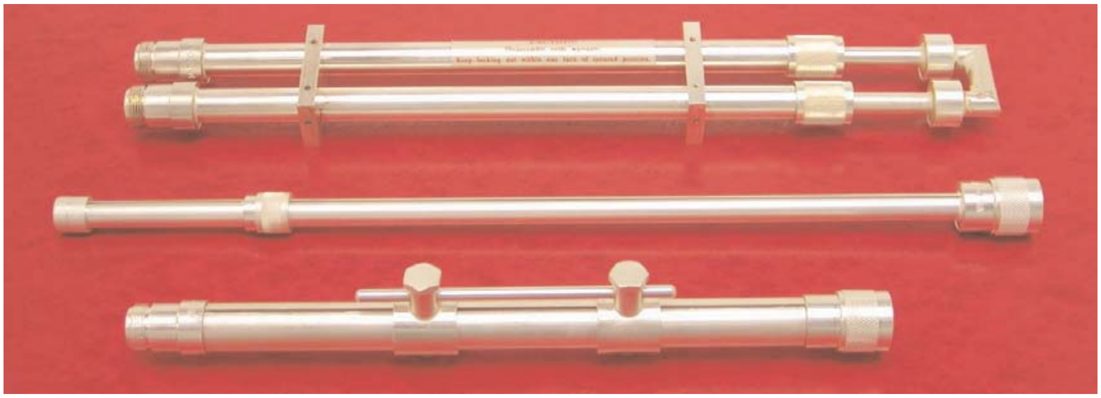


Mechanical tuning devices continue to be a necessary part of all well-equipped microwave laboratories as well as many microwave systems. Their convenience, power handling ability and linear properties can not be duplicated in comparable solid state devices. This paper provides an overview of these tuners, discusses recent design advances, and describes some new and exciting system applications.

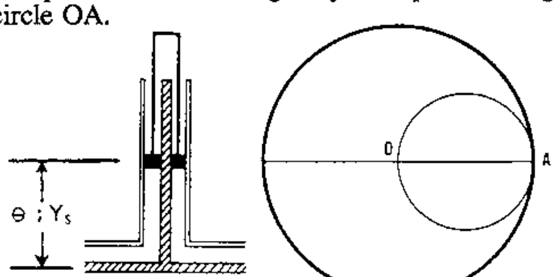
SINGLE STUB TUNERS

The single stub tuner consists of a main line with one variable length branch line or stub. The shorted stub introduces a shunt susceptance (**B**) into main line as follows:

$$B = -\cot \varnothing \;/\; Y_s$$

where $\varnothing$ = the electrical length of the stub
Y_s = characteristic admittance of the stub

The Smith chart describes the single stub tuner terminated in a matched load. The shorted stub is capable of introducing any susceptance along circle OA.

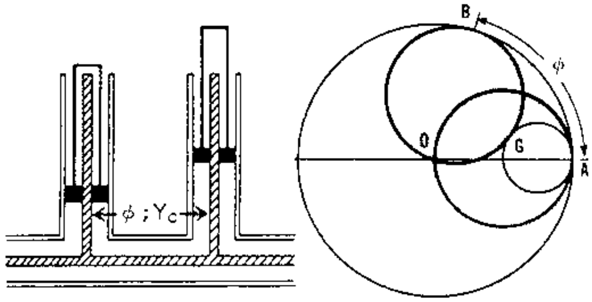


SINGLE STUB TUNER SMITH CHART

The stub must be adjusted over one-half wave-length to be able to provide all possible shunt susceptances. The low frequency limit of the tuner is determined by the frequency at which the maximum stub travel is equal to one half wave-length. No high frequency limit exists for a stub tuner, but the use of a tuner designed for a frequency much lower than required is often cumbersome and inconvenient because of the size of the lower frequency unit.

DOUBLE STUB TUNERS

The double stub tuner consists of a main line with two independently variable branch lines or stubs separated by a length of line. The operation of a double stub tuner terminated in a matched load may be explained with the aid of a Smith chart.



