Volume 2, Issue 4, Apr 2026 https://doi.org/10.5281/zenodo.19692876 ISSN : 3139-1478

STUDY OF PLANAR TRANSMISSION STRUCTURE

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***Abstract*—Stripline is a modified version of triplet structure, the first member of the planar transmission line family. It consists of a flat strip conductor placed symmetrically between two large ground planes with the intervening space homogenously filled with a dielectric substrate. The field lines concentrate around the strip conductor and decay rapidly with distance away from the strip in the lateral directions. The dominant mode of propagation is pure TEM. Microstripline is another member of planar transmission structure consisting of a metal strip attached with a dielectric substrate supported by metal plates which is the simplest and open structure used even in high frequency. The present work aim at the study of characteristic parameters of coupled microstripline composed of two metal strips placed in parallel with each other having a small spacing.**

***Index Terms*—Impedance, and Permittivity.**

I. Introduction

Because of the coupling of electromagnetic fields, a pair of coupled lines can support two different modes of propagation. These modes have different characteristic impedances. For coupled microstrip line the dielectric medium is not homogeneous. A part of the field extended into the air above the substrate [1]. This fraction is different for the two modes of coupled lines. Consequently, the effective dielectric constants and the phase velocities are not equal for the two modes. This non synchronous feature deteriorates the performance of circuits using these types of coupled lines. When the two lines of a coupled line pair are identical then it is symmetrical configuration and is useful for simplifying the analysis and design. This method of analysis takes into account the coupling between quassi-TEM mode along the microstrip line and TM_{10} surface wave mode on the dielectric substrate with metallization on the bottom surface reported by Hartwig et. al and John et. al.

The study of planar transmission structures involves analyzing flat, two-dimensional metallic patterns on dielectric substrates used to guide electromagnetic waves, primarily at microwave and radio frequencies. These structures are the foundation of **Microwave Integrated Circuits (MICs)** and **Monolithic Microwave Integrated Circuits (MMICs)** due to their compact size, low cost, and ease of fabrication.

Core Planar Transmission Structures

The most common types of planar transmission lines vary based on their conductor and ground plane arrangements:

- **Microstrip Line**: Consists of a conducting strip on top of a dielectric substrate with a single ground plane on the bottom. It is the most popular type due to its ease of mounting active and passive components.
- **Stripline**: A center conductor is sandwiched between two parallel ground planes, completely surrounded by a dielectric. It supports a pure **TEM (Transverse Electromagnetic) mode**, making it free of dispersion.

- **Coplanar Waveguide (CPW)**: The signal conductor and both ground planes are on the *same* top surface of the substrate. This eliminates the need for via holes for grounding, simplifying surface-mount component integration.
- **Slotline**: A narrow gap etched into a conducting layer on one side of a dielectric substrate. It is often used for shunt-mounting components and creating filters.
- **Substrate Integrated Waveguide (SIW)**: A newer technology that simulates a traditional rectangular waveguide by using two rows of metallic via holes in a planar substrate. It offers higher power handling and lower radiation loss than microstrip.

