RSGB EMC COMMITTEE WEB SITE REFERENCE SECTION

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These pages are taken from the draft copy of *The RSGB Guide to EMC,* which is now out of print. It will differ from the published version in format and in minor changes and corrections. It has not been updated but includes minor editorial changes to accommodate stand-alone presentation.

Figures and Tables are on pages 14 to 27. Original figure numbering is retained

Appendix 3

Characteristics of various filters and ferrites for amateur radio EMC use

This appendix is a report on work carried out by Dave Lauder, G0SNO, at the request of the RSGB's EMC Committee. The performance of the filters and chokes has been measured under defined conditions, and comments made on their effectiveness. The author is professionally involved in EMC, mainly in the field of education and training and has written the EMC Column in Radio Communication since August 1996.

The filters and chokes described are for use with broadcast radios, TVs or other affected equipment. They are not suitable for use at the output of an amateur transmitter.

Table A3.1 summarises the characteristics of various filters and ferrites for EMC use on various amateur bands. For an explanation of common-mode (in-phase) and differential-mode (anti-phase) signals, see Chapter 5 and also later in this appendix. Common-mode signals can be caused by amateur transmissions on any band where the braid of a TV antenna coaxial cable, rather than the antenna itself, acts as a receiving antenna for amateur signals, particularly at HF where a UHF TV antenna itself is not an efficient receiving antenna.

In the 'stop-band loss' column, the bar graphs represent the minimum filter loss in a particular amateur band to the nearest 5dB. The higher the stop-band loss, the better. One square represents 10dB which may cure minor breakthrough, but in most cases 20dB, 30dB or more may be required. Six squares represent 60dB or more.

In the 'pass-band loss' column, the bar graphs represent the loss in the UHF TV band to the nearest 1dB. The lower the pass-band loss, the better. In the case of the HPF2, the pass band includes the FM radio broadcast band (Band 2, 87.5 to 108MHz) as well as the UHF TV band. Many of the filters have 'N/A' in the FM broadcast pass-band loss column which means 'not applicable', ie the filter is not suitable for passing this band.

Where the UHF TV signal strength is high, a loss of 3 to 5dB may not be noticeable but, if the signal is weak, then even a 2dB loss could give a slight but noticeable increase in noise on the picture.

In some cases, the pass-band loss of a filter varies in different parts of the UHF TV band, particularly on the lowest channels. In this case, the relevant curve on Figs A3.10 to A3.14 should be examined to find the loss for the UHF TV channels used in a particular area.

For ease of reference, all figures and the tables are grouped at the end of this appendix.

Filters

For each filter, the principal characteristics are described, together with equivalent circuits and measured response curves for a typical filter. The responses are subject to some variation between samples of the same type, particularly in the case of the home-constructed filter. The test methods are described later.

Home-constructed high-pass filter and braid-breaker

Circuit and layout: see Fig A3.19.

Response curves: see Figs A3.1, A3.2, A3.11 (pass band), A3.16 (common mode).

Type: balanced L-C high-pass filter (UHF TV) with braid-breaking.

Pass band: Bands 4 and 5 (UHF TV).

Loss in pass band: typically 0.5ï 2dB.

Braid-breaking action: capacitive.

Remarks: This filter is simple but should be used with caution as it is a balanced filter used in an unbalanced feeder. It has good rejection of HF differential-mode signals but rejection of common-mode signals is not as good as a transformer-type braid-breaker. As its roll-off below 470MHz is not particularly sharp, this filter is not particularly effective at 144MHz. For improved rejection at 144MHz, the five element home-constructed high pass filter shown in Chapter 5 can be used. **[See Page 26 below]**

Fig A3.1 shows the response of this filter and the AKD HPF1 in a test circuit with a common ground between the input and output. This test bypasses the capacitor in series with the braid and gives sharp resonances which are unlikely to occur in practice at the frequencies shown. Fig A3.2 shows the response of the two filters with a 'floating' source (see 'Test methods' later).

AKD HPF1 high-pass filter

Equivalent circuit: see Fig A3.20.

Response curves: see Figs A3.1, A3.2, A3.11 (pass band), A3.16 (common mode).

Type: L-C high-pass filter (UHF TV) with braid-breaker.

Pass band: Bands 4 and 5 (UHF TV).

Loss in pass band: typically 0.5ï 2dB.

Braid-breaking action: capacitive.

Remarks: Similar performance to home-constructed filter above but slightly better stop-band performance. See notes in previous section regarding test methods.

AKD HPF2 high-pass filter

Equivalent circuit: see Fig A3.21.

Response curves: see Figs A3.3 (stop band), A3.12 (pass band).

RSGB description: Filter 2, HPF for FM Band 2.

Type: L-C high-pass filter (FM broadcast).

Pass band: Bands 2 (FM radio broadcast), up to 4 and 5 (UHF TV)

Loss in pass band: typically less than 1dB in most of Band 2 (2.5dB at 87.5MHz), 1ï 3dB in Bands 4 and 5.

Braid-breaking action: none.

Remarks: It is intended for reducing breakthrough on FM broadcast receivers (87.5ï 108MHz), particularly from HF signals but is also useful for rejecting 50MHz signals. It is only effective against differential-mode signals as it has no braid-breaking action, but an HPF2 with a BB1 or ferrite common-mode choke can be used together if this is required.

AKD HPF6 high-pass filter

Equivalent circuit and appearance: see Fig A3.22.

Response curves: see Figs A3.4 (differential mode overall), A3.13 (pass band).

RSGB description: Filter 8, six-section for UHF TV.

Type: Six-section L-C high-pass filter (UHF TV), sharp cut-off.

Pass band: Bands 4, 5 (UHF TV).

Loss in pass band: typically 1ï 3dB (Channels 21ï 40), 1ï 2dB (Channels 41ï 68).

Braid-breaking action: None.

Remarks: The HPF6 is a high-performance filter with a very sharp cut-off below 470MHz and is specifically designed filter for reducing breakthrough from the 430ï 440MHz amateur band. It also has very good rejection of all lower amateur bands. If a UHF TV masthead preamplifier is in use, the HPF6 should be mounted in a weatherproof box between the antenna and the preamplifier.

Trace B on Fig A3.4 shows the measured response of an HPF6 with 40dB loss at 435MHz. If the coaxial plug on the flying lead was grounded to the metal case of the filter, the response improved as shown in trace C with 50dB loss measured at 435MHz.