DOUBLE STUB TUNER SMITH CHART

The first stub introduces susceptance at any point along circle OA, as in the case of the single stub tuner. The connecting line ($\varnothing$) transforms the first stub susceptance to any point along circle OB. The addition of the susceptance from the second stub to points along circle OB will produce all admittances except those within circle AG. Thus the double stub tuner is capable of matching any admittance in the shaded area of the Smith chart.

ADMITTANCE RANGE: The spacing between the stubs determines the range of admittances that may be matched and the ease with which these admittances may be matched. The maximum conductance component (G_{max}) that may be tuned for any stub spacing ($\emptyset$) is:

$$G_{max} = Y_c^2 / Y_o \sin^2 \emptyset$$

where Yo = the characteristic admittance of the system

Yc = the characteristic admittance of the connecting line

The maximum conductance component that may be matched is proportional to the square of the characteristic admittance of the line connecting the stubs. This conductance may be increased by increasing the characteristic admittance of the connecting line. Microlab double stub tuners have a characteristic impedance of 35 ohms and will tune twice the conductance of a conventional double stub tuner.

CONVERGENCE: Convergence is an indication of the number of stub adjustments necessary to obtain a matched line and is a measure of the convenience in using the tuner. Optimum convergence occurs when the load conductance component (G_L) satisfies the following relationship:

$$\tan \emptyset = (Yo/G_L)^{1/2}$$

The convergence for load conductance components close to **Yo** is optimum when the spacing between the stubs is an odd number of eighth wavelengths. No convergence is possible for integral multiples of quarter wavelengths spacing.

TUNING SENSITIVITY: Very large stub susceptances are required to match relatively low standing wave ratios when the stub spacing is quarter or half wavelength. Such large susceptances require that the stub tuning be extremely precise and critical. When the stub spacing is an odd number of eighth wavelengths, the required stub susceptances are much smaller and the tuning less critical.

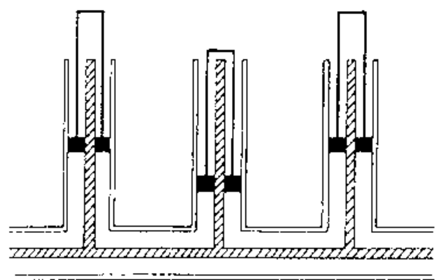
The relative merits of various stub spacings are summarized:

Stub Spacing	Gmax	Convergence	Tuning Sensitivity
45°	good	good	good
90°	excel	poor	poor
135°	good	good	good
180°	poor	poor	poor

Optimum operation of double stub tuner also indicates that the stub spacing should be an odd number eighth wavelengths.

TRIPLE STUB TUNERS--------------------

The triple stub tuner consists of a main line with three independently variable branch lines or stubs separated by lengths of line.

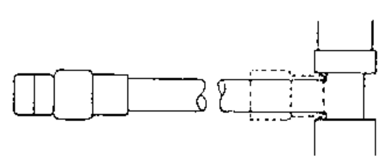


TRIPLE STUB TUNER

The triple stub tuner will match all load admittances, regardless of the stub spacing. However, the convergence and tuning sensitivity discussion of the double stub apply to the triple stub. Optimum operation of the triple stub also requires a stub spacing of an odd number of eighth wavelengths.

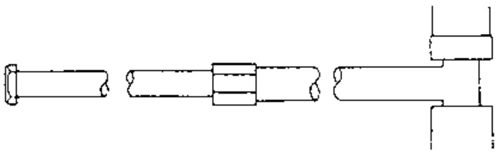
STUB TYPE: Microlab stub tuners employ two types of stubs or branch lines, depending on the frequency range. Both types employ beryllium copper contact springs, assuring long life and noise-free operation. Both types are provided with locking caps to adjust sliding tension and lock the desired settings.

STUB 1: Stub type 1 is designed for lower frequency operation. The outer conductor of the stub is slotted, permitting adjustment of the short position without increasing the overall dimensions of the tuner. A movable slider outside the stub positions the short contained within the stub. Radiation from the slot is negligible.



