

USE OF FERRITES IN MICROWAVE ENGINEERING

ECE 524E – MICROWAVE ENGINEERING

Friday, 10 April 2026

ANISOTROPIC MATERIALS

1. Most passive electrical components use **isotropic materials** and are therefore reciprocal. That is, the response between any two ports i and j of a component does not depend on the direction of signal flow, i.e. $S_{ij} = S_{ji}$.
2. However, if the component contains either **active devices or anisotropic material**, nonreciprocal behavior can be obtained.
3. **This nonreciprocity is sometimes a useful property during the design of circulators, isolators and other devices such as transistors and ferrite phase shifters.**
4. We can have **electric anisotropy (tensor permittivity)**, and **magnetic anisotropy (tensor permeability)**.

WHAT ARE FERRITES?

1. Ferrites are non-metallic materials with resistivity ρ nearly 10^{14} times greater than metals and with dielectric constant ϵ_r around 10^{-15} and relative permeabilities of 1000 order.
2. **Ferrites have atoms with large number of spinning electrons resulting in strong magnetic properties.** These magnetic properties are due magnetic dipole moment associated with the electron spin.
3. Ferrites contain a significant amount of anisotropy at microwave frequencies.

HOW ARE FERRITES MADE?

- **A ferrite** is a ceramic material made by mixing and firing **large proportions iron(III) oxide (Fe_2O_3 , rust)** blended with **small proportions of one or more additional metallic elements, such as barium, manganese, nickel, and zinc.**

TYPES OF FERRITES

Ferrites can be divided into two families based on their resistance to being demagnetized (magnetic coercivity), i.e. hard and soft.

1. Hard ferrites have high coercivity, so are difficult to demagnetize.

Applications

Hard ferrites are used to make permanent magnets for refrigerator magnets, loudspeakers, small electric motors, etc.

2. Soft ferrites have low coercivity, so they easily change their magnetization, and act as conductors of magnetic fields.

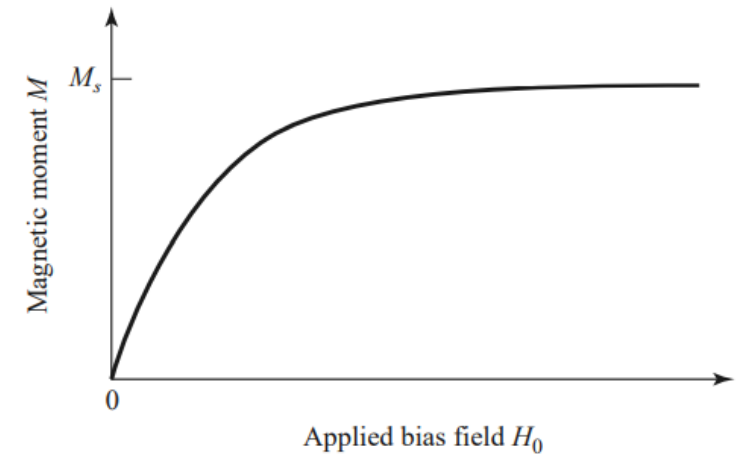
Applications

- Soft ferrites are used in the electronics industry to make efficient magnetic cores called ferrite cores for high-frequency inductors and transformers, and in various microwave components.

