

Tuning Element Application Guide

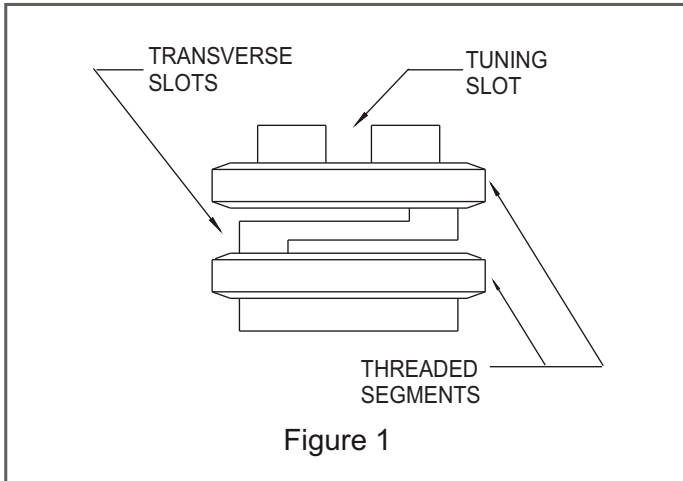
Johanson Microwave Tuning Elements are specially designed devices for tuning microwave circuits such as filters, oscillators, delay lines, multiplexers and dielectric resonant structures. Generally speaking, Johanson Tuning Elements consist of a mounting bushing with an integral tuning rotor. Adjustment of the rotor changes the capacitive loading between the ground plane and the active regions of the circuit.

Operating in the microwave through millimeter wave band, the Johanson Microwave Tuning elements are available in three basic material options: metallic, dielectric and resistive. The primary advantage of Johanson Microwave Tuning Elements over standard screws and nuts is the drastic reduction of technician tuning time, lower associated tuning losses and increased tuning resolution. In addition the proper use of Johanson Microwave Tuning Elements permits the relaxation of costly circuit mechanical tolerances. Specifications defining the exact parameters of devices, such as step recovery diodes, varactors, transistors and dielectric resonant materials may also be broadened with the resultant benefit of increased cost effectiveness.

Prior to the introduction of Johanson Microwave Tuning Elements, the microwave circuit designer was burdened

with the frustrating task of selecting from a makeshift conglomeration of “Hardware Store” nuts and bolts to tune precision microwave circuitry.

Non-precision threads, lack of tolerance, finish irregularities with associated binding and locking problems conspire to drastically increase the “installed” cost of seemingly inexpensive nuts and bolts hardware. Once adjusted, the hardware screw must be secured in place by jam nuts, perpendicular set screws or epoxy, all of which require additional labor while introducing a probability of disturbing the initial adjustment and severely limiting “retune” capability. In sharp contrast, Johanson Microwave Tuning Elements with the selflocking, constant torque drive mechanism, require no external locking devices and permits “one hand” tuning with virtually no dynamic tuning noise which could otherwise imperil associated solid state devices under “power on” conditions. This self-locking feature, coupled with tuning resolutions up to 200 threads per inch assure unparalleled control over the most critical of complex circuit tuning adjustments. In many instances, the use of Johanson Tuning Elements has halved technician’s tuning time. A detailed analysis of the Johanson tuning mechanism is shown in Figure 1.



Notice that the rotor consists of two threaded segments, which are coupled together by the spring effect of two transverse slots, which are axially compressed to effect a predetermined pitch distance offset relative to each threaded segment. This offset generates a dynamic tension between the threaded segments resulting in a constant contact, constant torque mechanism which is also self-locking.

APPLICATIONS.

