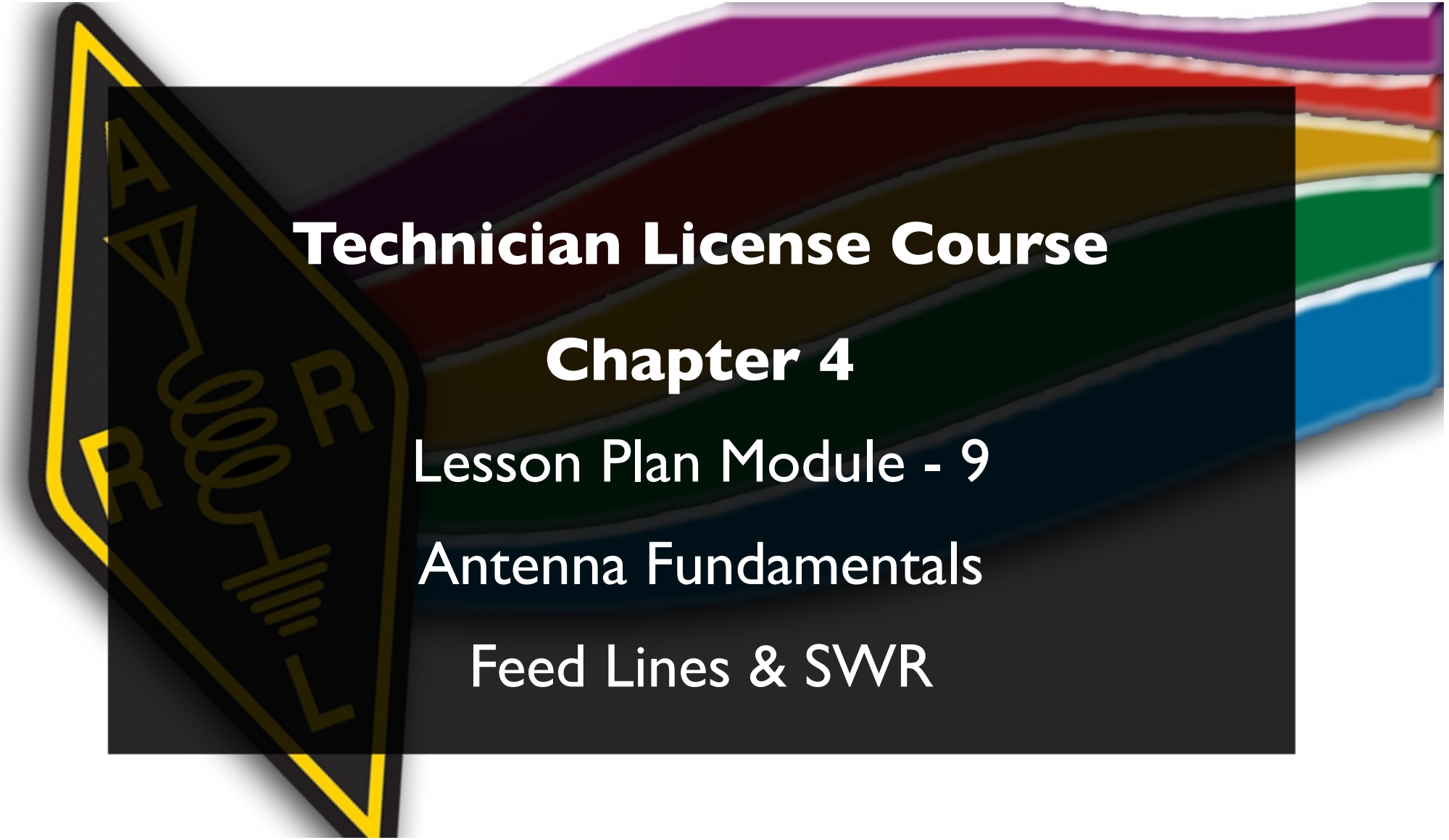

# Technician License Course



# Technician License Course

## Chapter 4

Lesson Plan Module - 9

Antenna Fundamentals

Feed Lines & SWR

# The Antenna System

- **Antenna**: Transforms current into radio waves (transmit) and vice versa (receive).
- **Feed line**: Connects your station to the antenna.
- **Test and matching equipment**: Allows you to monitor and optimize antenna system performance.

# The Antenna (Some Vocabulary)

- **Element**: The conducting part or parts of an antenna designed to radiate or receive radio waves.
- **Driven element**: The element supplied directly with power from the transmitter.
- **Array**: An antenna with more than one element.

# The Antenna (Some Vocabulary)

- **Parasitic element**: Elements not connected directly to a feed line.
- **Resonant**: An antenna is resonant when its feed point impedance has zero reactance.
- **Feed point**: Where the transmitted energy enters the antenna.
- **Radiation**: *NOT* radioactivity! An antenna emitting electromagnetic waves.

# Electromagnetic Waves

- Radio waves are electromagnetic waves
  - Electric and magnetic fields at right angles to each other, oscillating at the wave's frequency
  - Spread out into space from the antenna
  - Created by ac current
  - Wave and current have the same frequency

# Wave Polarization

- Orientation of the wave's electric field component with respect to the surface of the Earth
  - *Vertical* or *horizontal* – determined by elements
  - Can be *circular* if the orientation twists as the wave spreads through space
  - Combinations of polarization are called *elliptical* polarization

# Cross-Polarization

- Antenna and wave polarization must match for maximum reception.
  - **Cross-polarized**: antenna elements and the wave's electric field at right angles
  - Can reduce reception by a factor of 100
- For elliptically polarized waves (such as HF sky-wave) any antenna will respond at least partially.

# The Decibel (dB)

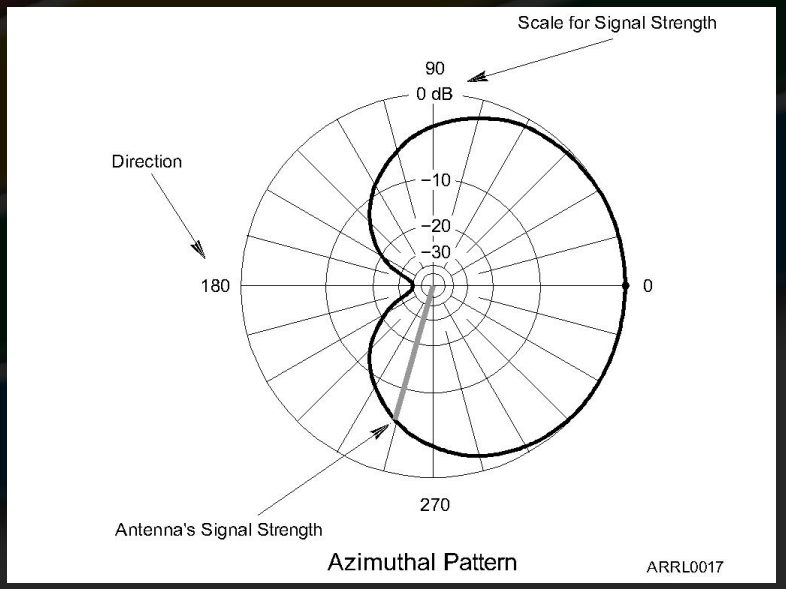
- A ratio expressed as an power of 10 to make large numbers easier to work with.
  - dB = 10 log (power ratio)
  - dB = 20 log (voltage ratio)
- Positive values in dB indicate ratios > 1 and negative values of dB are for ratios < 1.
- Antenna gain is discussed in terms of dB.

# The Antenna (Some Vocabulary)

- **Gain**: Apparent increase in power in a particular direction by focusing radiation in that direction. Measured in decibels (dB).
- **Isotropic**: Equal radiation in all directions.
- **Omnidirectional**: No preferred horizontal direction.
- **Directional**: Antenna that focuses radiation in specific directions.

# Antenna Radiation Patterns

- Radiation patterns are a way of visualizing antenna performance.
- The further the line is from the center of the graph, the stronger the signal at that point.
- Graph calibrated in dB.



# Radiation Pattern Vocabulary

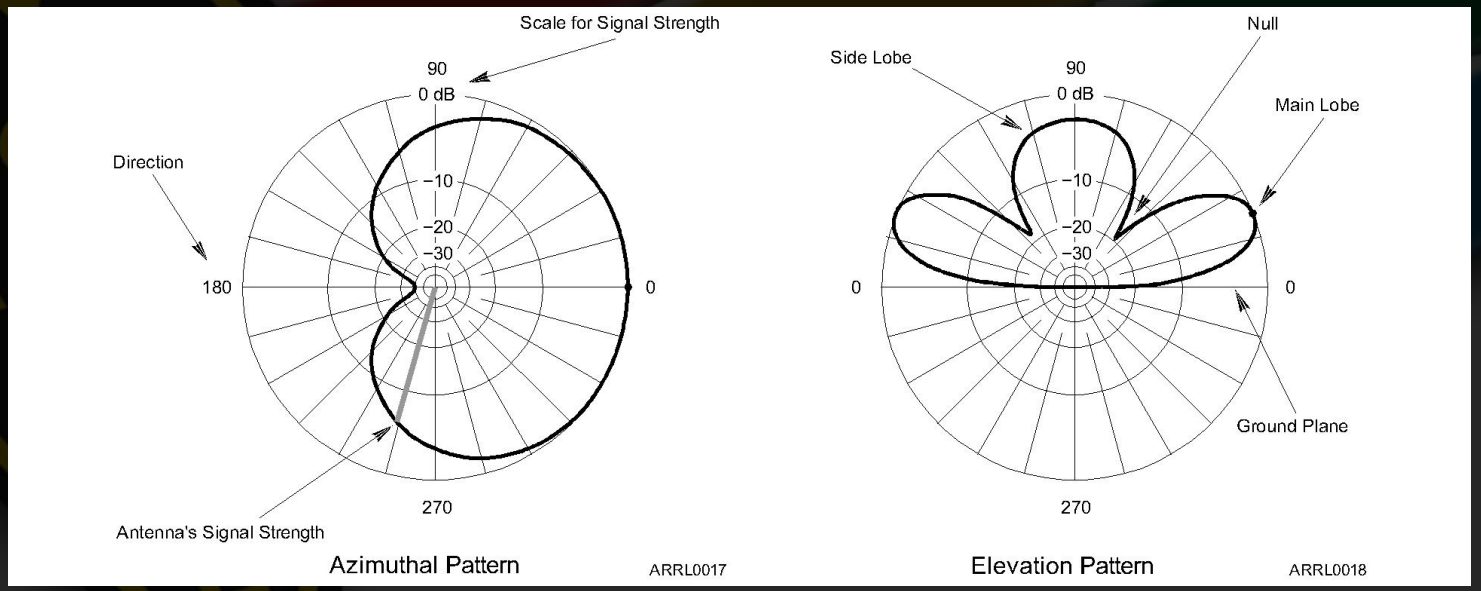
- **Nulls**: Directions of minimum gain
- **Lobes**: Regions between nulls
- **Main lobe**: Lobe with highest gain
- **Side lobe**: Any lobe other than the main lobe
- **Forward gain**: Gain in the direction assigned as forward

# Radiation Pattern Vocabulary

- **Azimuth pattern**: Radiation pattern showing gain in all horizontal directions around the antenna.
- **Elevation pattern**: Radiation pattern showing gain at all vertical angles from the antenna.
  - Often restricted to angles above horizontal

# Azimuth Pattern

# Elevation Pattern

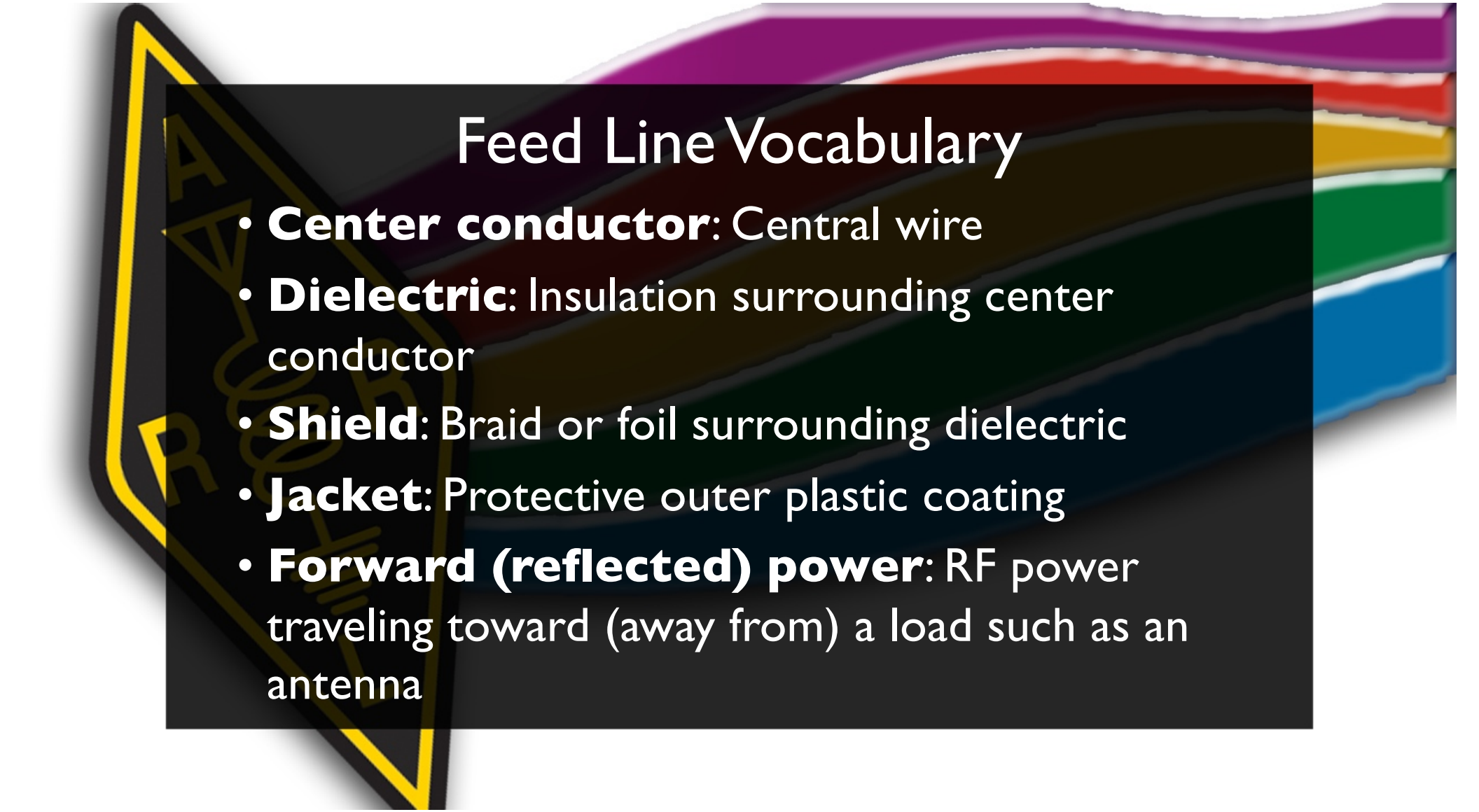


# Radiation Pattern Vocabulary

- **Front-to-back ratio**: Ratio of forward gain to gain in the opposite direction.
- **Front-to-side ratio**: Ratio of forward gain to gain at right angles to the forward direction.

# Feed Lines

- The purpose of the feed line is to get RF power from your station to the antenna.
- Basic feed line types
  - *Coaxial cable* (coax)
  - *Open-wire line* (OWL) also called ladder line or window line
- Power lost as heat in the feed line is called *loss* and it increases with frequency.

