stub-switched stub-matched antennas

A simple multiband antenna system that features automatic stub matching as you change bands

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Transmission lines can be used for various purposes besides transferring power to an antenna. Depending on the electrical length of the line, it can function as a frequency-dependent switch, an impedance-matching transformer or a reactive circuit element. You can devise a number of interesting antenna designs with the first two functions. Normally these characteristics are used separately, but there is no reason why they can't be combined.

Before you digest any designs, it's important to have a clear idea of how transmission-line sections work as impedance-matching transformers and frequency-dependent switches.

transmission line characteristics

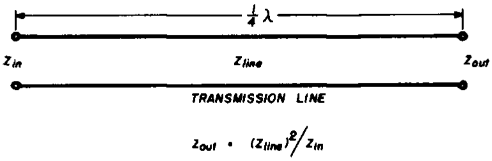
A lossless transmission line one-quarter wavelength long will transform the impedance at its input terminals to an impedance at its output terminals equal to

$$\frac{(Zo)^2}{Zin}$$

where Zo is equal to the impedance of the line.

However, this is only true when the input

fig. 1. Basic quarter-wave transmission-line transformer; limiting cases occur where input impedance is either zero or infinite.

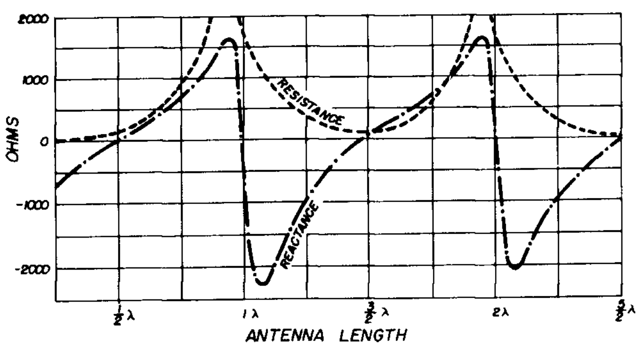


or output impedance is a pure resistance. Although the whys of this impedance transformation can be shown mathematically, the proof is somewhat tedious. Perhaps the simplest way to visualize the action is to remember that the input voltage and current vectors undergo a 90° phase shift on the quarter-wave line. Therefore, their relative amplitude values are reversed. If the input impedance is lower than the line impedance, the output impedance is always higher. If the input impedance is greater than the line impedance, the output impedance is always lower.

Any number of quarter-wave sections can theoretically be used in series if one particular line does not provide the desired transformation. If the transmission line is one-half wavelength long, the output impedance is the same as the input impedance since this is the same as putting two quarter-wave sections back-to-back.

The limiting case occurs as shown in **fig. 1** when the input impedance is either zero (short circuit) or infinite (open circuit). It can be seen from the impedance-transformation formula that the output impedance must be opposite from the input impedance. With this in mind, we can use the quarter-wave transmission line as an rf switch.

fig. 2. A dipole antenna has reactive and resistive components at harmonic frequencies as shown here.



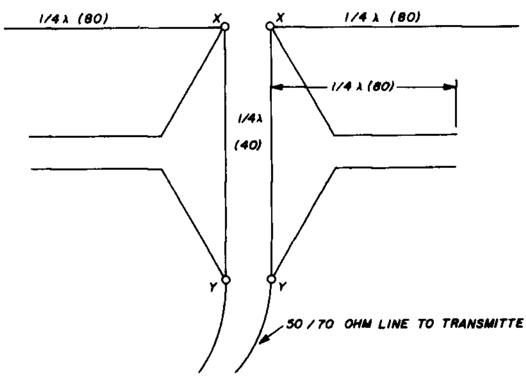
However, the switch is frequency dependent. If the input impedance is zero at a frequency where the transmission line is a quarter-wavelength long, the output impedance is infinite and looks like an open circuit. If line length is fixed and the frequency is doubled, the transmission line represents one-half wavelength and the output impedance is the same as the input impedance.

