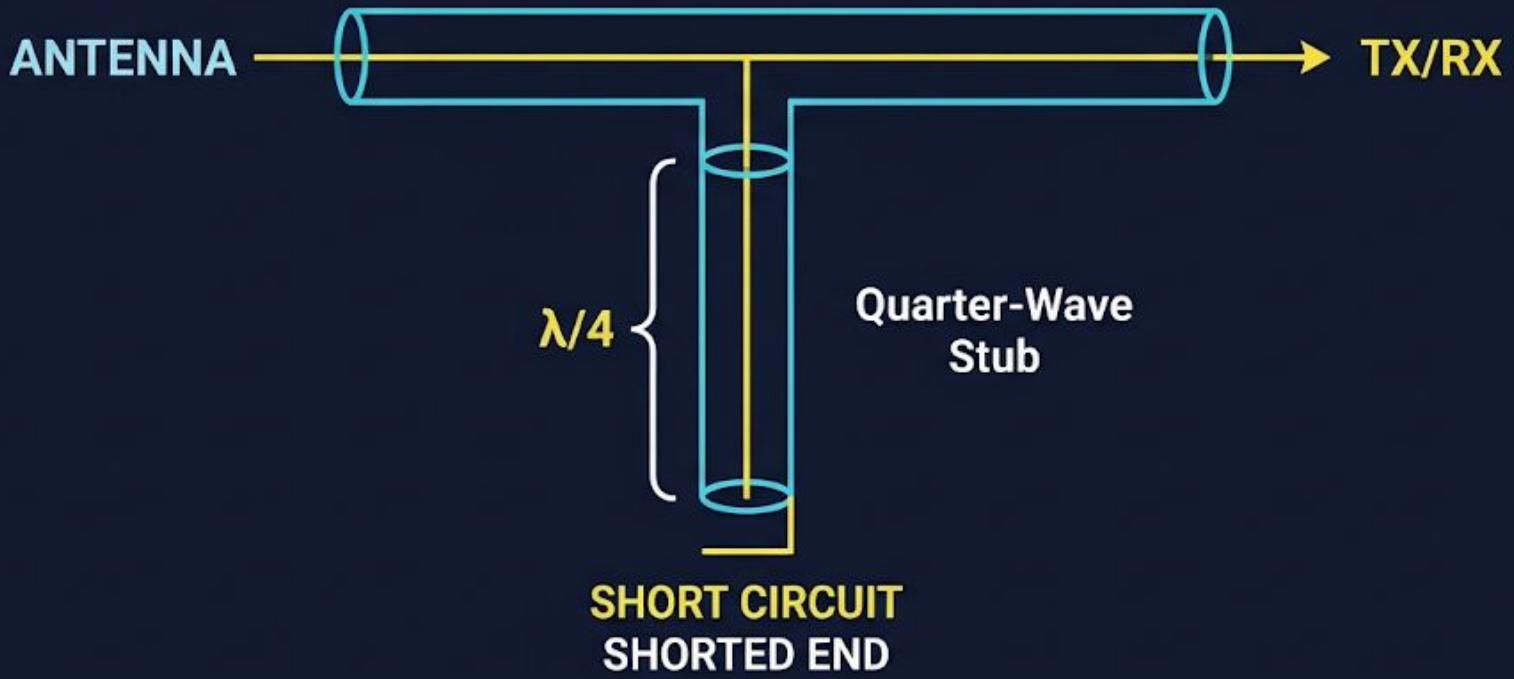
# Quarter-Wave Stub Filters and measuring  Filters  on NVNA

# Shorted Quarter-Wave Stub Filter



# Quarter-Wavelength Transmission Lines

A quarter-wave (λ/4) coaxial stub acts as an impedance transformer without lumped coils or capacitors.

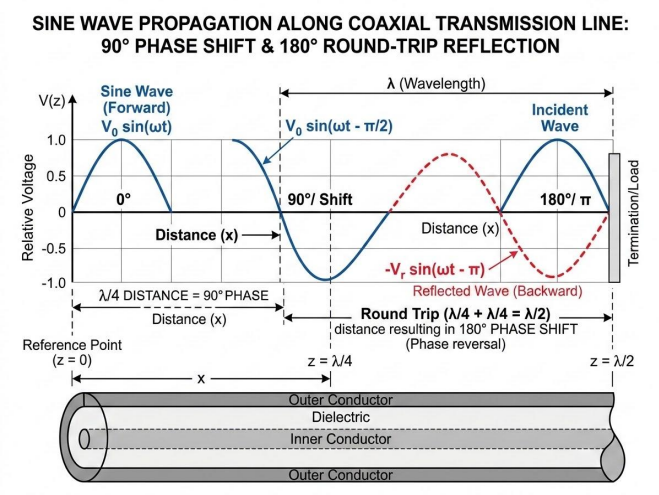
## Why Transmission Lines Behave Differently at RF

At radio frequencies, a piece of coaxial cable isn't just a wire—it is a distributed circuit. Signals travel as electromagnetic waves that bounce and reflect when hitting the end of the line.