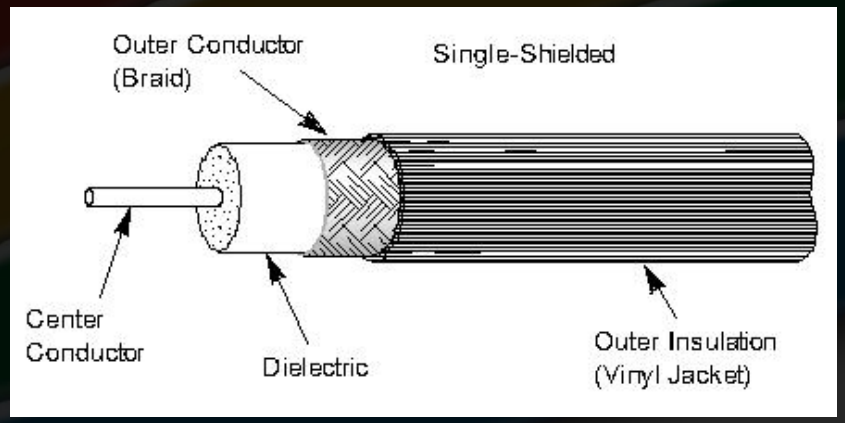


# Feed Line Vocabulary

- **Center conductor**: Central wire
- **Dielectric**: Insulation surrounding center conductor
- **Shield**: Braid or foil surrounding dielectric
- **Jacket**: Protective outer plastic coating
- **Forward (reflected) power**: RF power traveling toward (away from) a load such as an antenna

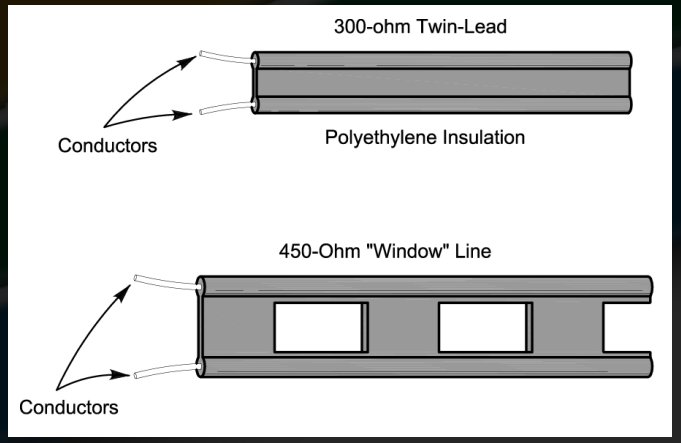
# Coaxial Cable

- Most common feed line
- Easy to use
- Not affected by nearby materials
- Has higher loss than open-wire line at most frequencies
- Air-insulated "hard line" has lowest loss




# Open-Wire Line

- Lighter and less expensive than coax
- Has lower loss than coax at most frequencies
- More difficult to use since it is affected by nearby materials
- Requires impedance matching equipment to use with most transceivers



# Characteristic Impedance

- The impedance presented to a wave traveling through a feed line
- Given in ohms (Ω), symbolized as $Z_0$
- Depends on how the feed line is constructed and what materials are used
  - Coax: 50 and 75 Ω
  - OWL: 300, 450, and 600 Ω

# Standing Wave Ratio (SWR)

- If the antenna feed point and feed line impedances are not identical, some RF power is reflected back toward the transmitter.
  - Called a *mismatch*
  - Forward and reflected waves create a pattern of *standing waves* of voltage and current in the line
  - SWR is the ratio of standing wave max to min
- Measured with an *SWR meter* or *SWR bridge*

# Standing Wave Ratio (SWR)

- Reflected power is re-reflected at the transmitter and bounces back and forth.
  - Some RF power is lost as heat on each trip back and forth through the feed line
  - All RF power is eventually lost as heat or transferred to the antenna or load
- High SWR means more reflections and more loss of RF power (less transferred to the antenna or load).

# Nothing Is Perfect

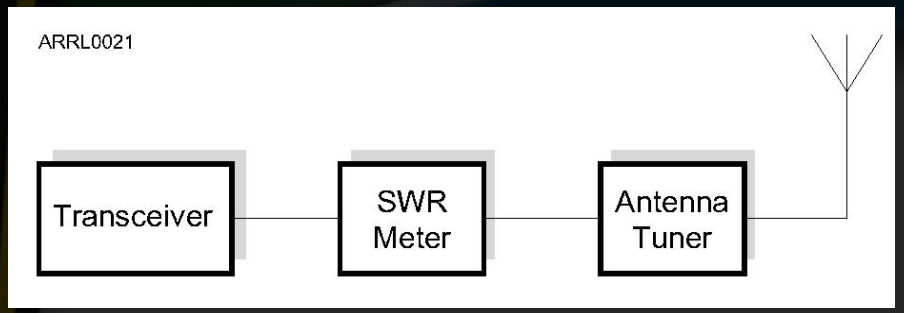
- SWR equals the ratio of feed point (or *load*) and feed line impedance, whichever is greater than 1 (SWR always greater than 1:1).
- What is an acceptable SWR?
  - 1:1 SWR is perfect – no power reflected
  - Up to 2:1 SWR is normal
  - Modern radios lower transmitter output power for protection when SWR is above 2:1

# Nothing Is Perfect

- SWR above 3:1 is considered high in most cases.
- Erratic SWR readings may indicate a faulty feed line, faulty feed line connectors, or a faulty antenna.
- High SWR can be corrected by
  - Tuning or adjusting the antenna
  - With impedance matching equipment at the transmitter
    - Called an *antenna tuner* or *transmatch*
    - Does not change SWR in the feed line

# Adjusting SWR

- An SWR meter is inserted in the feed line and indicates the mismatch at that point.
- Either adjust the antenna to minimize the reflected power or adjust the antenna tuner for minimum SWR at the transceiver.



# Dummy Loads

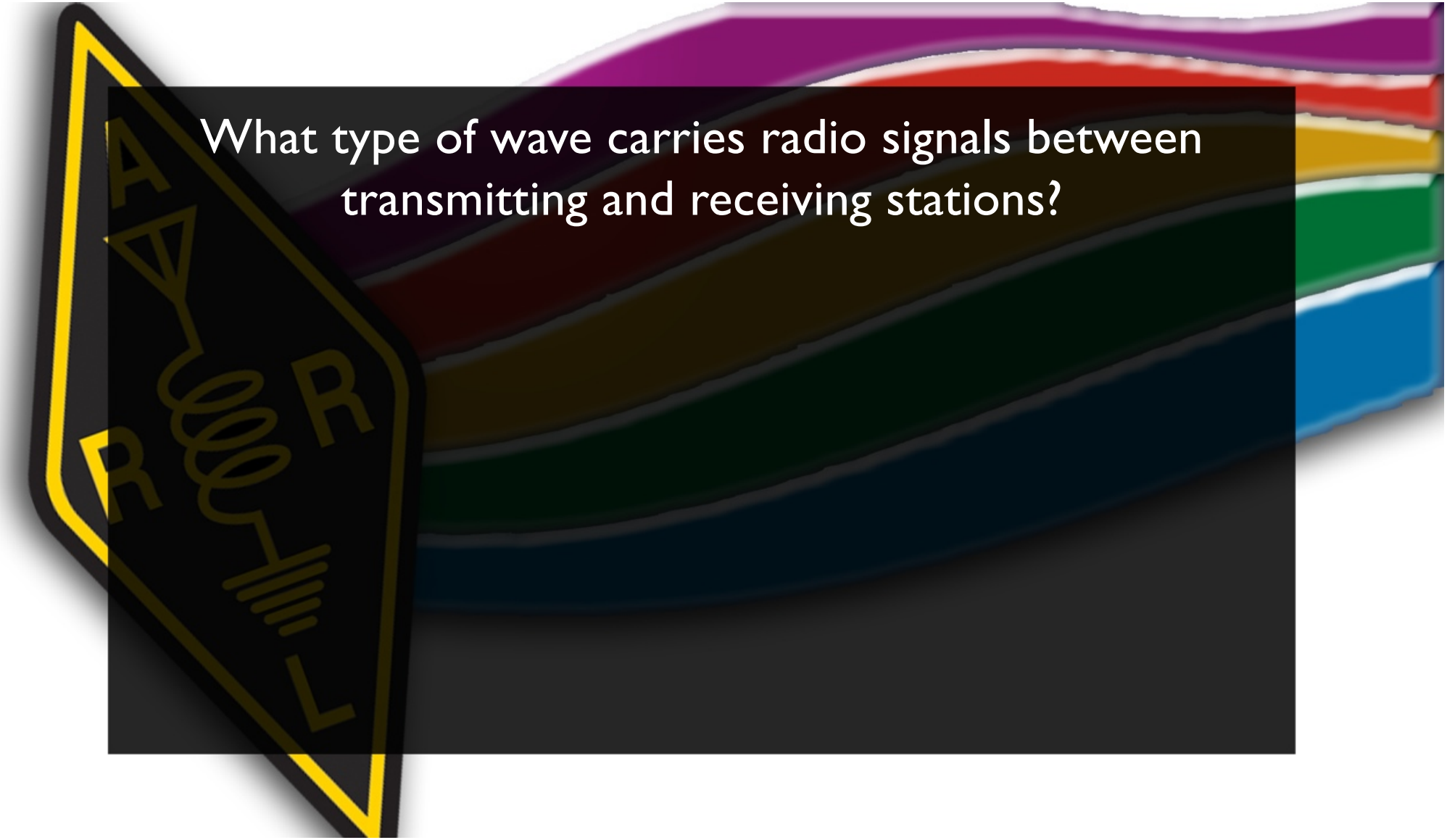
- A dummy load is a resistor and a heat sink
- Used to replace an antenna or other piece of equipment during testing.
- Dummy loads dissipate signals in the feed line as heat
- Allows transmitter testing without sending a signal over the air
- Helpful in troubleshooting an antenna system

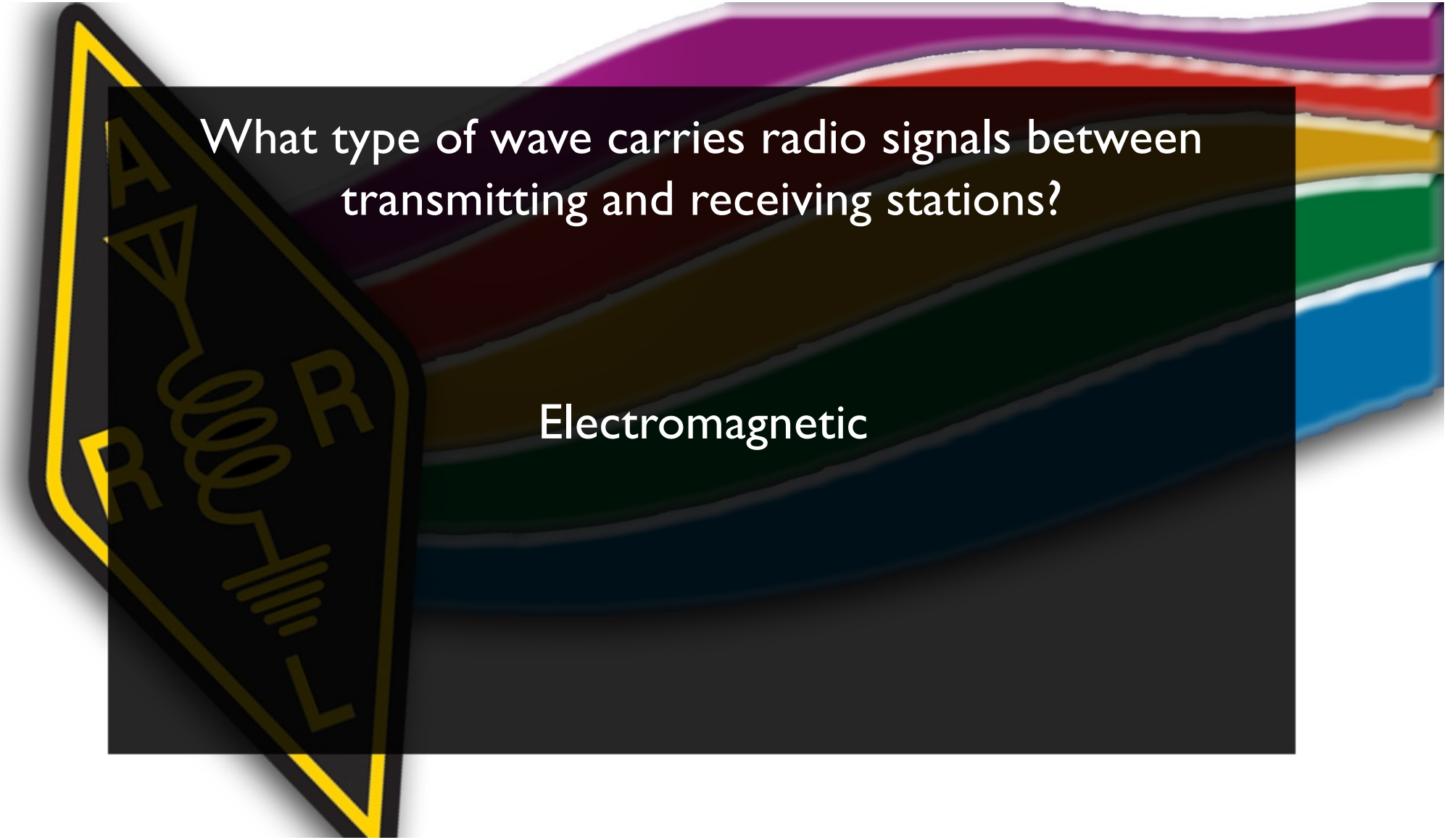

# Practice Questions


What can happen if the antennas at opposite ends of a VHF or UHF line of sight radio link are not using the same polarization?

What can happen if the antennas at opposite ends of a VHF or UHF line of sight radio link are not using the same polarization?

Signals could be significantly weaker

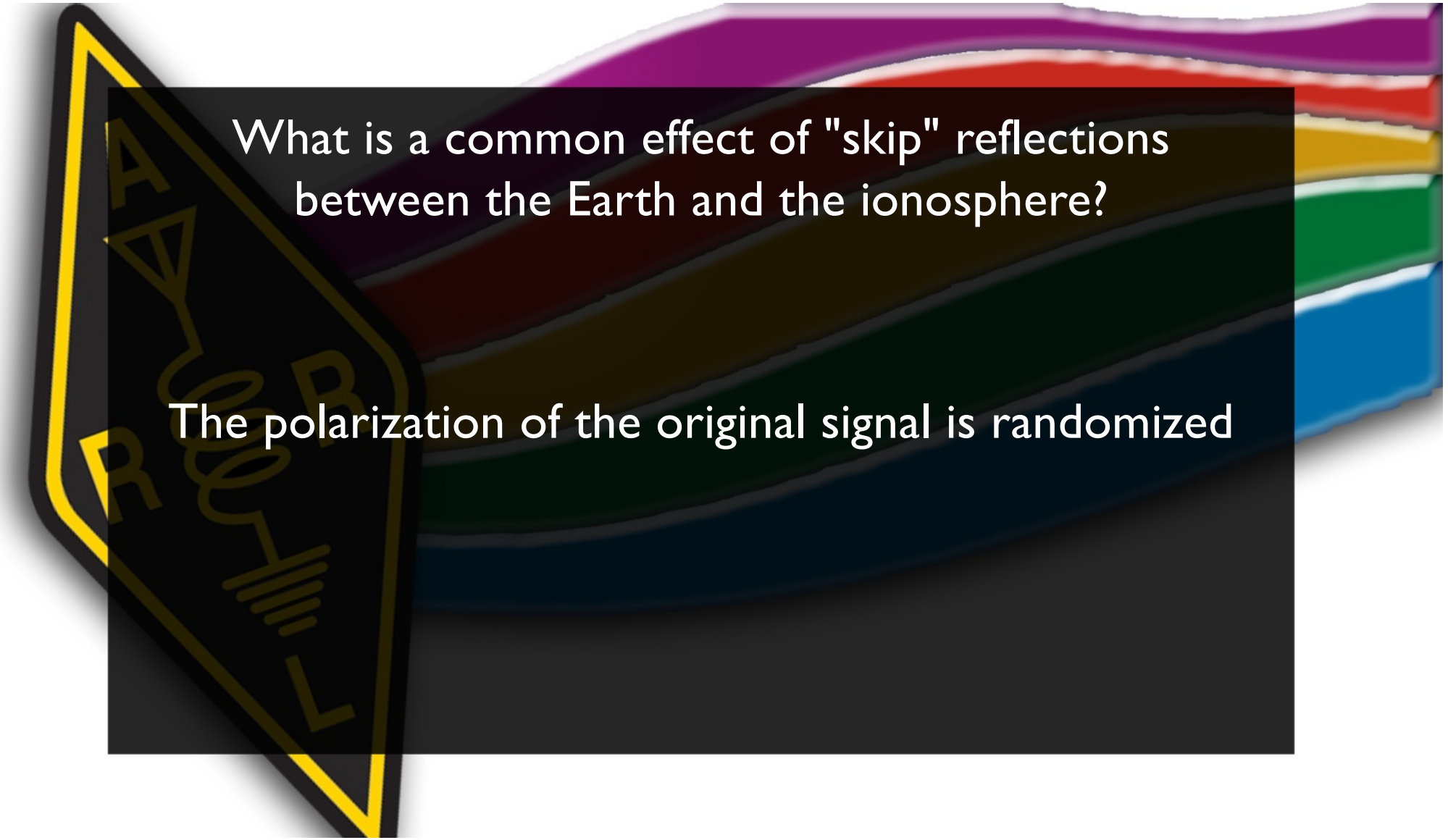

What type of wave carries radio signals between transmitting and receiving stations?




What type of wave carries radio signals between transmitting and receiving stations?

