Kokusai Mechanical Filters as fitted to the KW2000 series of transceivers (including the KW202/204 and Vespa)

This relates my experience with the repair/refurbishment of the Kokusai mechanical filters. I have owned a KW2000 and two KW2000A's over the years and have repaired filters in these and a KW2000B belonging to a friend. I am an electronic engineer by training but have, like many others, obtained much of my 'RF' knowledge through experimentation and reading the experiences of others. Therefore, what follows may not be 100% technically correct. It is intended as a guide for those who have problems with these filters so, if you spot any inaccuracies, mistakes or bits that are simply wrong, or if you can add to the knowledge then please let me know and I'll correct it/add it in.

Operation in the KW2000.

The KW2000 first appeared in the early 1960s. This transceiver was developed in response to the growing use of single sideband on the amateur bands. Unlike the earlier AM transmitters, single sideband, whilst amplitude modulation, is more complex to generate. There are a few methods of generating SSB and I'll not speculate upon the reason for selecting the filter method. Suffice to say the Phasing method requires accurate component values to be employed and in that way (among others) doesn't lend itself easily to mass production. The filter method was employed in Collins equipment, utilising a mechanical filter operating at the standard IF frequency of 455kHz. This was carried over into the KW design with the Kokusai filter, again operating at 455kHz. Once the SSB has been generated, the KW2000 series mixes this signal with the VFO frequency (bringing the signal up to 2.955MHz to 3.155MHz, variable by tuning the VFO), and then further mixing with an HF crystal oscillator to bring it up (or down) to the band required.

The Kokusai MF-455-10CK filter has a response approx. 2.1kHz wide, quite narrow for audio bandwidths and is centred on 455.0kHz. In order to generate lower sideband (LSB), the carrier frequency (crystal controlled) should be on the high side of the filter. Let's put in some values taken from a filter I mended back in 1989.....

Driven from a 3v RMS source with a 100k load.....

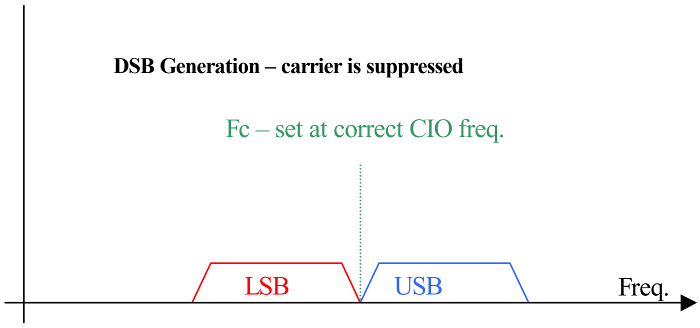
- Minimum insertion loss = 13dB
- Centre frequency 455000Hz (measured).
- -6dB points at 453800Hz and 456200Hz (Width = 2400Hz measured).
- -20dB points at 453700Hz and 456300Hz (Width = 2600Hz measured).
- -40dB points at 453600Hz and 456400Hz (Width = 2800Hz measured).
- Passband ripple 6dB max.

A datasheet for the Kokusai MF-455-10CK can be found on the KW Yahoo! Group Files Section.

Double sideband generator spectrum contains energy in the lower sideband and upper sideband but little or no energy in the carrier (typically 40dB of suppression). The filter is used to remove the unwanted sideband and pass the required sideband.

Now let's consider how the SSB is generated in the KW2000 series.

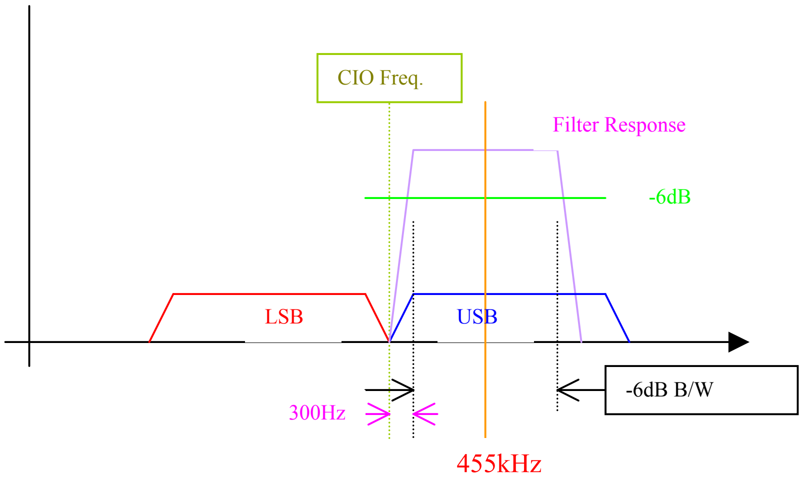
Speech bandwidth for communication purposes needs a response of 300Hz to about 3300Hz. Both these figures can be varied a bit but tend to degrade the quality of the signal to some degree. Minimum bandwidth is, however, desirable for use on the amateur bands.