3. Microwave Ferrites: Specially engineered for gyromagnetic applications (YIG, Li ferrite)

USE OF FERRITES IN MICROWAVE COMPONENTS /01

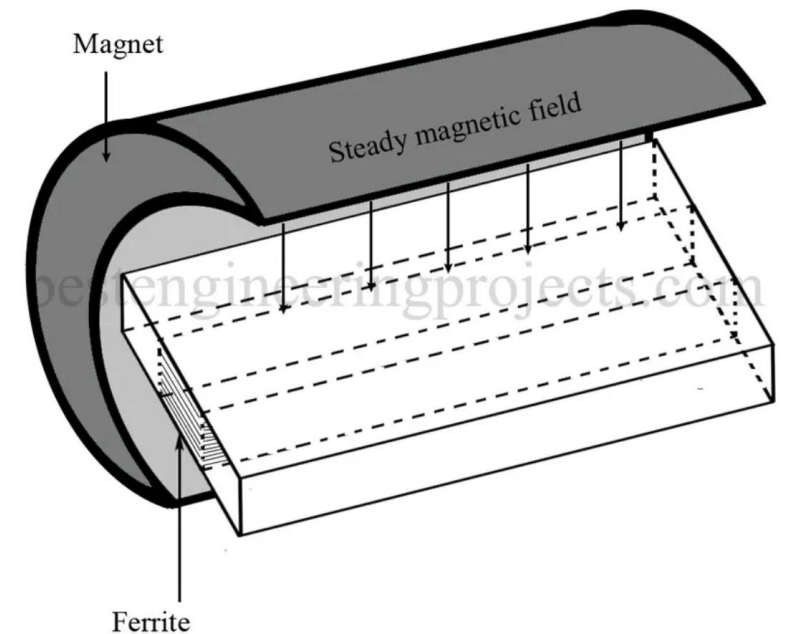
- **Magnetic anisotropy** of a ferrimagnetic material is actually induced by applying a DC magnetic bias field.
- This field aligns the magnetic dipoles in the ferrite material to produce a net (nonzero) magnetic dipole moment, and causes the magnetic dipoles to precess at a frequency controlled by the strength of the bias field.
- A microwave signal circularly polarized in the same direction as this precession will interact strongly with the dipole moments, while an oppositely polarized field will interact less strongly.



(a) Magnetic moment of a ferrimagnetic material versus bias field, H_0

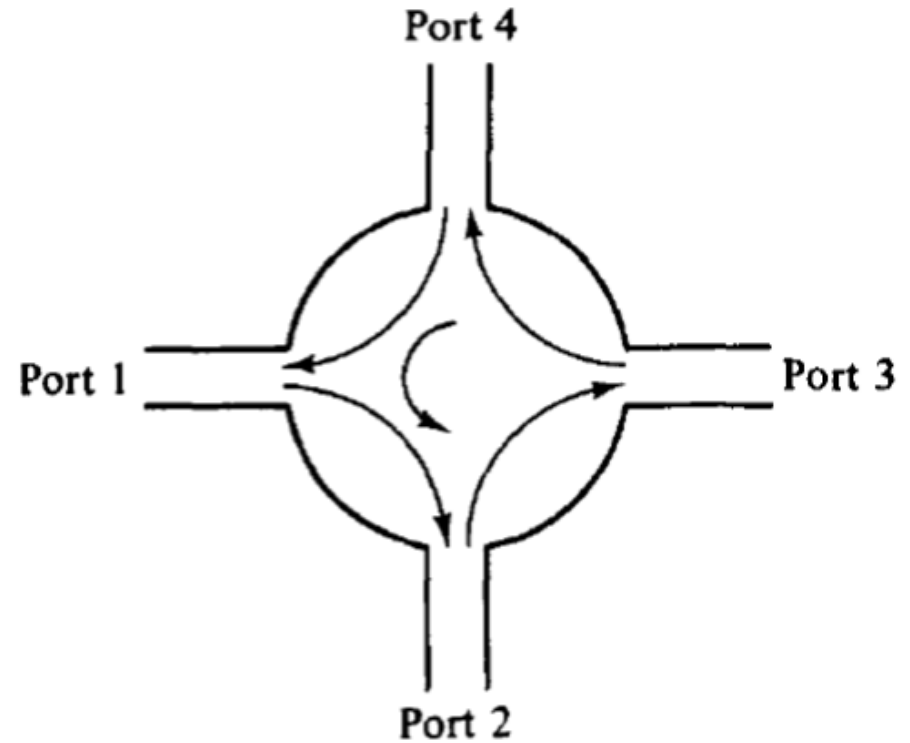
USE OF FERRITES IN MICROWAVE COMPONENTS

1. Since, for a given direction of rotation, the sense of polarization changes with the direction of propagation, a microwave signal will propagate through a magnetically biased ferrite differently depending on the direction.
2. This effect can be utilized to fabricate directional devices such as isolators, circulators, and gyrators.
3. The interaction with an applied microwave signal can be controlled by adjusting the strength of the bias field. **This effect leads to a variety of control devices such as phase shifters, switches, and tunable resonators and filters.**