Mutek XBF700 television band stripline filter

Appearance: see Fig A3.23.

Response curves: see Figs A3.5 (differential mode overall) and A3.13 (pass band).

Type: stripline band-pass filter (UHF TV).

Pass band: Bands 4, 5 (UHF TV).

Loss in pass band: typically 2ï 3dB, channels 24ï 65, rising to 9dB on channel 21, and 4dB on channel 68.

Braid-breaking action: none.

Remarks: This is the only filter tested with a stop band which includes 1.3 GHz. It is also usefat 430ï 440MHz and good on the 144MHz band and below. The pass-band loss rises at the top of Band 5 and

at the lower end of Band 4, particularly on channels 21 and 22. The XBF700 is a stripline filter PCB (size 145 ´ 57mm) which requires the addition of connectors or flying leads and a case.
The loss measured above 1GHz is affected by stray capacitive coupling between the input and output of the filter. The result shown in Fig A3.5 is likely to be representative of the performance of the filter in practice, although better performance may be measured using an improved test set-up.

AKD BB1 braid-breaker

Equivalent circuit: see Fig A3.24.

Response curves: see Figs A3.6 (differential mode overall), A3.14 (pass band), A3.16 (common mode).

RSGB description: Filter 1, braid-breaker.

Type: 1:1 transformer braid-breaker.

Pass band: below 10MHz to over 1GHz.

Loss in pass band: typically 2dB over most of its range but 3 to 4dB at UHF channels 50ï 68.

Braid-breaking action: 1:1 transformer.

Remarks: The BB1 is a transformer-type braid-breaker which is more effective against common-mode signals picked up 'on the braid' than a capacitive braid-breaker such as the HPF1. The BB1 is particularly effective at HF. The braid-breaking action diminishes at VHF due to interwinding capacitance of the transformer, with only 7ï 8dB loss to common-mode signals in the 144MHz band.
A BB1 can be cascaded with other filters such as HPF2, HPF6 or XBF700 which do not have any braid-breaking action, although the total pass-band loss is then the sum of the pass-band losses (in decibels) of the two filters.

Although not intended as a high-pass filter, the differential mode response of a BB1 starts to roll off below 10MHz, with some attenuation to differential mode signals in the 3.5 and 1.8MHz bands.

A BB1 can also be effective on the 1.8, 3.5 and 7MHz bands in reducing HF interference produced by TV line timebase harmonics and switch-mode power supply harmonics by preventing these from being radiated by the braid of the TV antenna cable.

Where a braid-breaker is required with negligible insertion loss to differential-mode signals at all frequencies, a common-mode choke may be used (see 'Ferrites' sections below). A suitable type of common-mode choke can be a more effective braid-breaker than a BB1 at VHF, but the BB1 will generally be more effective at HF.

AKD HPFS high-pass filter (special)

Equivalent circuit: see Fig A3.25.

Response curves: see Figs A3.6 (differential mode overall), A3.14 (pass band), A3.16 (common mode).

RSGB description: Filter 3, HPF & Braid Breaker.

Type: L-C high-pass filter with transformer braid-breaker.

Pass band: Bands 4, 5 (UHF TV).

Loss in pass band: typically 3ï 4dB (Channels 21ï 40), 4ï 5dB (Channels 41ï 68).

Braid-breaking action: 1:1 transformer.

Remarks: The HPFS is a BB1 combined with a high pass filter. See BB1 section above for braid-breaking performance. The HPFS is a good all-round filter for all amateur bands up to and including 144MHz but it has negligible effect at 432MHz.

Due to the relatively high pass-band loss, the HPFS is not suitable for areas where the TV signal strength is low. For the lowest possible pass-band loss, the home-constructed filter shown in Chapter 5 can be used, in conjunction with a ferrite ring choke (if required). See also the section on ferrite rings below.

Another filter with identical electrical characteristics to the HPFS is sold by Maplin Electronics and Waters & Stanton as 'Global HP-4A'.

AKD RBF1/70cm notch filter

Equivalent circuit: see Fig A3.26.

Response curves: see Figs A3.7 (differential mode overall), A3.15 (pass band).

Type: series-resonant trap between inner conductor and braid.

RSGB description: Filter 5, notch tuned to 435MHz.

Pass band: Bands 4, 5 (UHF TV).

Loss in pass band: typically 2ï 5dB (Channels 21ï 30), 1ï 2dB (Channels 31ï 68).

Braid-breaking action: none.

Remarks: The RBF1 is called a 'radar blip filter' because it was designed to notch out airport radar signals on UHF TV channel 36. The RBF1/70cm version is pre-tuned to 435MHz, although it is possible to adjust the tuning if necessary by means of a trimmer capacitor which is accessible through a hole in the plastic sleeving under the label. A non-metallic trim tool should be used to avoid detuning, as neither side of the trimmer capacitor is grounded. The RBF1 also has a high-pass action with useful rejection of HF differential-mode signals.

AKD TNF2 tuned notch filter range

Equivalent circuit: see Fig A3.27.

Response curves (VHF): see Figs A3.8 (stop band), A3.15 (pass band), A3.17 (common mode).

Response curves (HF): see Figs A3.9 (stop band), A3.15 (pass band), A3.18 (common mode).

AKD type	*RSGB description*
TNF2/2 metres	Filter 4, notch tuned to 145MHz
TNF2/70MHz	Filter 7, notch tuned to 70MHz
TNF2/50MHz	Filter 6, notch tuned to 50MHz
TNF2/10	Filter 10, notch tuned to 28MHz
TNF2/15	Filter 15, notch tuned to 21MHz
TNF2/20	Filter 20, notch tuned to 14MHz

Type: L-C notch filters in series with inner conductor and braid.

Pass band: Bands 4, 5 (UHF TV).

Loss in pass band: typically 0.5ï 2dB (Channels 21ï 40), 2dB (Channels 41ï 68)

Braid-breaking action: Resonant, only at tuned frequency.

Remarks: Each filter provides rejection of differential-mode and common signals over a certain range of frequencies only. These have low insertion loss in UHF TV Bands 4 and 5 but a high insertion loss in Band 2 and are therefore not suitable for passing FM broadcast Band 2 signals. For amateur bands below 14MHz, tuned notch filters are not generally used as a high-pass filter/braid-breaker will normally be equally effective.