The balanced modulator produces both upper and lower sidebands either side of the carrier frequency. The carrier itself is suppressed by some 40dB or so in the modulator. The diagram (left) shows the relative positions of LSB, USB and carrier frequency.

If we set the carrier insertion oscillator (CIO) frequency at 300Hz below the filter LF –6dB cut off point, then the upper sideband from 300Hz to (300Hz + 2400Hz) = 2700Hz passes through the filter. The lower sideband falls in the stop band and is attenuated. Consequently, energy passing through the filter is from the upper sideband between 300Hz and 2700Hz only. A similar argument applies to the lower sideband - this time, the carrier frequency is set 300Hz above the filter's HF cut-off point and only the lower sideband passes through the filter, the upper sideband being attenuated.

Diagrammatically, the **upper sideband** generation with the above filter looks like this...

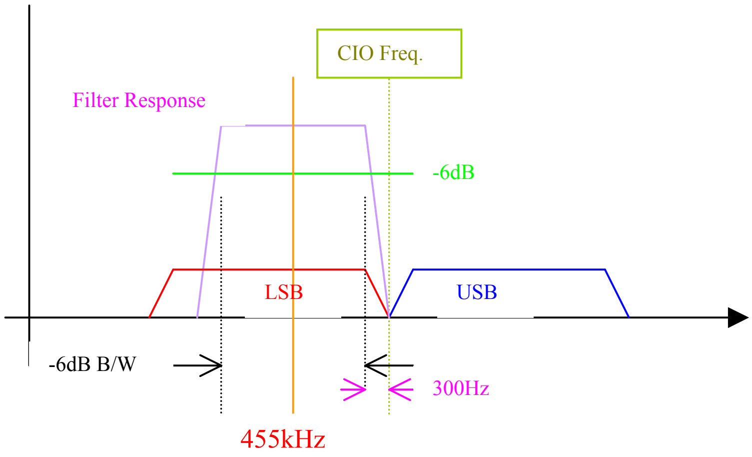


The filter is nicely centred on 455kHz with lower -6dB point at 453800Hz and upper -6dB point at 456200Hz
This gives a –6dB bandwidth of 2400 Hz.

For USB, the CIO frequency is therefore set at 453800Hz - 300Hz = **453500Hz**.

The bandwidth is 300Hz to (300Hz + 2400Hz) = 2700Hz - a total of 2400Hz.

For **Lower Sideband**, the CIO changes thus…
Again, the Filter centre is 455000Hz with the upper –6dB point at 456200Hz and lower –6dB point at 453800Hz



The LSB CIO is therefore set at 456200Hz + 300Hz = **456500Hz**.

The CIO frequency is therefore critical and would ideally be selected for each filter, depending upon the exact characteristic.

One other advantage of using the filter method is that the carrier, suppressed in the modulator by about 40dB is further attenuated by the filter as the CIO frequency falls outside the filter response some 40 or 60dB down.

The continuing signal.

The transmit signal goes on to the TX IF Amplifier (V4) and then to the first Transmit mixer where it is mixed with the VFO. From there to the wideband coupler – a filter with a 200kHz wide response (allowing for the frequency range of the signal with the swing generated by the VFO). This signal then passes to the 2nd transmit mixer where it is mixed with the output of the HF Crystal Oscillator to put it on the band required. The preselector control filters/tunes this frequency and it passes to the driver (V6) and the PA (V8 and V23).