Generally speaking, applications for Microwave Tuning Elements are divided into three categories as follows:

1. Filters
2. Oscillators
3. Impedance Transformers

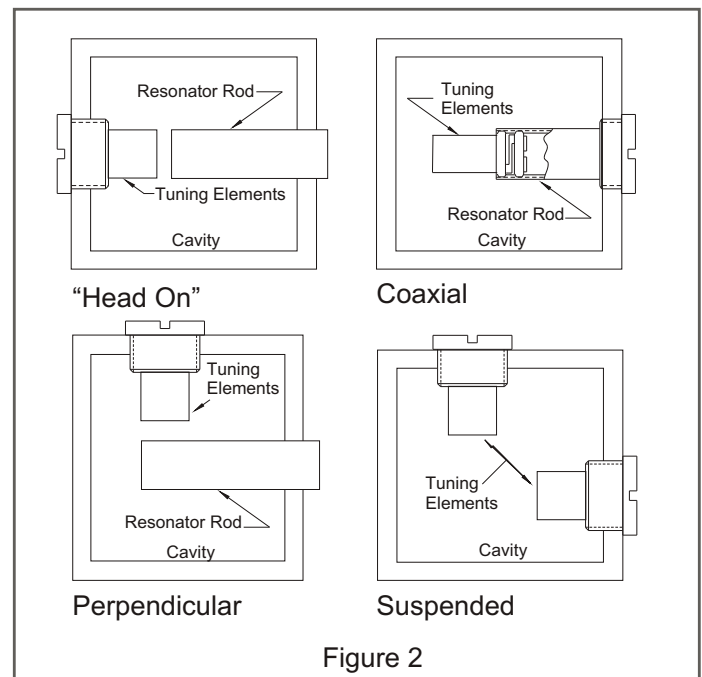
Filters, whether cavity, coaxial cavity, interdigital or combline, consist of resonant members whose design inductance must resonate with a predetermined capacity

to satisfy the initial design parameters. The inherent variations in fabrication and assembly tolerances usually demand some type of adjustable compensation in the form of a shunt capacitance. This shunt capacitance must be located at the “open” or ungrounded end of the resonator structure.

Relative to the resonator axis, the tuning element may be positioned as follows:

(See Figure 2)

1. “Head on” to the resonator rod.
2. Perpendicular to the resonator rod.
3. Coaxially within the resonator rod.
4. Suspended into a cavity or waveguide.



Filter packaging and access considerations are the primary factors which should ultimately determine location of Tuning Elements.

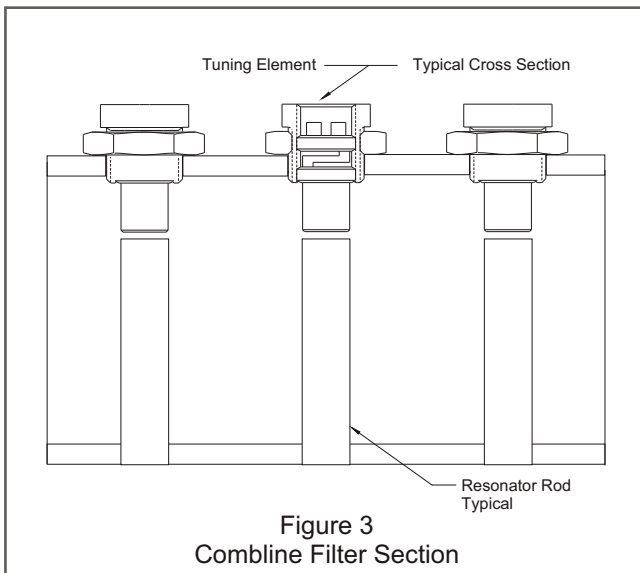


Figure 3
Compline Filter Section

Upon integrating a pre-tuned filter into a particular circuit, the input and output coupling sections usually require “touch-up” for optimum circuit performance. The self-locking one hand tuning capability of Johanson Microwave Tuning Elements is especially significant in this regard. The broad range of available rotor materials addresses the most perplexing temperature compensation requirements.

Circuit Q aside, the wider the range of capacitive loading, the greater the range of Δf . The primary factors which govern maximum capacitive loading are the tuning element’s surface finish, material, pitch resolution and maximum diameter. For optimum results,

Tuning Elements must be positioned at the points of maximum field intensity; in plateline filters these points are located at the open end of each inductive resonant section. Resonant points of waveguide filters designed to propagate the TE₁₀ mode are located along the center axis of the “a” or broad dimension of the waveguide. Figure 3 shows several sections of a combline filter with Microwave Tuning Elements properly positioned.