The test methods used to obtain Figs A3.8, 3.9, 3.17 and A3.18 are different from the test methods used by the manufacturer of the filters. This may be why some of the notches measured do not coincide exactly with the specified amateur bands. Nevertheless, in most cases there is still a good level of attenuation in the specified band. See later for details of test methods.

In general, this type of filter should only be used if no other type is suitable as it can cause 'mode conversion' of common mode signals to differential mode. This may increase breakthrough of certain signals well away from the notch frequency. In particular, the TNF2 type of tuned notch filter is not recommended for use at the input of a UHF TV pre-amplifier or a distribution amplifier as it may increase rather than decrease the unwanted signal or may cause the amplifier to oscillate.

Home-constructed 5 element high pass filter

Equivalent circuit: see Chapter 5, Fig 5.11**. [Page 26 below]**

Response curves: see Fig A3.10

Type: High pass

Pass band: Bands 4, 5 (UHF TV)

Loss in pass band: 1dB or less

Braid-breaking action: none.

Remarks: Constructional details for this filter are given in Chapter 5.**[page 26 below]** It has a sharper roll-off below 470MHz than the filter shown in Fig A3.19 with about 60dB of attenuation at 144MHz. It does not have any braid-breaking action but can be combined with a ferrite ring (see below).

Antiference TVI/U

Response curves: see Fig A3.10

Type: High pass

Pass band: Bands 4, 5 (UHF TV)

Loss in pass band: 1dB or less

Braid-breaking action: none.

Remarks: This filter is housed in an all metal case only 1.75 inches (45mm) long. It is quite widely available from electrical shops and DIY warehouses. It is intended to reject 27MHz but is useful on all amateur bands up to 70MHz. It has poor rejection of 144MHz however.

Ferrite Chokes

Various types of ferrite cores can be used to make common-mode chokes on coaxial cables, mains cables and audio cables etc. These chokes introduce a series impedance to unwanted common-mode signals picked up from a transmitter but have negligible effect on the wanted differential-mode signal in the cable.

The ferrite rings currently available from RSGB are Fair-Rite type 2643802702. They have an inside diameter of 0.9 inch (22.85mm) and a width of 0.5 inch (12.7mm). These are made of grade 43 material and are also sold by Amidon Associates as FT140-43.

For maximum impedance on the lower HF bands, at least 12-14 turns on one or two cores are recommended. As the inductance is proportional to the number of turns ***squared,*** 6 turns on ***four*** cores are equivalent to 12 turns on a single core. At about 10MHz and above, stray capacitance in parallel with the winding starts to become significant and can be reduced in two ways:

(a) By winding the turns in two halves as shown in Fig A3.30, taking care that all the turns are threaded through the hole in the SAME direction. This allows the ring to be wound to full capacity so there is no loss of performance on the lower HF bands.

(b) By winding the ring as shown in Fig A3.31, that is, only about two thirds full with the ends of the winding kept apart. This has the disadvantage of reduced performance on the lower HF bands due to the reduced number of turns.

At VHF, stray capacitance becomes particularly important and performance may be improved by winding the ring only half full.

TV antenna cables

A ferrite ring choke on a TV antenna coaxial cable can be used on its own to reduce HF breakthrough due to pick-up of signals on the braid of the coaxial cable or it can be used in conjunction with any high pass filter which does not have built-in 'braid breaking'. Although the ring core is not a true transformer type 'braid breaker', it can give excellent results on most HF bands if enough turns are used. It also has the advantage of a lower pass-band loss than the transformer type. The additional loss introduced at UHF is small, typically 1dB or less, due to loss of the additional cable and connectors. This is clearly an important factor in areas where UHF TV signals are weak.

There are two ways to make a common mode choke using coaxial cable. If standard 'low loss' cable is used, it should not be wound tightly as the sharp bending will damage it. Instead, it should be left loose as shown in photo A3.2. As this loose winding is rather unsightly, it should only be used on a neighbour's TV or satellite system if there is no alternative. As there will only be room for 6-7 turns, ***four*** rings are required to achieve the results shown in Fig A3.28 for 12 turns on a single ring.

An alternative solution is to wind a length of miniature 2.5 - 2.8mm diameter 75 coaxial cable such as RG179 or Maplin XR88V through a single ferrite ring. This cable is not compatible with standard coaxial plugs and sockets unless the outside diameter is increased using rubber sleeving. Even then, it is easily damaged so a more robust solution is to house the ring in a small plastic box with coaxial sockets as shown in photo A3.1. A metal box, a metallised plastic box or a box with a metal lid should not be used as even if the connectors are insulated from the box, the metal adds stray capacitance in parallel with the ferrite ring. The five element home constructed filter - Chapter 5 fig 5.11 **[Page 26 below]** can also be housed in the same box if a Maplin Electronics type MB1 box is used (stock No. LH20W). To fit the PCB slots in this box, the strip of Veroboard for the filter should be 22 holes long. It should be glued in place to keep it away from the ferrite ring.

A Fair-Rite type 2643802702 ring can easily accommodate 18 turns using less than one metre of cable. To reduce stray capacitance, the winding is wound in two halves, as shown in Fig A3.30. Self-locking cable ties secure the cable to the ring and the ring to the box. A 0.9m length of this miniature coaxial cable adds only about 1dB of additional loss in the UHF TV band. The impedance of this winding to common mode signals is between curves B and C in Fig A3.28.

Cable TV

If amateur HF transmissions cause breakthrough on a cable TV system and other types of filtering have not cured the problem, it may be necessary to fit a ferrite ring on the cable to the RF input of the cable TV converter box but a UHF high-pass filter must NOT be included at this point. 'F' type connectors are required but 'F' type plugs cannot be fitted to miniature coaxial cable because the centre core of the coaxial cable acts as the centre pin of the plug. A boxed ferrite ring can be used with panel mounted 'F' type sockets as shown in photo A3.1. A Maplin H2855 ABS box (BZ72P) can be used but it is necessary to trim off the PCB mounting ridges where the 'F' type sockets are fitted. The sockets can be Maplin FE98G. A short length of coaxial cable with 'F' type plugs is also required. Maplin FE98X plugs are suitable but need to be fitted using a crimping tool. Alternatively, there is a screw-on type (FU04E) which does not require crimping.