TYPE 1

STUB 2: Stub type 2 is designed for higher frequency operation. The position of the short is adjusted by a handle extending from the open end of the stub. The extended stub is approximately twice as long as the minimum length.

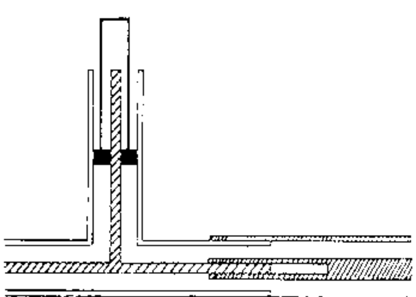


TYPE 2

BASIC APPLICATION: Single, double and triple tuners are impedance matching devices which will introduce a variable susceptance into a coaxial transmission line. Single stub tuners will improve most standing wave ratios, increase the power transfer between a source and its load and provide a DC return if required. Double stub tuners provide greater range. They can also be used to match a wide range of load impedances or introduce a similar range of impedance into an otherwise matched system. Triple stub tuners will match practically any impedance and therefore are the most versatile.

STUB STRETCHERS---------------------

The stub stretcher is a tuner capable of matching any value of impedance. The only limitation to such transformation is the travel of the contacts and resistive loss within the tuner. The conventional stub stretcher is shown below:

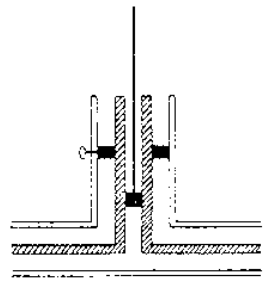


CONVENTIONAL STUB STRETCHER

Any load admittance Y_L is transformed by the line stretcher such that it appears at the stub as **Yo ± jB**, where **Yo** is the characteristic admittance of the system and **B** is any value of susceptance. The stub is then adjusted to provide a susceptance of magnitude equal to **B** but of opposite phase. The line is then matched.

In order to match all impedances, either the line stretcher must be capable of one-half wavelength of travel and the stub of one-quarter wavelength, or the stub of a half wavelength of travel and the line stretcher of a quarter wavelength.

Microlab SL stub stretchers are shown schematically below.



MICROLAB STUB STRETCHER

The center conductor of the main line is broken to provide the line stretcher. The outer conductor of the stub is slotted, permitting adjustment of the short position without increasing the overall dimensions of the tuner. A movable slider outside the stub positions the short contained within the stub. Radiation from the slot is negligible.

The design of the Microlab SL stub stretcher provides the most compact tuner for a given frequency range. The line stretcher is capable of a half-wavelength of travel at the lowest frequency but is only a quarter-wavelength long because of its folded construction. The stub travel is accomplished within the same quarter-wavelength.

Locking caps are provided to adjust sliding tension and to lock desired settings. Beryllium copper contact springs are employed, assuring long life and noise-free operation. Internal stops are provided to prevent damage to the contacts and to prevent the tuner from accidentally pulling apart. The unit is asymmetrical because the stretcher must be located between the mismatched load and the stub. A male RF connector is normally supplied at the input terminal and female connector on the load or stretcher terminal.

BASIC APPLICATION: Stub stretchers perform functions similar to that of a stub tuner.

A comparison between the two is helpful in determining suitable application for stub stretchers. Although stub tuners are the most popular method of tuning a coaxial line, the stub tuner is subject to a number of electrical and mechanical limitations which do not restrict the stub stretcher. The two tuners may be compared as follows:

SIZE: The stub tuner requires at least two stubs, each one of which must be at least a half wavelength long. The Microlab SL stub stretchers have only one stub a quarter wavelength long. Thus the stub stretchers are considerably smaller and lighter than the equivalent double stub tuner.

ADMITTANCE RANGE: The double stub tuner will only match a limited range of admittances, depending upon the length of the connecting line. The stub stretcher can match all admittances and thus is a much more versatile instrument.