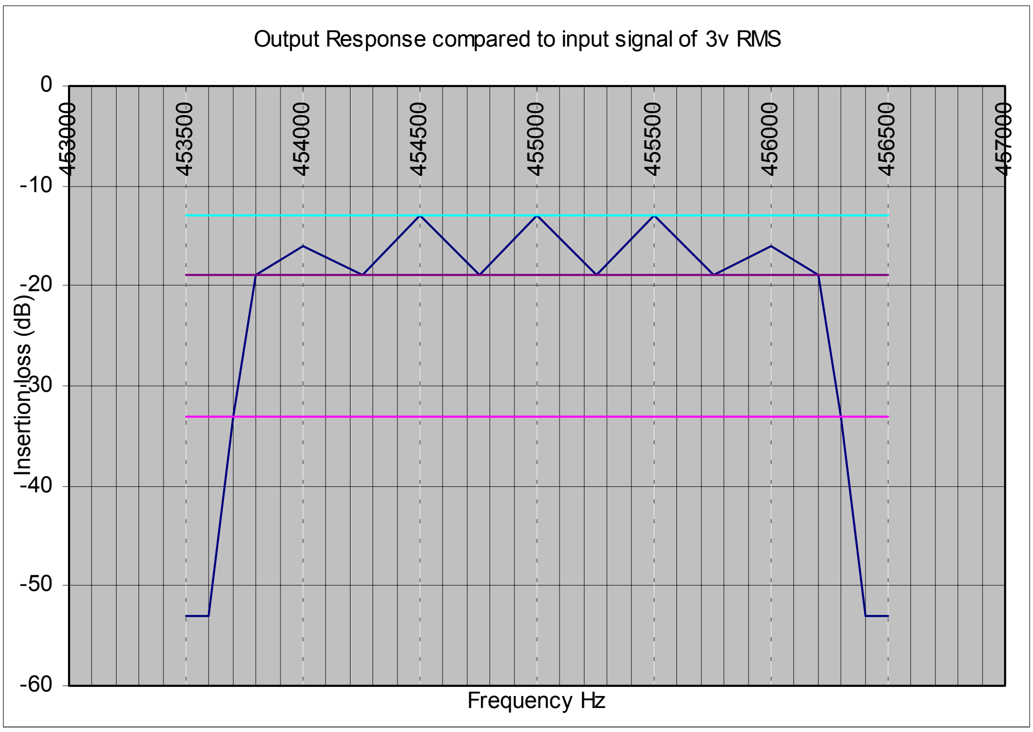
The Receive Chain.

On the receive chain, the incoming RF is amplified by the RF amp (V7) and tuned by the preselector before passing to the 1st receive mixer where it is mixed with the HFCO signal. The wanted mixer response is at about 3.155MHz and passes through the wide band coupler into the 2nd receive mixer where the VFO frequency is subtracted. This 455kHz signal is presented to the mechanical filter. Only signals centred on 455kHz pass through. These are amplified in the 1st and second IF amplifiers and then the product detector. This performs the reverse of the balanced modulator and mixes the correct CIO for upper or lower sideband to create an audio signal which is amplified to drive speaker or phones.

(You will sometimes see crystal CIO frequencies quoted as the -20dB point. If placed here, the USB CIO would be at 453700Hz and frequencies of 453800 to 453800+2400Hz = 456200Hz would pass through the filter - audio wise, this is 100Hz to 2500Hz. This spec generally applies to filters with a lower shape factor.)

Here are the results of tests I made on a repaired filter.

Drive = 3v RMS					
Freq Hz	Output	Atten	-20dB	0dB	-6dB
453500	-53	-40	-33	-13	-19
453600	-53	-40	-33	-13	-19
453700	-33	-20	-33	-13	-19
453800	-19	-6	-33	-13	-19
454000	-16	-3	-33	-13	-19
454250	-19	-6	-33	-13	-19
454500	-13	0	-33	-13	-19
454750	-19	-6	-33	-13	-19
455000	-13	0	-33	-13	-19
455250	-19	-6	-33	-13	-19
455500	-13	0	-33	-13	-19
455750	-19	-6	-33	-13	-19
456000	-16	-3	-33	-13	-19
456200	-19	-6	-33	-13	-19
456300	-33	-20	-33	-13	-19
456400	-53	-40	-33	-13	-19
456500	-53	-40	-33	-13	-19



Graphical representation of the filter response. The turquoise line is -13dB below the drive signal. This is the insertion loss. The filter exhibits 6dB of variation within the passband. The purple line shows the -20dB level.

So you think you filter is duff?