Satellite TV

The downlead from the LNB (Low Noise Block converter) in a satellite TV dish carries the first IF at 950 - 1750MHz on older systems or 950 - 1950MHz on newer systems covering the Astra 1D satellite. The coaxial cable is normally fairly well screened with foil and braid so there should be little leakage of signals into or out of the cable. Nevertheless, the braid of the cable can act as a receiving antenna for amateur HF signals and can also radiate RFI generated by the digital electronics in some satellite receivers. Either problem can be tackled by winding the satellite downlead through a ferrite core near the indoor receiver. Other types of filter cannot be fitted in a satellite TV downlead as it also carries the DC supply to the LNB.

The boxed ferrite ring described above for cable TV might appear suitable for satellite TV but on the prototype model, the loss increased significantly above 850MHz. The loss in 0.9m of miniature coaxial cable is about 2dB at 1800MHz but a much larger loss was caused by the mismatch of the panel-mounted 'F' type connectors which are only intended for use below 1000MHz. The mismatch introduced by two Maplin FE98G 'F' type sockets starts to become significant above 800MHz and can cause a loss of up to 20dB at some frequencies around 1800MHz.

Unless better quality 'F' type sockets are available and are specified for use up to 2GHz, the best solution is to use a 1.5m length of 75 satellite TV cable such as CT100 type, threaded 7 times through two or four Fair-Rite grade 43 rings as shown in photo A3.2. Two 'F' type plugs should be fitted to the cable and an 'F' type straight coupler should be used to connect this to the satellite downlead. This coupler should be a high quality type suitable for use up to 2GHz.

Clip-on cores

The split bead clip-on ferrite cores shown in photo A3.3 are sold by Maplin Electronics as computer data line noise filters and are also available from other suppliers such as RS Components and Farnell Components. They are useful for cables which cannot be threaded through a ring core but it is important to ensure that the two halves of the core can close together without the slightest air gap. A core with a 13mm diameter hole such as Maplin BZ34M can accommodate about six turns of thin loudspeaker cable or eight turns of miniature coaxial cable (see photo A3.3). Curve 'A' in Fig A3.29

shows the characteristics which were measured with a six turn winding on a Maplin BZ34M core. As these cores are primarily intended for EMC use at VHF, the performance of different manufacturers' products can vary significantly on the lower HF bands. With a multi-turn winding, a split bead offers poorer high frequency performance than a ring core due to greater stray capacitance in parallel with the winding.

For a thick cable such as a SCART cable which can only pass through the core once, the impedance of a split bead is typically 100 at 14MHz rising to 200-300 at 144MHz. A single 'turn' on this type of core generally has little or no effect on the HF bands although it may damp a cable resonance if placed at a particular point on the cable. Three or four cores in series may start to give a useful impedance in some cases but over 100 clip-on chokes with a single turn would be required to achieve the same impedance as 18 turns on a ferrite ring!

Other types of clip-on ferrite core are available in the form of pairs of 'U' shaped cores but these can be an expensive solution because typically, four pairs of 'U'cores are required to achieve the same effect as a single split bead core.

Yoke rings

A typical deflection coil assembly from the CRT in a TV receiver or computer monitor is shown in photo A3.2. This assembly can be salvaged from a scrap CRT, taking care not to fracture the neck of the tube and not to remove the EHT connector as the tube may still be charged. The windings can be stripped off to reveal a ferrite yoke ring core with an inside diameter of 30 - 50 mm depending on the size of the CRT. The ring is split into two halves which are clipped together. Although not intended for RF use, ferrite yoke rings normally have about the right permeability for amateur EMC applications. Results can be somewhat variable but a 14 turn winding typically gives the characteristics shown by curve D in Fig A3.29 for any size of yoke ring. If possible, up to 20 turns should be used for HF. It is advisable to check the characteristics of a yoke ring core against a known good ferrite ring (See Chapter 5, fig 5.7) **[Page 27 below]**. Other types of scrap ferrite cores such as TV line output transformer cores have completely different RF characteristics and are NOT normally suitable for EMC use.

The main application for yoke ring cores is for choking SCART cables as these are thick and the connectors cannot be threaded through a ring. In some cases of HF breakthrough on a TV, video recorder or satellite receiver, a ferrite choke is required on the SCART cable in addition to other types of filtering. This can also be used to reduce RFI radiated by some types of TV via the SCART cable. A typical 1.5m long SCART lead is only long enough to allow about seven turns however. The impedance would therefore be only one quarter of that shown by curve D in Fig A3.29.

Ferrite rods

An MW/LW ferrite antenna rod can be used to make a common-mode choke as shown in Fig A3.32. Curve C in Fig A3.29 shows the typical characteristics of a 25 turn winding on a ferrite rod 200mm long by 9.5mm diameter. This gives reasonably good results at 21MHz and above.

A ferrite rod should not be wound with semi-airspaced coaxial cable as the tight bend radius may cause the cable to collapse internally and short-circuit. A 25-turn winding requires about 1.2m of cable.

Test methods

A Hewlett-Packard 8591A spectrum analyser with tracking generator was used for the tests. A tracking generator is a signal generator which is built into a spectrum analyser and whose output frequency follows (tracks) the frequency sweep of the spectrum analyser. When the tracking generator output is fed via a filter to the spectrum analyser's RF input, the frequency response of the filter is displayed.

Due to the noise floor of the spectrum analyser and the additional attenuators used, measurements of filter loss greater than 60dB could not be made, hence losses greater than 55dB are not shown on the response curves.

Differential mode, 75ohm

Figs A3.33 and A3.34 show the test set-up for measuring differential-mode characteristics of filters which have transformer braid-breaking or no braid-breaking. The 50ohm output of the tracking generator is connected via a 10dB attenuator with 50ohm input impedance and 75ohm output impedance to the filter under test. Another attenuator with 75ohm input impedance and 50ohm output impedance is used to match the output of the filter under test into the 50ohm input of the spectrum analyser. The resistor values shown are designed to give a true 10dB power loss, for example 0dBm in 50ohm at the tracking generator output results in -10dBm in 75ohm at the output of the attenuator.

Above 600MHz, most of the filters tested allow some UHF signal to pass from the inner of the coaxial cable to the outside of the braid, resulting in standing waves on the outside of the cable. These standing waves cause variations in the apparent filter loss, depending on the exact cable length used. To give more repeatable test results, a ferrite clip-on choke is fitted to the output lead of the filter under test to attenuate such signals on the outside of the coaxial cable.

The arrangement in Fig A3.33 is used to give the 0dB reference trace, then the filter under test is plugged in as shown in Fig A3.34. For the 2dB/division pass-band loss tests, the reference trace is not perfectly flat but has up to ±0.25dB ripple at UHF. For the 2dB/division curves, the filter loss is the difference between the filter response trace and the reference trace.