When rotated inward, the elements increase capacitive loading thereby lowering the resonant frequency and loaded Q. Although somewhat affected by intersection coupling, bandwidth is increased. This capacitive loading or electrical elongation of the resonant sections explains why broadband filters occupy less space than their narrow counterparts. Figure 4 shows a popular method of achieving maximum capacitance loading by coaxially mounting Tuning Elements in close proximity to the I.D. of the fixed rod section.

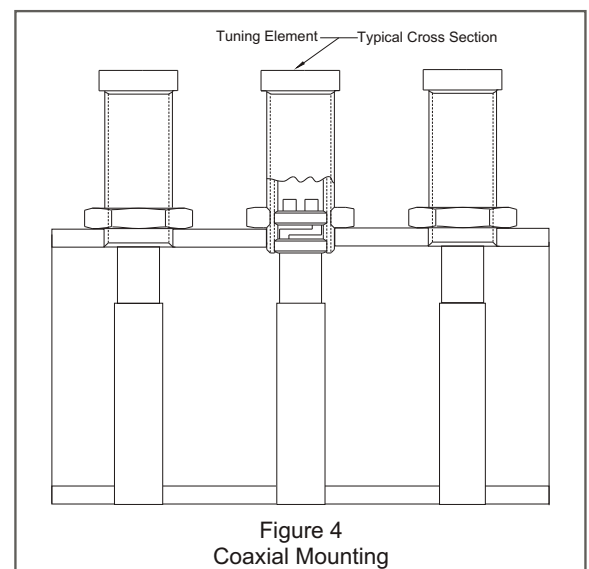
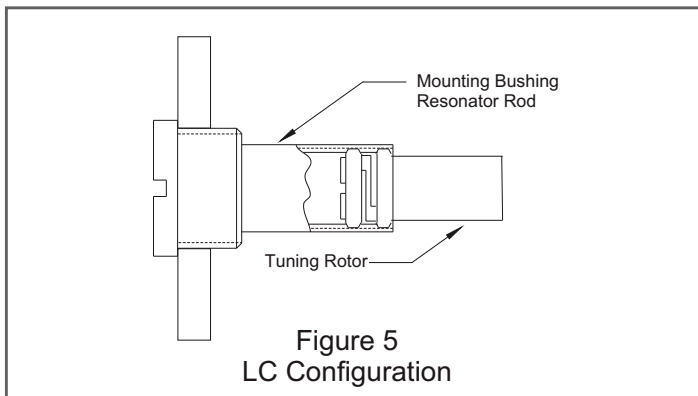


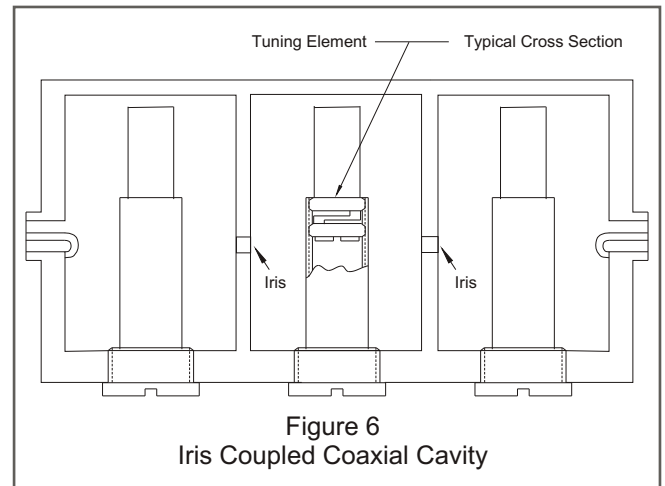
Figure 4
Coaxial Mounting

Should a thin, high ke dielectric sleeve be inserted between the Tuning Element O.D. and rod I.D. even more loading can be accomplished.

