has decreased with the reduction in height. This is due to the magnetic wall at the symmetry plane $x = a/2$, which leads to the concentration of field only in the outer slots. For the even mode at low frequencies, more field lines terminate on the enclosure leading to reduction in characteristic impedance. For the dominant odd mode, there is not much effect in both dispersion and characteristic impedance with the change in height.
Next, the cut-off frequency of finline like mode, which results from an electric wall at the centre, increases with the decrease in \( h_1 \) and \( h_3 \) due to the change in the dimensions of the corresponding waveguide. The \( \text{TE}_{10} \) mode of the dielectric filled metal waveguide, which results
from a magnetic wall, has very little change since the width in lateral direction remains unchanged. The cut-off frequency of this mode primarily depends on the width of waveguide. To summarize, the decrease in height of the enclosure affects the performance mainly in two ways: first, the cut-off frequency of finline like mode increases and second, the characteristic impedance of the dominant even mode decreases.

5.4.2 Variation of Width of the Enclosure

For the edge coupled CBCPW with partial dielectric overlay (Fig. 5.3c) with dimensions $h_1 = h_3 = 1.0$ mm, $h_2 = 0.254$ mm, $w = s_1 = s_2 = 0.3$ mm, $\varepsilon_{r2} = \varepsilon_{r3} = 2.22$, the dispersion characteristics and characteristic impedance are shown in Fig. 5.9 for the two sets of lateral dimensions given below:

(i) $a = 6.0$ mm and $b = 1.9$ mm

(ii) $a = 4.0$ mm and $b = 1.525$ mm

From Fig. 5.9, one notices that the reduction in the width of the enclosure mainly affects the cut-off frequencies of the finline like mode and the $\text{TE}_{10}$ mode of dielectric filled metal waveguide. Reduction in $b$ also contributes to an increase in the cut-off frequency of the fine-line like mode. Due to the increase in the cut-off frequency of the $\text{TE}_{10}$ mode, the synchronous coupling with the dominant even mode reduces, which in turn lowers the dispersion in dominant even mode. The reduction in mode coupling also reduces the variation in the dominant even mode characteristic impedance over the frequency range of 100 GHz.

The reduction in the width of the enclosure does not have much effect on the dispersion and characteristic impedance behavior of the dominant odd mode. The other characteristics, viz., mode coupling, dispersion, characteristic impedance and band width of the structure also improve with the reduction in “a”. This configuration would also yield good isolation characteristics. For this configuration, design data for various values of $w$, $s_1$ and $s_2$ is presented in the next section.
Figure 5.9  Dispersion characteristics and characteristic impedance for enclosed edge coupled CBCPW with partial dielectric overlay (Fig. 5.3c) with \( h_1 = h_3 = 1.0 \text{ mm}, h_2 = 0.254 \text{ mm}, w = s_1 = s_2 = 0.3 \text{ mm}, e_r_2 = e_r_3 = 2.22 \) for the two sets of a & b

i)  \( a = 6.0 \text{ mm}, \) and \( b = 1.9 \text{ mm}; \)

ii) \( a = 4.0 \text{ mm}, \) and \( b = 1.525 \text{ mm}. \)

5.5 EFFECT OF VARIATION OF SLOT AND STRIP WIDTH

This section presents detailed study on the effects of variation in parameters of edge coupled CBCPW with partial overlay. The parameters varied are width of outer slots \((s_2)\), width of centre strips \((w)\) and width of centre slot \((s_1)\). The dispersion characteristics of the first four
modes and the characteristic impedance of the dominant even and odd modes have been obtained for different values of $w$, $s_1$ and $s_2$. The data generated and presented here is expected to help in understanding the effects of variation in slot and strip widths. In addition, it should prove useful for practical circuit design.

Figure 5.10 (a) Dispersion characteristics of enclosed edge coupled CBCPW with partial dielectric overlay (Fig. 5.3c) with $h_1 = h_2 = 1.0$ mm, $h_3 = 0.254$ mm, $w = s_2 = 0.3$ mm, $a = 4.0$ mm, $b = 1.525$ mm, $\varepsilon_{r2} = \varepsilon_{r3} = 2.22$ and for different values of $s_1 = 0.1, 0.3, 0.5$ mm.
Figure 5.10 (b) Characteristic impedance of enclosed edge coupled CBCPW with partial dielectric overlay (Fig. 5.3c) for different values of $s_1 = 0.1, 0.3, 0.5$ mm and other parameters are as in Fig. 5.10a.
5.5.1 Variation of Outer Slot Width