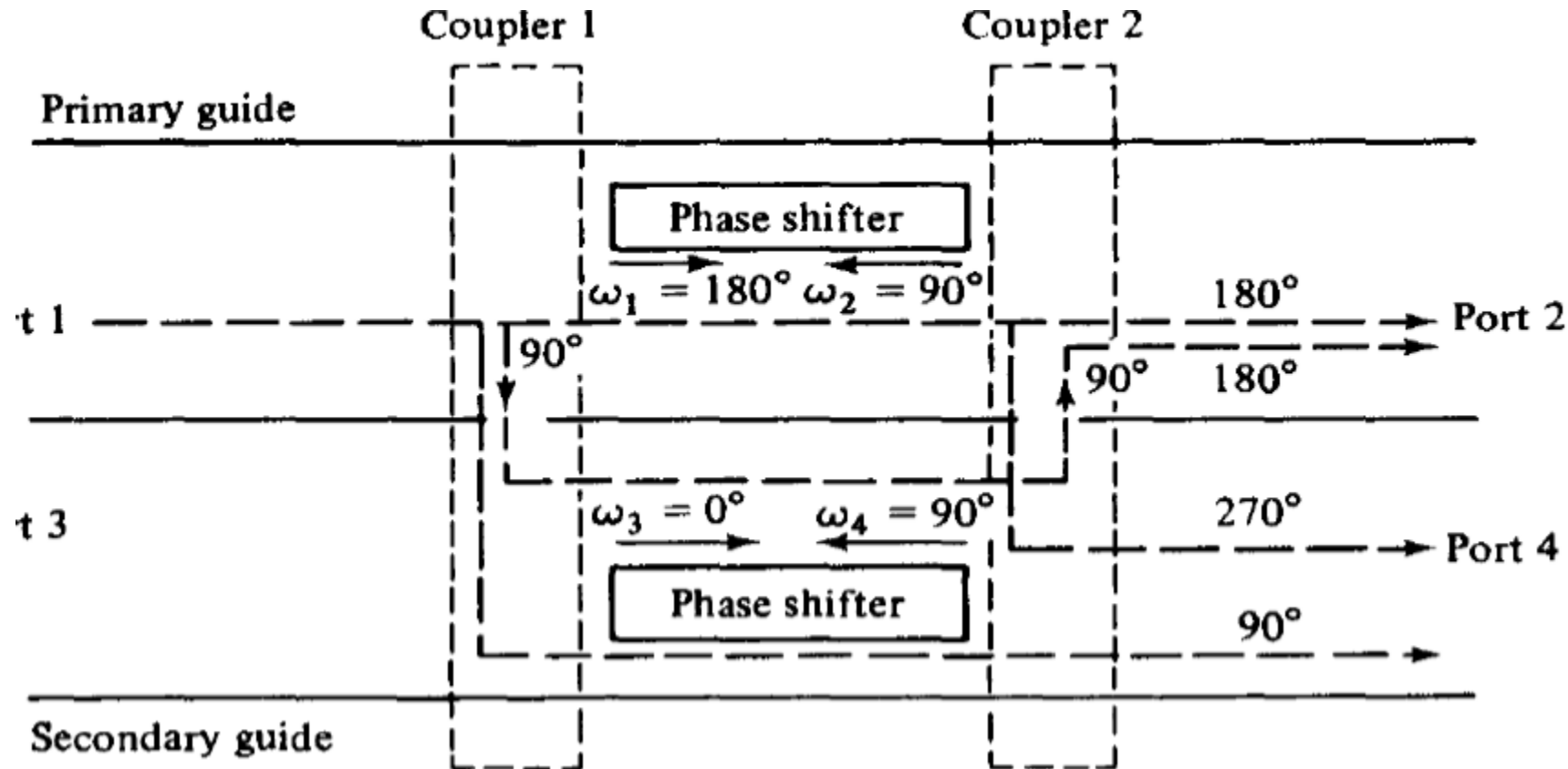
RECAP-MICROWAVE CIRCULATOR

- A microwave circulator is a multiport waveguide junction in which the wave can flow only from the n th port to the $(n + 1)$ th port in one direction.
- The four-port microwave circulator is the most common.



