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Screw-Tuned Filter for the X-Band

It is astounding the things that one can do with M3 screws! A successfully completed printed circuit board can be fastened into its case and an moonshiner's exploded boiler can be repaired using these tiny helpers. They are even to be found as fashion accessories in the ear-lobes of punkers, complete with locking nuts as insurance that they do not fall out in a hurry. Who would have imagined, however, that these unlikely examples of their utility could be outdone by their use as microwave resonators. The following article will describe the construction of a microwave filter which uses M3 screws as the selective elements.

Many publications have already described methods of selection for the 10 GHz region. If now another species is added to the existing well-known ones, such as cavity filters and stripline resonators, it should be differentiated by either its electrical data or its method of fabrication. With the exception of the SMA input and output connectors, all the necessary material for this project may be obtained from the local hardware store. The cheap and easy construction together with the facile alignment procedure should stimulate an immediate urge to get to grips with this project.

There are two basic types of filter structures, the finger arrangement (i.e. resonators arranged on one side of the cavity) or the inter-digital (i.e. resonators arranged on both sides of the cavity). One could also consider the perpendicular positioned resonators but they exhibit, for the most part, only capacitive coupling between each resonator element. For the same bandwidth, the finger structure is always the physically shorter, and is therefore to be preferred.

The degree of coupling between the resonators is, in the first approximation, a function of the proximity of the posts to one another. Critical, and greater coupling factors, can result in bandwidths of up to 500 MHz whereas under-critical couplings of similar dimensioned posts can produce 3 dB bandwidths of only 20 MHz. It can be used to suppress a local oscillator at 10.3 GHz, which is only removed from the signal frequency by 145 MHz, by some 30 dB; the image frequency, 290 MHz away, being suppressed by 40 dB – albeit at the cost of increased insertion loss.

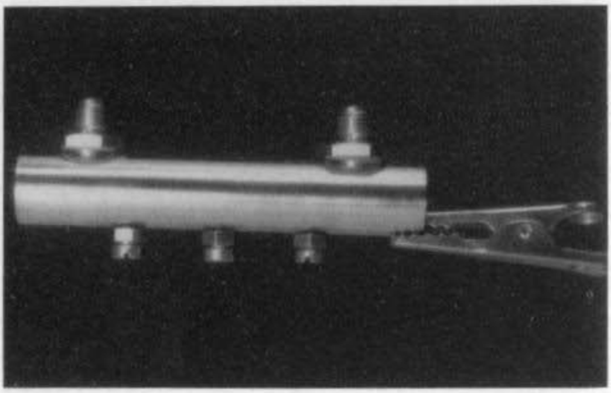

Fig. 1: Completed resonator filter with SMA sockets

1. MECHANICAL CONSTRUCTION

The individual resonators of the finger or interdigital filter for say, the 23 cm band, have a mechanical length of about 10 to 20 % below λ/4. The fine-tuning is carried out by capacitive loading (screws) at the hot end. The resonators, discussed here, consist of only screws and protrude equally from the cavity wall. A λ/4 at 23 cm is 8 mm long.

The filter housing should not offer much more space than absolutely necessary to accommodate the screw resonators, otherwise, there could be a possibility of mode changes occurring. A particularly favourable type would be of circular cross-section, as the cut-off frequency of the lowest stable mode for round waveguides lies considerably above those of rectangular cross-section. In the following constructional example, a standard brass tube of 12 mm external, and 10 mm internal diameter, is employed. The lowest cavity transmission frequency for this type of tubing lies above 20 GHz. The 1 mm wall thickness is sufficient for a stable M3 screw-thread to be cut (**fig. 1**).

It has been found in practice, that the M3 brass screws which have been polished with steel wool

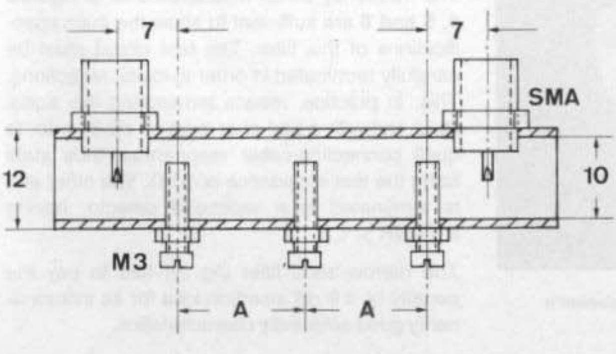

Fig. 2: Cross-sectional view of X-band finger filter

filter	bandwidth MHz	insertion-loss/dB	spacing A/mm
1	20	9	18
2	80	2.5	15
3	110	2.5	13
4	220	1	10

Table 1: Results for the 4-stage versions

and then plated with rubbing silver, possess a higher Q than untreated screws. Treating the inside of the brass tube, however, results in only a small improvement. In order to guard the treated screws against subsequent corrosion they must be cleaned carefully with a brush and hot water.

Figure 2 shows the principle of construction of this filter: for the dimension A can be found four examples in **table 1**. The distances A of the resonators' spacing were dimensioned according to cut-and-try methods. In principle, a smaller

Fig. 3: Coupling by means of the SMA-socket's spigot

spacing increases the bandwidth. The upper limit of the bandpass is reached when the bandpass ripple becomes unacceptably high. A 450 MHz wide filter (undocumented) should just about mark the absolute limit.

The under-critically coupled example, shown in fig. 6, represents what this technique can yield in the way of selectivity. The circuit Q is over 500 and there is a great possibility of the circuit being de-tuned under the influence of varying temperature, oxidization or the aging of the materials.