Electromagnetic

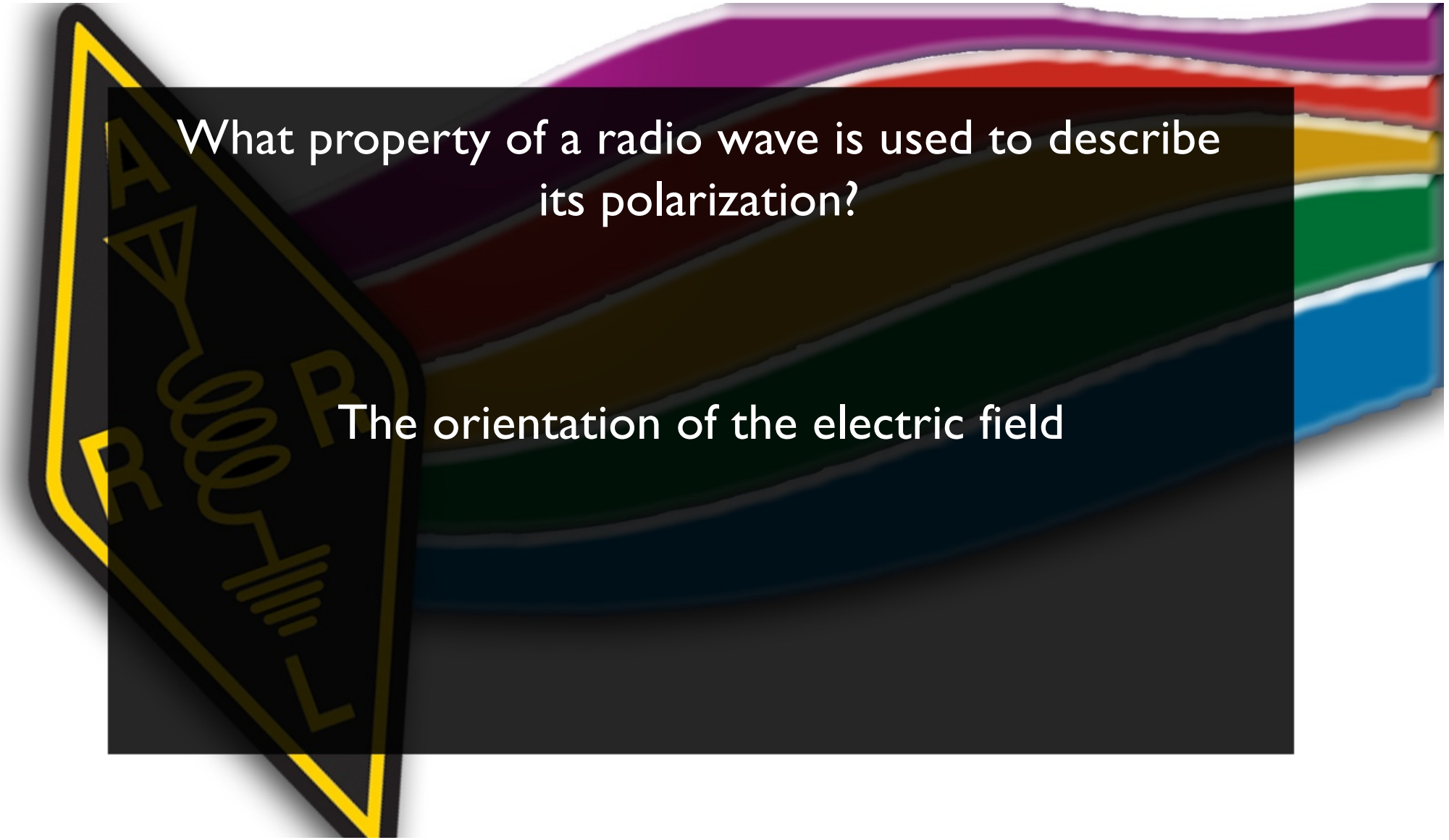

What is a common effect of "skip" reflections between the Earth and the ionosphere?



What is a common effect of "skip" reflections between the Earth and the ionosphere?

The polarization of the original signal is randomized

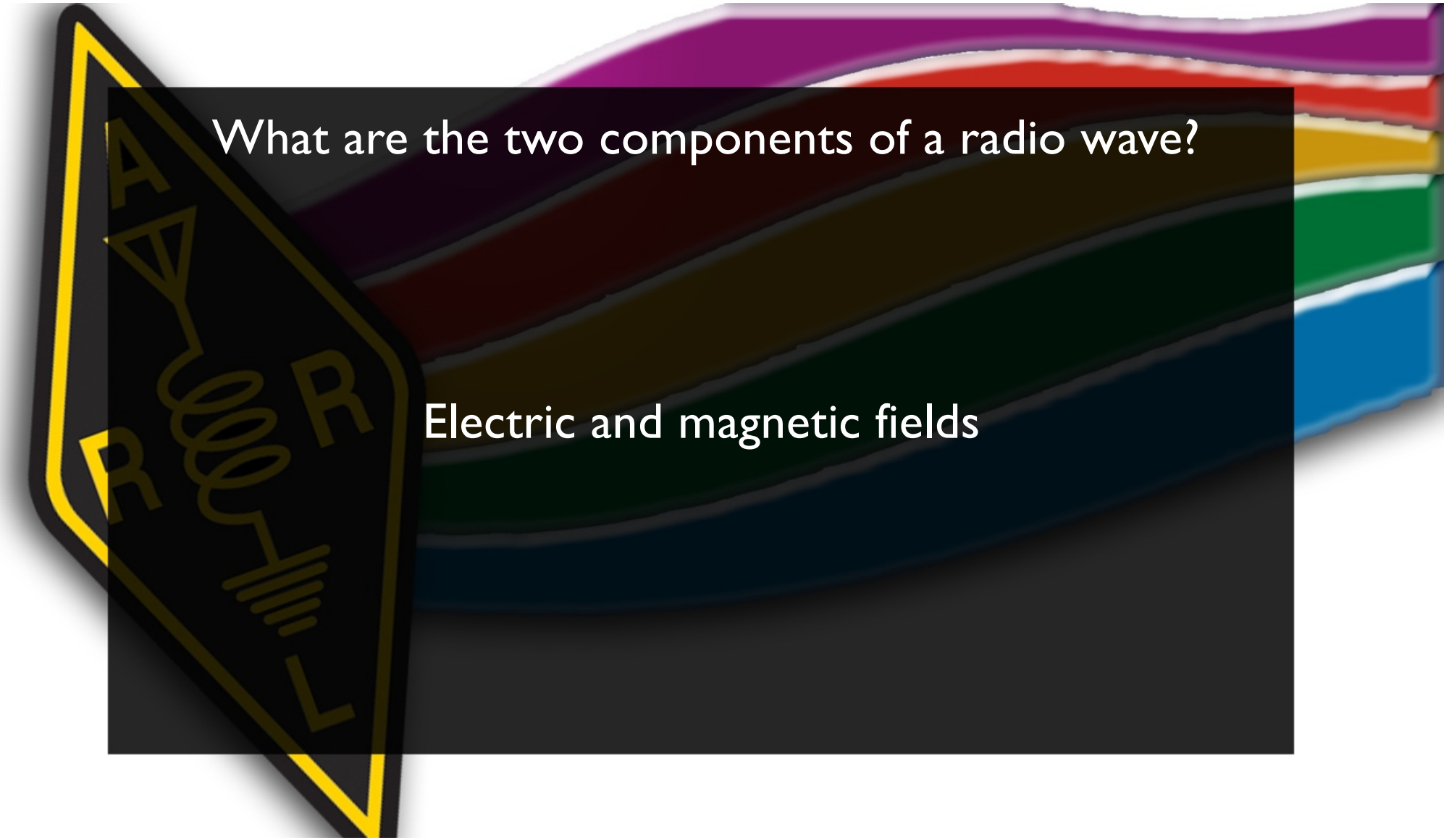

What property of a radio wave is used to describe its polarization?



What property of a radio wave is used to describe its polarization?

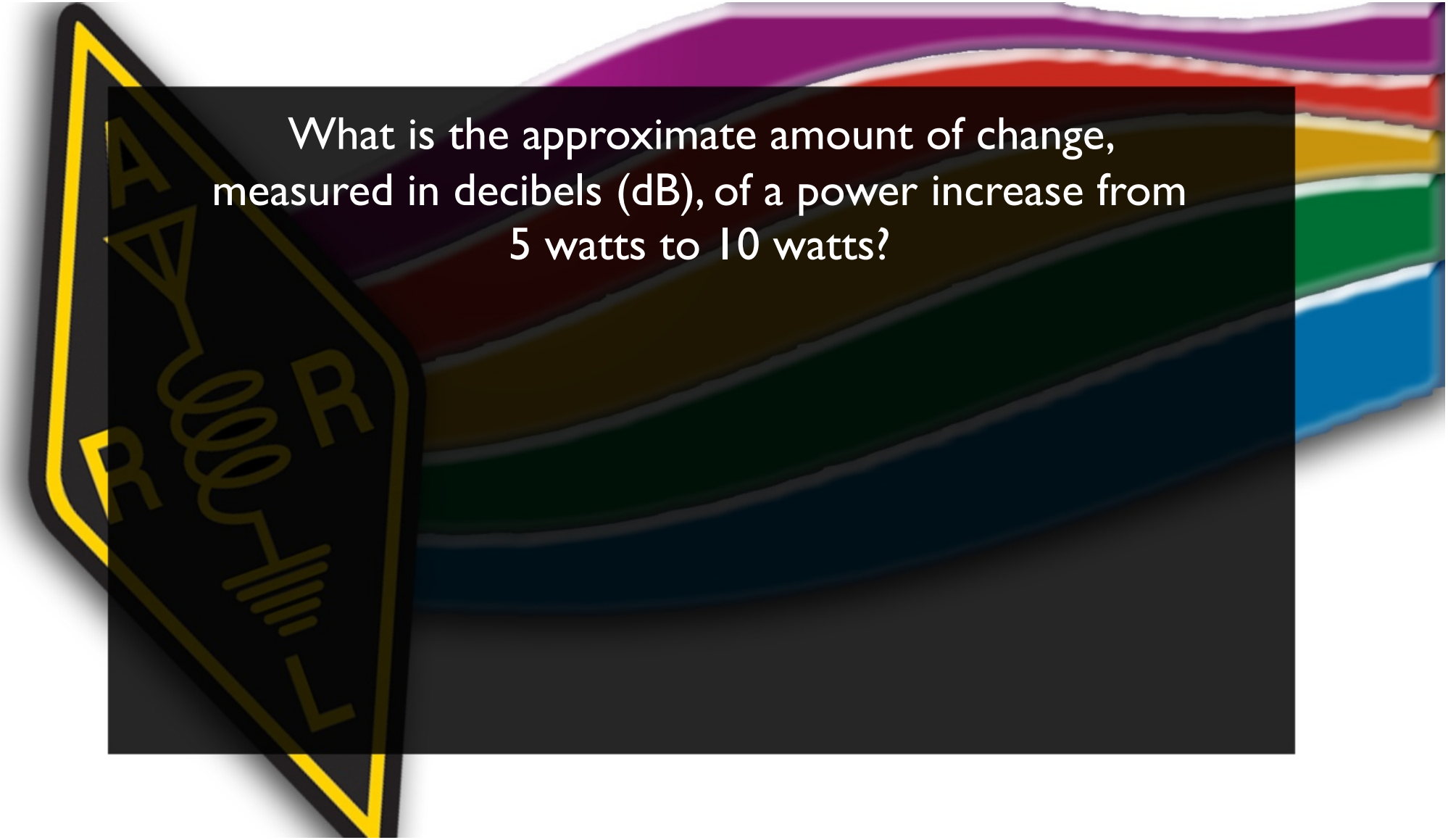
The orientation of the electric field

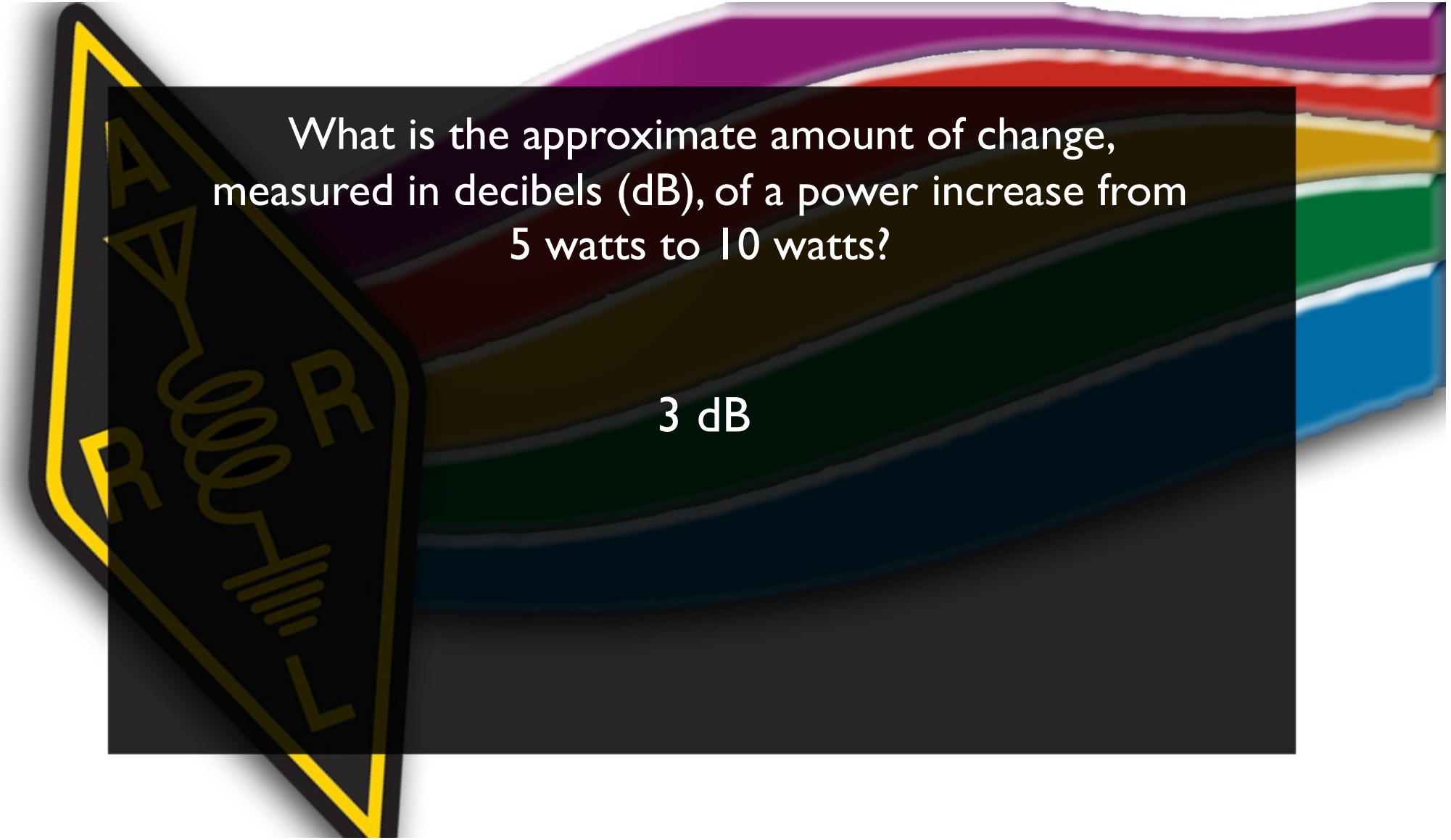

What are the two components of a radio wave?



What are the two components of a radio wave?

