5.7 Isolators

Module:5 Microwave Passive components

Course: BECE305L – Antenna and Microwave Engineering

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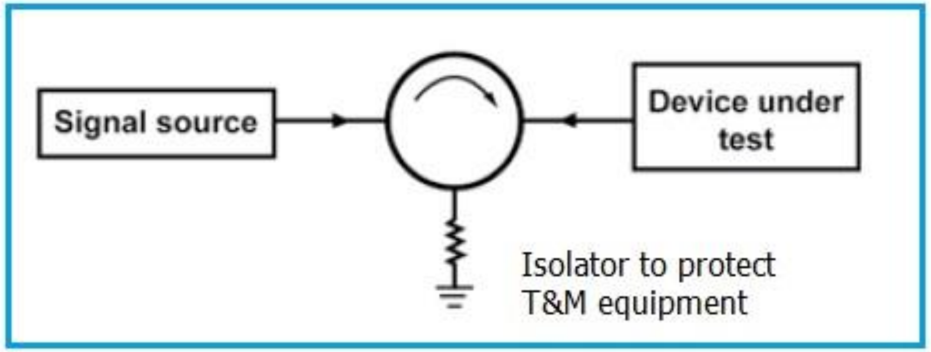
Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)
CHENNAI

Module:5 Microwave Passive components 6 hours

- Microwave Networks - ABCD, ‘S’ parameter and its properties. E-Plane Tee, H-Plane Tee, Magic Tee and Multi-hole directional coupler. Principle of Faraday rotation, isolator, circulator and phase shifter.

- Source of the contents: Pozar

7.1 Introduction to Isolator



- Two-port device
- Non-reciprocal device
- Produces a minimum attenuation to wave propagation in one direction and
  very high attenuation in the opposite direction

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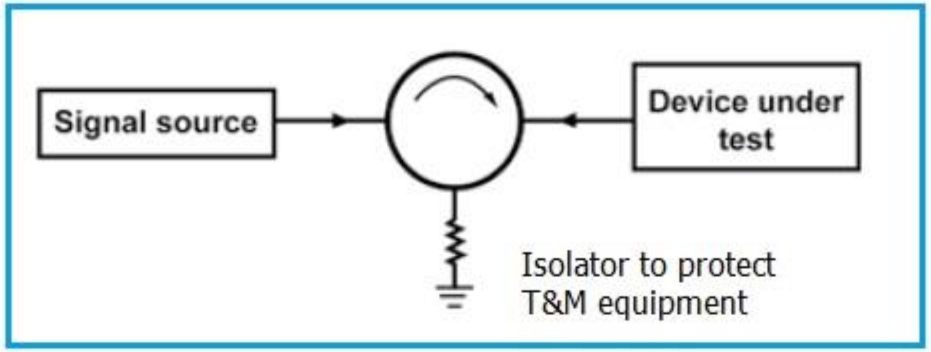
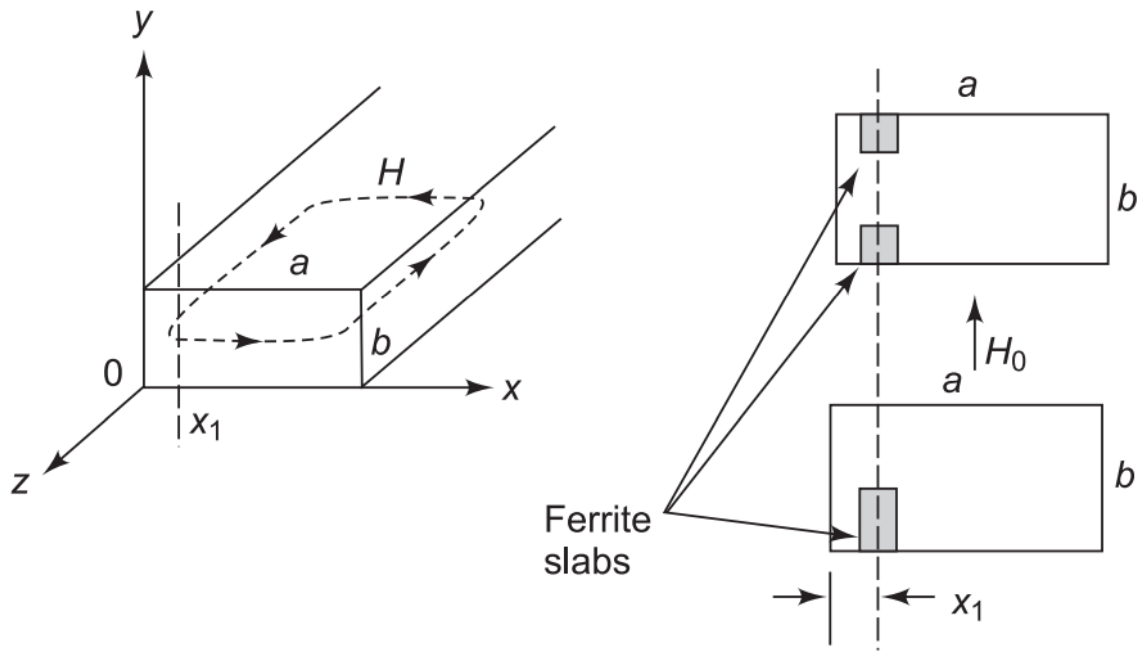


- Two-port device
- Non-reciprocal device
- Produces a minimum attenuation to wave propagation in one direction and
  very high attenuation in the opposite direction
- When placed between a signal source and load:
  Almost all the signal power can be transmitted to the load and
  any reflected power from the load is not fed back to the generator output port.
- This eliminates variations of source power output and frequency pulling due to changing loads.

7.1 Introduction to Isolator

- Can be constructed in a rectangular waveguide (a ×b) operating in dominant mode



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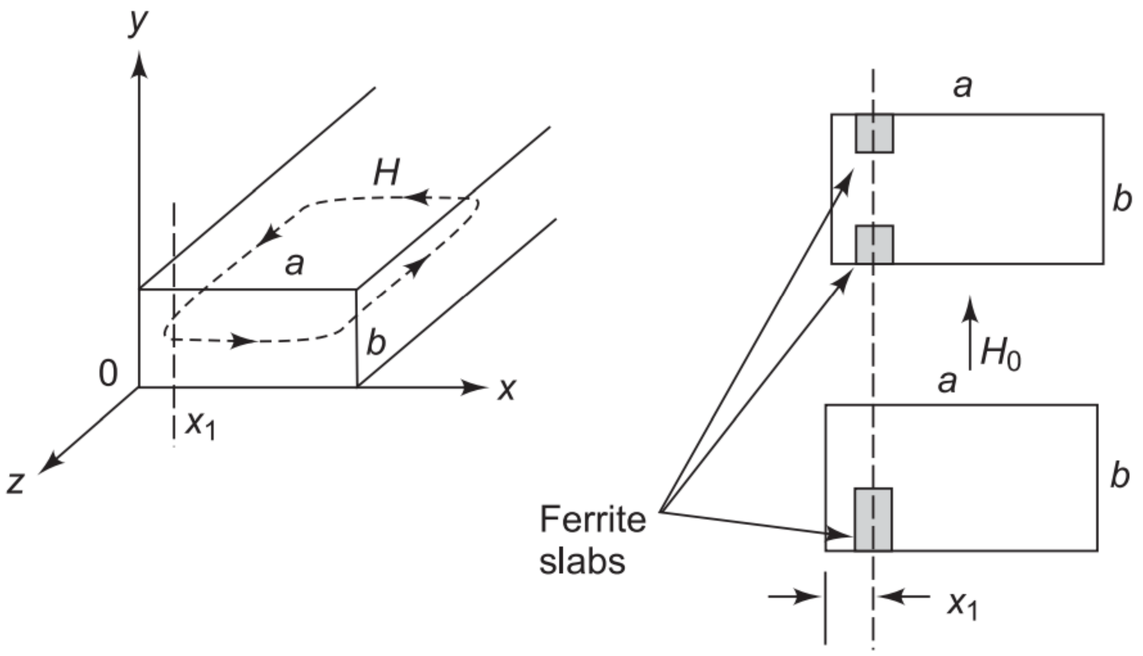