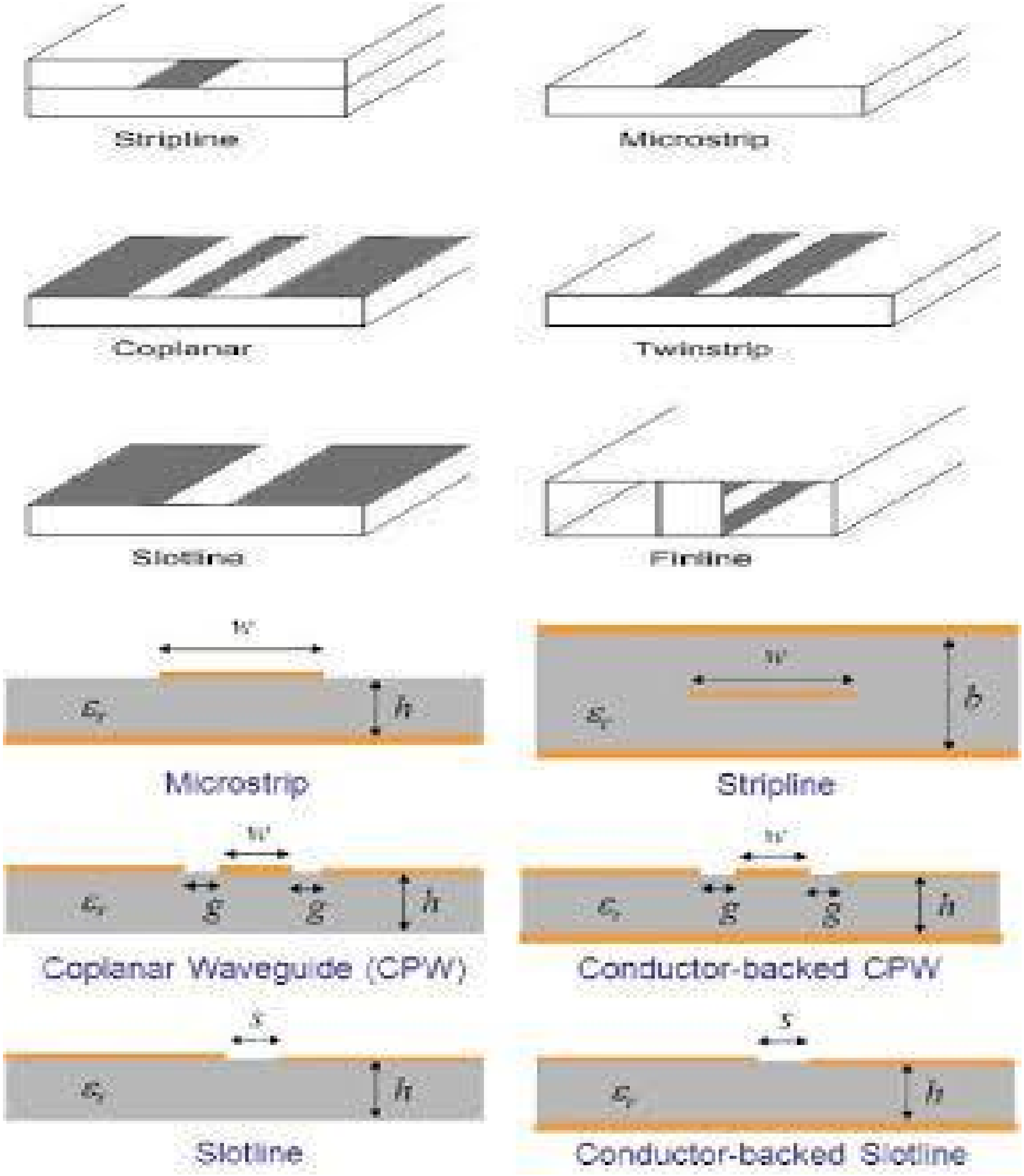

Fig 1 Different types of Planar Transmission Structure

Key Design Parameters

Analysis typically focuses on how physical dimensions affect electrical behaviour:

- Characteristic Impedance (Z_0): Controlled by the width of the conductor (w), spacing (s), and the height (h) of the dielectric substrate.
- Effective Dielectric Constant (ϵ_{reff}): For open structures like microstrip, the field exists in both the dielectric and air, requiring a weighted average for calculations.

- Propagation Modes: Most planar lines support quasi-TEM modes where the fields are almost entirely transverse to the direction of travel.
- Losses: Designers must account for conductor (ohmic) loss, dielectric loss, and radiation loss, which increases at higher frequencies.

II. FORMULATION OF EVEN AND ODD MODE CHARACTERISTIC IMPEDANCE

The coupled microstripline and its field configurations are shown in figure 1 and figure 2 a & 2 b.

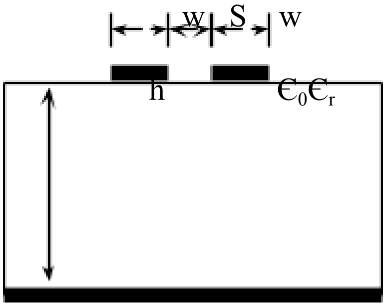

Fig 2Coupled microstrip (cross-section)

Fig 2 a The Even-mode forward Coupling

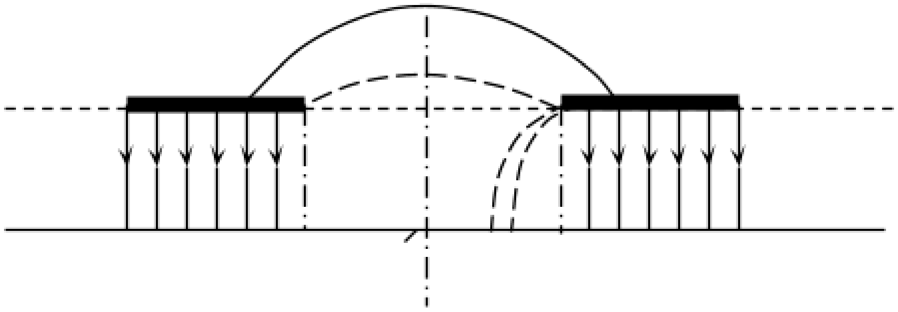

Fig 2 b The odd mode reverse coupling

The derivation of the characteristic impedance of the single microstrip conductor will be carried using the conformal transformal method developed by H. A. Wheeler. In this method microstripline is considered as a parallel plate capacitors whose characteristic impedance is given by

$Z_o \quad = \quad 1/V_PC_P$ --------------- 1

Where,

V_P= phase velocity of the wave traveling along the microstrip line.