When the filter is actually in use, however, the source and load impedances which are presented to it may be far from 75ohm, particularly at frequencies far outside the UHF TV bands. This means that its loss in practice may be significantly different from the test results.

Differential mode, 75ohm, floating source

Figs A3.35 and A3.36 show the test set-up for measuring differential-mode characteristics of filters which have an impedance in series with the braid as well as in series with the inner conductor. A BB1 braid-breaker is used to provide a 'floating' source, that is a source with neither side grounded to the chassis of the spectrum analyser. At HF, this is close to a true 'floating' source, but at VHF, and especially above 150MHz, the interwinding capacitance of the BB1 transformer makes the source 'float' less well. A clip-on ferrite choke was fitted to the output lead of the filter under test.

This test method was used when testing the HPF1, all the TNF2 range and the home-constructed high-pass filter/braid-breaker. The 0dB reference traces take account of the additional loss introduced by the BB1 so that the curves show only the loss of the filter under test. The filter responses are not shown below 10MHz because the response of the BB1 transformer starts to fall off.

If the test set-up shown in Fig A3.34 is used for filters with an impedance in series with the braid, the common ground between input and output short-circuits the impedance which is in series with the ground side of the filter, affecting the response of the filter. Fig A3.1 shows the response of two filters using the test method in the previous section but without the ferrite choke. Fig A3.2 shows the response with the 'floating source' test method, which is more likely to be representative of what happens in practice.

In the case of the tuned notch filters (see Fig A3.27), there is some interaction between the two tuned circuits L1/C1 and L2/C2, making it difficult to tune the filter so that it gives a differential-mode notch and a common-mode notch at the same frequency. In some cases the notch is not centred on the specified amateur band but the filter still provides a useful attenuation on the latter.

When the filter is actually in use, the differential-mode current on the inner conductor which flows through L1/C1 returns via the braid and L2/C2, except for a small proportion of the current which returns via stray capacitances external to the filter. The 'floating' source test models this situation with nearly equal but antiphase currents through L1/C1 and L2/C2. The two tuned circuits are in series as far as differential-mode signals are concerned, and this test shows a double notch response for some of the filters. In practice, the actual notch frequencies may also be affected by stray capacitances which are effectively in parallel with the tuned circuit L2/C2.

Common-mode filter test, 50ohm

Fig A3.37 illustrates the situation where unwanted signals are picked up by the outside of a coaxial cable braid acting as a receiving antenna. These unwanted signals appear to come from a source impedance which is not well defined but which could be hundreds of ohms, except in the case where the coaxial cable forms a resonant antenna for a particular amateur band. These unwanted signals flow via the chassis of the TV or other equipment and then to earth via capacitance and via the mains earth wire if any. Where there is no mains earth wire, there is still an RF path to earth via the mains due to capacitance from the chassis of the equipment to the mains 'live' and neutral, and capacitance from these conductors to earth. (In PME installations, the mains neutral and earth are actually joined where the supply enters the house.) The 'load' impedance seen by common-mode signals is also not well defined but could be hundreds of ohms.

Amateur signals may also cause common-mode signals directly in the mains cable, either due to pick-up in the mains cable itself or in the mains wiring of the house. In such cases a common-mode choke is required.

In order to reduce the common-mode current resulting from this unwanted pick-up, it is necessary to introduce an impedance in series with the unwanted signal path without significantly affecting the wanted differential-mode signal flowing in the TV antenna cable, the mains cable or other cable. This common-mode impedance should be relatively large compared to the sum of the source and load impedances of the common-mode signal. This means that a filter which shows an attenuation of, for example, 20dB to common-mode signals in a 50ohm test circuit may give significantly less common-mode rejection in practice because the source and load impedances are likely to be greater than 50ohm near the affected equipment.

Unwanted common-mode (in-phase) signals are sometimes loosely referred to as being 'on the braid' of a coaxial cable, meaning that there is an RF voltage between the braid of the cable and earth, but the phrase 'on the braid' obscures the fact that there must also be an equal RF voltage between the inner and earth. The braid and the inner are connected together at the TV antenna by a low-impedance folded-dipole element. Therefore, if there is a signal which is on the outside of the braid with respect to earth but which was not picked up by the TV antenna itself, then an equal or nearly equal signal must also exist on the inner with respect to earth, although it can only be measured at the ends of the cable. In any case, with a perfectly shielded coaxial cable, a signal outside the cable cannot pass through the shield and produce a potential difference between the inner conductor and the inside of the braid. To reduce common-mode currents it is therefore necessary to introduce an impedance in series with both the braid and the inner, either by winding the cable through a ring core or by using a filter which has impedance in series with both the braid and the inner.

Figs A3.38 and A3.39 show the test set-up for common-mode testing of filters which have any form of braid-breaking action. The 50ohm output of the tracking generator is connected to a 10dB attenuator with 50ohm input and output impedance. This attenuator also provides an approximate 50ohm termination for the tracking generator even when the impedance on the output of the attenuator is far from 50ohm, thus minimising standing waves in the input cable to the test jig. A second 10dB attenuator with 50ohm input and output impedances ensures that the filter under test is presented with a load impedance very close to 50ohm.

The input and output of the filter under test are terminated with 75ohm resistors to simulate the actual conditions of use, although in practice the source and load impedances may be significantly different from 75ohm at frequencies below UHF. The fact that the filter is designed to be used in 75ohm circuits is of little relevance to common-mode signals. The common-mode performance has been measured in a 50ohm circuit to be consistent with the test method in the next section.

In the case of the TNF2 range of tuned notch filters (see Fig A3.27), the two tuned circuits L1/C1 and L2/C2 are effectively in parallel as far as common-mode signals are concerned but in series as far as differential-mode signals are concerned.

Common-mode ferrite test, 50ohm

This type of measurement in the field of EMC is normally made with 50ohm source and load impedances. Fig A3.40 shows the test set-up for measuring the characteristics of common-mode chokes wound onto ferrite rings and other types of core. Fig A3.38 shows the configuration for the 0dB reference trace.

This test method is similar to the test method in the previous section except that where a ferrite ring is wound with coaxial cable, it makes no difference to the result whether the signal is driven onto the braid only or onto the braid and inner together.

As mentioned above, the source and load impedances for common-mode signals are not well defined and could be as high as several hundred ohms. Thus a common-mode choke which shows an attenuation of, for example, 20dB in a 50ohm circuit may give significantly less common-mode rejection in practice.