TUNING SENSITIVITY: The stub tuner requires the introduction of very large stub susceptances to match relatively low standing wave ratios, especially when the stub spacing is a quarter wavelength. Such high stub susceptances require critical stub tuning, increase the possibility of voltage breakdown and increase the effective resistive loss within the tuner. The stub stretcher requires a stub susceptance equal to the effective susceptance component of the load and thus is less critical to tune, has less probability of voltage breakdown and lower resistive loss.

CONVERGENCE: The convergence (or number of tuning adjustments) of the stub tuner is a function of the length of the connecting line. It is theoretically impossible for the stub tuner to converge for certain stub spacing. The stub stretchers converge rapidly for all frequencies.

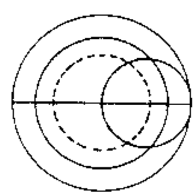
DOUBLE SLUG TUNERS----------------

Double slug tuners consist of two slugs or impedance transformers mounted in a 50 ohm transmission line. The separation between the slugs may be adjusted from contact to a quarter wavelength, controlling the magnitude of the resultant VSWR. The slug separation may be locked and the two slugs moved together to vary the phase of the resultant VSWR.

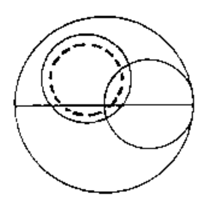
The slugs are positioned by rods extending through a slot extending the length of the tuner. Radiation from the slot is negligible at all frequencies below 7000 MHz. A tie bar is provided to which the slugs may be separately or jointly locked. The housing containing the slugs is carefully matched and has a VSWR less that 1.05 over the entire frequency range.

Microlab's double slug tuners are available in two frequency ranges and two impedance ranges. The lower frequency tuners have larger slugs, greater slug separation and longer slug travel. The tuners with lower maximum VSWR contain air and Teflon slugs and are designed to tune a VSWR from 1.0 to 2.0. The tuners with larger maximum VSWR contain a combination dielectric and metallic slug and are designed to tune a VSWR from 1 to 10. Contact between the slug and the outer conductor is made through beryllium copper contact fingers, assuring long life and noise-free operation.

The operation of the double slug tuner is shown on the Smith chart. The tuner is capable of matching all impedances that lie within the shaded circle. The impedance plot for the tuner with slugs locked in an arbitrary position over a half wavelength of travel is shown by the dotted circle. The radius of the dotted circle is proportional to the magnitude of the VSWR of the two slugs and is controlled by the slug separation. The radius of the shaded circle is the maximum VSWR that the given slug combination can introduce. The angular position around the dotted circle is controlled by the lateral displacement of the load impedance prior to the insertion of the slug tuner.



MATCHED LOAD



MISMATCHED LOAD

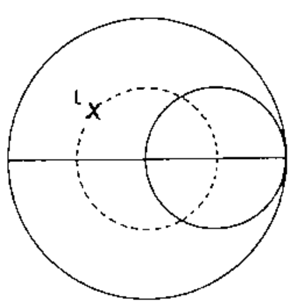
The choice of the correct double slug tuner depends on the required application. The maximum VSWR of the tuner must be at least as large as the maximum VSWR to be matched or generated. However, if the tuner is capable of introducing much larger VSWR than necessary, tuning becomes more critical and larger internal voltage gradients increase the possibility of voltage breakdown. The slug separation must be adjustable over a quarter wavelength and the slug travel, when the slugs are fully separated, must be at least a half wavelength for full impedance coverage.

The tuner consists of two slugs or impedance transformers mounted in a 50 ohm transmission line. The two slugs are identical and introduce equal VSWR. The amplitude of the VSWR resulting from the two slugs may be varied from unity to the maximum value shown on the curves by adjusting the separation between the slugs. The slug separation may be locked and the two slugs moved together to vary the phase of the resultant VSWR without affecting the magnitude of the reflection coefficient.

BASIC APPLICATION: The double slug tuner is a device to introduce a standing wave or mismatch into a system. The phase angle of this standing wave may then be adjusted without affecting the magnitude of the standing wave or the reflection coefficient. They are employed to determine the effect of load or generator impedance on such equipment as magnetrons and other microwave tubes, power dividers, and other transmission line components. They are also used to match a wide range of impedances to the transmission line, to introduce a mismatch into an otherwise matched system, or to provide maximum power transfer.