CIRCULATOR USING DIRECTIONAL COUPLERS

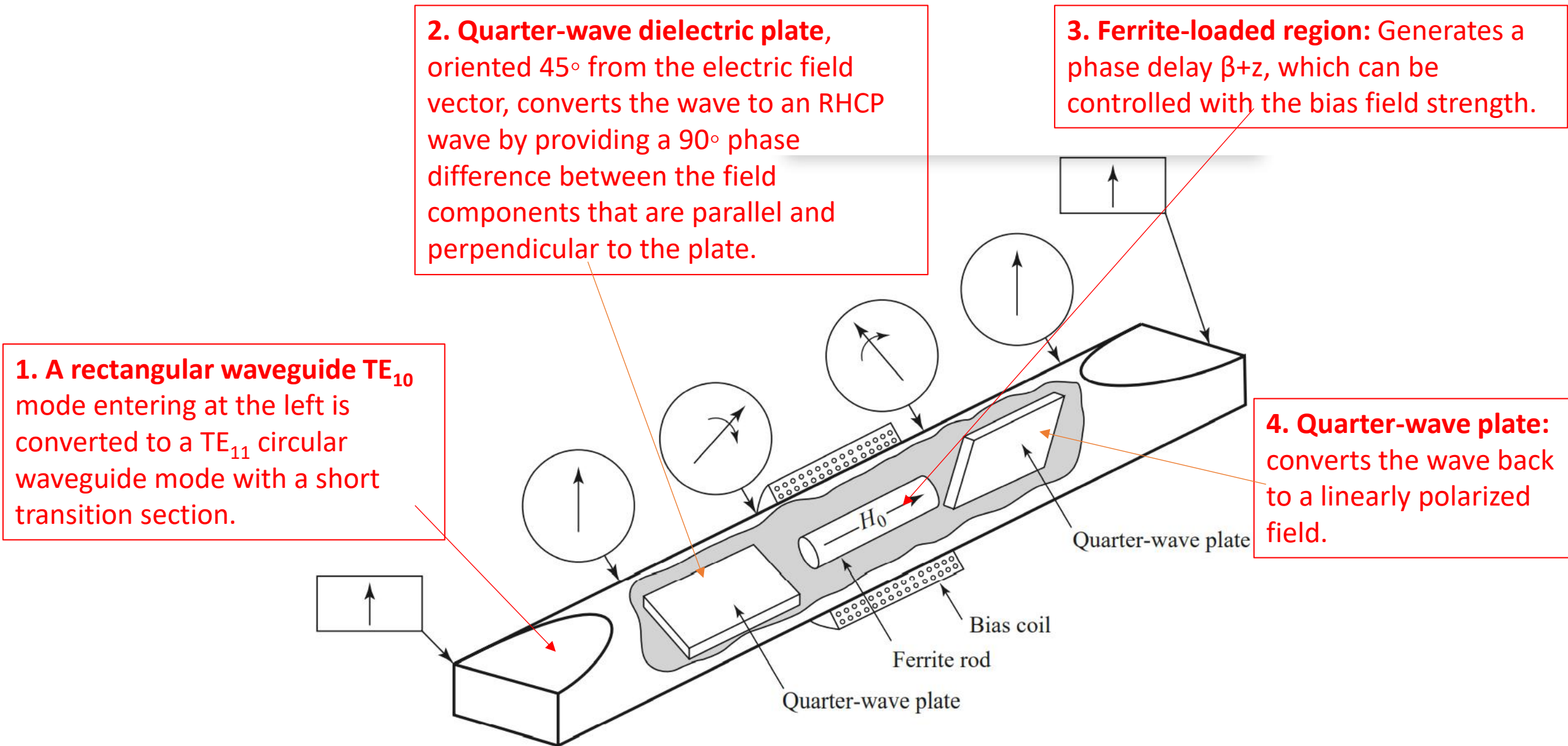
- One type of four-port microwave circulator is a combination of two 3-dB side-hole directional couplers and a rectangular waveguide with two nonreciprocal phase shifters as shown.