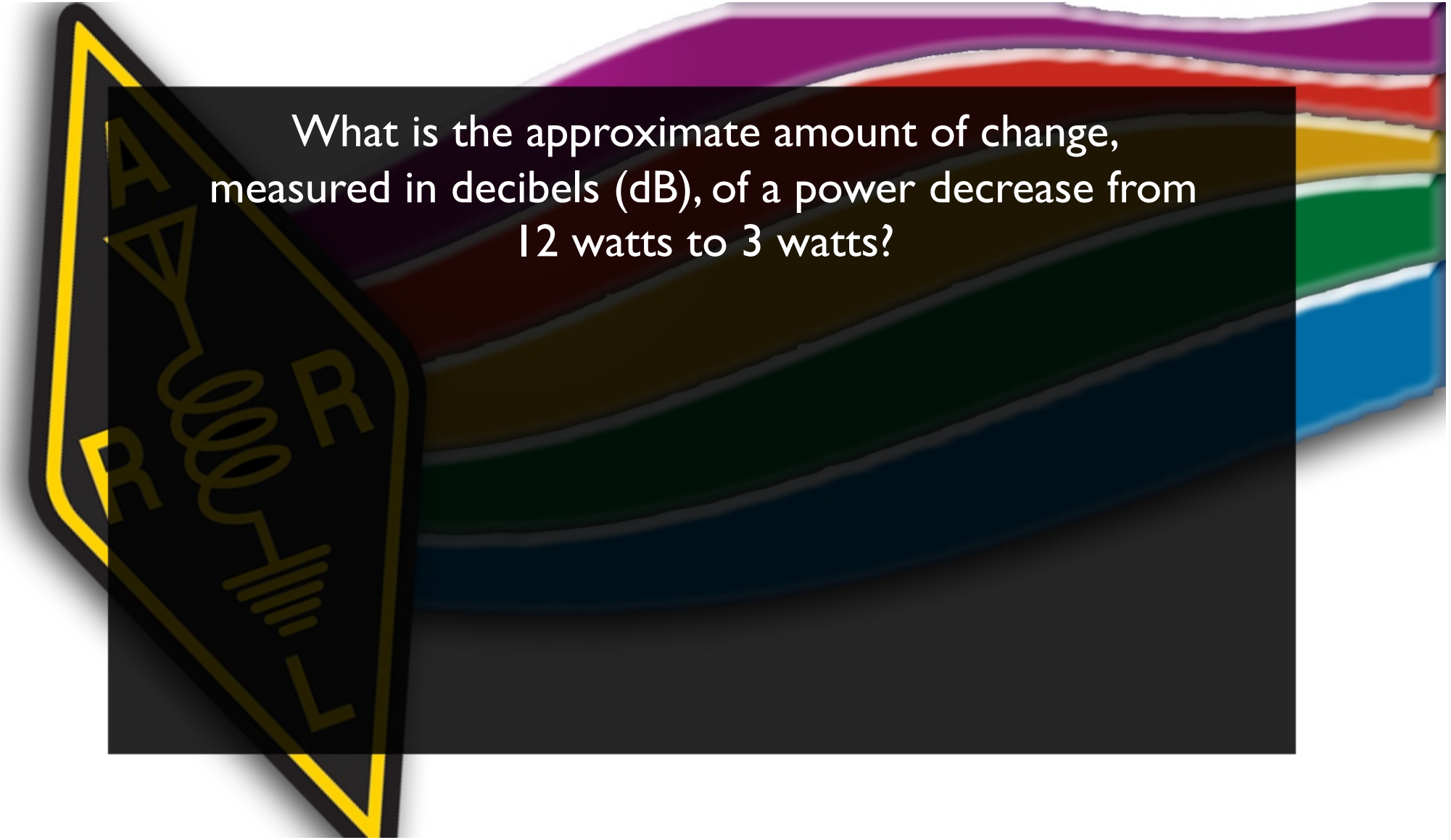
Electric and magnetic fields


What is the approximate amount of change,
measured in decibels (dB), of a power increase from
5 watts to 10 watts?



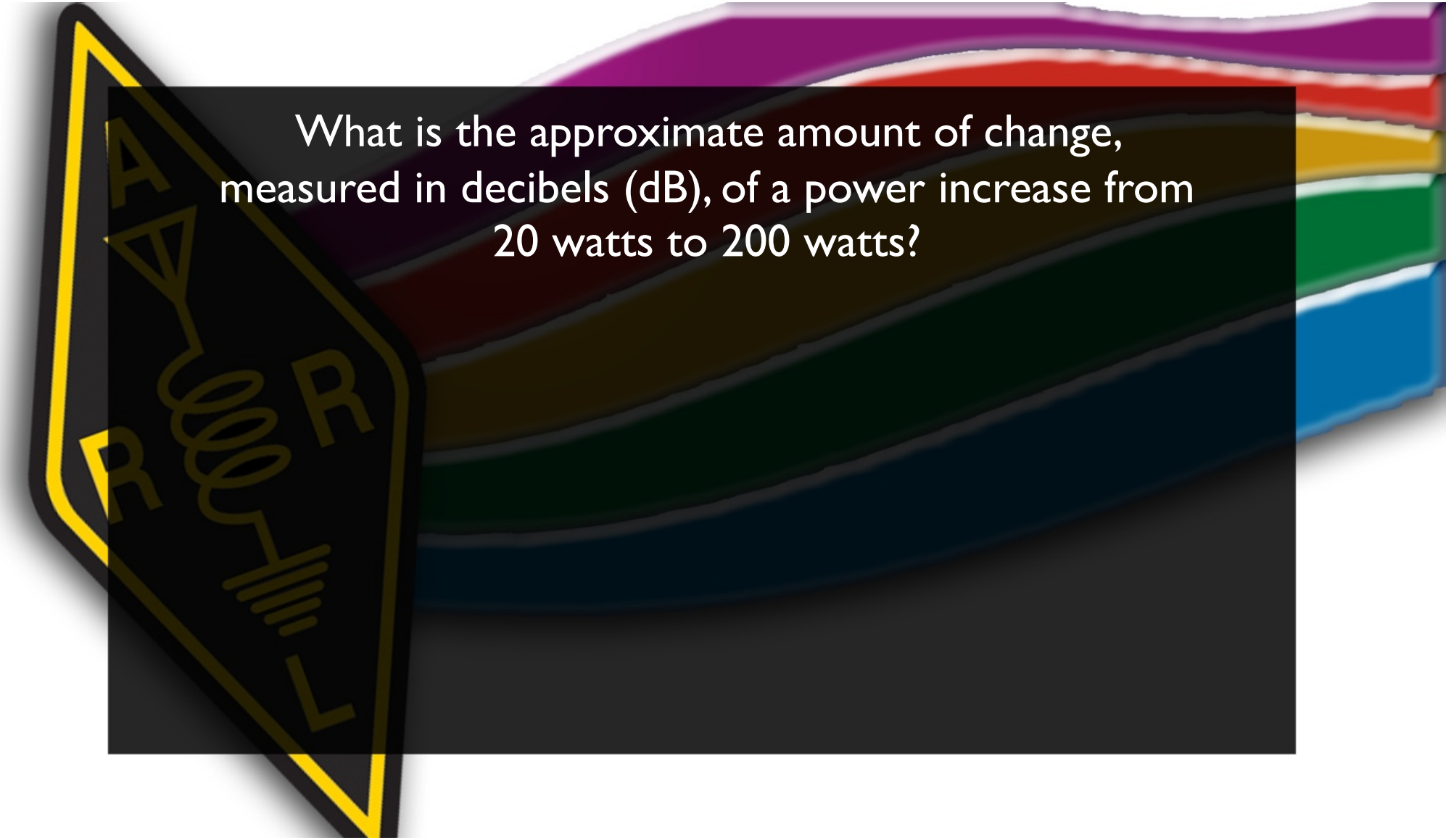
What is the approximate amount of change, measured in decibels (dB), of a power increase from 5 watts to 10 watts?

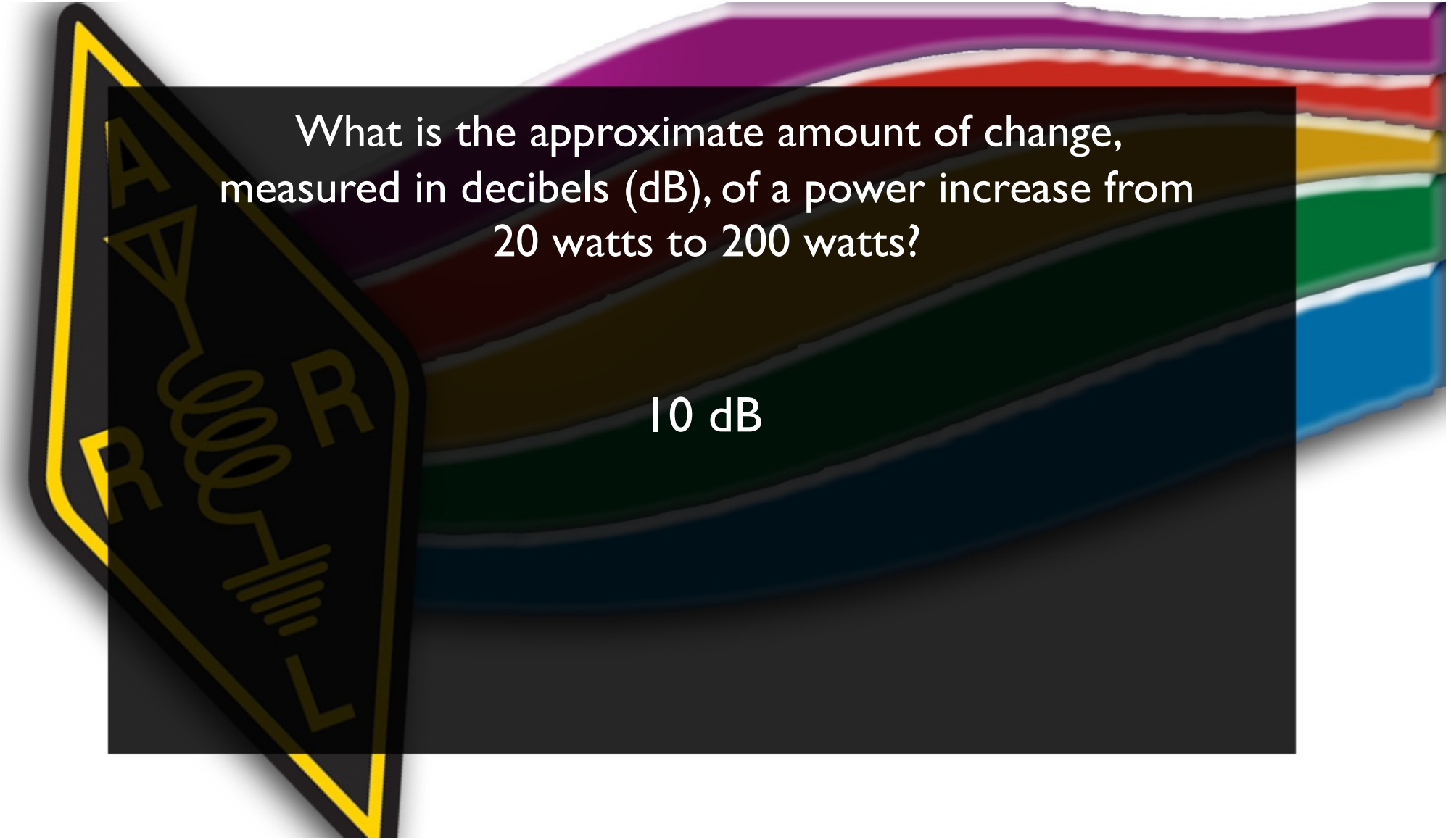
3 dB


What is the approximate amount of change, measured in decibels (dB), of a power decrease from 12 watts to 3 watts?

What is the approximate amount of change, measured in decibels (dB), of a power decrease from 12 watts to 3 watts?

-6 dB


What is the approximate amount of change, measured in decibels (dB), of a power increase from 20 watts to 200 watts?



What is the approximate amount of change, measured in decibels (dB), of a power increase from 20 watts to 200 watts?

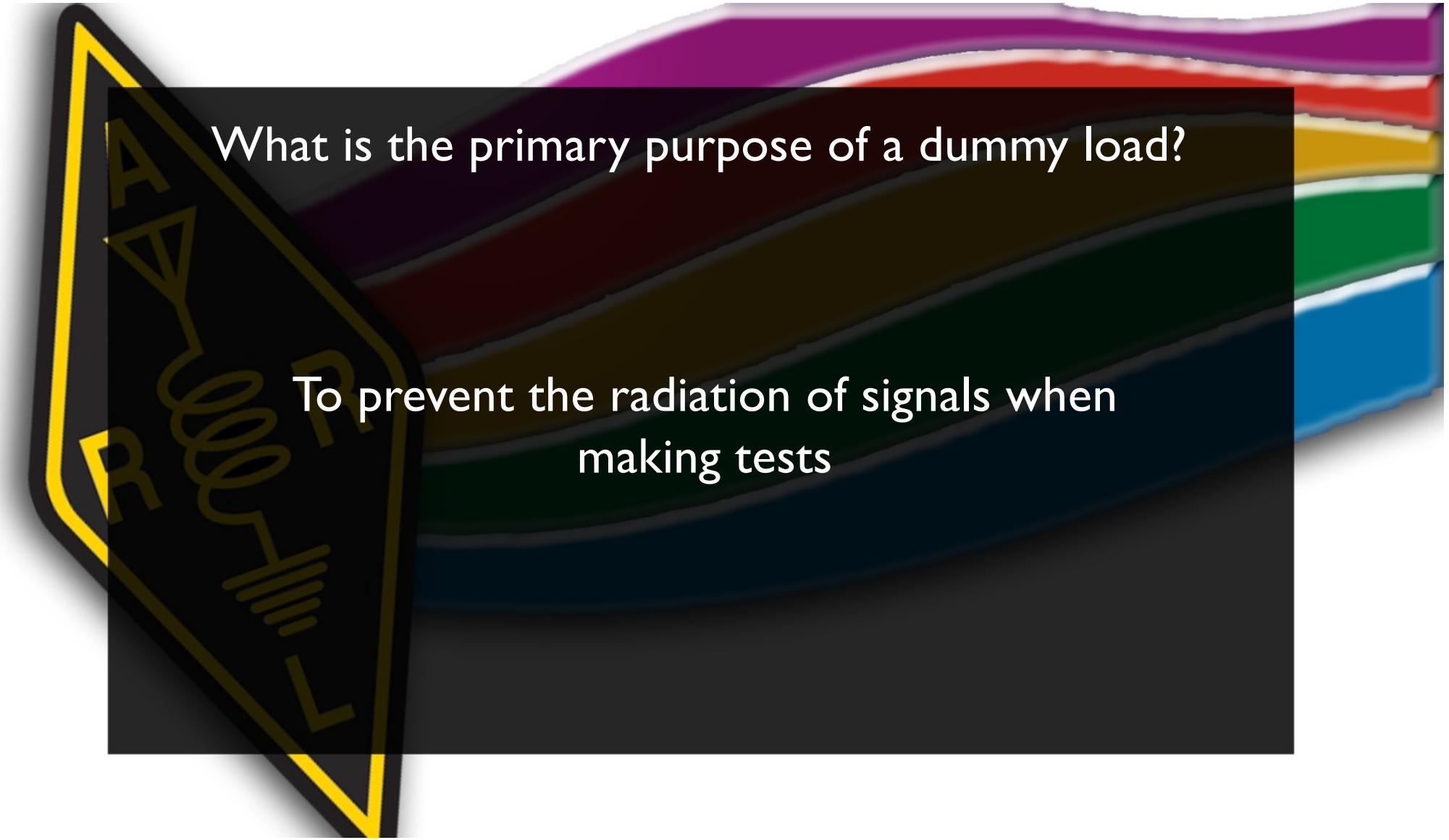
10 dB


What is a usual name for electromagnetic waves
that travel through space?

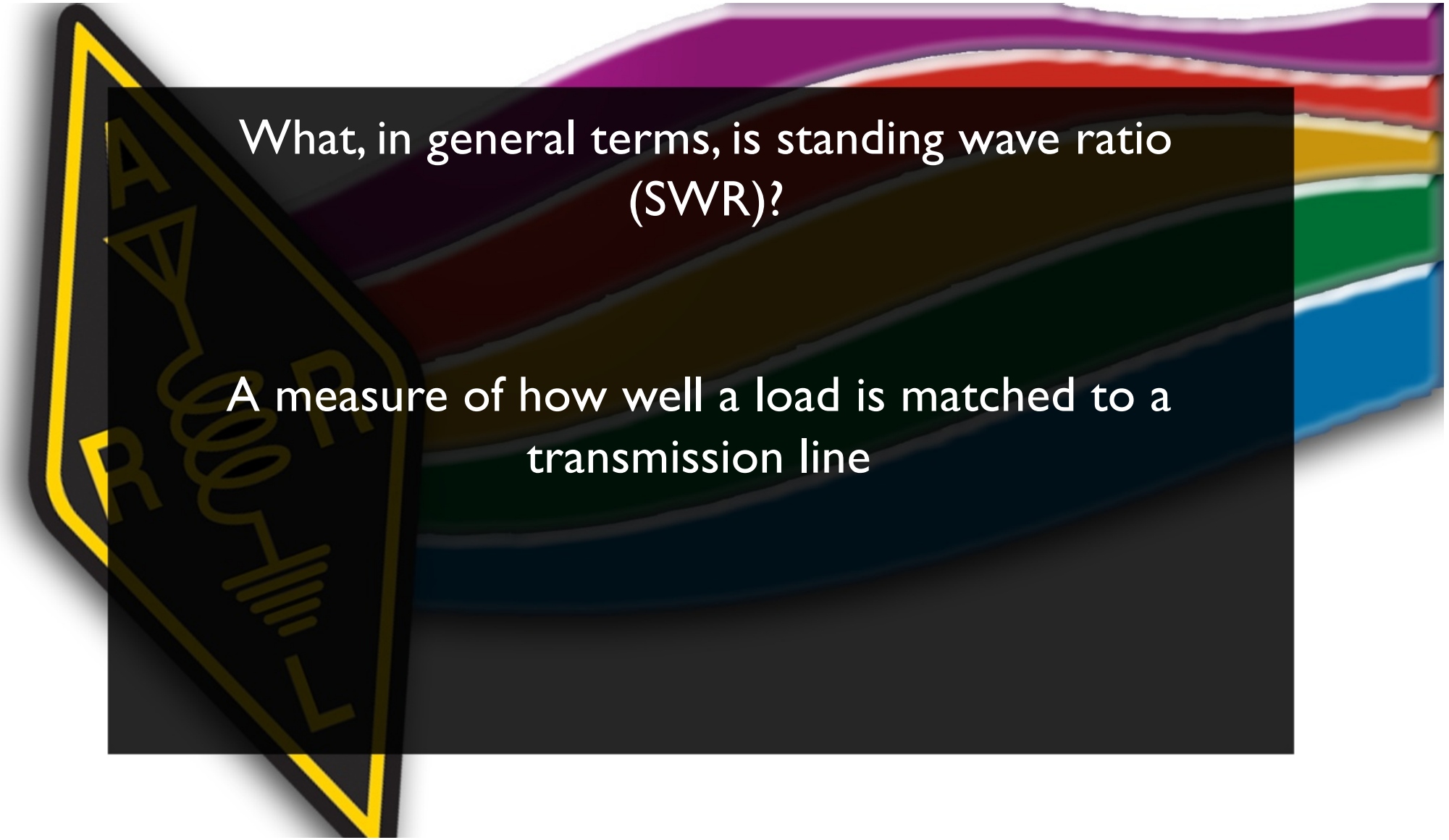
What is a usual name for electromagnetic waves that travel through space?