The SMA sockets (SMC is just as usable) are screwed in. The method of doing this may be clearly seen in **fig. 3**. As the thread is 3/8", many builders in Europe may not easily acquire a set of taps to cut the thread and it may therefore be expedient to solder the socket in. The hole in the tube has a diameter of 2.75 mm for an impedance of 50 Ω. If the spigot is teflon covered, the hole diameter is then 4.1 mm. The length of the coupling spigot is not too critical, being somewhere between 3 and 4 mm.

With the aid of nomograms (unavailable to the author), all the important parameters may be easily obtained without having to calculate them. This, more exact approach, will result in the insertion-loss being a little smaller. The ends of the tube can be, but need not be, capped.

2. MEASUREMENT RESULTS

The frequency swept measurements of **figures 4, 5 and 6** are sufficient to show the main specifications of this filter. The test circuit must be carefully terminated in order to inhibit reflections. This, in practice, means terminating the signal input end with a pad of at least 10 dB in order to quell connecting-cable resonances thus stabi lizing the test impedance at 50 Ω. The other end is terminated in a wideband detector having a VSWR ≤ 1.2.

The narrow-band filter (fig. 6) has to pay the penalty of a 9 dB insertion loss for its extraordinarily good selectivity characteristics.

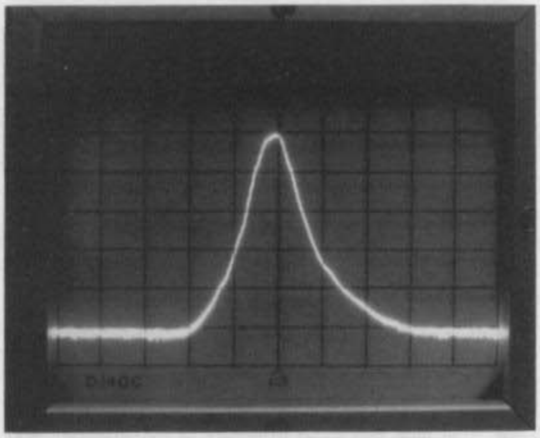

Fig. 4:
Selection characteristics of the 200 MHz wide 10.3 GHz filter
h = 500 MHz/cm, v = 10 dB/cm

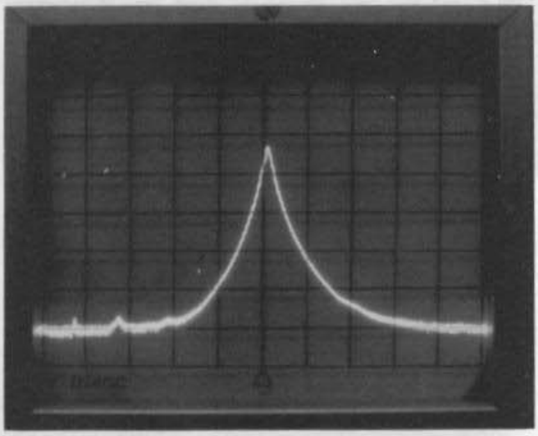

Fig. 5:
Bandwidth approx. 80 MHz at 10.3 GHz
h = 250 MHz/cm, v = 10 dB/cm

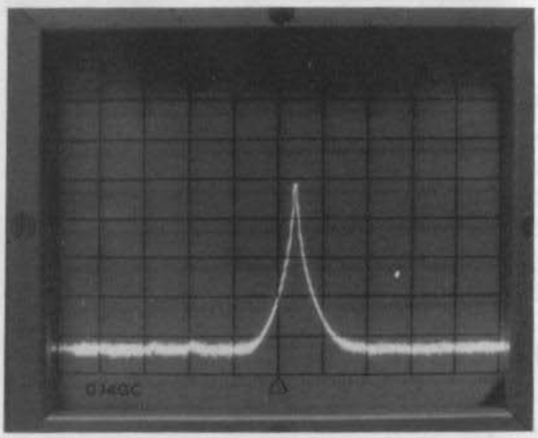

Fig. 6:
Only using a higher resolution the 3 dB bandwidth of only 20 MHz is measurable at 10.3 GHz
h = 250 MHz/cm, v = 10 dB/cm

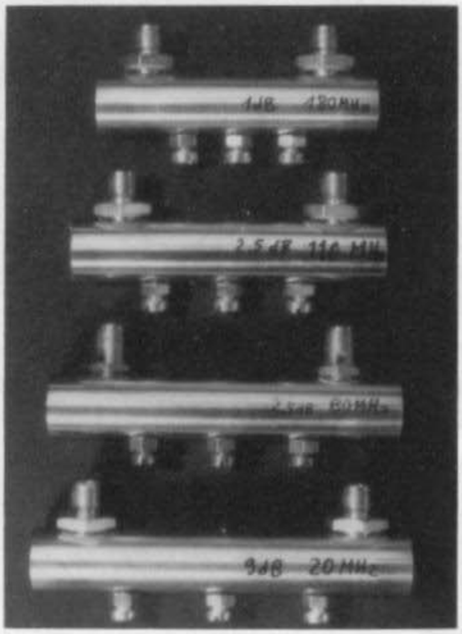

Fig. 7: "Still life" in brass

The three narrow-band versions can be aligned by simply adjusting for maximum output at 10.3 GHz. Filters having bandwidths of over 200 MHz can only be satisfactorily aligned, for minimum insertion-loss consistent with low ripple, with a 10.3 GHz sweeper test set-up.

A 5-stage version of this filter resulted in better selectivity characteristics but no improvements in the bandpass region and at the cost of increased insertion loss.

The most important characteristic of this type of filter lies in its simplicity of construction, and thereby, the amazingly short time it takes to construct and commission it. The four filters shown in **figure 7** were mechanically constructed within one hour. Apart from a vernier-gauge and the 3/8" taps, the only tools required were a drill-press and a circular-saw to cut the lengths of tubing with.