$= c / \sqrt{\epsilon_{reff}}$, For narrow strip, $\epsilon_{reff} \sqrt{(\epsilon_r + 1) / 2}$ = Effective Permittivity and
C_P= capacitance per unit length of the line.
$C_P= (\epsilon_{reff} / c.\eta) (w/h) + (2/3) (\epsilon_{reff} / c.\eta) (w/h) (\epsilon_{reff} / c.\eta). (2.7/\text{Log}4h/t)$ -----------2
And $Z_o = (\eta/\sqrt{\epsilon_{reff}}). [1/[(w/h) + (2w/3h) + (2.7/\text{Log}4h/t)]]$ ---------- 3
Now for coupled microstripline even-mode impedance for zero strip thickness is given as
$Z_{oe}= (\eta/\sqrt{\epsilon_{reff}}). [1/ \{(w/h) [1+ (1/3/\sqrt{\epsilon_{reff}})] + (1/3\sqrt{\epsilon_{reff}}) (1/(w/s)+1)\}$ --------- 4
And odd-mode impedance is given as
$Z_{oo} = (\eta/\sqrt{\epsilon_{reff}}). [1/ \{(w/h) [1+ (1/3 \sqrt{\epsilon_{reff}}) + (4/3\sqrt{\epsilon_{reff}}) (1/(s/w) +1)\}]$ --------- 5
Where, η = Intrinsic impedance = 377 ohm.

Above expressions show that the even and odd mode impedances are the functions of width of metal strip, height of the dielectric substrate and spacing between two strip lines. The spacing and stripwidth play a significant role in coupling of the power flowing through them. Our present study is related to the variation of these impedances with stripwidth and spacing [2-3].

III. STUDY OF VARIATION OF EVEN AND ODD MODE CHARACTERISTIC IMPEDANCES

After exhaustive computational work results for different metal strip width has been obtained which reveals that with increase of strip width characteristic impedance decreases both for even and odd-modes [4-5].

But the rate of decrease is faster for even-mode than that for odd-mode. Also with increase of spacing, characteristic impedance for even-mode decreases and that for odd-mode increases. These results have been placed in table 1 assuming frequency (f) = 3 GHz, h = 100 mils and 1 mil = 2.54 x 10^{-3} cm.

Table 1 Variation of even & odd mode impedances with stripwidth & spacing between two strips

	S = 10 mils		S = 20 mils		S = 50 mils	
Stripwidth (w) mils	Z_{0e} (Ω)	Z_{00} (Ω)	Z_{0e} (Ω)	Z_{00} (Ω)	Z_{0e} (Ω)	Z_{00} (Ω)
10	165.65	45.35	153.90	61.10	133.45	77.75
50	98.62	36.55	94.55	42.30	46.57	51.47
100	69.38	29.95	67.42	33.35	63.45	40.15
150	59.25	27.55	53.95	28.32	52.82	29.30
200	44.65	23.40	42.66	25.34	41.15	28.05

IV. DISCUSSION AND CONCLUSIONS

of odd-mode. The rate of decrease of even-mode characteristic impedance with stripwidth is greater than that for odd-mode. It can be concluded that with the increase of stripwidth electric flux lines and flow of energy below the stripwidth increases. Further it is observed that the spacing between two strips affects the odd-mode coupled lines more than the even-mode coupled lines. Because increase of spacing increases the odd-mode characteristic impedance and decreases the even-mode characteristic impedance. This means electric flux lines and energy are larger in the coupled region. These results have been utilized in the design of different capacities of directional couplers and also the losses of energy can be computed.

The study of planar transmission structures also concludes that these technologies are essential for the miniaturisation and mass production of modern microwave and radio-frequency (RF) systems. By moving away from bulky coaxial and waveguide components, planar structures enable the creation of lightweight, cost-effective, and highly reliable integrated circuits.

- **Versatility in Design**: Planar lines like microstrip and CPW act as more than just interconnections; they are used to realize lumped elements such as inductors, capacitors, and filters directly on the substrate.
- **Fabrication Efficiency**: The primary advantage of these structures is their compatibility with photolithography and standard PCB manufacturing, allowing complex circuits to be etched in a single step.
- **Operational Trade-offs**:
  - **Microstrip** is favored for its ease of component mounting and fabrication.
  - **Stripline** provides superior shielding and zero dispersion but is harder to modify once assembled.
  - **Coplanar Waveguide (CPW)** offers the best integration for both series and shunt components without requiring via holes.
- **Losses and Power Handling**: While compact, planar structures generally have lower power-handling capabilities and higher radiation losses compared to traditional waveguides. Radiation loss is especially prevalent in "open" structures like microstrip.
- **Future Directions**: Emerging technologies like **Substrate Integrated Waveguides (SIW)** are bridging the gap between planar ease-of-use and high-power waveguide performance. Newer materials, including flexible substrates and low-loss ceramics (LTCC), continue to push these structures into the millimetre-wave and sub-THz ranges.

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