- Can be constructed in a rectangular waveguide (a ×b) operating in dominant mode
- The **non-reciprocal characteristics are obtained by establishing a steady magnetic field H_0 in the y direction** and
  - placing a ferrite slab at any of the longitudinal planes $x = x_1$ near and parallel to the narrow waveguide wall,
  - where the magnetic field exhibits circular polarization.

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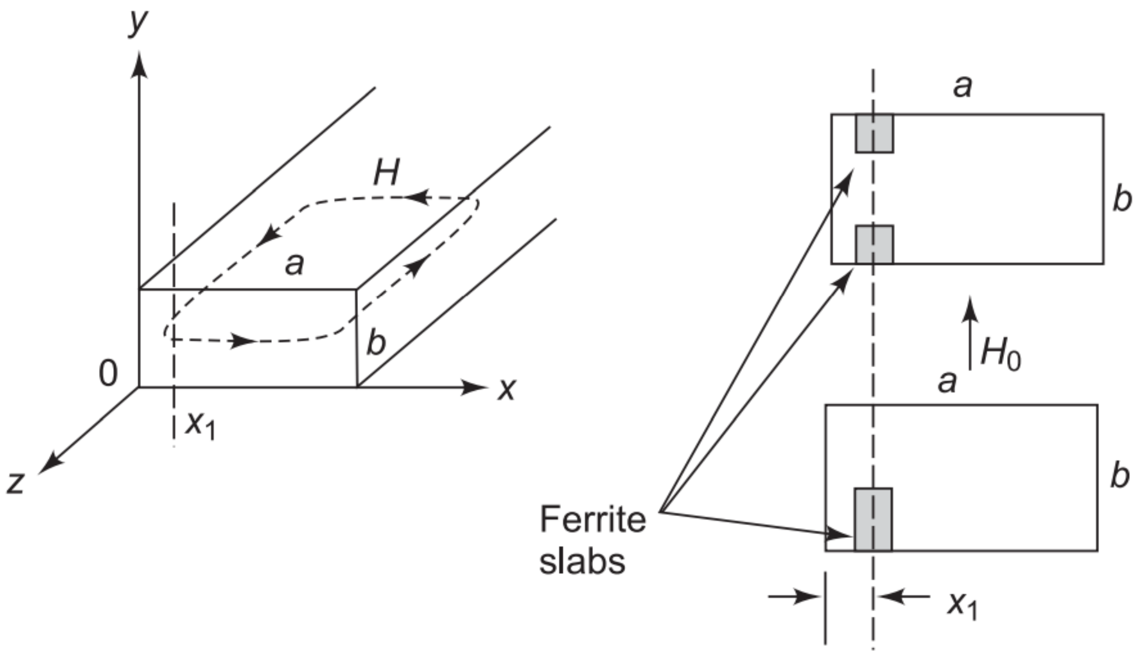

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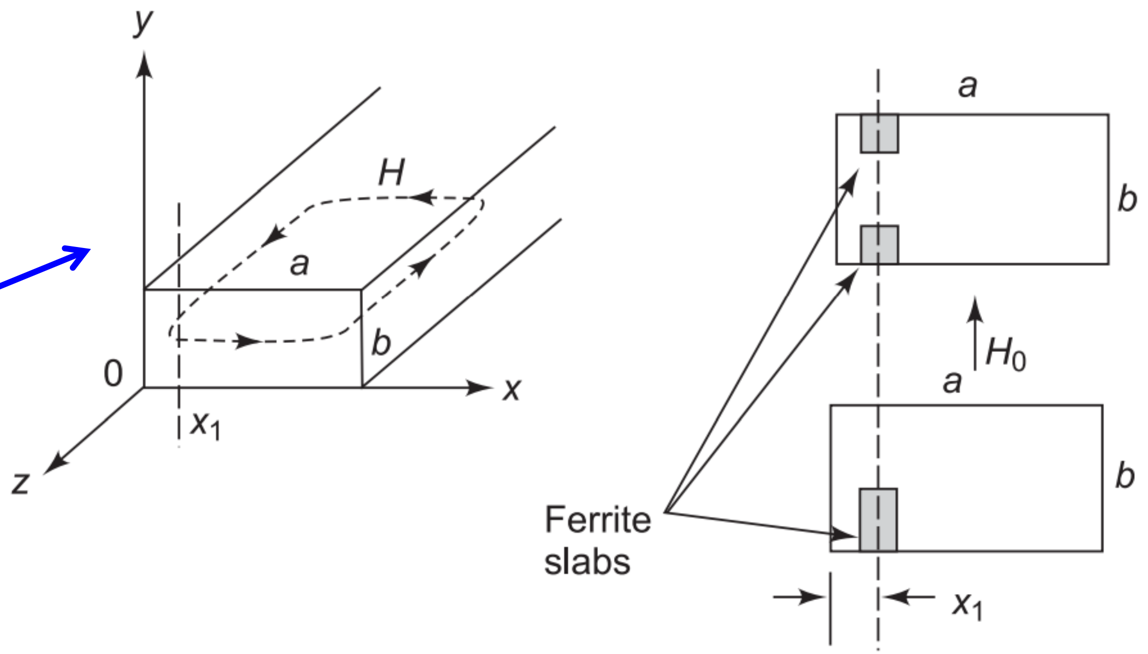
  - **placing a ferrite slab at any of the longitudinal planes $x = x_1$ near and parallel to the narrow waveguide wall**,
  - **where the magnetic field exhibits circular polarization**.
- This occurs at $x1 = a/4\ or, 3a/4$.

7.1 Introduction to Isolator

- For the propagation of waves in +z direction, direction of rotation of H in the planes at $x_1 = a/4\ and\ 3a/4$ are opposite to each other.