Radio waves


What is the primary purpose of a dummy load?

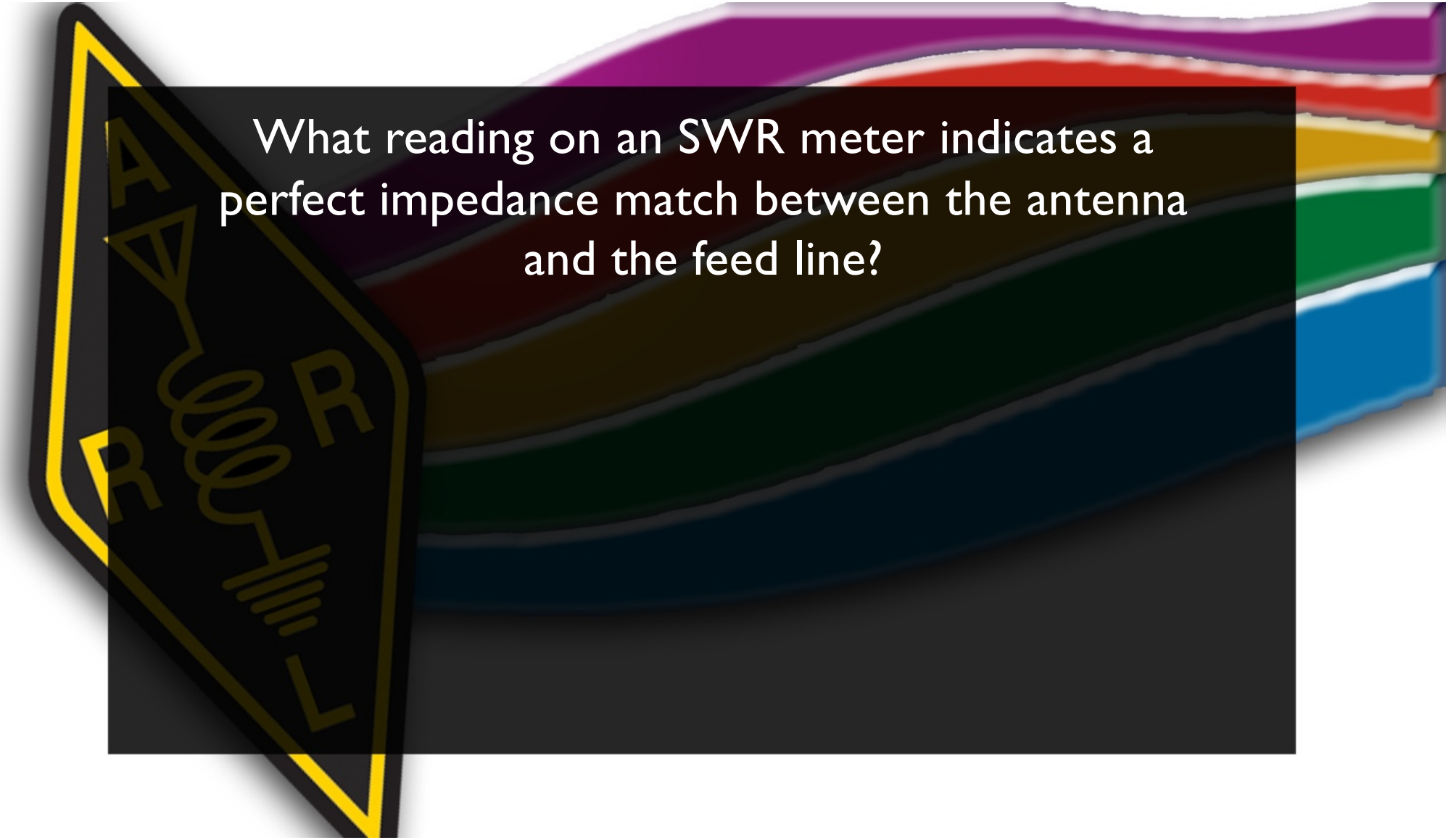

What is the primary purpose of a dummy load?
To prevent the radiation of signals when making tests

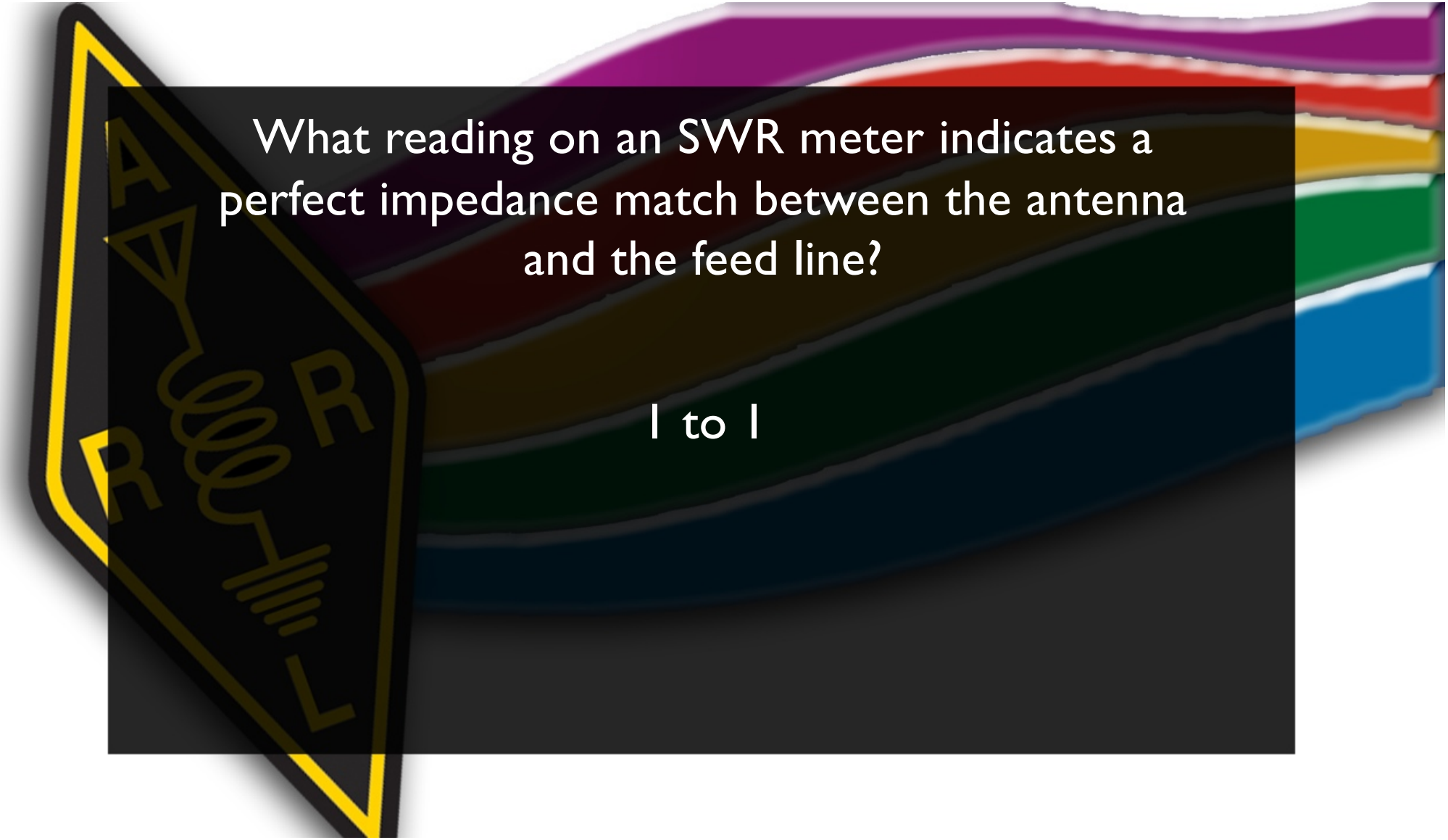

What, in general terms, is standing wave ratio (SWR)?

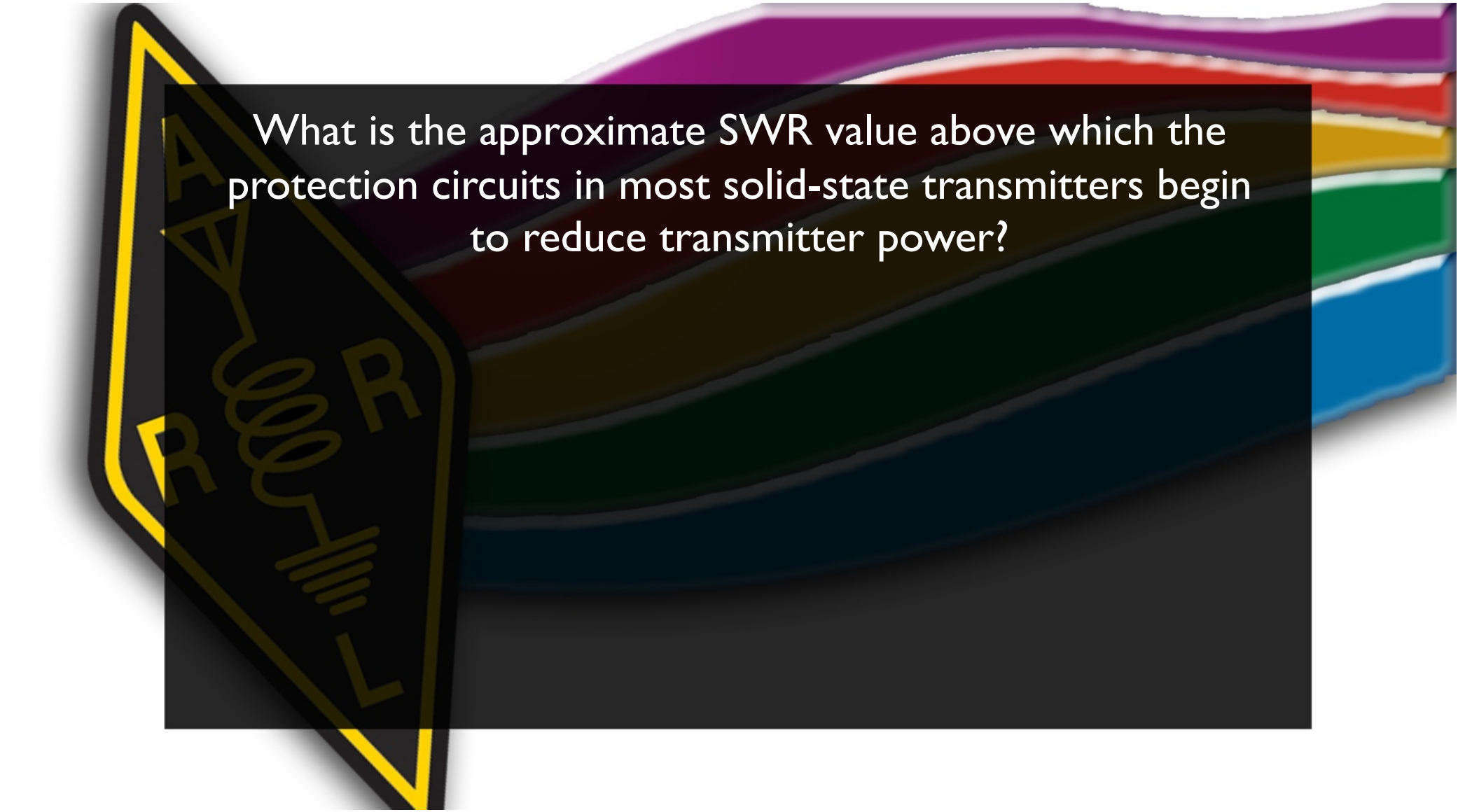


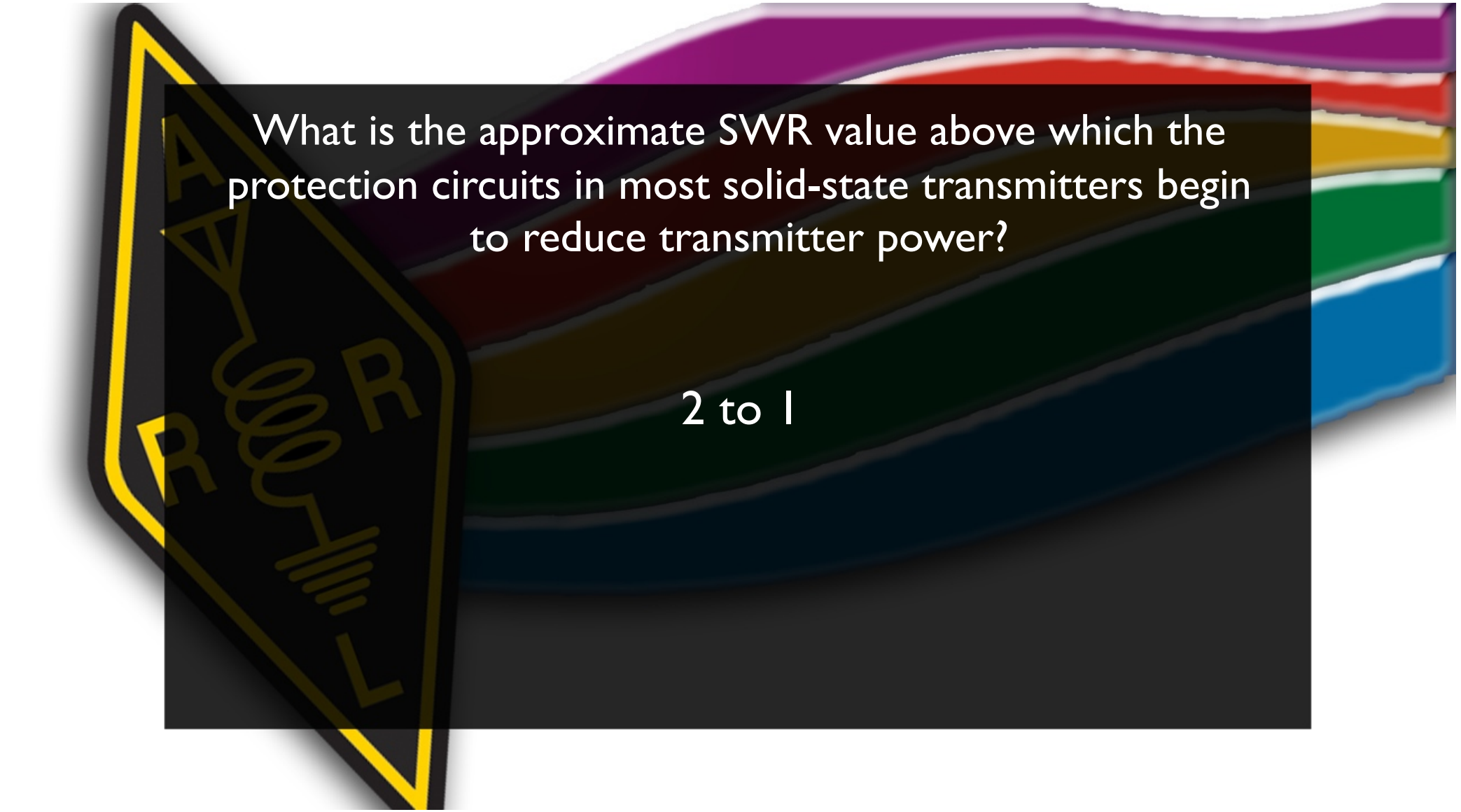
What, in general terms, is standing wave ratio (SWR)?