After many years of service, it is often found that the receiver goes deaf and the output on transmit drops off. There can, of course, be many reasons for this and the manual suggests various paths to follow in order to determine the cause. Valve degradation, particularly those that are hard worked, are likely targets as are cathode decoupling capacitors (notoriously although not exclusively Hunts). However, when the problems mount up on transmit as well as receive, the mechanical filter might be suspected. Valve voltmeter readings as suggested in the manual give a good indication of the signal levels passing through the filter on transmit and where large attenuations are found, the filter may be suspected. Another receiver, capable of receiving and demodulating signals at 455kHz, 2.7MHz, 3.155MHz and the amateur bands is a very valuable tool for listening to the rig's signal generation at each of the stages of DSB generation, VFO and mixing frequencies.

Before delving into measurements on the KW2000, it is imperative that you are aware of the supply voltages on the pins. The G and E pins are relatively safe. E is grounded anyway and G is capacitively coupled to the next stages.
The P and B pins are where the danger lies - these are connected via 4k7, to the +245v rail and will bite.

The KW2000B manual suggests that with the rig in tune mode on 80m, operating into a dummy load, the signal at the wiper of the 'Mic Gain' pot should be advanced to give 1.0v ac (RMS). This should cause PA current to be drawn and 12.5v of 455kHz RF on the 'G' pin of the filter.
The signal on the 'P' terminal (note the dc is up to 245v on this pin) should be 5.5v.

The attenuation of the filter may be calculated from: Attenuation = $20*Log_{10}$ (signal on pin 'P' / signal on pin 'G').

In this case, Attenuation = $20 * Log_{10}(5.5v / 12.5v)$ = **-7.1dB**

This may be the case for a good filter but figures up to -12dB are still OK.

If these values are not as the table, the calculation still holds good and the filter attenuation may be calculated. Simply measure the difference in signal level and feed the results into the formula.

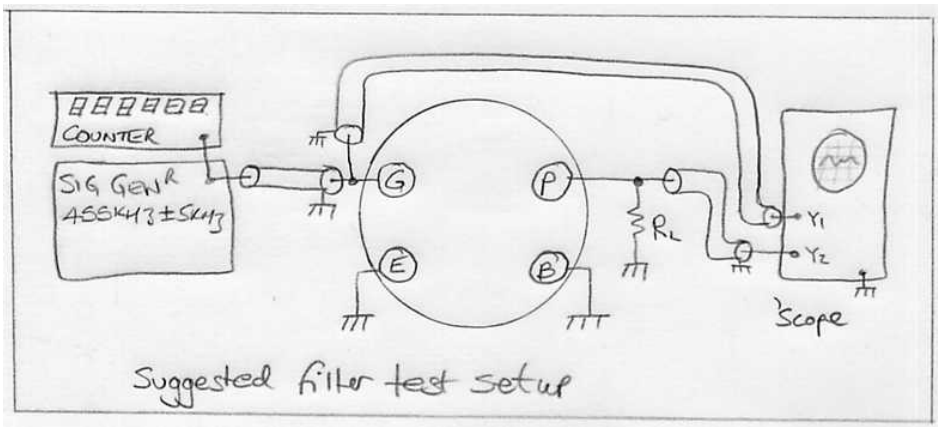
A good filter will have an attenuation figure of 6 to 12 dB.

If the signal level at the filter 'G' pin cannot be achieved, disconnect the 'G' pin connection and try again. If this still cannot be achieved, look elsewhere for the fault! It may be in the TX IF amp, the balanced modulator or the tone generator. This fault should be cured before the filter assessment is undertaken.

If the filter is found to be high in attenuation and nothing else appears wrong (check the resistance measurements and Tx/Rx voltage charts) then it may be time to consider the filter at fault.