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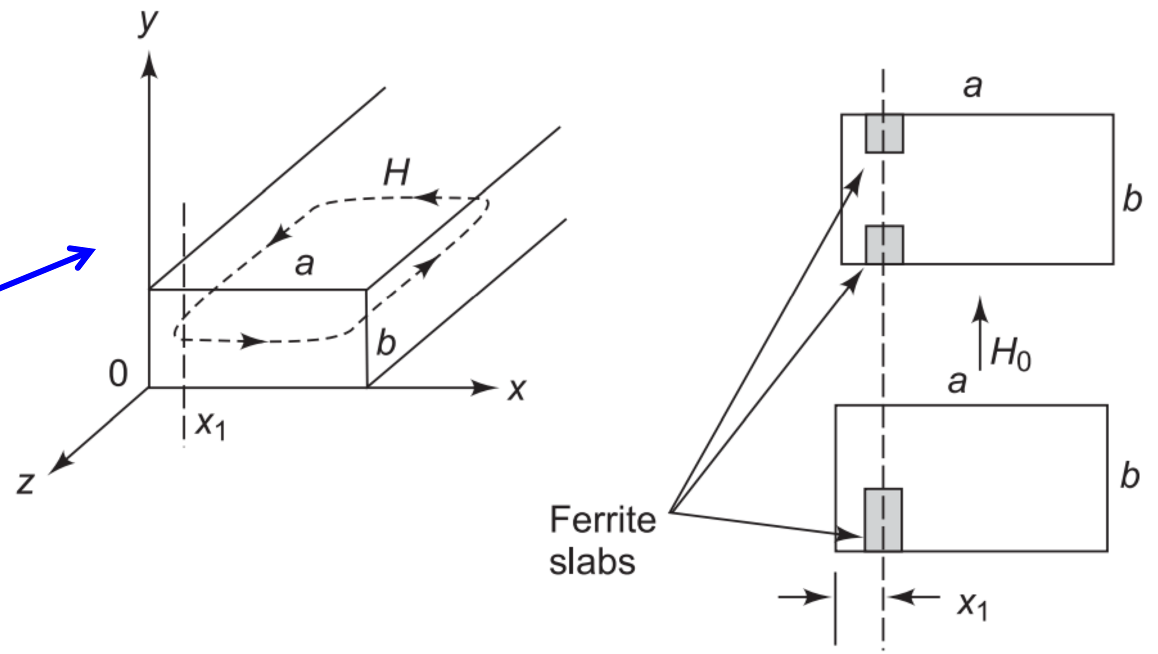

- For the propagation of waves in +z direction, direction of rotation of H in the planes at $x_1 = a/4 \; and \; 3a/4$ are opposite to each other.
- Non-reciprocal characteristic: achieved by placing a ferrite slab at any one of these two planes.
- Required steady state magnetic field H_0 in the y-direction is established by placing permanent magnetic poles between the two broad walls.

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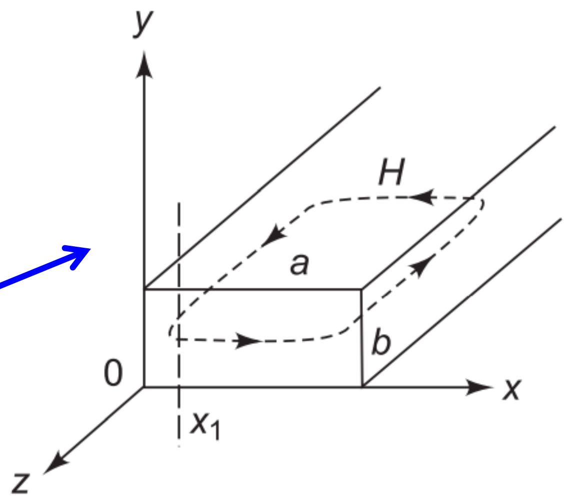

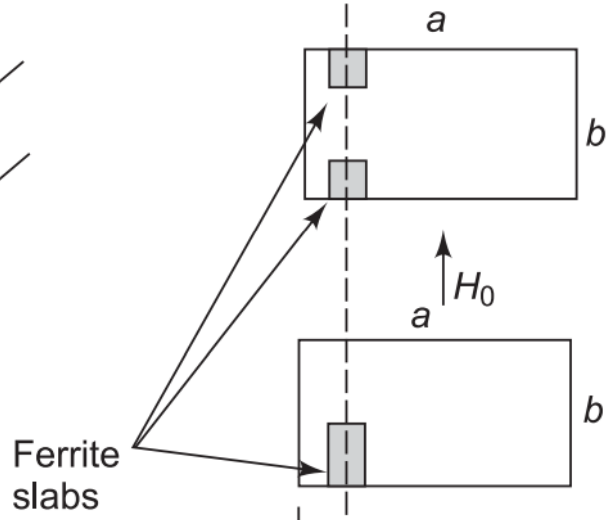

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- **Attenuation in ferrite for negative/ clockwise circular polarization is very small**
  Attenuation in ferrite for positive/counter clockwise circular polarization is very high (near resonance frequency $f \approx f_0$).
- Ferrite slab – placed to obtain negative circular polarization in reverse direction.

7.1 Introduction to Isolator

- **Steady magnetic field – set to be equal to resonant value.**
- Isolation of 20-30dB in backward direction (0.1-1% reflection) and transmission loss of 0.5dB in forward direction (upto 0.89% transmission)
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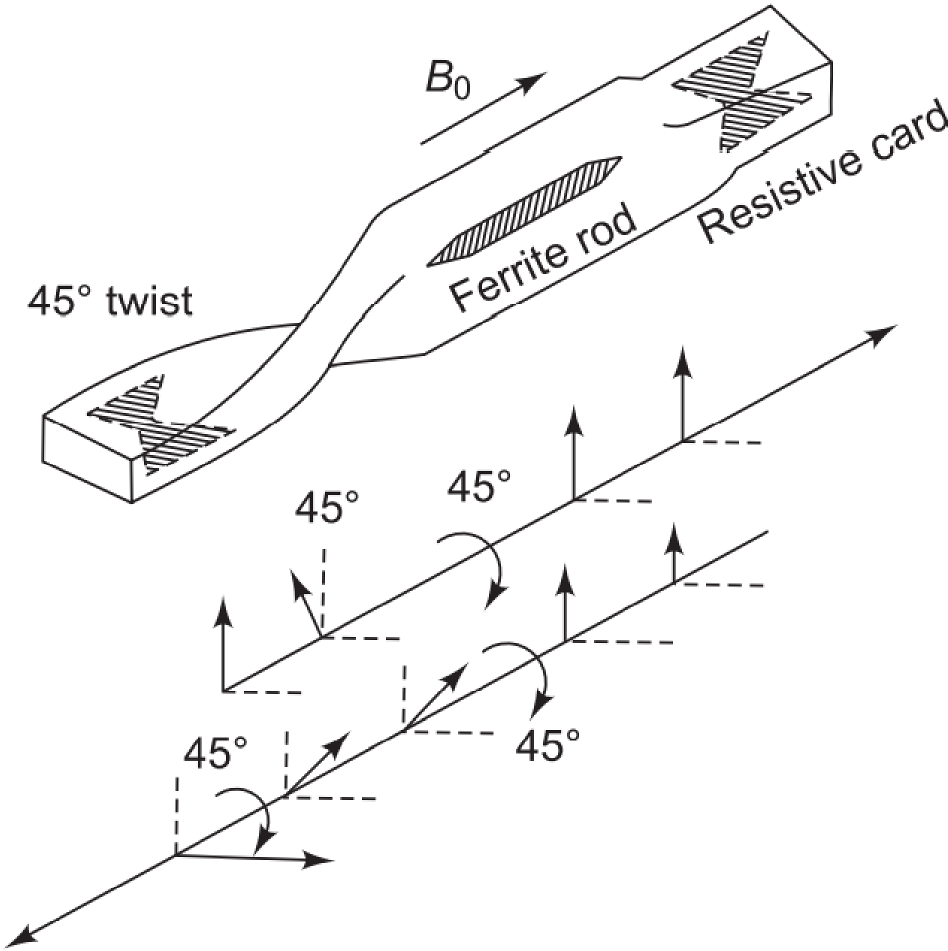
- Higher frequencies: Drawback – very high steady magnetic fields (10000 oesterds at $\lambda = 1cm$).