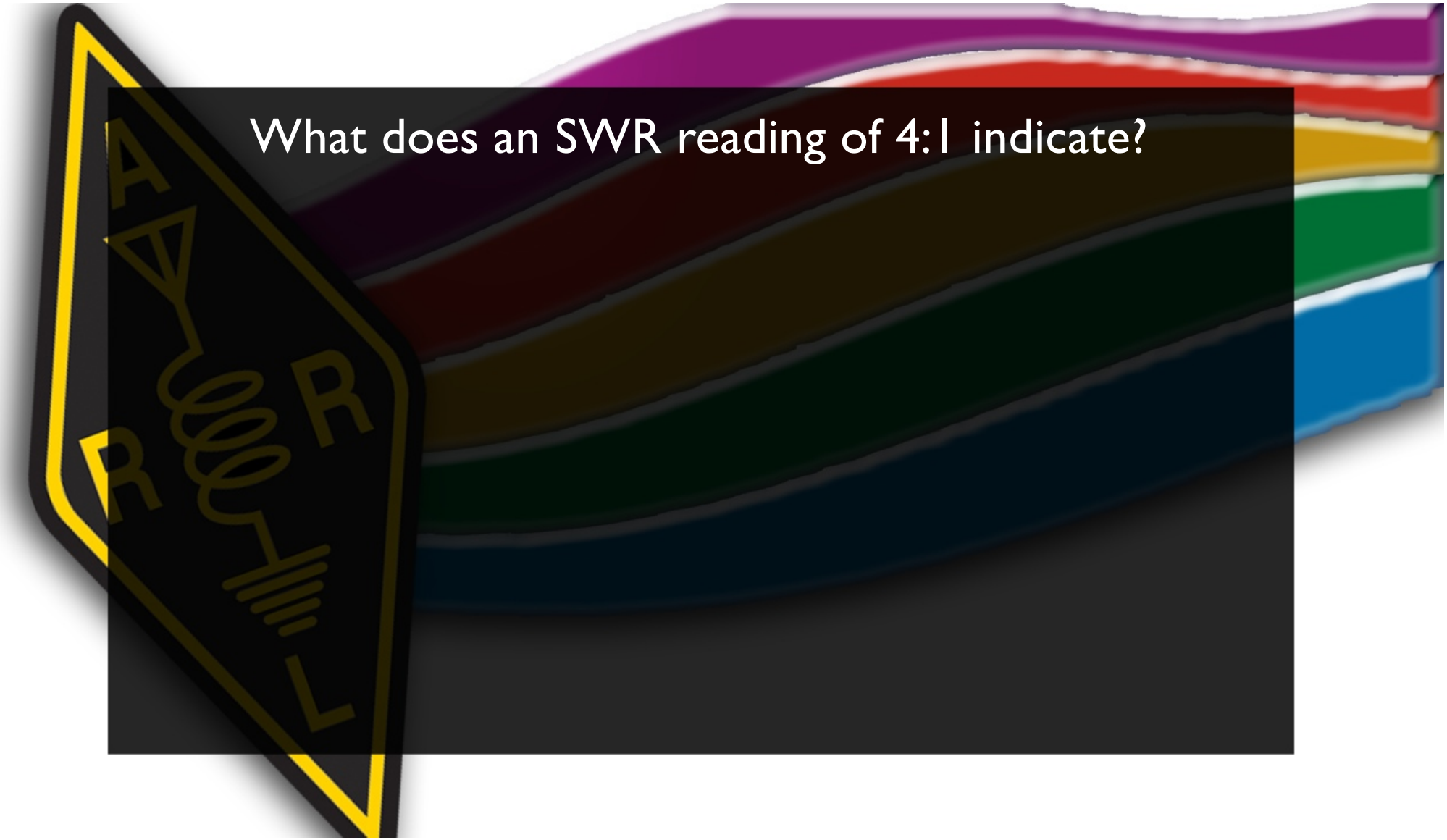
A measure of how well a load is matched to a transmission line


What reading on an SWR meter indicates a perfect impedance match between the antenna and the feed line?

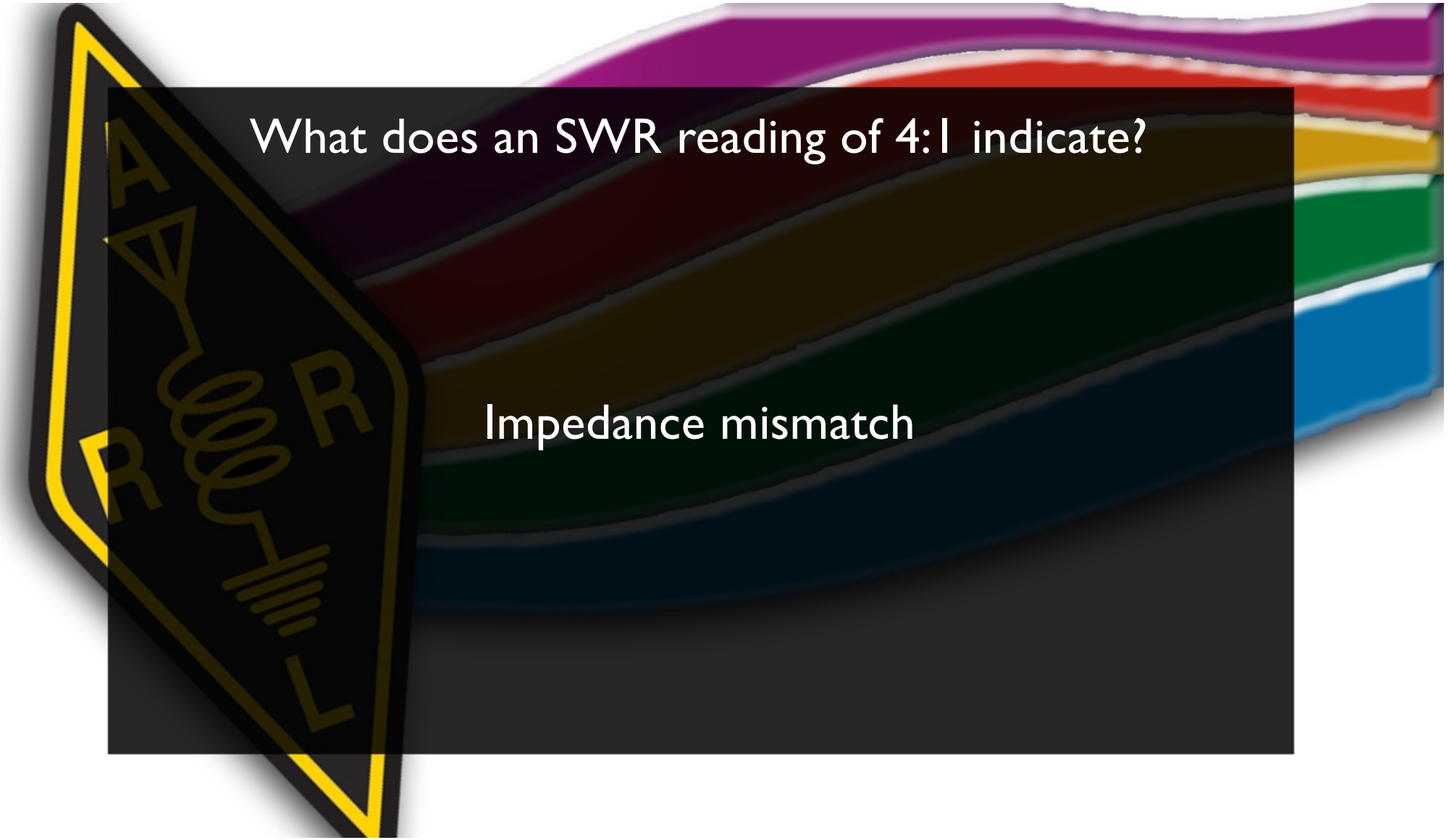

What reading on an SWR meter indicates a perfect impedance match between the antenna and the feed line?
1 to 1


What is the approximate SWR value above which the protection circuits in most solid-state transmitters begin to reduce transmitter power?


What is the approximate SWR value above which the protection circuits in most solid-state transmitters begin to reduce transmitter power?
2 to 1




What does an SWR reading of 4:1 indicate?



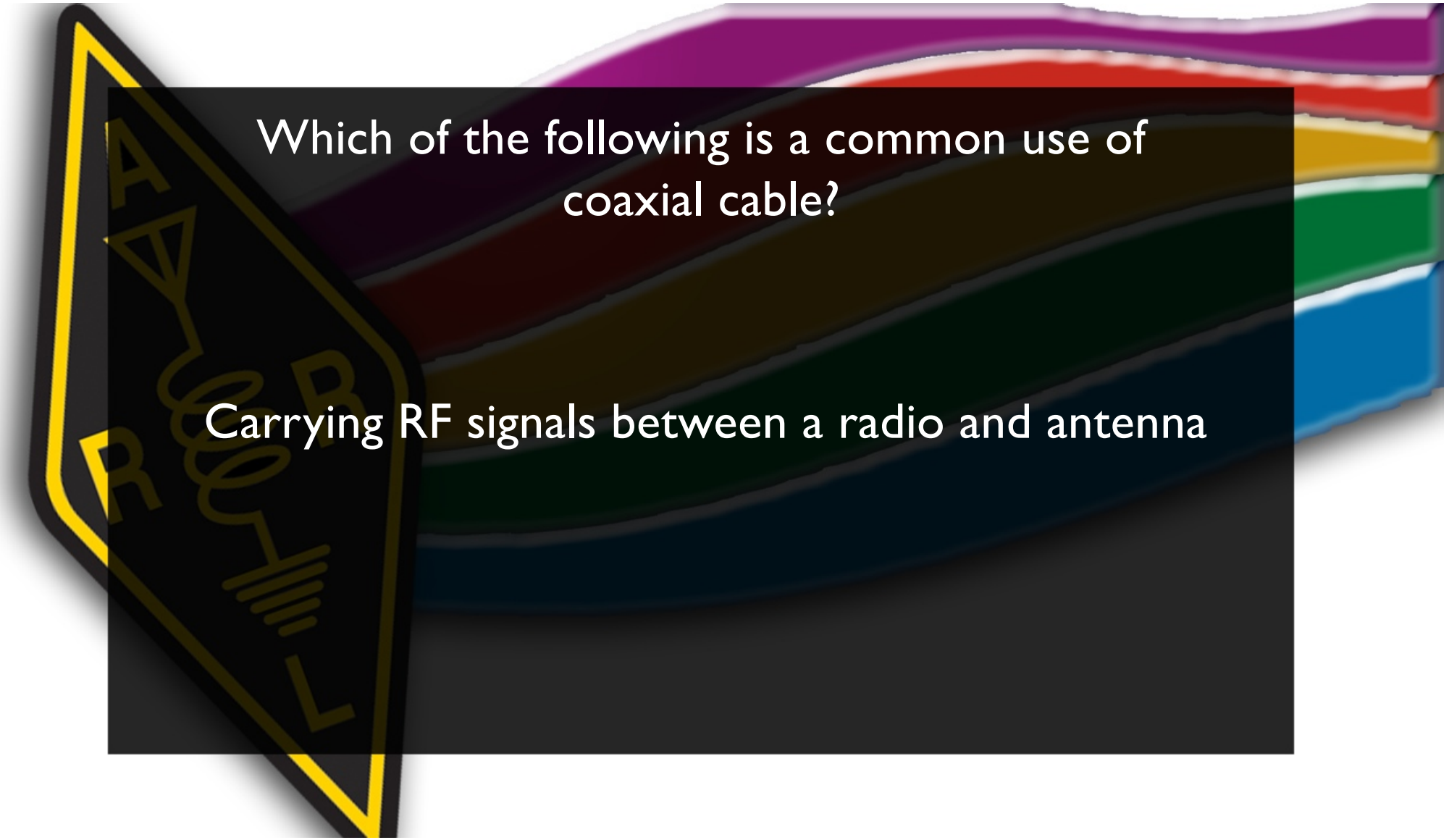
What does an SWR reading of 4:1 indicate?

Impedance mismatch


What happens to power lost in a feed line?


What happens to power lost in a feed line?
It is converted into heat

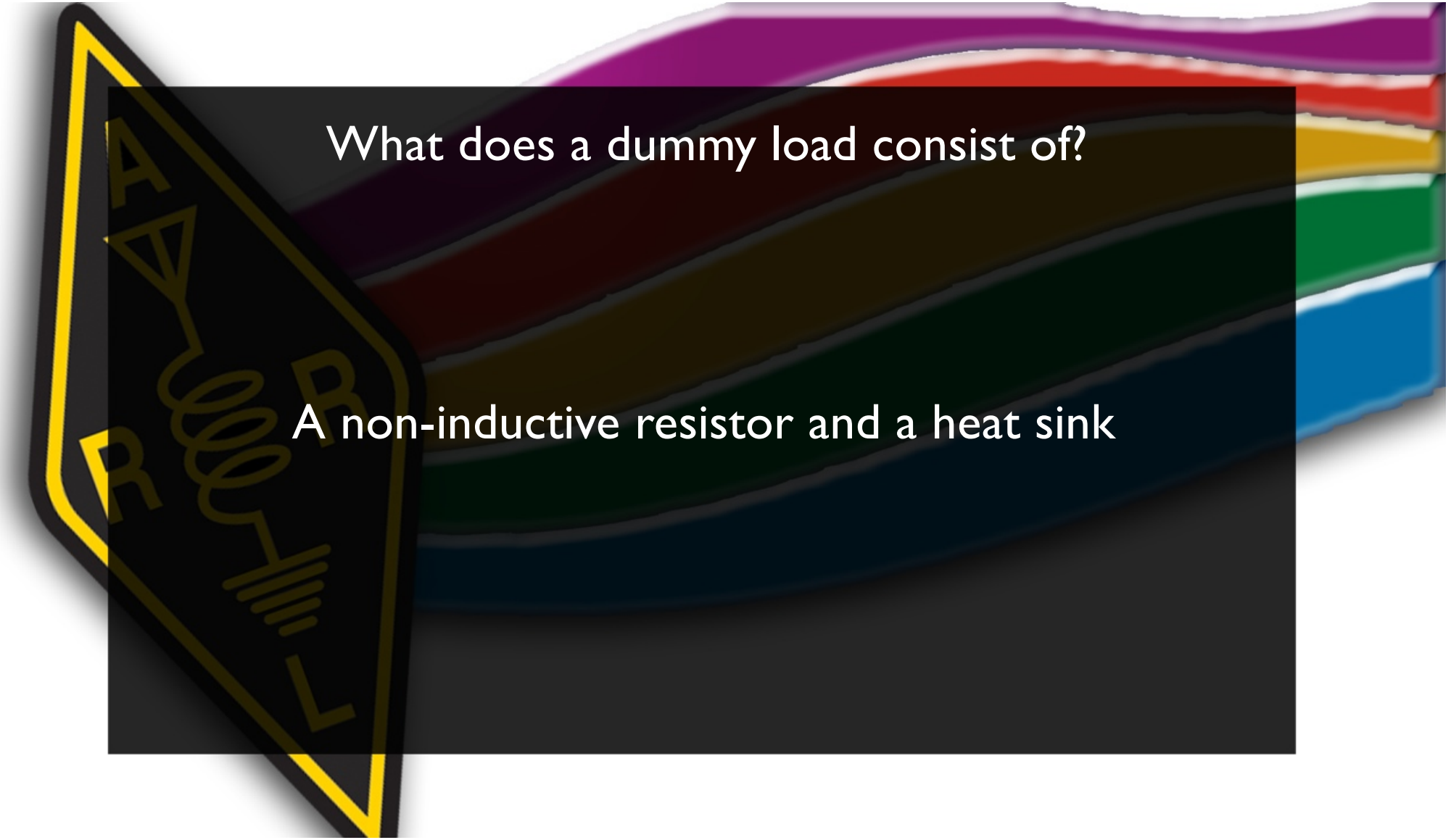
Which of the following is a common use of coaxial cable?



Which of the following is a common use of coaxial cable?

Carrying RF signals between a radio and antenna


What does a dummy load consist of?