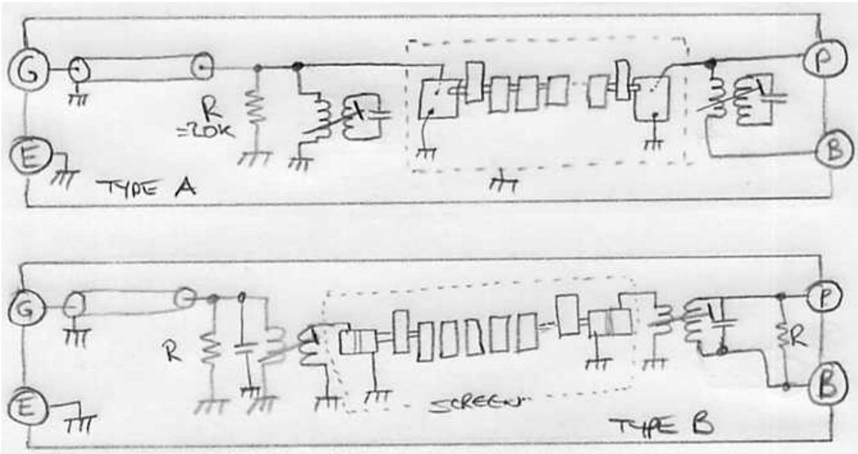
One last check is advisable - with the power off, connect a 0.01uF cap (500v wkg silver mica is good!) across the 'G' and 'P' pins on the filter. Run the rig in receive mode. If the filter is really causing the problem, "all hell will break loose" and the receiver will appear very lively. Both sidebands of signals will be heard and these sidebands will have a wide audio frequency range. This happens because there is no filtration at 455kHz but it does show that the basic receiver is operating. If this doesn't happen, look elsewhere for the fault before attacking the filter.

Remove the filter from the chassis - set aside the nuts and washers and also (where fitted) the small screen.



Ideally, the filter should be further tested in order to assess its condition. A signal generator at 455kHz is very useful as this can be used, in conjunction with an RF voltmeter or suitable oscilloscope, to check the filter on the bench. If the incremental; frequency steps can be made small enough, the filter's characteristics can be plotted out. It's worthwhile doing this if possible as so that the repaired filter may be compared. RL may be required on type A filters - I'd suggest 10k-100k. The CIO frequencies can also be checked. I used the setup below…

Electrically, there are two internal circuits that I’ve come across – I suspect they are defined by age. The KW2000 and 2000A had type A and the 2000B had type B. I don’t know for sure whether they are time correlated with a particular filter type.



In Type A, the transformers are used as 'resonators' - tuned to 455kHz. These provide no electrical isolation. The natural high impedance of the Piezo type transducers is shunted by the 20k resistor across the input.

In Type B, the lower impedance of (what I suspect are) electromagnetic transducers is transformed up by the IFT’s. (Resistor values unknown but suspect 20k).

Dismantling the filter...

There is no easy way to get the filter apart and some ingenuity and considerable dexterity, not to mention perseverance and care is needed! (Plus some luck for good measure).

The outer can is soldered to the base to form a hermetic seal. The can is a huge heatsink and heating it to the required temperature to melt the solder is not recommended. I've always used a combination of prising and de-soldering but I know others have simply sawn the case open. I will describe my method firstly.

Fix the filter upside down in a vice or suitable holder. I made a wooden block to grip the filter. Do not over tighten the vice as the can will distort/crush.

You'll need a 60Watt soldering iron with a largish bit and either solder wick or a solder sucker plus a small electrician's screwdriver and some patience. Some damage will undoubtedly occur but it can be minimised such that re-assembly is possible.

Heat the joint in one place. It will take some time as the can will absorb a lot of heat. Use the sucker/wick to remove as much solder as possible from the area and then move on round the filter base until you've removed all you can.

Now, re-heat an area and tap the electrician's screwdriver between the can and the base. This may split the can but that doesn't matter - in fact it helps. Continue heating around the base, tapping the screwdriver in, gradually separating the can from the base. The base is pushed in 6-7mm. Try and restrict the damage by only splitting the can a short way and only as often as required. Eventually the base may be carefully pulled free of the can.

Allow the unit to cool before handling it! Straighten the can in preparation for re-assembly.

Alternatively, carefully cut the can about 2mm up from the base as the can is only soldered round the lip. This may be an easier option.

Once de-soldered or cut, the can may be withdrawn and the internals of the filter may be inspected. Be careful - the filter resonant element, its transducers and connecting wires are **very fragile** and should be handled with great care. Do not allow the resonator element to rattle around inside the inner screen as the transducers are easily broken off with disastrous consequences.