7.2 Faraday rotation Isolator

- **Circular waveguide section axially loaded with a ferrite rod of smaller diameter**:
- Ferrite rod – steady axial magnetic field H_0 of strength much smaller than resonant intensity – Low/negligible ferrite loss.



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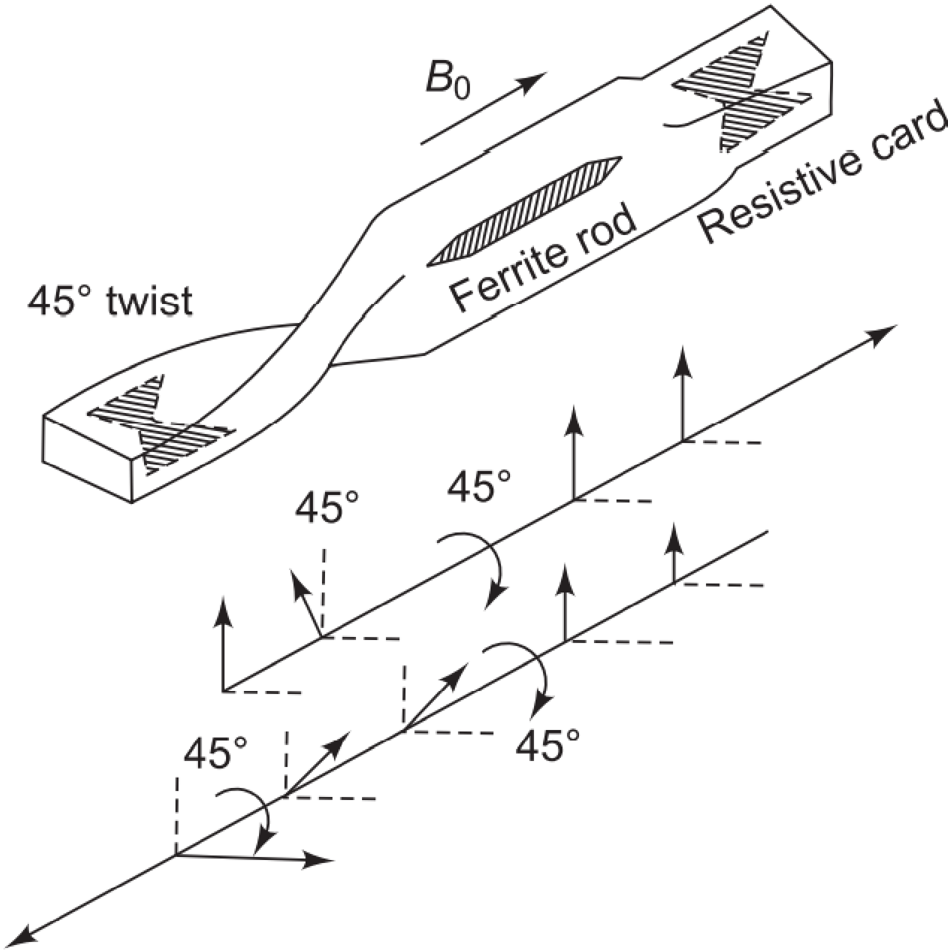

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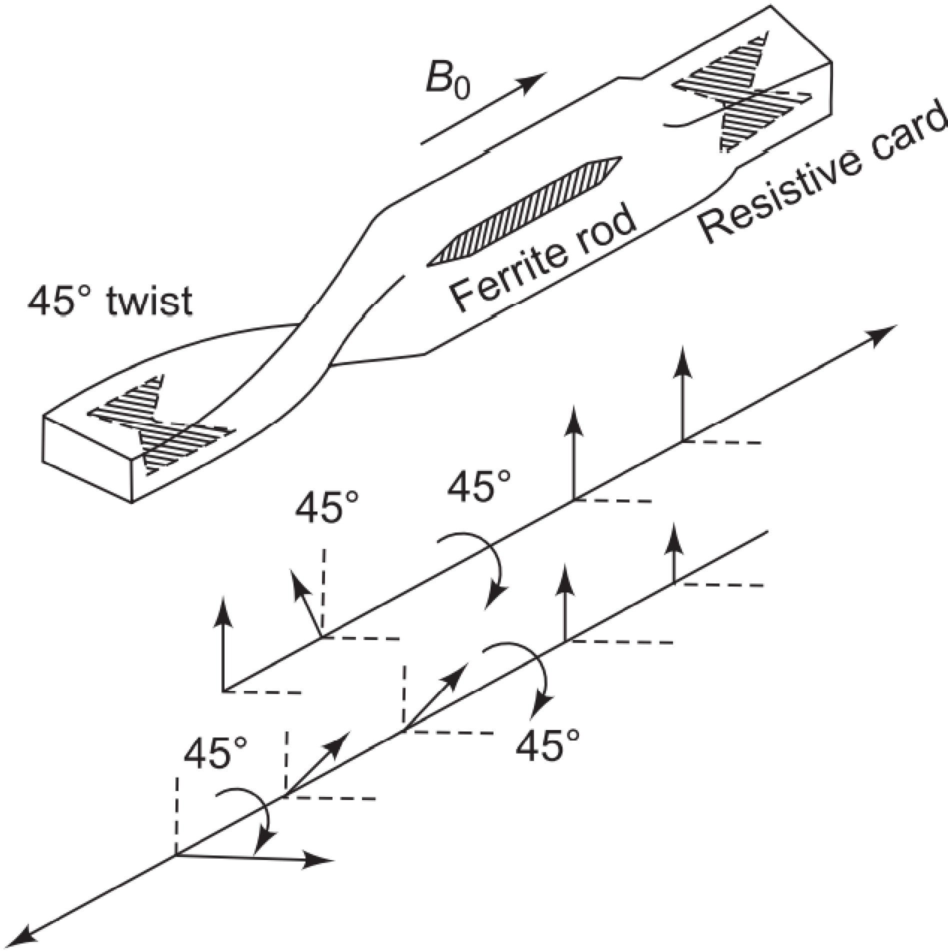