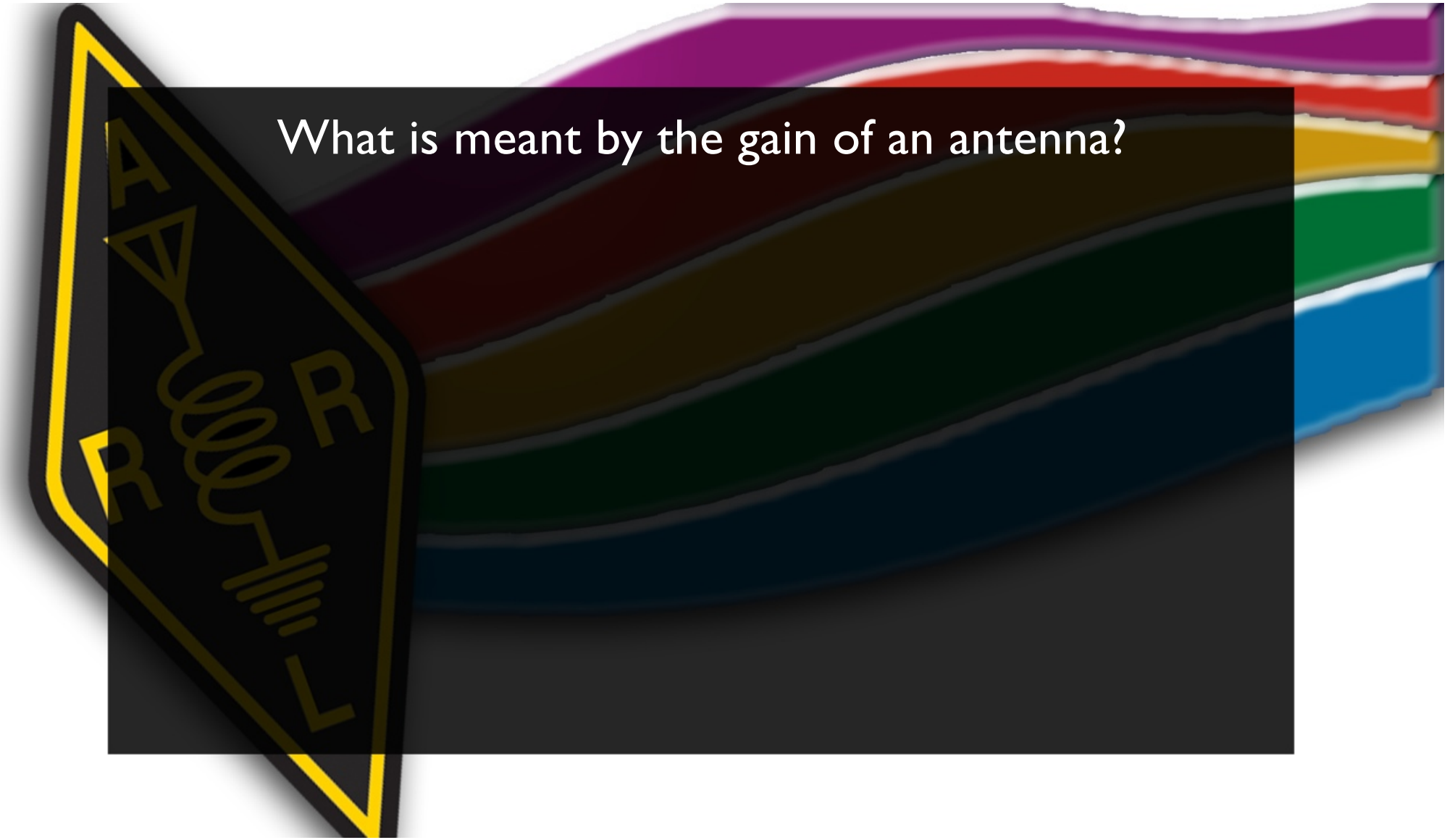
What does a dummy load consist of?

A non-inductive resistor and a heat sink

What is true of the electric field in vertical antennas?

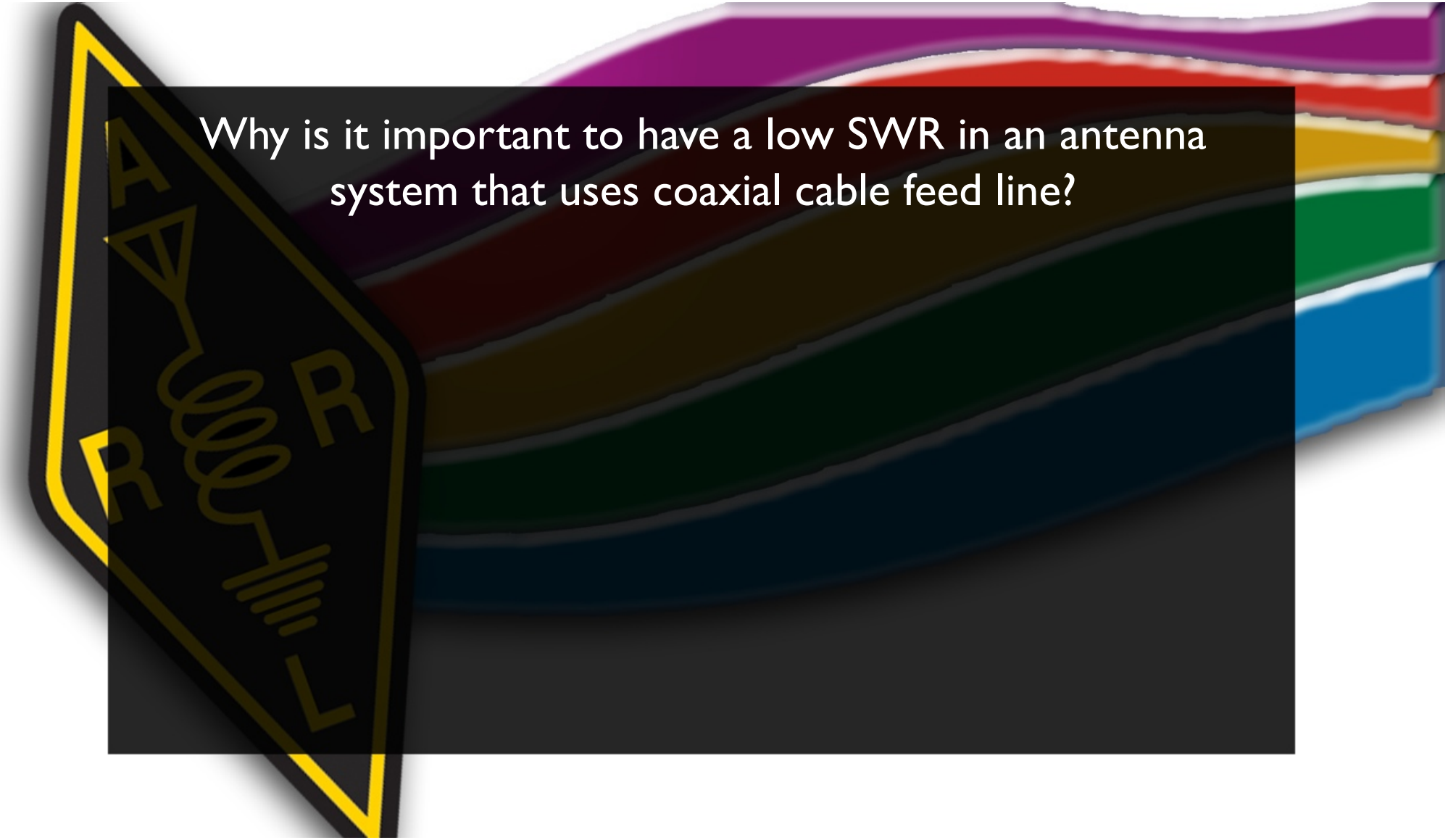
What is true of the electric field in vertical antennas?

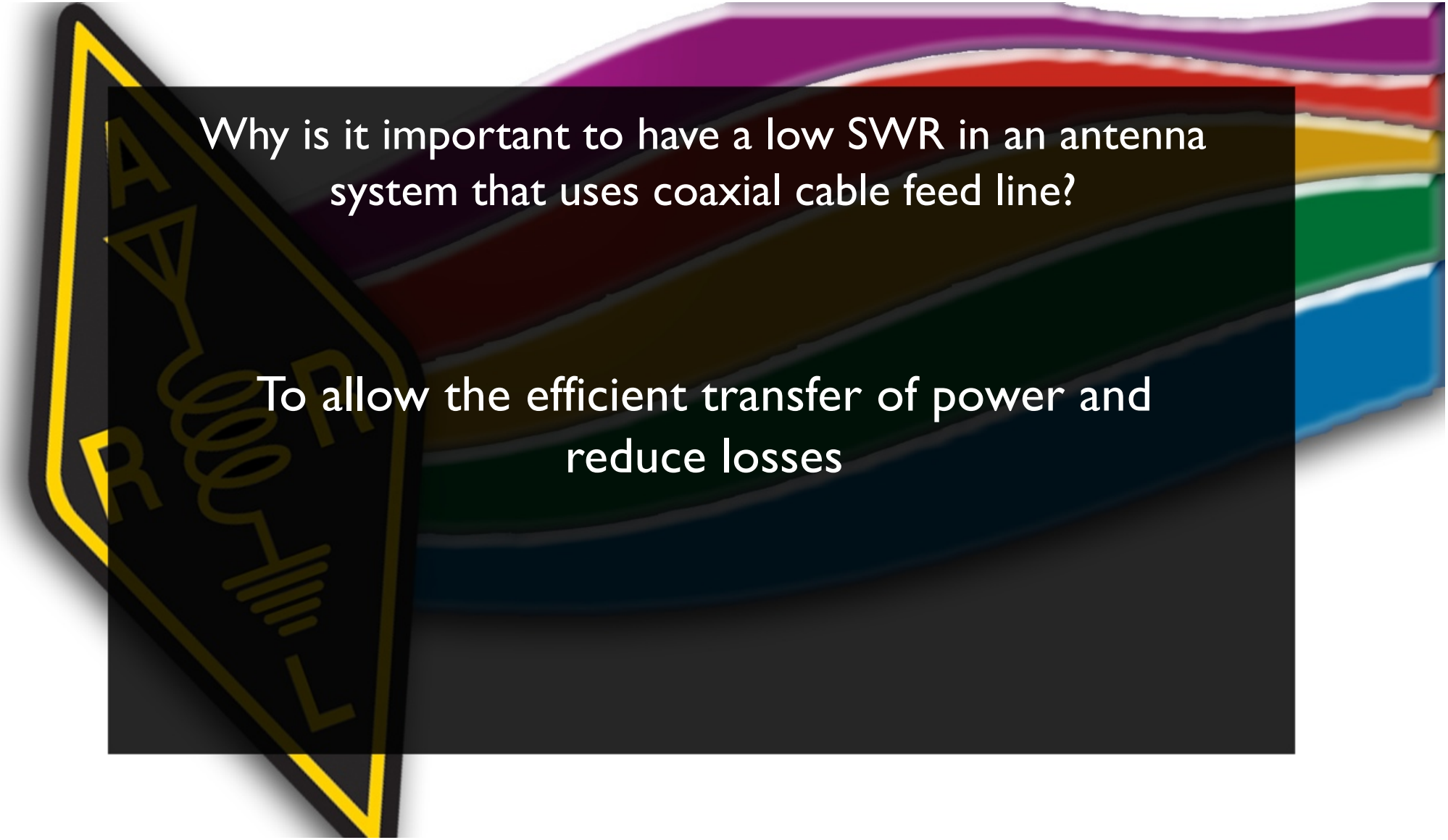
The electric field is perpendicular to the Earth


What is meant by the gain of an antenna?

What is meant by the gain of an antenna?

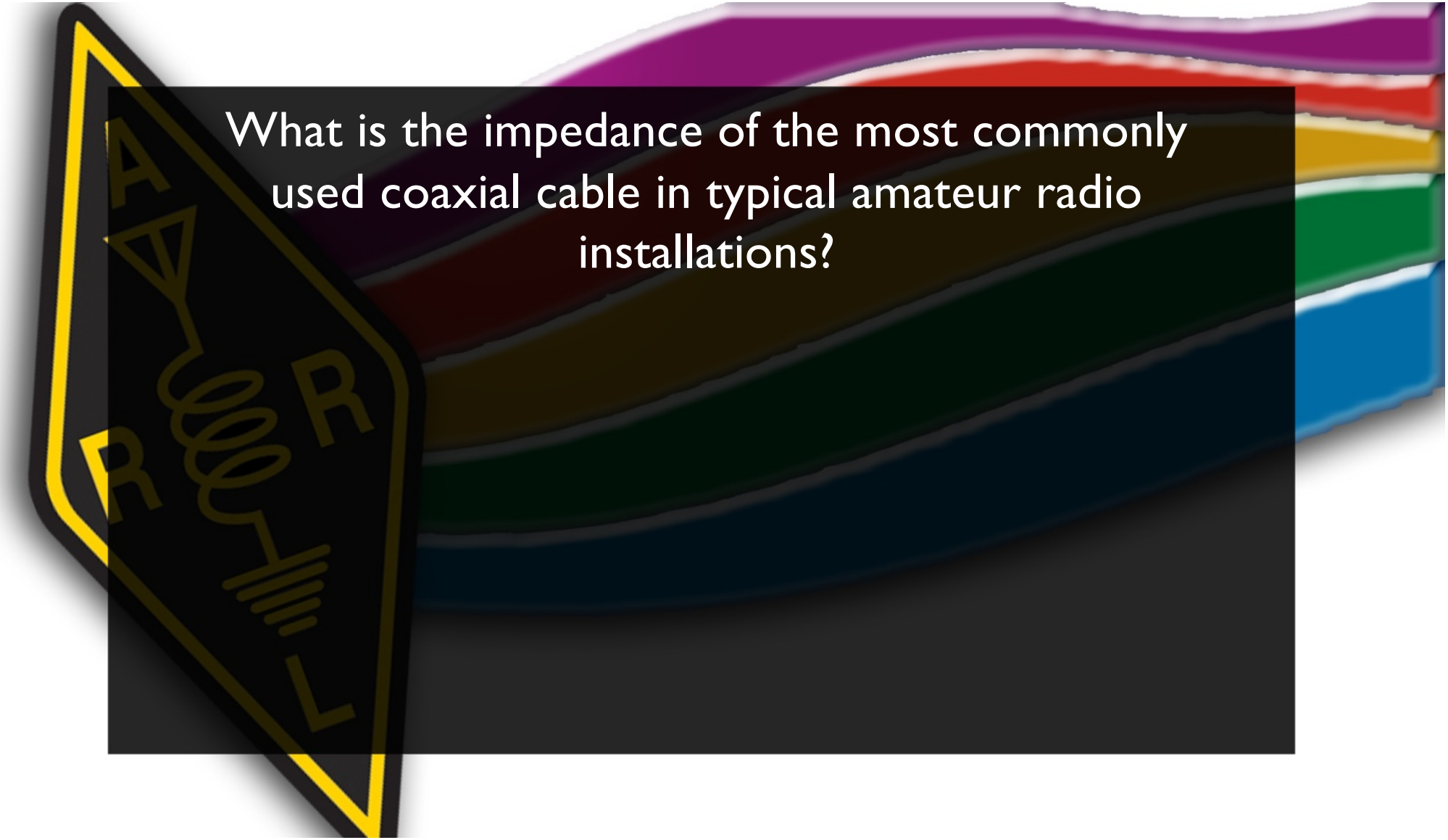
The increase in signal strength in a specified direction when compared to a reference antenna


Why is it important to have a low SWR in an antenna system that uses coaxial cable feed line?