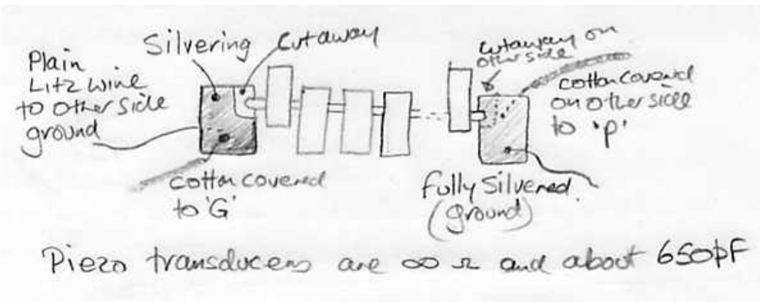
There are various modes of failure for the filter - some are pretty terminal, others easier to deal with.

It is possible for the resonator transformers to become open circuit. Check them with a VOM for continuity - both sides! If there is doubt over their integrity, remove them and check them out - the capacitors can also become unserviceable. I've replaced the transformers in more than one filter with TOKO types - the RZES 1A 7151 733Z1 is a possibility but I would suspect many '10K' types would do the job.

Perhaps most common is the degradation of the foam that supports the filter inside the inner screen. This foam turns to an orange or yellow gunge that spreads itself liberally over the filter disks and the internals if the inner screen. This should be cleaned off with methylated spirit, alcohol, nail varnish remover or similar.

Broken wires are also a possibility. Check for continuity with a VOM meter. Lead failure can also be brought about by the degrading foam.

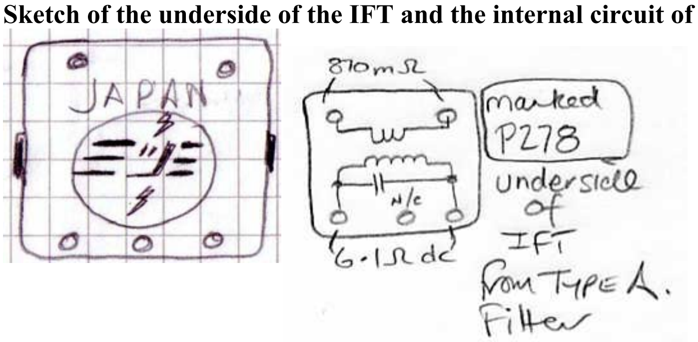
The transducers can also fail. There appears to be two types - inductive and capacitive. The inductive type (may be seen in pictures at http://jlkolb.cts.com/site/koku.htm) appear to have a small 'bobbin' fixed over a rod protruding from the filter ends. This has a winding from which two flying leads emerge. These appear to be fairly robust compared to the capacitive type. An open circuit in the winding itself may prove difficult to cure. I found this type in a KW2000B - clearly a later type.



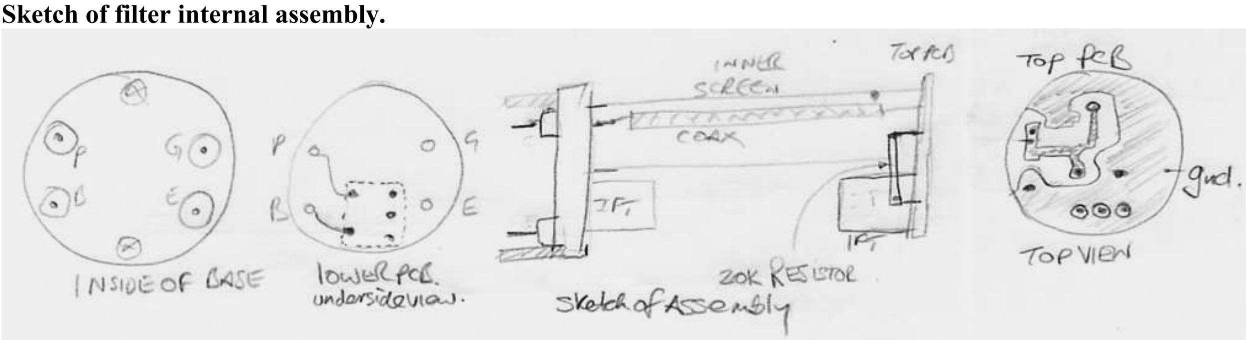
The capacitive type (left) is more fragile and takes the form of what appear to be small rectangles of double-sided printed circuit board mechanically fixed to a short rod protruding from the end of the filter resonator elements. This 'flag' has a wire connected to each side and appears to work in a piezo mode. One side of each 'flag' is electrically connected to the resonator stack and this is the ground connection. The other side has a cutaway around the point where it is bonded to the resonator rod, providing electrical isolation. These are the 'G' and 'P' pin connections. These 'flags' will break off easily and may also fail due to the silvered coating corroding -(again, I suspect, due to the degrading foam. If wires have broken off the 'flag', they can be soldered back on but use a small Iron and one corner of the 'flag' - do not overheat such that the silvered layer de-laminates.