Any common-mode chokes with a measured loss greater than 20dB at VHF tend to be very sensitive to the stray capacitance of nearby conducting objects so that the repeatability of such measurements is poor. The test method used for common-mode tests on chokes and filters was not considered suitable for frequencies above 200MHz.

If a spectrum analyser with tracking generator is not available, the test jig shown in Fig A3.40 can still be used to make measurements at spot frequencies or to adjust the tuning of a tuned common-mode choke. The 10dB 50ohm attenuators can be omitted if only relative measurements are required. The signal source could be a signal generator or a steady signal such as a beacon received by an amateur antenna. The signal level at the output of the test jig can be measured by any receiver tuned to the required frequency, provided it has an S-meter. Ideally the S-meter should have a large scale which has been calibrated in decibels relative to 1mV against a signal generator, or calibrated against a beacon or other source in decibels relative to the weakest signal detectable on the S-meter (S1 reading) using a calibrated variable attenuator. With a calibrated S-meter, the loss of various common-mode chokes can be measured in decibels. With a meter calibrated only in S-points, useful relative measurements can still be made to compare two different chokes at a particular frequency or to tune a tuned braid-breaker. (See also Chapter 5, Fig 5.7) **[Page 27 below]**

Table A3.1. Summary of filter performance

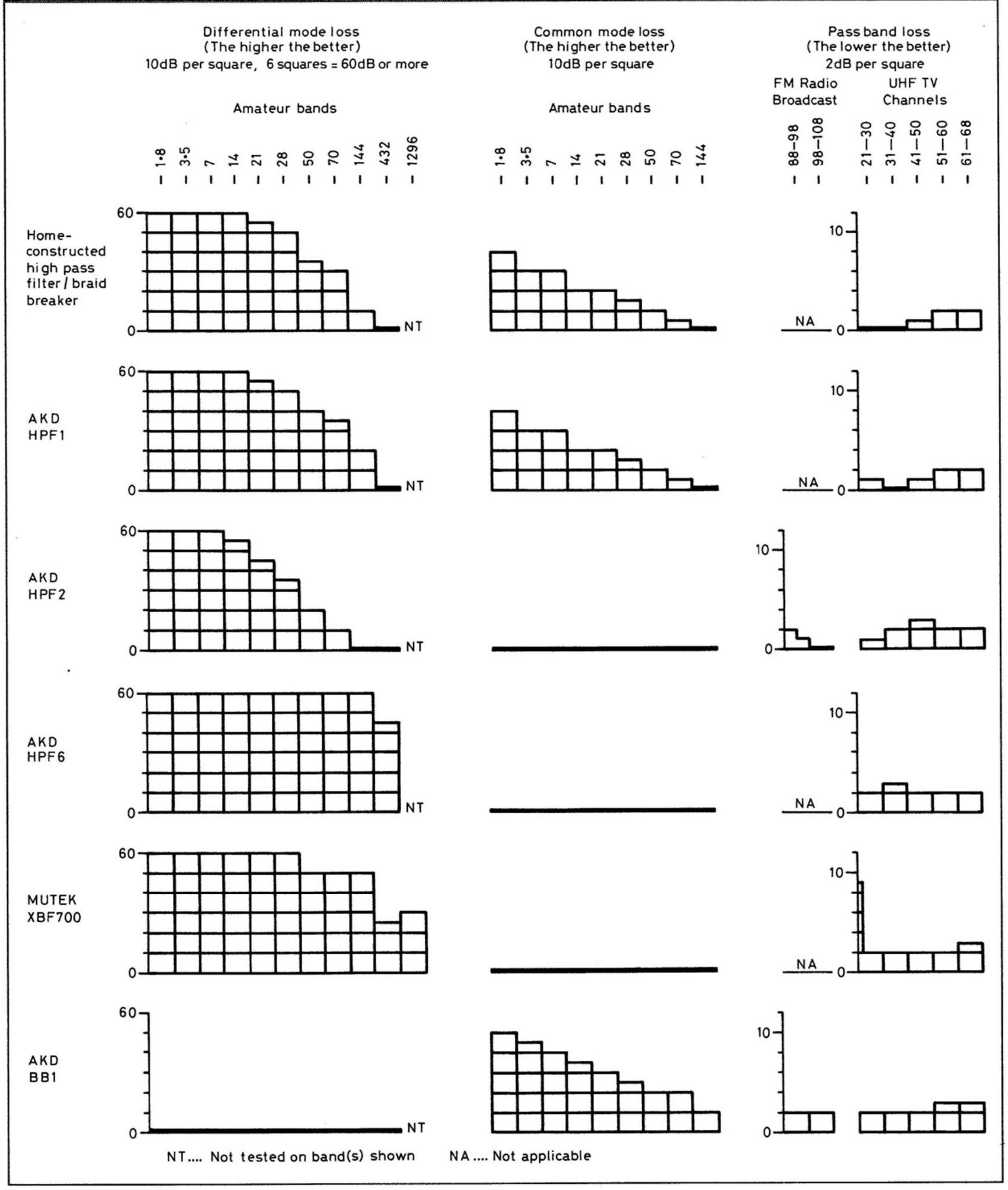