The dispersion characteristics and characteristic impedance of edge coupled CBCPW with partial dielectric overlay (Fig. 5.3c), are presented in Figs. 5.10a and b, respectively. The results have been calculated for $h_1 = h_3 = 1.0 \text{ mm}$, $h_2 = 0.254 \text{ mm}$, $w = s_2 = 0.3 \text{ mm}$, $a = 4.0 \text{ mm}$, $b = 1.525 \text{ mm}$, $\varepsilon_{r2} = \varepsilon_{r3} = 2.22$ and for $s_1 = 0.1$, 0.3, 0.5 mm. Fig. 5.10a shows the dispersion characteristics of the dominant even and odd modes, finline like mode and TE$_{10}$ mode of dielectric filled metal waveguide for different values of $s_1$. The characteristic impedances of dominant even and odd modes up to 100 GHz are given in Fig. 5.10b. There is considerable field over the outer slots for both even and odd modes as shown in Chapter III, Section 3.4, but the even mode with magnetic wall at the centre has more fields in the outer slots compared to that for the odd mode. Due to this, the change in the dispersion characteristics of dominant even mode is more with the variation in $s_1$ compared to that for the dominant odd mode. The cut-off frequency of the finline like mode (with electric wall at the symmetry plane) increases uniformly with the increase in the outer slot width. The cut-off frequency of the TE$_{10}$ mode of dielectric filled metal waveguide has very little change with the variation in $s_1$; at higher frequencies the phase shift constant reduces because of greater penetration in the air region with increase in $s_1$.

The variation of characteristic impedance of the dominant even mode for $s_1 = 0.1 \text{ mm}$ is the smoothest with frequency due to strong confinement of field over the slot. For dominant odd mode the characteristic impedance decreases with the increase in outer slot width because of the increase in $s_1/w$. It is known that in coplanar waveguides the characteristic impedance mainly depends on the strip to slot width ratio.

5.5.2 Variation of Centre Strip Width

For other structural parameters identical to the previous section but $s_1 = 0.3 \text{ mm}$, $w = 0.1$, 0.3, 0.5 mm, the dispersion characteristics and characteristic impedance are shown in Figs. 5.11a and b, respectively. The dispersion characteristics shown up to 100 GHz include dominant even and odd modes, finline like mode and TE$_{10}$ mode of dielectric filled metal waveguide. The phase constant of the dominant odd and even modes (with electric and magnetic walls at $x = a/2$) decrease uniformly with the increase in strip width due to the distribution of more field in layer I. For the same reason, the cut-off frequency of the finline like mode increases with the rise in
The TE$_{10}$ mode of the dielectric filled metal waveguide changes only slightly with the variation in $w$.

The characteristic impedance (defined as the ratio of voltage at outer slot to the current on the centre strip) of both dominant even and odd modes, shown in Fig. 5.11 b, decreases with the increase in centre strip width since the current on the centre strip increase with the increase in $w$. 

**Figure 5.11 (a)** Dispersion characteristics of enclosed edge coupled CBCPW with partial dielectric overlay (Fig. 5.3c) for different values of $w = 0.1, 0.3, 0.5$ mm and $s_i = 0.3$ mm, other parameters are as in Fig. 5.10a.
The shift in characteristic impedance is uniform throughout the frequency range for different values of strip width.

**Figure 5.11 (b)** Characteristic Impedance of enclosed edge coupled CBCPW with partial dielectric overlay (Fig. 5.3c) for different values of $w = 0.1, 0.3, 0.5 \text{ mm}$ and $s_i = 0.3 \text{ mm}$, other parameters are as in Fig. 5.10a.
5.5.3 Variation of Centre Slot Width

The dispersion characteristics and characteristic impedance of edge coupled CBCPW with partial dielectric overlay (Fig. 5.3c) with \( s_2 = 0.1, 0.3, 0.5 \) mm are shown in Fig. 5.12a and b respectively. The other structural parameters remain unchanged. Fig. 5.12a shows the dispersion characteristics of the first four modes and Fig. 5.12b.
A study of different types of dielectric loadings has been carried out to improve the characteristics, viz., dispersion and characteristic impedance, of enclosed edge-coupled CBCPW with respect to mode-coupling, for applications in pulsed signals. Next, the effects of enclosure
dimensions have been studied for the optimum dielectric loading i.e., the partial dielectric overlay with $\varepsilon_{r3} = 2.22$, to enhance the single mode bandwidth. Finally, the design data is obtained with the variation of different strip and slot widths.