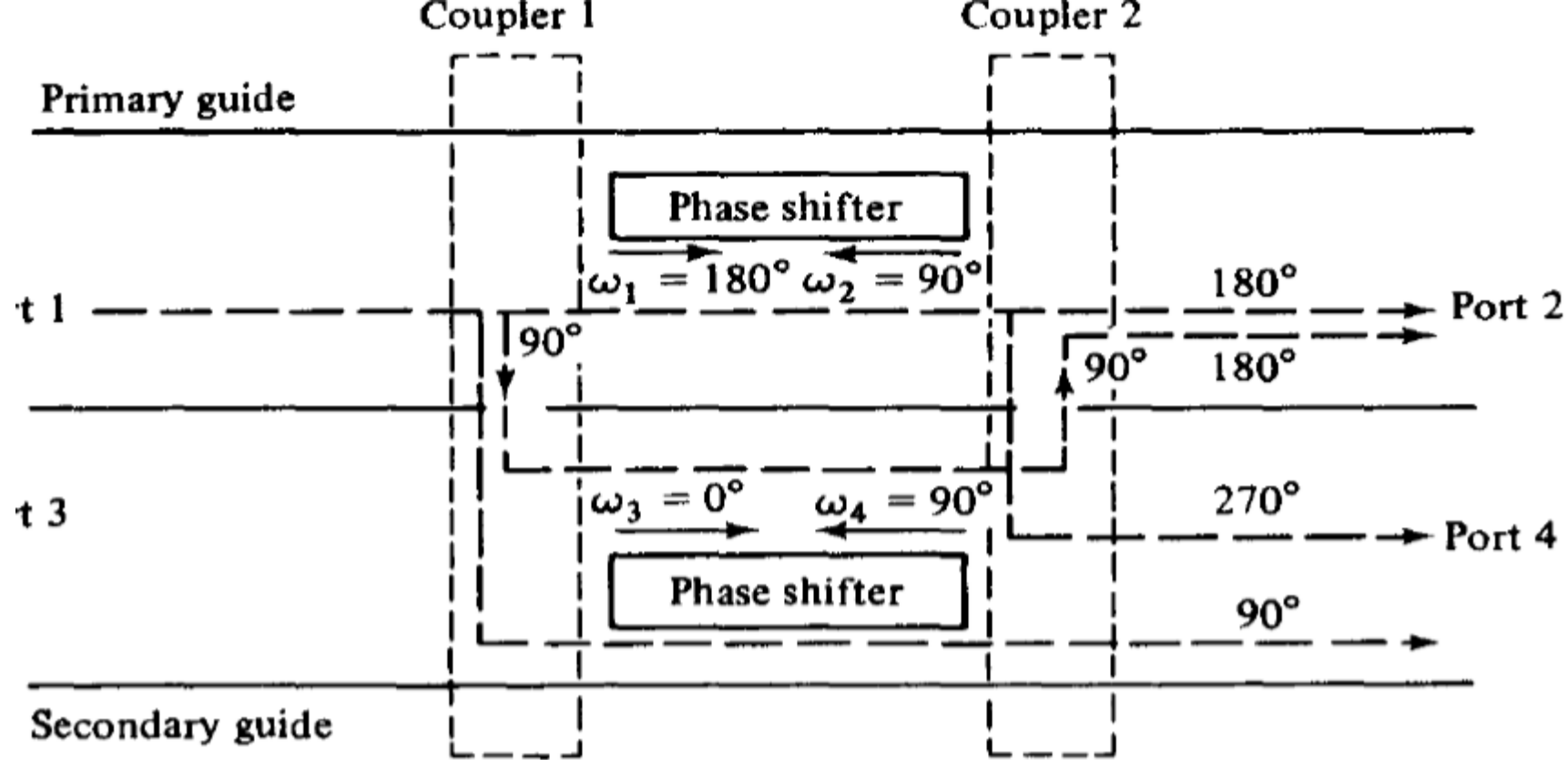


FERRITE PHASE SHIFTERS

1. A **ferrite phase shifter** is two-port components that provide variable phase shift by changing the bias field of the ferrite.
2. Microwave Diodes and FETs can also be used to implement a phase-shifter.
3. Applications of phase shifters include:
 - a) Test and measurement systems
 - b) Phased array antennas where the antenna beam can be steered in space by electronically controlled phase shifters.

NONRECIPROCAL FARADAY ROTATION PHASE SHIFTER





- Each of the two 3-dB couplers in the circulator introduces a phase shift of 90° and each of the two phase shifters produces a certain amount of phase change in a certain direction as indicated.
- Since the two waves reaching port 4 are out of phase by 180° , the power transmission from port 1 to port 4 is zero.