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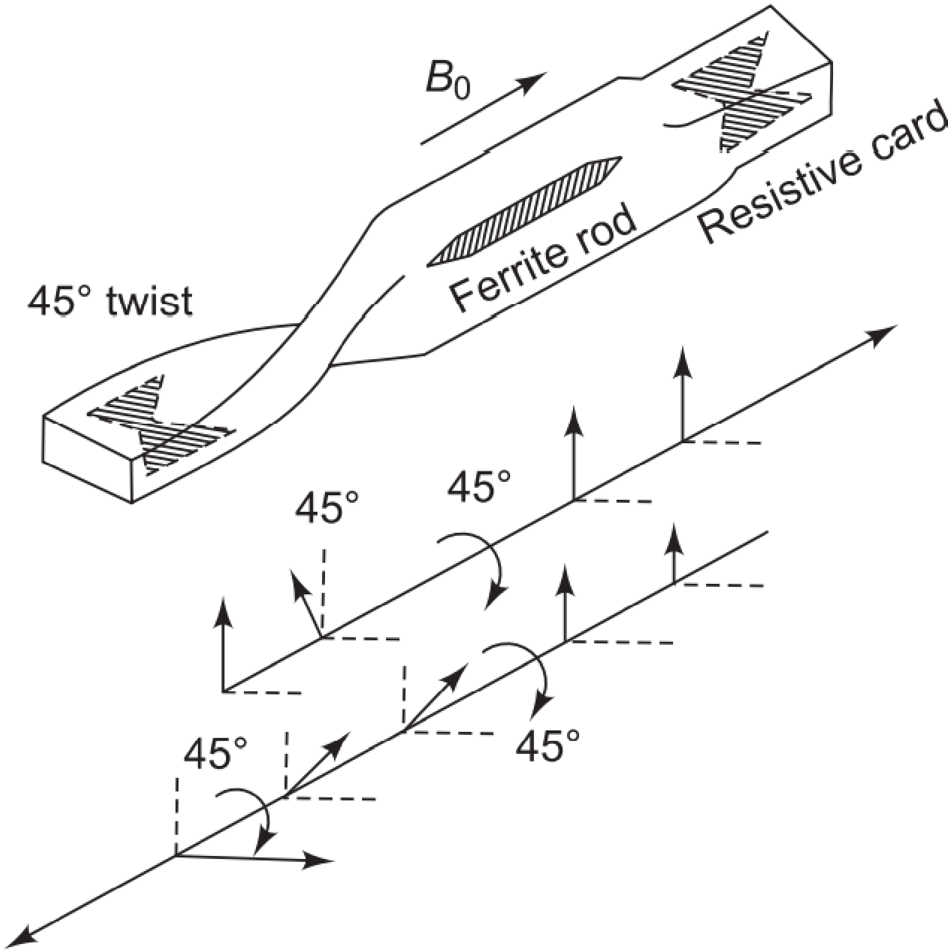

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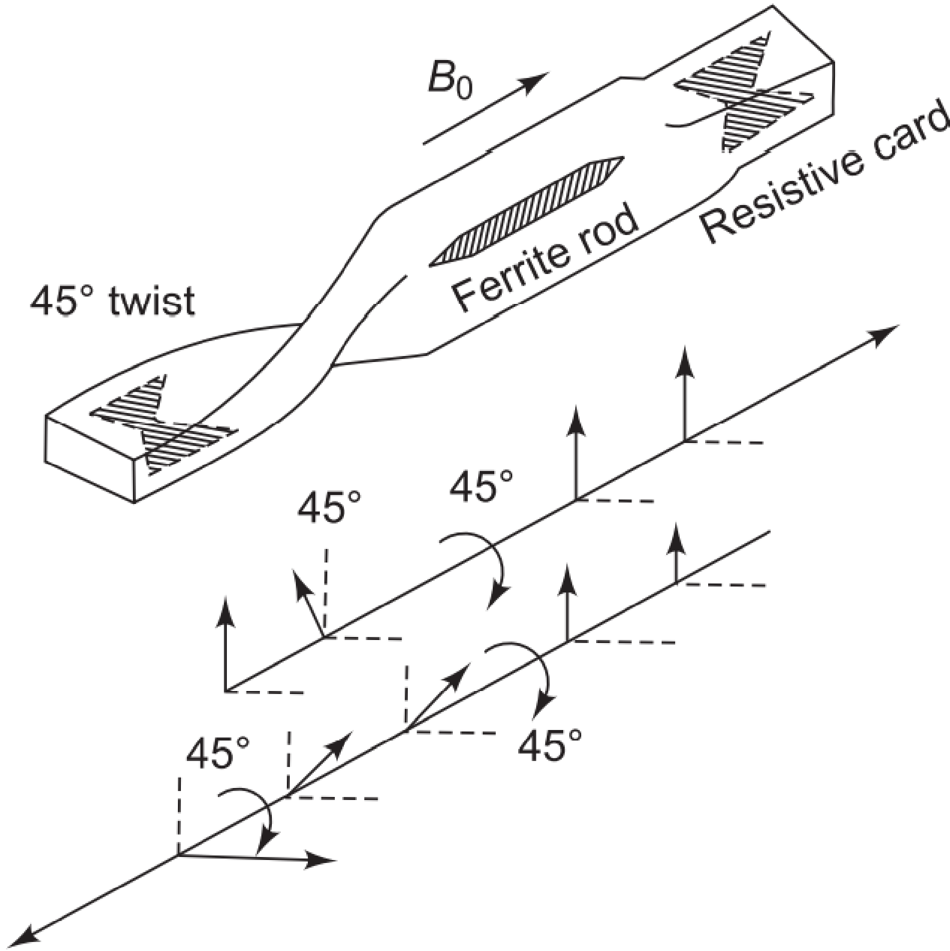

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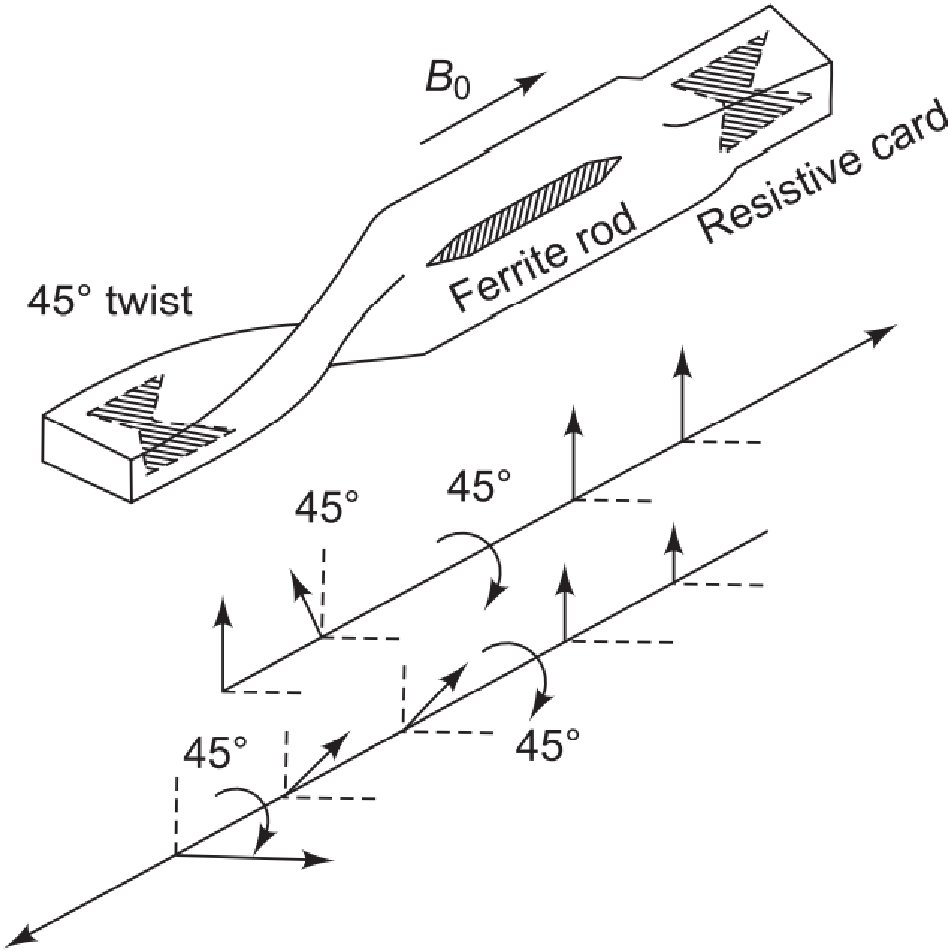