## The 90° Wave Trip (180° Round Trip)

When a stub is exactly one-quarter wavelength (λ/4) long:

- **Forward Travel:** The wave travels down the stub, shifting phase by 90° (λ/4).
- **Reflection & Return:** The reflected wave travels back 90°, creating a 180° total round-trip shift.
- **Impedance Inversion:** This 180° phase flip inverts the impedance seen at the input: an open end looks like a dead short, and a shorted end looks completely open!




**λ/4 PHASE SHIFT MECHANISM**

Forward propagation creates a **90° phase shift** over λ/4 distance. Reflection doubles this path to **180° total round-trip shift**, yielding complete wave cancellation at input.

# Stub Response Across Frequencies: Overview

Because stub electrical length scales with frequency, a transmission line periodically alternates between **passing** and **notching** signals across consecutive harmonic intervals.

## 1. OPEN-CIRCUITED (OC) STUB

**Far End:** Left open (unterminated / insulated)

**Periodic Response Across Harmonics:**

- **Even Harmonics (0, $2f_o$...):** Stays high impedance; signal passes freely.
- **Odd Harmonics ($f_o$, $3f_o$...):** Quarter-wave inversion creates a dead short (0 Ω), forming a deep notch trap (30–40+ dB).

## 2. SHORT-CIRCUITED (SC) STUB

**Far End:** Center conductor shorted directly to shield

**Periodic Response Across Harmonics:**

- **Even Harmonics (0, $2f_o$...):** Direct electrical short to ground (notches out DC and even harmonics).
- **Odd Harmonics ($f_o$, $3f_o$...):** Quarter-wave inversion flips the short into high impedance (parallel resonant tank), passing $f_o$ transparently.

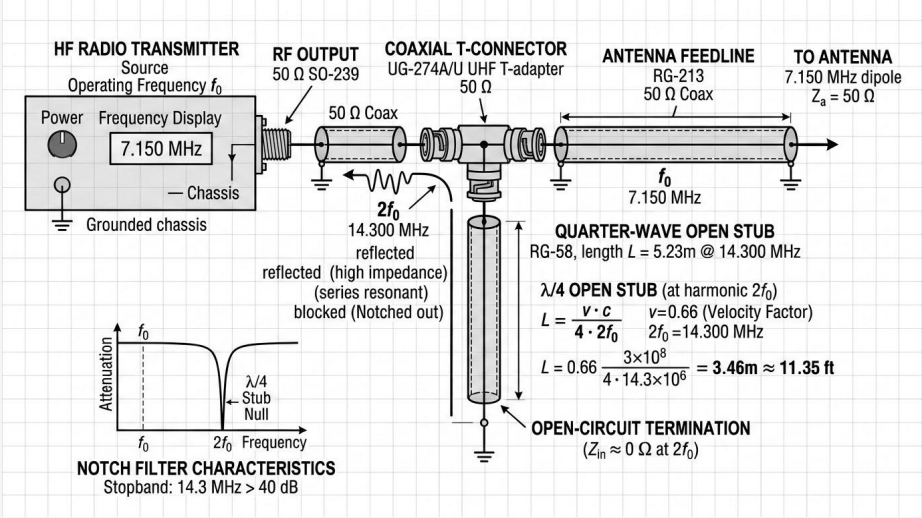
**Velocity Factor**

Velocity factor is the speed at which a radio frequency signal travels through a transmission line compared to the speed of light in a vacuum typically to between 66% and 85% of light speed—the physical length of a radio wave becomes compressed inside the cable compared to open air. The practical effect of this is that when you are cutting a coaxial stub filter for a specific frequency, you must multiply the calculated free-space wavelength by the cable's specific velocity factor to determine the correct physical length.

# Stub Response Across Frequencies

| FREQUENCY | OPEN-CIRCUITED (OC) STUB | SHORT-CIRCUITED (SC) STUB |
|---|---|---|
| **DC (0 Hz)** | Passes (Transparent) | **NOTCHES** (Short Circuit) |
| **$f_o$** (Fundamental) | **NOTCHES** | Passes (High Z Tank) |
| **$2f_o$** (2nd Harmonic) | Passes | **NOTCHES** |
| **$3f_o$** (3rd Harmonic) | **NOTCHES** | Passes |

# Quarter-Wave Stubs for Harmonic Suppression




## Practical Application

- **Harmonic Trapping:** A 7 MHz transmitter can radiate a 2nd harmonic into a 14 MHz receiver. An open λ/4 stub cut for 14 MHz traps that harmonic cleanly.
- **NearBy Stations:** Allows multiple stations to operate without interference.
- **Low Cost & High Power:** Built from standard coax and a T-connector, handling full legal power limits without burning out.

**KEY ADVANTAGE // CONTEST & FIELD DAY OPERATION**

"Quarter-wave coaxial stubs provide a robust, filtering mechanism with ultra-high power handling, making them the ultimate passive solution for multi-transmitter environments."