LINE STRETCHERS----------------------

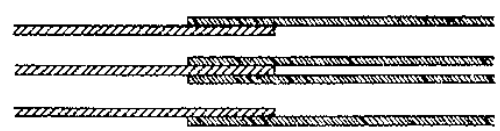
The operation of a line stretcher is described with the Smith chart below:



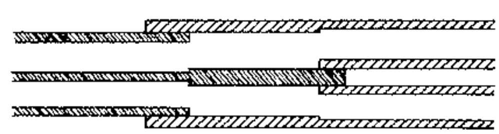
An arbitrary load impedance L may be transformed to any other impedance along the dotted circle provided the travel of the line stretcher is at least one-half wavelength.

The conventional line stretcher consists of simple telescopic tubing and is not a constant impedance device. Microlab line stretchers employ a compensating third telescoping section and maintain constant impedance throughout the device. Such compensation is necessary if the magnitude of the standing wave ratio is to be unaffected during phase adjustments. The step discontinuities at the line junctions have also been carefully compensated.

A locking cap is provided to adjust sliding tension and to lock desired adjustments. Stops at both ends of travel prevent the stretcher from pulling apart and prevent damage to the contacts. Beryllium copper contacts are employed, assuring long life and noise-free operation. The stretchers are silver plated and are normally supplied with male and female connectors. They are bi-directional, exceptionally rugged, and unaffected by temperature and humidity changes.



CONVENTIONAL LINE STRETCHER



CONSTANT IMPEDANCE LINE STRETCHER

The ST trombone line stretchers consist of two SR stretchers mounted in parallel and joined at one end with a 180 degree connector. This arrangement permits adjustment of line length without moving either terminal connector. Right angle connectors (not supplied) permit insertion of the device between opposing connectors.

The trombone is rigidly constructed and is suitable for vertical or horizontal operation. The unit is normally supplied with two male connectors. They incorporate the locking device, travel stops, and other features of the SR stretchers.

BASIC APPLICATION: Line stretchers are constant impedance phase shifters. They are employed to adjust the electrical separation of other components without introducing additional mismatch. They are used to obtain operational stability of microwave tubes such as magnetrons, to phase antennas and other components, to eliminate Smith chart corrections, and for numerous laboratory and component applications.

Microlab/FXR hopes you have found this information useful. Please refer to our catalog for specific model numbers and performance specifications. We welcome your suggestions and corrections. If you have questions, our Sales and Technical staff is available to help.

We also offer a wide spectrum of passive microwave components such as couplers, power dividers, attenuators, terminations, and waveguide products. We feature delivery from stock on many items and the ability to provide custom components for your specific needs.

SPECIAL APPLICATIONS

Microlab's tuners and line stretchers have been used to solve many technical problems, whether it be simply to improve the efficiency of transfer of power or something more complex. Shown below are a few examples of the varied applications.

*** STUB STRETCHER: Our SL-B27 stub stretcher is used to maximize the coupling of RF energy into a plasma cavity. While other types of tuners were considered, only the stub stretcher provided the short insertion length allowed by the customer between the RF source and the cavity.**

*** LINE STRETCHER: Microlab's SR-A88 is used in the installation, maintenance and fault diagnosis of the ILS Glideslope systems. In-line configuration permits a 1.05:1 maximum VSWR to be maintained as the phase length is varied from 300 to 420 degrees at 332 MHz.**

*** DOUBLE SLUG TUNER: A leading UHF transmitter manufacturer uses the Microlab SF-A35 double slug tuner to tune the input cavity of an inductive output tube amplifier. Capable of handling 500 watts, the tuner enables maximum amplifier gain to be achieved.**

*** TROMBONE STRETCHER: Microlab's ST-A37 is used to trim the electrical lengths of cables in a phased array antenna system. The unit provides up to 5 degrees of adjustment at 10 MHz with less than 0.1 dB loss. The trombone configuration allows hard mounting with fixed connector locations.**