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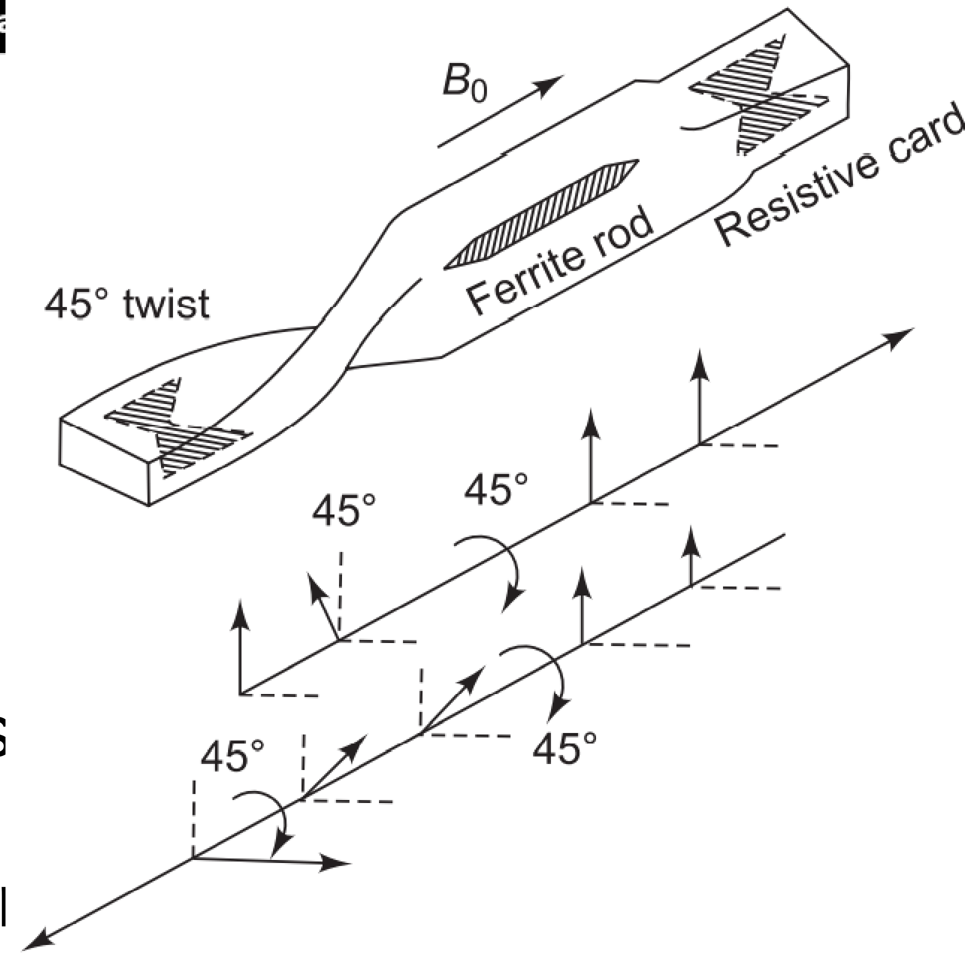

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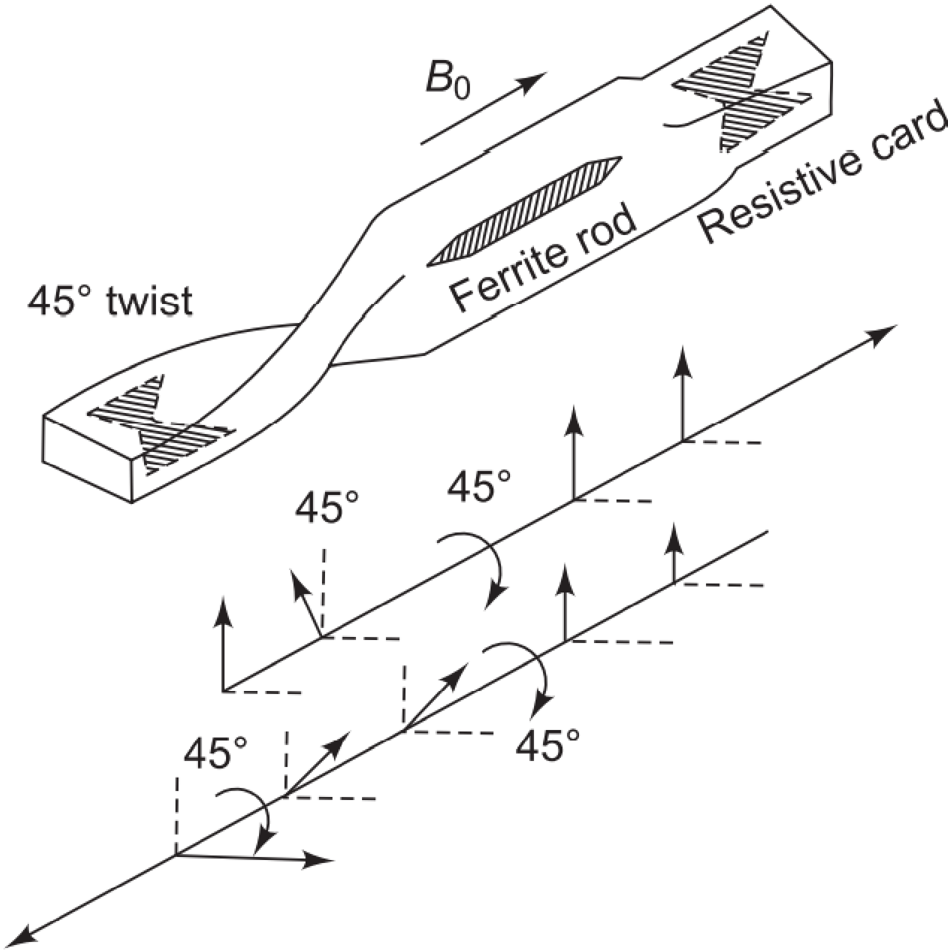
- Rotation angle θ is proportional to length of the ferrite rod.
- Reverse wave: direction of rotation remains same confirming the non-reciprocal properties
- Input is $45°$ twist where tapered resistive card is mounted parallel to broadwall of rectangular waveguide.
- Dominant mode TE_{10} does not get attenuated while transmission Rotated at $45°$ at twist output and enters circular waveguide through rectangular to circular waveguide transition at $TE11$ mode.