Therefore, by controlling the termination and length of the transmission line, it can be used as an impedance transformer, a 1:1 impedance transfer element or a frequency-dependent switch.

dipole harmonic operation

A simple resonant half-wave dipole presents a pure resistive impedance which matches 50- or 70-ohm cable fairly well. If the dipole is used at harmonic frequencies, its terminal resistance and reactance will vary as shown in **fig. 2.** At even multiples of a half-wavelength, the terminal impedance is highly resistive with practically no reactive component; at odd multiples, the terminal impedance is resistive at almost the same value as at the fundamental frequency with no appreciable reactive component. This is the reason you can use a 7-MHz dipole successfully on 15 meters with the same feedline.

fig. 3. A stub-switched and -matched antenna for 80 and 40; construction is shown in fig. 6.



To feed maximum power into a dipole at any multiple frequency of its fundamental, you have to match the antenna's terminal impedance. The usual way to do this is to use a resonant transmission line and an antenna coupler at the transmitter. By using combinations of quarter-wavelength transmission line sections at the antenna, however, it's possible to obtain multiband operation without an antenna coupler or any tuning or bandswitching circuits. The transmission line going to the transmitter will still operate at a low swr on each band.

some basic antennas

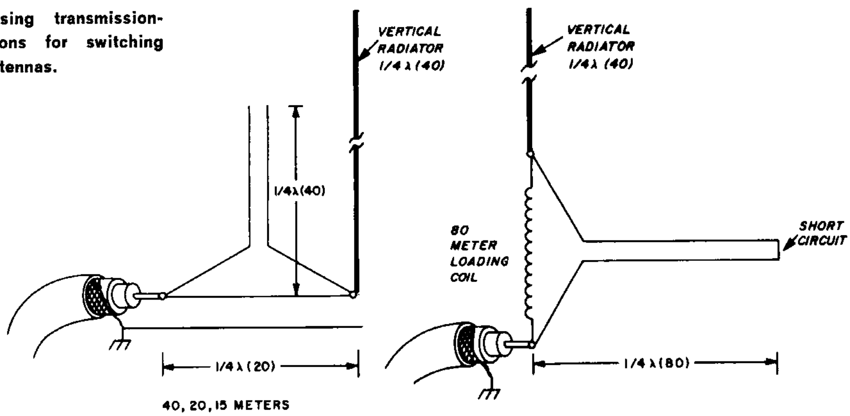
Once you understand how the transmission line sections can be used, you'll undoubtedly be able to come up with designs of your own. As a starter, here are some basic designs I have investigated.

horizontal transmission line section which was one-quarter wavelength long on 80 meters is one-half wavelength long on 40 and presents an open circuit between terminals X and Y.

The vertical quarter-wavelength section is effectively connected between terminals X and Y; this section acts as a transformer, and its characteristic impedance is chosen to match the transmission line to the transmitter.

Normally, if 50- or 70-ohm coaxial cable is used, the matching section can be made from 300-ohm twinlead. The characteristic impedance of the horizontal transmission line sections aren't particularly important since they only perform a switching function.

fig. 5. Using transmission-line sections for switching vertical antennas.



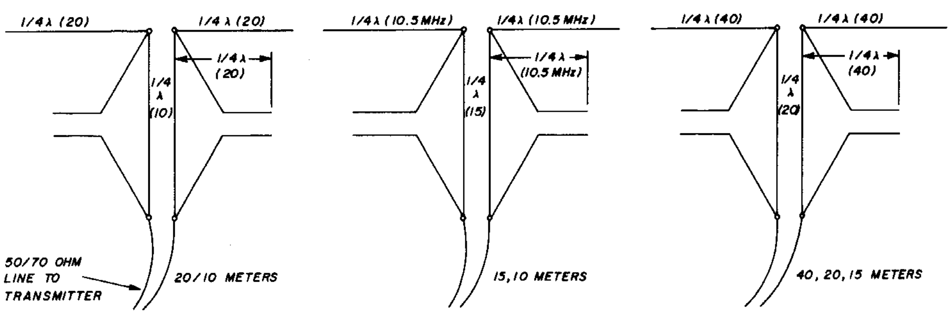
A dipole which automatically bandswitches from 80 to 40 meters is shown in **fig. 3.** On 80 meters, the open-circuited quarter-wavelength sections (shown horizontally) between points X and Y effectively short out the vertical quarter-wavelength section. This effectively connects points X and Y together as in a normally fed dipole.