LC TUNED ELEMENTS. Designed especially for combline, interdigital and coaxial cavity filters, the Johanson LC Tuning Elements (series 6939, 6940, and 6941) eliminate the need for separate resonator rods and Tuning Elements. The mounting bushing of LC Tuning Elements is the filter's resonant rod section. The coaxially mounted tuning rotor fine tunes the resonator to the precise electrical length as shown in Figure 5.



In high Q applications where wideband tuning is a requirement, the direct-coupled TEM mode coaxial configuration is usually chosen. A long-travel tuning post is selected that will cover the desired range. The circuit is then designed around the tunable posts so that each section approximates 76 ohms of optimum resonator Q and best selectivity. Figure 6 shows such a scheme with each section lightly iris-coupled.



A word of caution: Whenever Tuning Elements are mounted in the high current region of any microwave circuit, intimate contact with the ground will insure minimum circuit losses. This can be accomplished with tightly secured fine pitch mounting threads and/or soldered joints.

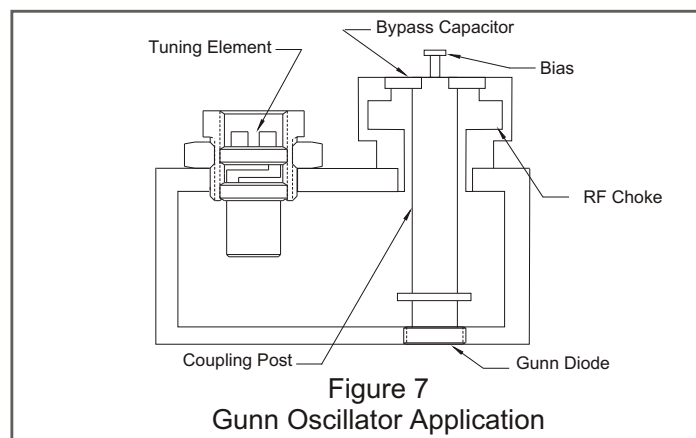
At frequencies above C band, concern about circuit losses usually dominates any other factor. Shallow skin depth, propagation, material and plating conductivity, surface finish and contact resistance act together to erode theoretical circuit performance. Here again, Johanson Microwave tuning Elements, incorporating the self-locking, constant torque mechanism with negligible contact resistance, surface finishes of 32 micrometers nominal and wide range of plating options, are specifically designed to meet the stringent requirements of high Q, high frequency, mechanical tuning.

OSCILLATORS can be thought of as filters which



contain a power generation device such as transistor, bulk effect device, or diode. Tuning is therefore accomplished in much the same manner as filters. In most instances the power generation device does not determine the final frequency; an associated cavity or resonant structure provides ultimate control. It is precisely here in the resonant structure where the opportunity exists not only to mechanically tune the oscillator but to temperature compensate it as well. A single Johanson Microwave Tuning Element of the proper configuration and material can be a most cost effective and efficient method of satisfying both mechanical tuning and temperature compensation.

The Gunn Oscillator application as shown in Figure 7 is a typical example of collateral tuning and temperature compensation. The Gunn Oscillator is an ideal application for low loss Tuning Elements. While impedance considerations dictate the Gunn Diode location, tuning resolution determines tuner location.



IMPEDANCE TRANSFORMERS. Microwave Tuning Elements and Tuning Rotors may be used to introduce shunt susceptances at specific locations along the length of a coaxial or microstrip impedance transformer.

The proper selection of metallic or dielectric Tuning Elements enables the designer to custom tune critical circuits without modifying the physical properties of the transmission line. This type of tuning is especially useful and cost effective when matching expensive FETs, bipolars and other active devices in critical circuits where device selection is necessary.