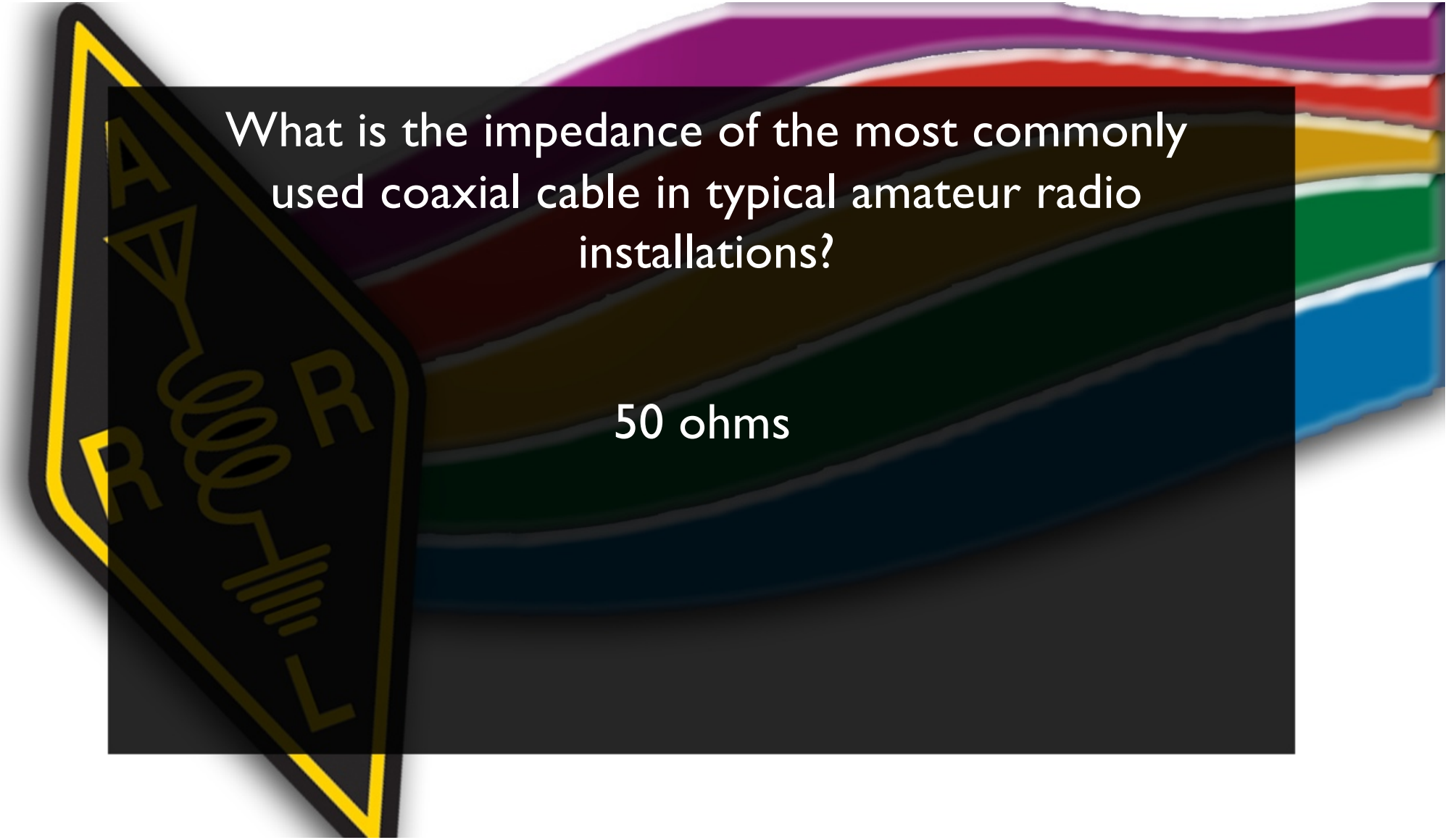


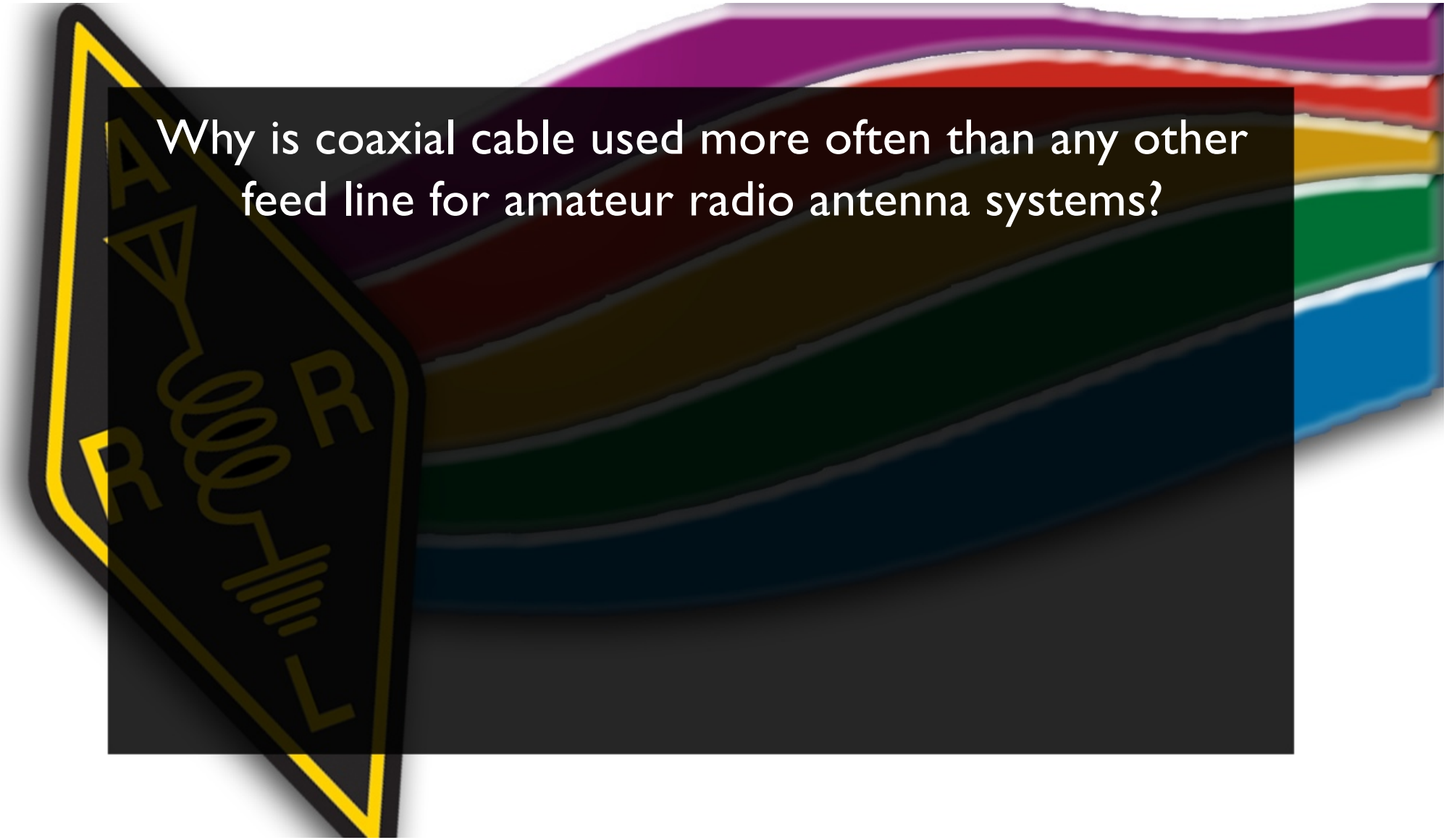
Why is it important to have a low SWR in an antenna system that uses coaxial cable feed line?

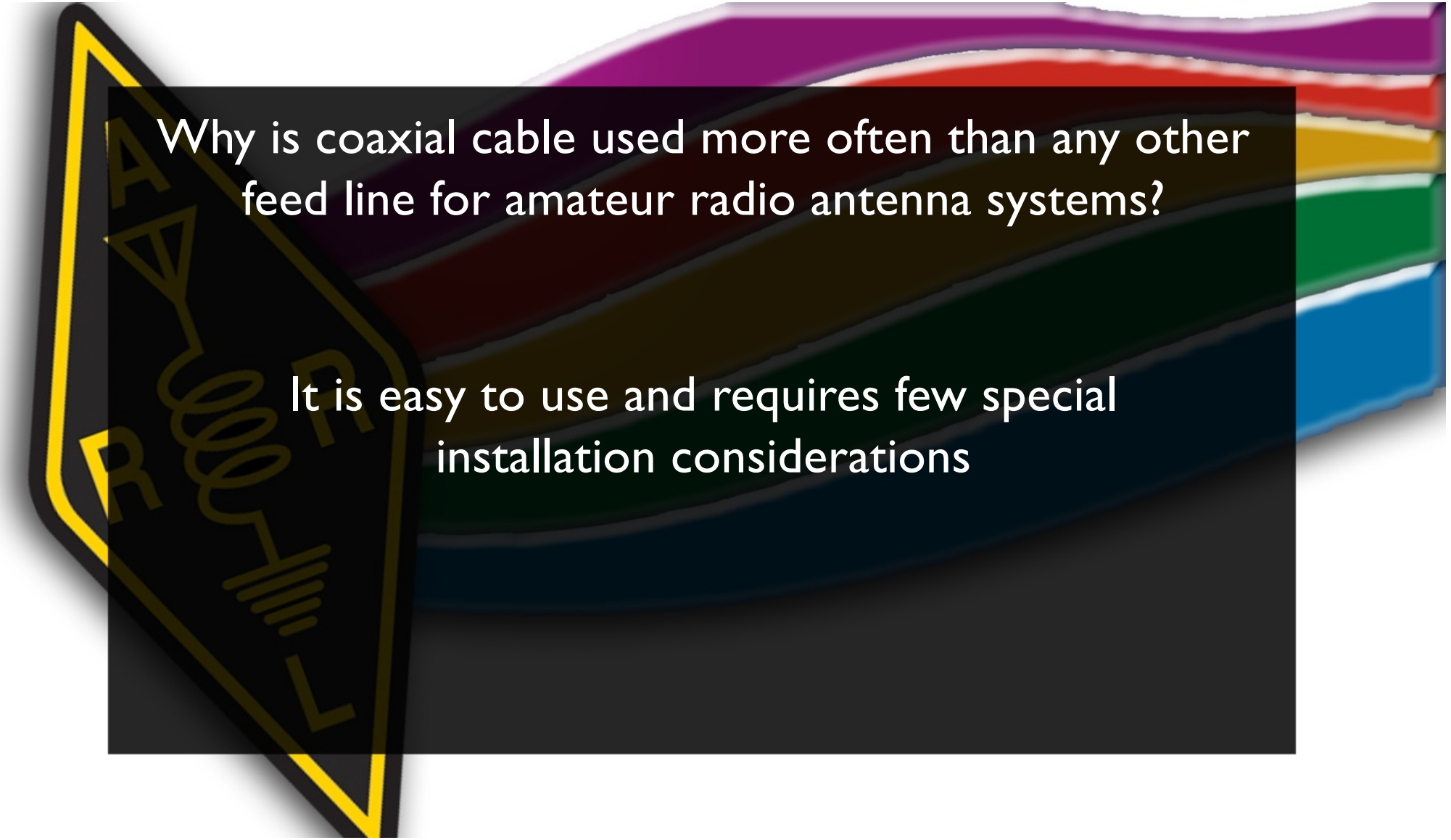
To allow the efficient transfer of power and reduce losses



What is the impedance of the most commonly used coaxial cable in typical amateur radio installations?


What is the impedance of the most commonly used coaxial cable in typical amateur radio installations?
50 ohms

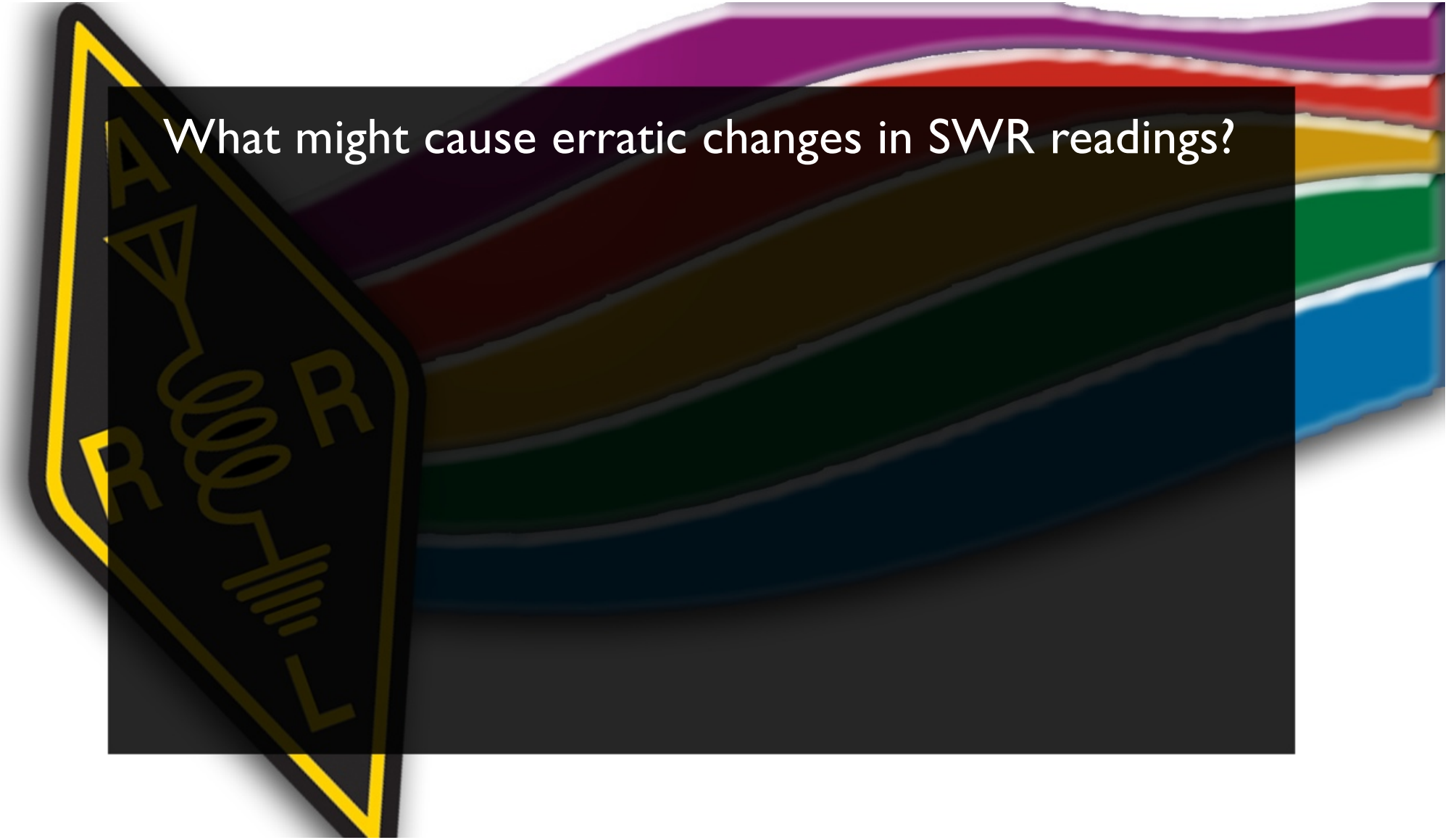

Why is coaxial cable used more often than any other feed line for amateur radio antenna systems?


Why is coaxial cable used more often than any other feed line for amateur radio antenna systems?
It is easy to use and requires few special installation considerations

What generally happens as the frequency of a signal passing through coaxial cable is increased?

What generally happens as the frequency of a signal passing through coaxial cable is increased?

The loss increases


What might cause erratic changes in SWR readings?

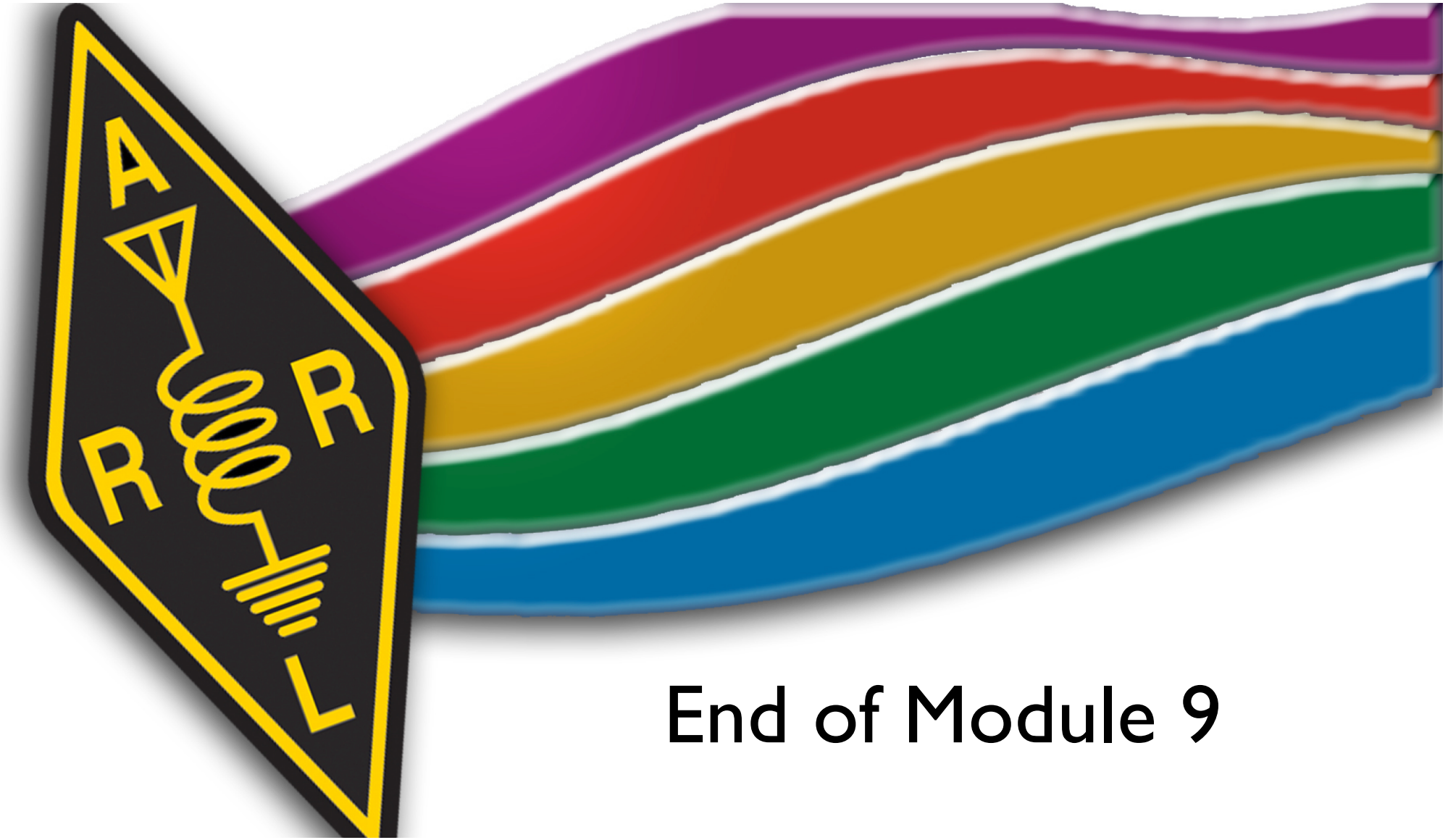
What might cause erratic changes in SWR readings?

A loose connection in an antenna or a feed line

Which of the following types of feed line has the lowest loss at VHF and UHF?

Which of the following types of feed line has the lowest loss at VHF and UHF?

Air-insulated hard line




End of Module 9