On 40 meters, the flat-top portion of the antenna is a full wavelength long with a rise in input impedance as shown in **fig. 2.** The

The antenna operates as a normal dipole on 40 meters; the main radiation remains broadside to the line of the flattop with about 1.8-dB gain.

Variations of the same antenna for different bands are shown in **fig. 4.** The antenna of **fig. 4A** is designed for 20 and 10 meters

fig. 4. Variations of the antenna of fig. 3 for other bands.



and is simply a scaled version of the antenna shown in **fig. 3.** The antenna of **fig. 4B** is for 15 and 10 meters but is a bit different. Since you can't cut a half-wave dipole for 15 meters and use it as a full-wave dipole on 10, a different approach is used. The dipole is cut one-half wavelength long on 10.5 MHz; this makes it a full-wave dipole on 15 and approximately three half waves long on 10.

If you analyze the switching section, you'll find it produces a short circuit on 10.5 MHz, an open circuit on 15 meters and a short circuit again on 10 meters. The antenna is matched on 10.5 MHz and while this feature has no amateur value, it may be useful for WWV reception. Because of the length of the flattop, the antenna has about 1.8-dB on 15 and 10 meters. However, on 10 meters the radiation pattern takes the form of a cloverleaf characteristic of a 3/2-wave dipole.

The antenna shown in **fig. 4C** is a little more conventional although it is basically the same as **fig. 3.** Operation is possible on three bands —40, 20 and 15 meters—because the flattop is 3/2-wave long on 15 and the transmission-line switch shorts out the matching section.

The use of transmission line sections doesn't have to be limited to dipoles; they can be used just as easily with unbalanced vertical antennas. The antenna in **fig. 5A** is basically one half the antenna shown in **fig. 4C.** Although it resonates on 40, 20 and 15 meters, it is mainly useful on 40 and 20 since the radiation angle is quite high on 15 meters. This is because the vertical radiator exceeds 0.64 wavelength. A simple two-band antenna can also be built as shown in **fig. 5B;** in this design the transmission line section acts as a switch.

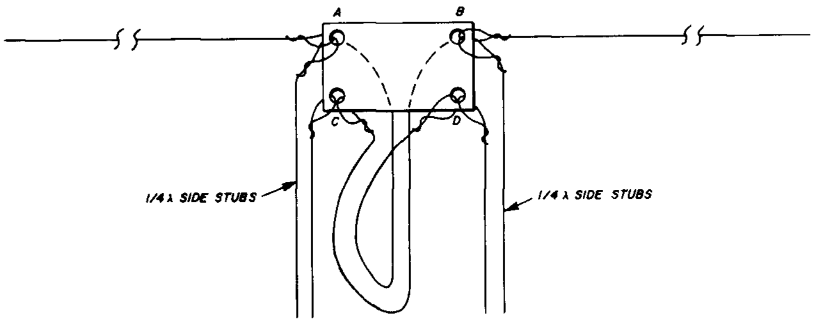


fig. 6. Construction of the stub-switched antenna. The center stub section is looped between terminals AB and CE. The coaxial feedline is connected to terminals C and D.

construction

You should observe a few precautions when building any antenna. For one thing, the physical length of the transmission line must take the velocity factor of the line into consideration (typically 70% for 300 ohm twinlead). The line sections shouldn't be formed into coils and placed at the center of the flattop since this will introduce spurious resonances. It's better to bring both ends of the sections to the center of the antenna in the form of a drooping "U" as shown in **fig. 6** and then make all the interconnections.

The values shown in **fig. 2** are typical for wire antennas made from number 12 or 14 wire. If the antenna is made from very thin wire and used on 80 meters, the impedance values at harmonic frequencies may be higher than those shown. In this case it's a good idea to put the antenna together temporarily without the switching sections and operate it on the harmonic frequency; then measure the swr to determine if you've picked the right impedance for the matching section.

You should have no difficulty with the switching sections if they are cut to formula length. The power handling capability of the antenna is determined by the rating of the transmission line used for the line sections.

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