MICROWAVE TUNING ELEMENT CATEGORIES

Metallic

The metallic tuning elements (series 6924, 6925, 6926, 6927, 6928 and 6929) consist of a copper alloy mounting bushing with an integral tuning rotor of the same material. Although construction details have been addressed previously, it should be mentioned that the mounting bushing with its associated locking nut is frequently used as a “coarse” frequency adjustment while the rotor finalizes the intended frequency. At microwave frequencies, the configuration and placement of Tuning Elements in a circuit play a vital role in circuit performance. Tuning rotor exposure should be kept to a minimum and placement should be where circuit voltage fields are maximum and RF currents minimum. An obvious exception to this method exists when maximum tuning resolution requires the relocation of adjustment to an area of less intense electric field at the expenses of



slightly degraded Q. The alternate approach of using a smaller diameter tuner may also be effective. Optional materials are available.

Dielectric

Dielectric Tuning Elements are used whenever the ultimate in low loss/high resolution tuning is required. When a dielectric wand is introduced into cavity, the resonant frequency is lowered due to the cavity “appearing” larger in proportion to the square root of k_e of the dielectric material. The exact change is also influenced by other factors such as wand penetration, diameter and placement.

The three basic dielectrics used in Johanson Microwave Tuning Elements are:

1. Sapphire
2. Quartz
3. Alumina

A matrix of the electrical properties of each dielectric is shown below:

Dielectric Material	Approximate k_e @ 10GHz	Approximate DF @ 10GHz
Sapphire	9.9	.0001
Quartz	3.8	.0001
Alumina	9.7	.0002

Care must be exercised in the selection of dielectric tuners to avoid the phenomenon of wand resonance

whereby the tuning wand itself appears as a secondary cavity in the fundamental operating mode.

Secondary wand resonance is a function of dielectric constant and diameter. The following equation permits calculation of the approximate cutoff wavelength for which this condition could occur.

$$\text{Cutoff Wavelength} = 1.705 (Dk_e)^{1/2}$$

Where D = wand Diameter in inches
and k_e = wand Dielectric constant

Dielectric Tuning Elements may also be used for very high tuning resolution in interdigital, combline and coaxial filters with the additional benefit of reduced losses.

Resistive

The 6950 series Tuning Elements provide a very consistent and accurate means of attenuating microwave energy. When properly located, the magnetically loaded epoxide wand exhibits broadband lossy properties. In addition to simple power reduction, the 6950 series is also used to introduce a precision return loss where critical impedance matching between active and passive components must be achieved.

TUNING ROTORS

In addition to the standard Johanson Microwave Tuning



Elements, Microwave Tuning Rotors are available in Johanson series 6930 and L6990. The use of these lubricated Tuning Rotors without mounting bushings is sometimes necessary where center-to-center spacing of high density circuits precludes the use of a mounting bushing. In such cases, appropriate taps and tap drills are available to assure proper thread engagement. Tuning Rotors are available in the same materials as their Tuning Element counterparts.

DYNA-TRIM™ Tuning Devices for Dielectric Resonator Oscillators (DRO'S) and Filters

Dielectric Resonance is the newer answer for generating and filtering microwave frequencies in much smaller space at considerable cost reduction. The basic metallic cavity resonator is replaced by a dielectric resonator several times smaller in size and more stable with temperature. Stable high Q materials now available, with a dielectric constant range between 20 and 90, are utilized for these dielectric resonator oscillator (DRO) applications. Frequency stability of DROs in many cases is $0\pm 1\text{ppm}/\text{C}$. In most cases the DRO is comprised of a FET oscillator section, coupled to a dielectric stabilization section. In other designs, Gunn diodes or bipolar transistors are used as the active devices. In such cases the basic design criteria for the puck and tuner remain essentially unchanged. To summarize, the DRO is a very inexpensive way to generate microwave frequencies with exceptionally good oscillators. Tuning of dielectric resonant filters is essentially identical to that of DROs.

Dielectric Resonator Tuners

As a matter of practical necessity, DROs must be mechanically tuned to the desired operation frequency. Temperature compensation is accomplished with the proper selection of tuning wand material. This situation has launched Johanson into a new market with a product line of “Dielectric Resonator Tuners” or DRTs known as the Johanson DYNA-TRIM™.