7.2 Faraday rotation Isolator

- Length of ferrite rod: selected to obtain Faraday rotation of $\theta = 45°$
- Plane of polarization of reflected wave from load is again rotated by $\theta = 45°$



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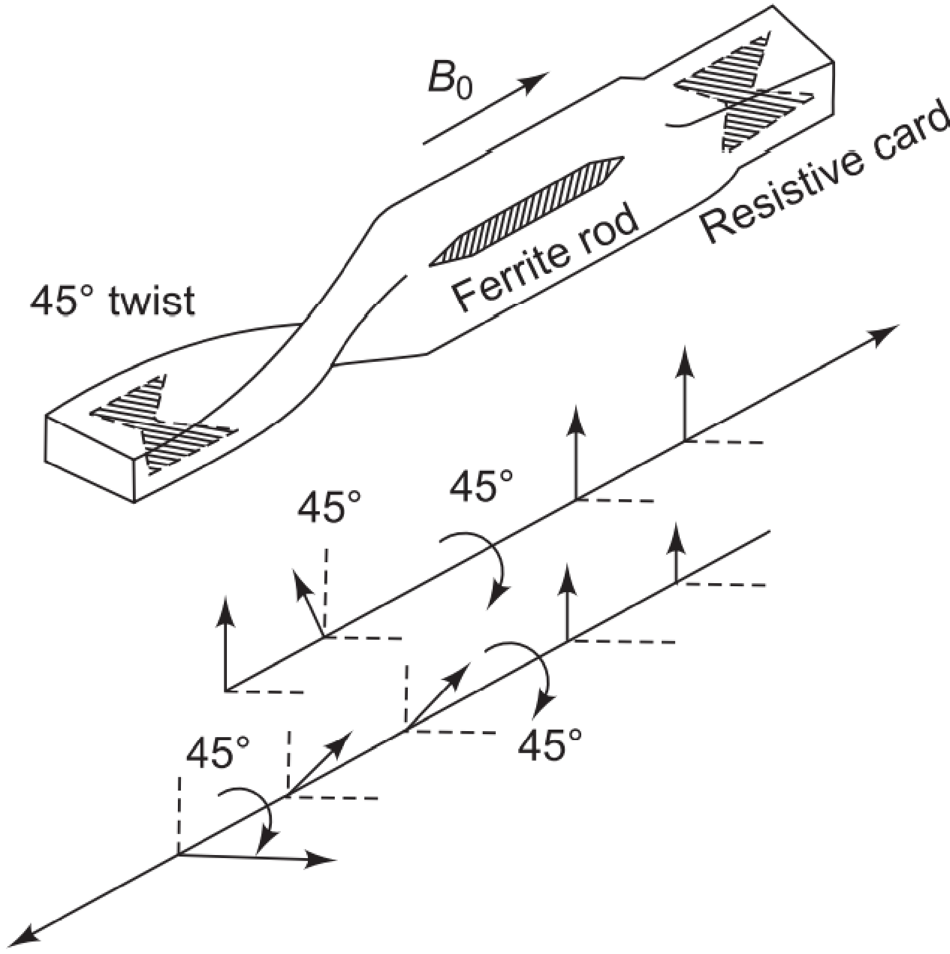

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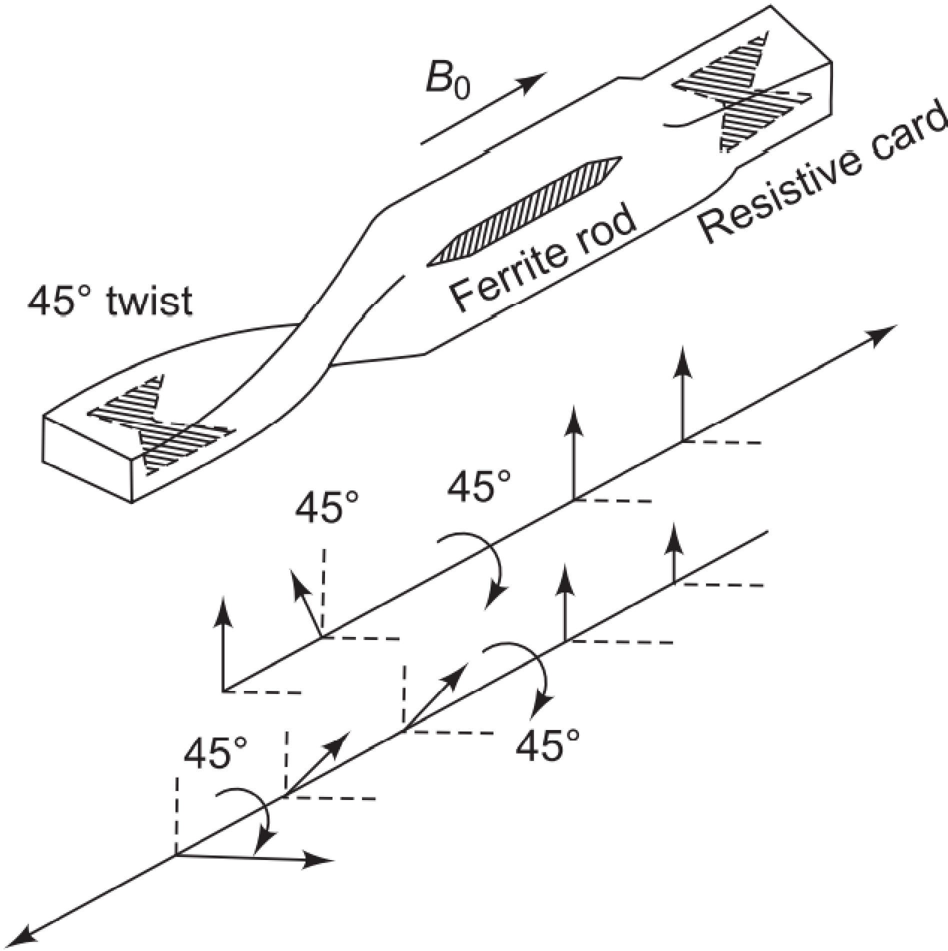
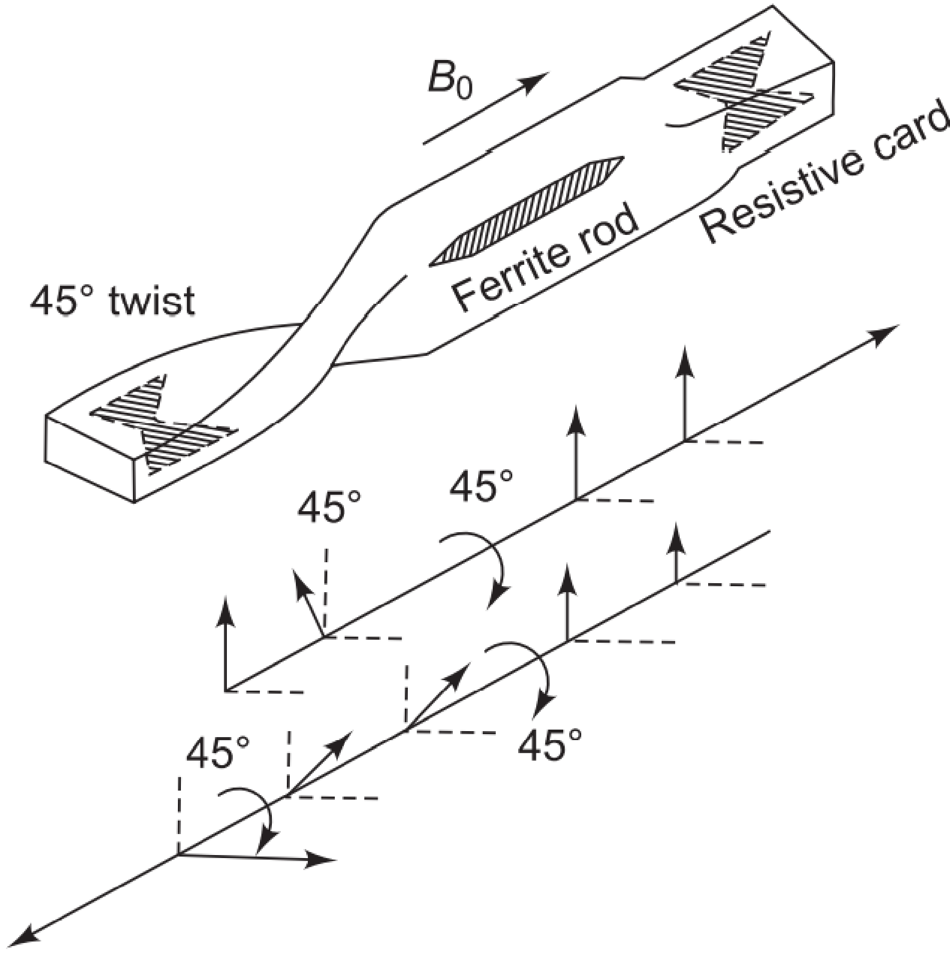
- The signal rotates and gets aligned with surface of absorbing plate, and gets absorbed
- Non-reciprocal behavior.
- Isolation – 20-30dB
  Insertion loss: 1dB