Look also for degradation the solder joints and the general condition of the PCB's.

Sketch of the underside of the IFT and the internal circuit of the IFT



Sketch of filter internal assembly.



Re-Assembly.

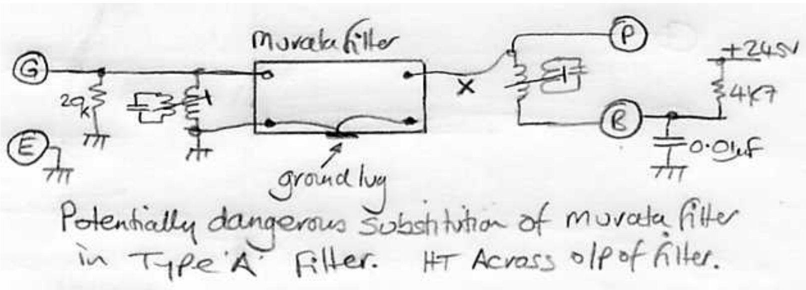
After ensuring the resonator is clean and the wiring correct, the resonator assembly should be lightly rolled in tissue paper or foam and coaxed back into the inner screen. I suspect other materials could be used to support the filter but paper is pretty inert. Check the wiring again and the transformer integrity. I would suggest checking the filter before you re-solder it. If you have access to test gear, it's worth checking the parameters on the bench and comparing with earlier results. Failing that, re-assemble into the rig with the can off and try it. Go through the measurements you made when determining the filter as the problem to see if the attenuation has dropped to the 6-12dB level. I've has filters exhibiting 13 - 14dB that are still fine. If it's much greater than 20dB though, I'd suggest the filter was duff.

Assuming all is well, the can may be re-soldered and the rig brought back into service. You may well wear a broad grin on your face!

Other potential solutions...

If the filter cannot be repaired (and I've tried bonding broken 'flags' with limited success), you may need to look at replacing the filter in its entirety. The filters have not been produced for 20 years or more and are not easy to come by. There are some about - answers to requests in the Radcom ads have borne fruit and they appear on e-bay occasionally but the sources are drying up. It has to be said that, of course, any filter you buy will itself be old and may well be in a similarly gunged-up condition within so there is no guarantee they will work or be any better than the sad case you have.

There have been valiant attempts to replace the filter in its entirety with other types, notably the ceramic filters that Murata have produced. I suspect that with perseverance, this can provide a solution and an article in Radcom for May1999 by Bruce Edwards G3WCE describes such a procedure. However, the circuit he suggests, whilst being fine for some versions of the MF-455-CK are positively dodgy for the ‘Type A where the original Piezo transducers provided electrical isolation. However, if the modification described is applied to a Type A filter, the output is connected across the +245v supply via 4k7. Adding a capacitor at ‘X’ would isolate the HT but the modification also has no impedance matching with the Type ‘A’ filter. In order for the modification to work safely, I would suggest some re-wiring to bring the transformers into play in the same way as the Type ‘B’ filter. That way, the impedance mismatch is dealt with and the filter is isolated from the HT by the transformer.



As the filter is different, it’s likely to require new CIO crystals to match it. The Murata filters are also no longer made although some suppliers may have stock and alternatives may be available.

One could also consider fabricating a crystal filter or experiment with ceramic resonators but this is beyond the scope of this article. There may also be filters available from the Collins series.

Good Luck!
Graham Adcock. G4EUK.

References and acknowledgements.

Thanks to Don Vosper for a copy of the Kokusai Datasheet (Now on the KW Yahoo! Group Files Section).
There are a few websites where filters and filter repair are featured...

- http://tibblestone.users.btopenworld.com/kw2000.htm
- http://amateur.duncanamps.com/kw2000.php
- http://jlkolb.cts.com/

There is an article in Radcom May 1999 pp32-33 by Bruce Edwards G3WCE - replacing the filter with a Murata ceramic. See my notes regarding the type of filter and this modification.