MICROWAVE ISOLATOR

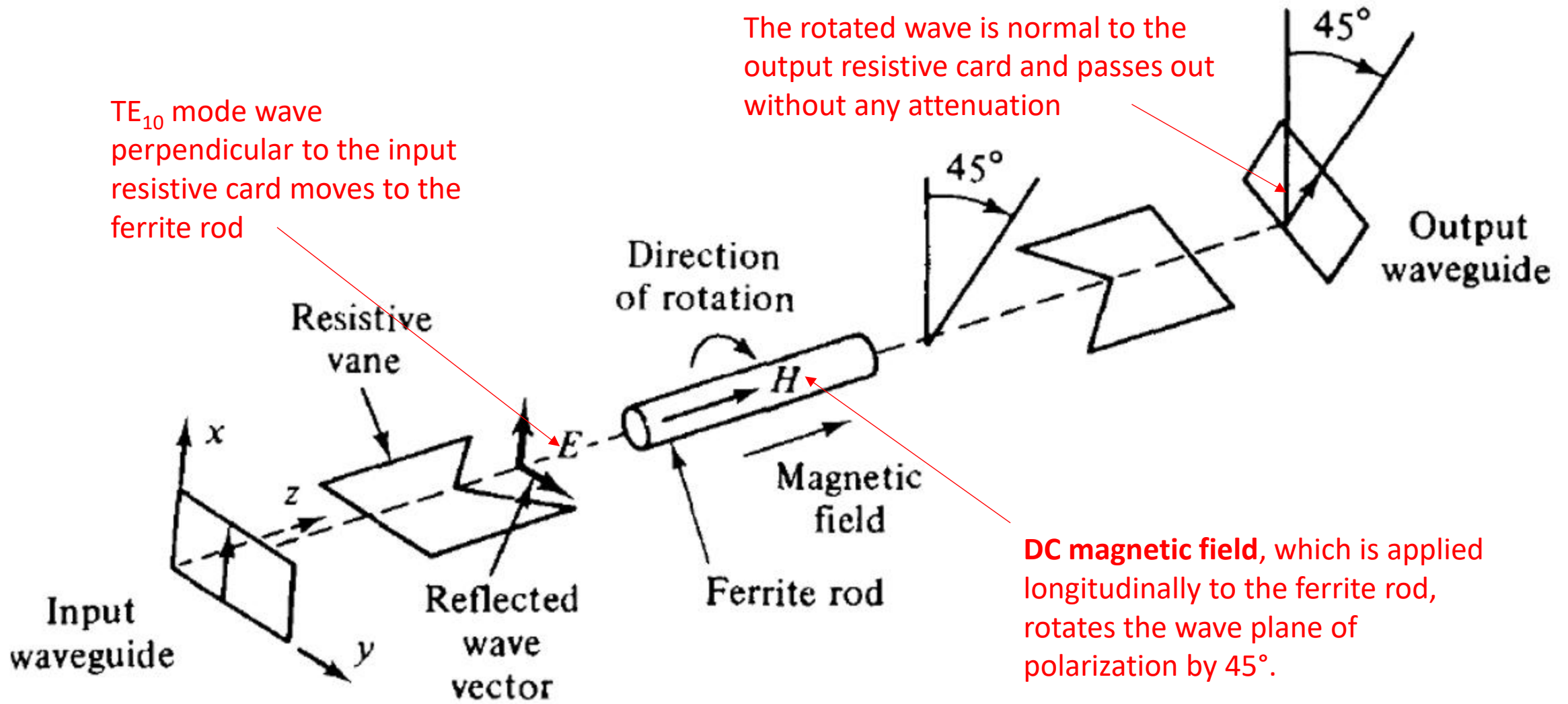
1. An isolator is a nonreciprocal transmission device that is used to isolate one component from reflections of other components in the transmission line.

2. The scattering matrix for an ideal isolator has the form

$$S = \begin{bmatrix} 0 & 0 \\ 1 & 0 \end{bmatrix}$$

1. An ideal isolator completely absorbs the power for propagation in one direction and provides lossless transmission in the opposite direction.

ISOLATOR USING FARADAY ROTATION



The typical performance of these isolators is about 1-dB insertion loss in forward transmission and about 20- to 30-dB isolation in reverse attenuation.