7.2 Faraday rotation Isolator

- Ideal lossless matched isolator
- $|S_{21}| = 1$
  $|S_{12}| = |S_{11}| = |S_{22}| = 0$
- $[S] = \begin{bmatrix} 0 & 0 \\ 1 & 0 \end{bmatrix}$



7.3 Problem: A matched isolator has insertion loss 0.5dB and isolation of 25dB. Find S parameters

- Insertion loss = $0.5dB = -20\log_{10}|S_{21}|$
- $S_{21} = 10^{-0.5/20} = 0.9441$

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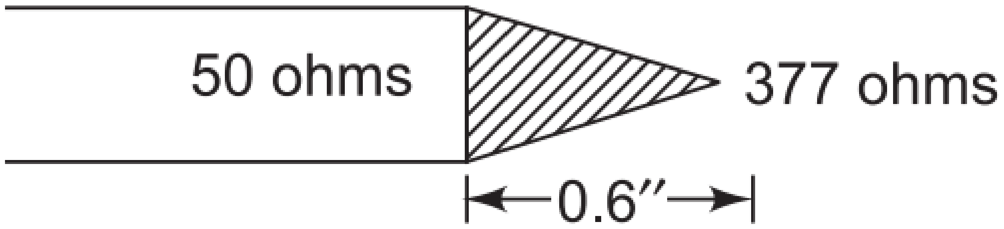
- No reflection: $S_{11} = S_{22} = 0$
- $[S] = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} = \begin{bmatrix} 0 & 0.0631 \\ 0.9441 & 0 \end{bmatrix}$

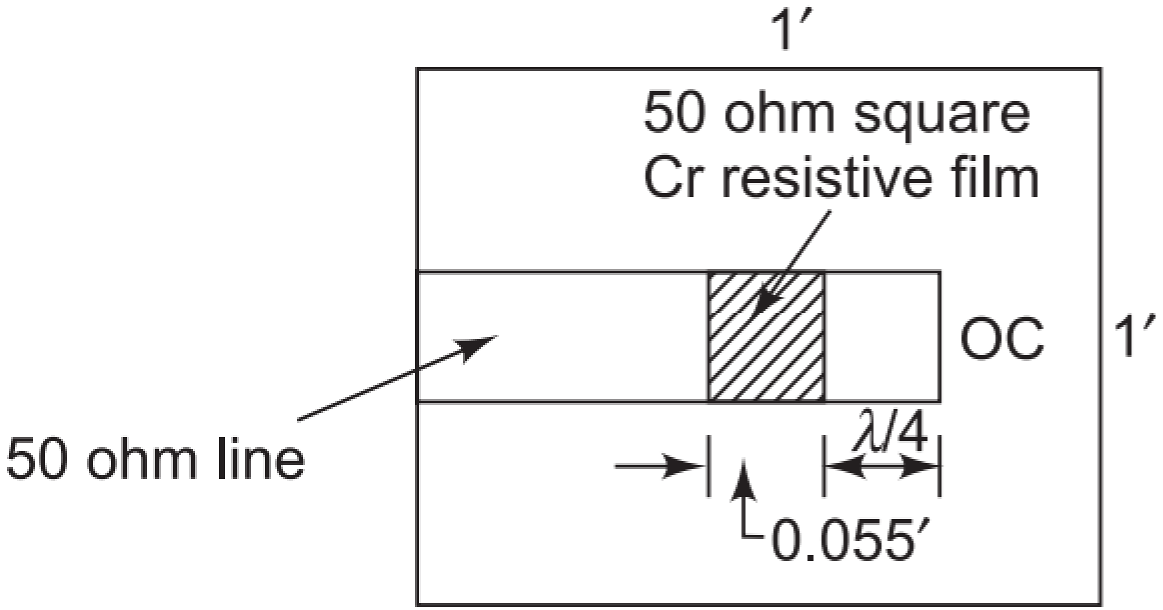
7.4 Microstrip Isolator

- Formed by match terminating one port of 3 port circulator.
- Method 1: A chromium layer is deposited on ferrite initially in all circuits for adherence. A tapered Cr fi lm of 0.6” long with a surface impedance of 270-ohm termination gives VSWR < 1.2 over the frequency range 5.5–11.0 GHz.



7.4 Microstrip Isolator

- Formed by match terminating one port of 3 port circulator.
- Method 2: Initial Cr adherence is done as Method 1. Then the Cr film acts as a lumped 50-ohm resistor which is terminated in a quarter wavelength open circuit impedance. This arrangement provides VSWR < 1.2 over the frequency range 4.5–6.0 GHz.



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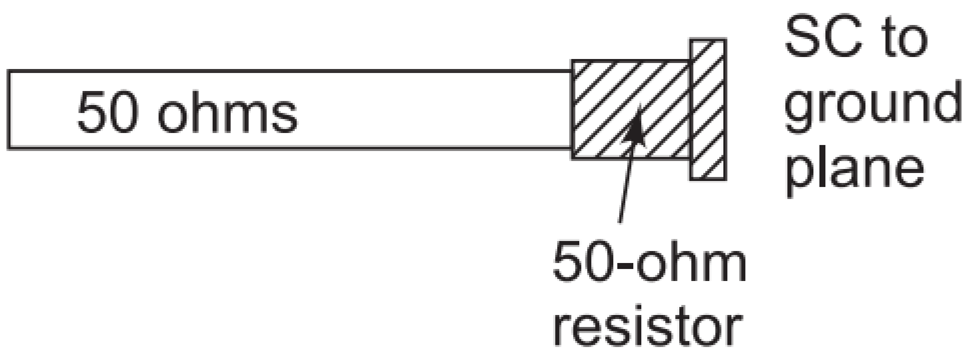
- Method 3: 50-ohm lumped resistor shunt mounted across the strip line and terminated by a short at the end.



7.4 Microstrip Isolator

- Formed by match terminating one port of 3 port circulator.
- Method 4: An isolator in MIC form on ferrite substrate can be designed with a triangular patch having a narrow transverse slot and corner cuts.
- The dc magnetic field is applied perpendicular to the substrate plane