REAL-WORLD APPLICATION // MULTI-OP CONTESTING

# The Classic Multi-Op Scenario: Coax Stub vs. De-sense

### THE PROBLEM: 2ND HARMONIC INTERFERENCE

**Station 1 Transmitting:** Operating at 100W+ on **40m (7.1 MHz)**.

**Station 2 Receiving:** Trying to hear weak signals on **20m (14.2 MHz)**.

**Harmonic Conflict:** Because 14.2 MHz is exactly **2 × 7.1 MHz**, Station 1's RF field severely desensitizes Station 2's receiver.

**Result:** Station 2's noise floor is destroyed, making multi-station operation impossible without filtering.

### THE SOLUTION: OPEN λ/4 STUB FOR 7.1 MHz

**1. Kills 40m Interference:** At 7.1 MHz, the open quarter-wave stub acts as a **dead short to ground**, violently notching out 40m RF.

**2. Passes 20m Signals:** At 14.2 MHz, the same stub is electrically a **half-wavelength (λ/2)** long, presenting infinite impedance (invisible).

**3. Low Insertion Loss:** 20m signals pass cleanly straight into the receiver.

**Setup:** Simple T-connector on the back of Station 2's radio attached to the open stub line.

### WHY COAX STUBS BEAT COMMERCIAL FILTERS Occasionally

"Commercial 1kW filters require huge, costly high-voltage capacitors that can arc. A simple scrap length of RG-213 or LMR-400 coax handles full legal transmit power effortlessly, costs virtually nothing, and can be built in 10 minutes."

# How to measure a Filter on NVNA

- **The Two-Port System:** The NanoVNA has two physical connections: CH0 (Port 0) and CH1 (Port 1). To measure a filter, we place it inline between these two ports.

- **CH0 (The Source & Reflection Receiver):** This port acts as the RF transmitter. It generates the sweep of frequencies and fires them into the input of the filter. It also contains a directional coupler to measure any energy that bounces back (S11 Reflection).

- **CH1 (The Through Receiver):** This port acts strictly as a receiver. It sits at the output of the filter and measures whatever portion of the original CH0 signal successfully makes it through the filter (S21 Through).

- **The S21 Measurement (Through):** The VNA calculates the difference between the signal strength leaving CH0 and the signal strength arriving at CH1. If CH0 sends 0 dBm and CH1 receives -30 dBm, the filter has 30 dB of rejection at that frequency.

- **The S11 Measurement (Reflect):** The VNA compares the signal leaving CH0 to the signal bouncing back into CH0. If almost all the energy returns, the VNA calculates a high SWR, indicating that the filter is blocking that frequency by reflecting it.

## Checking Filter Response

Step 1: Press DISPLAY > TRACE. Keep only Trace 1 (Blue).",
Step 2: Select Trace 1. Press DISPLAY > CHANNEL > S21 CH1 THROUGH.",
Step 3: Press DISPLAY > FORMAT > LOGMAG.",
Step 4: Press DISPLAY > SCALE > SCALE/DIV. Set to 5dB/div.",
Step 5: Press STIMULUS. Set START and STOP frequencies.",
Step 6: Connect filter to CH0 and CH1. Observe passband shape.",

## Checking VSWR

Step 1: Press DISPLAY > TRACE. Turn on Trace 0 (Yellow).",
Step 2: Select Trace 0. Press DISPLAY > CHANNEL > S 11 CH0 REFLECT.",
Step 3: Press DISPLAY > FORMAT S11 > SWR.",
Step 4:: Observe how blocked frequencies create high SWR."

# Quarter-Wave Stubs: Short-Circuit vs. Open-Circuit

## How Quarter-Wave Inversion Works

At the resonant frequency, a quarter-wave stub acts as an **impedance inverter**. Whatever termination is placed at the far end is flipped upside down at the feedline junction.

**THE INVERSION RULE**

$$Z_{in} = (Z_0)^2 / Z_{load}$$

Short (0 Ω) flips to Open (∞) | Open (∞) flips to Short (0 Ω)

## Why This Matters for Ham Radio

By simply picking an open or shorted end, you can either completely short out an unwanted harmonic or pass your desired signal with near zero loss—all using a piece of ordinary coax attached to a T-connector.

## Side-by-Side: SC vs. OC Stub Comparison

**1. Short-Circuited (SC) Stub** [Far end connected together]

Input Impedance: **HIGH IMPEDANCE / OPEN CIRCUIT ($Z_{in} \approx \infty$)**

- **Behavior:** Acts as a parallel resonant tank circuit.
- **Practical Use:** Transparent to operating band (passes signal freely while providing DC ground).

**2. Open-Circuited (OC) Stub** [Far end left open / insulated]

Input Impedance: **DEAD SHORT TO GROUND ($Z_{in} \approx 0$ Ω)**

- **Behavior:** Acts as a series resonant circuit (Notch / Trap).
- **Practical Use:** Eliminates unwanted harmonics by shunting them directly to ground (30-40+ dB notch).