Potential customers for DYNA-TRIM™ include all organizations involved in the generation or filtering of microwaves. The market includes military, commercial and consumer segments, with end products such as radar systems, communications systems, electronic countermeasures, door openers, radar detectors, and other related devices. The specific circuit most likely to use a DRO is the local oscillator section. DYNA-TRIM™ is available in three basic configurations to satisfy the unique demands of the military, commercial and consumer markets.

Military DYNA-TRIM™

The Military DYNA-TRIM™, consists of metallic bushing with an integral hermetically sealed ceramic dielectric housing inside which an adjustable tuning rotor is located. A detailed outline of the military DYNA-TRIM™ is shown in Figure 8.

Notice the mechanical captivation of the rotor which

prevents its contacting the dielectric housing when

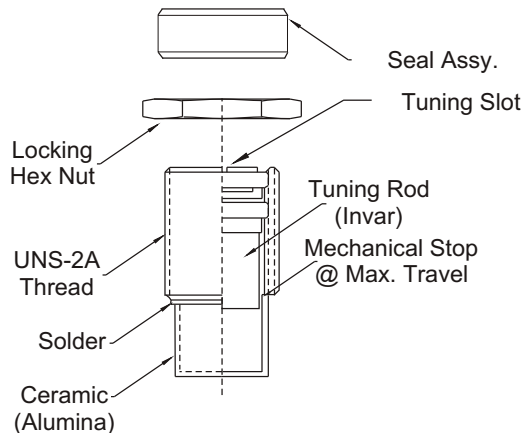


Figure 8

tuned to the maximum travel position. In actual use, a particular DYNA-TRIM is selected according to a diametric parity with the DRO puck and is installed directly above and in close proximity to the puck by screwing in the mounting bushing and securing it with the locking nut. Since tuning rotor proximity affects bandwidth, the tuner-to-puck gap is critical and must be selected carefully and maintained during a particular production run. To effect a leak rate of 10^{-6} or better, the mounting bushing must be soldered in place.

Available rotor materials which are selected primarily for temperature compensation purposes are:

1. Brass
2. Invar
3. Stainless Steel
4. Aluminum

Commercial DYNA-TRIM™

The commercial DYNA-TRIM™ as shown in Figure 9, although not hermetic, features a process seal designed to prevent intrusion of dust, cleaning agents and atmospheric contamination. A variety of materials are available.

As shown, the Johanson torque mechanism eliminates

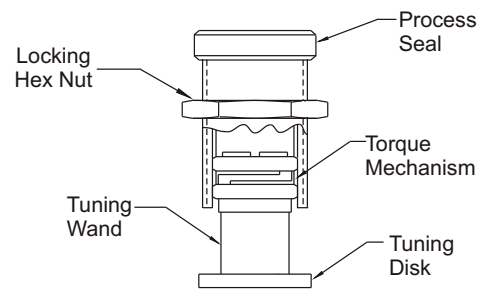


Figure 9

the need for locking nuts or jam screws. Tuning resolutions of 64 threads per inch are standard. Long term sealing is accomplished with the installation of a seal assembly which consists of a threaded metallic cap with an internal silicon rubber gasket. With a soldered mounting bushing and seal assembly installed, the commercial DYNA-TRIM™ meets the gross leak requirements of Mil-C-14409.

Consumer DYNA-TRIM™

The consumer DYNA-TRIM™ is designed to meet very cost sensitive DR tuning requirements while providing a precision surface finish on high resolution threads.



These units consist of a threaded rotor with a hexagonal locking nut. The basic configuration shown in Figure

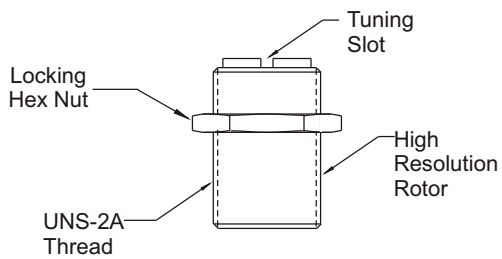


Figure 10

10 is available in various materials and sizes as well as a choice of optional plating finishes.