Table A3.1 *(continued)*

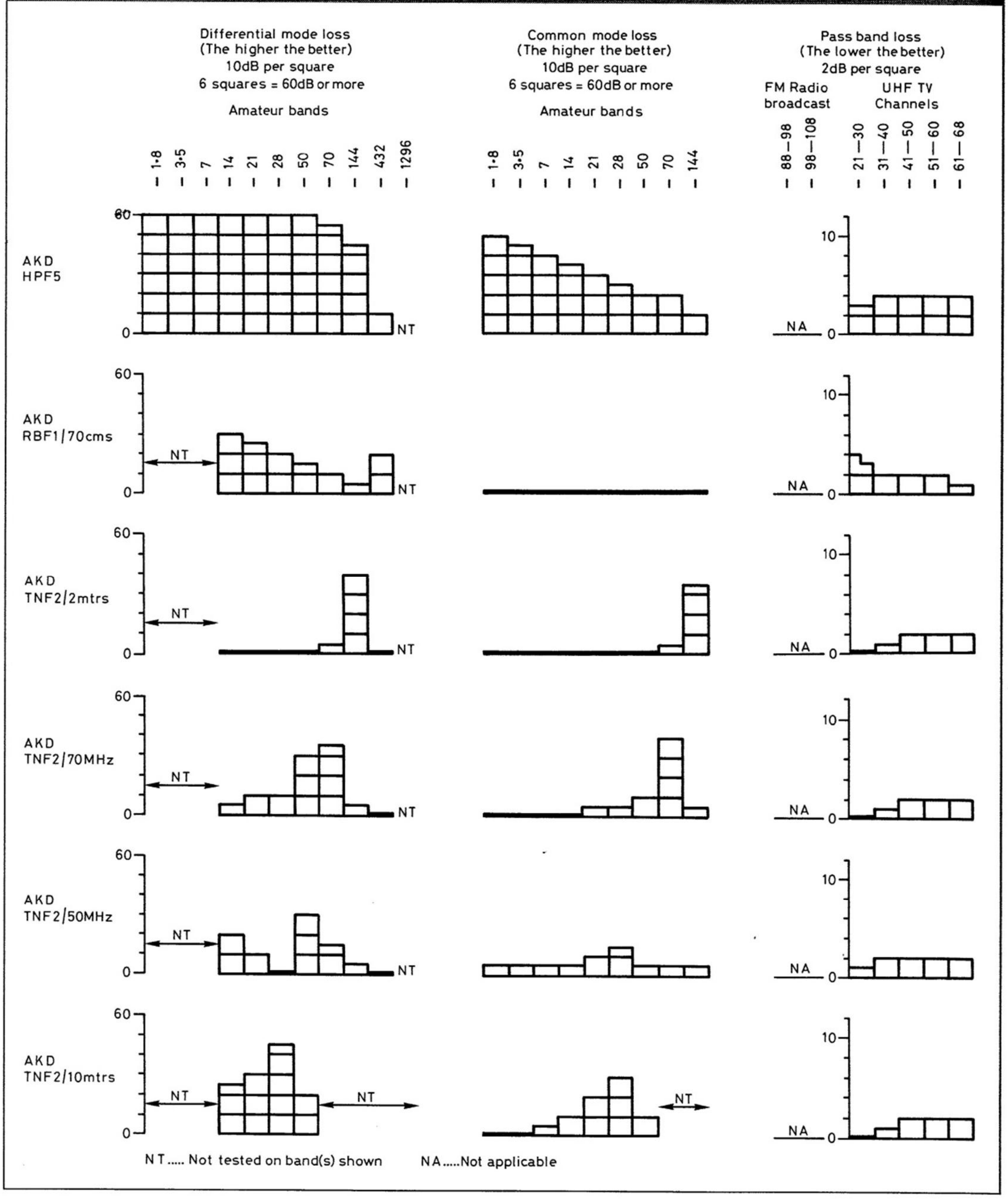


Table A3.1 *(continued)*

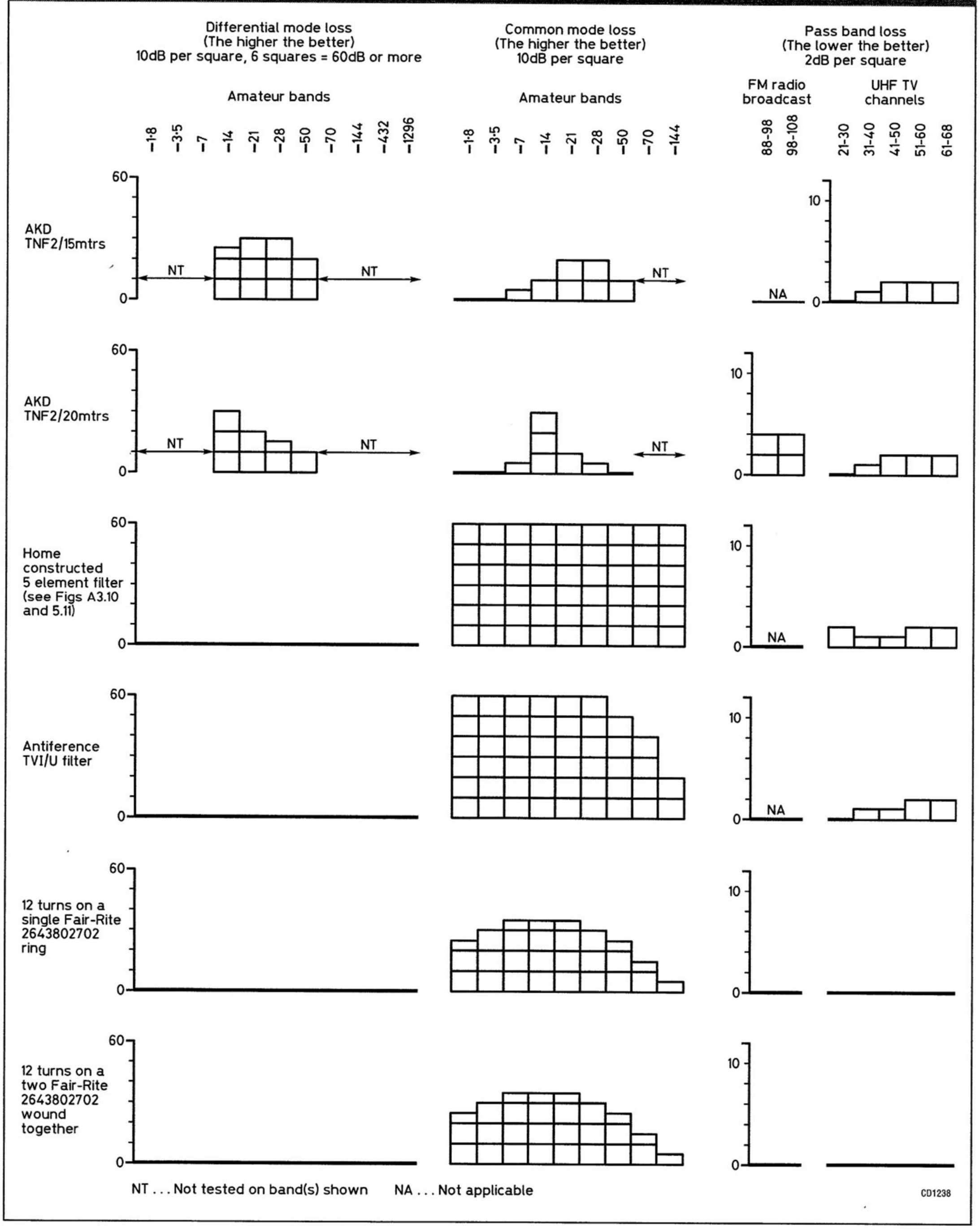
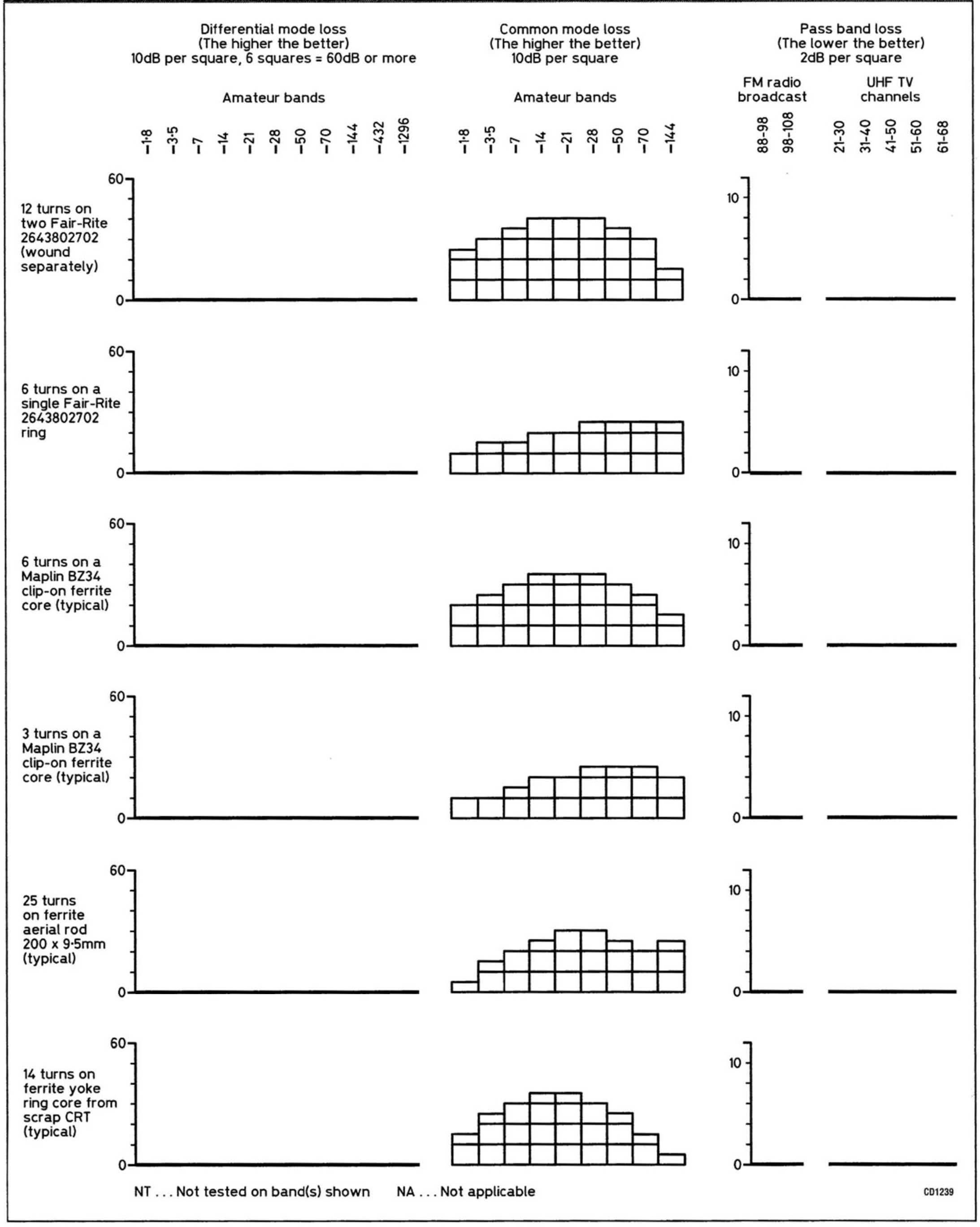


Table A3.1 *(continued)*



Filter stop-band loss – differential mode

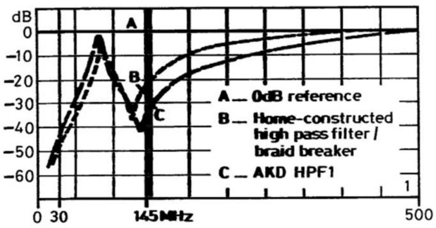


Fig A3.1. Home-constructed high-pass filter/braid-breaker and AKD HPF1, grounded source and load, 0–500MHz

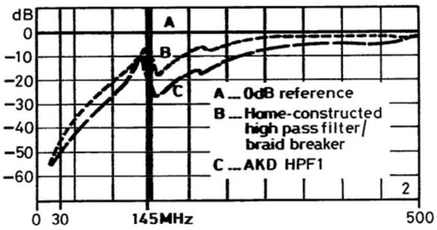


Fig A3.2. Home-constructed high-pass filter/braid-breaker and AKD HPF1, 'floating' source, 0–500MHz

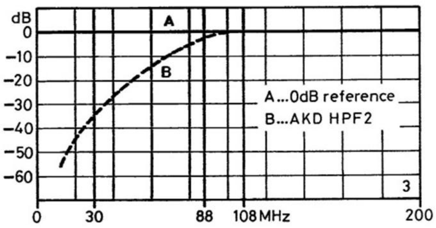


Fig A3.3. AKD HPF2, 0–200MHz

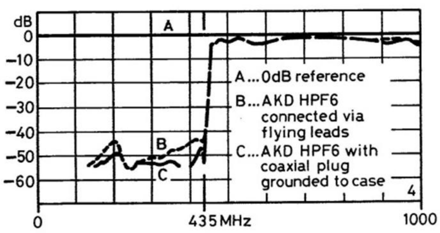


Fig A3.4. AKD HPF6, 0–1000MHz

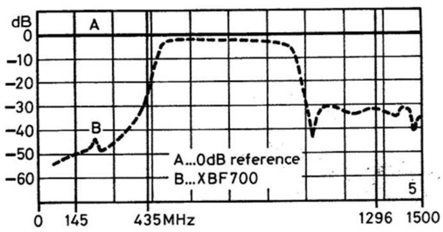


Fig A3.5. Mutek XBF700 stripline filter, 0–1500MHz

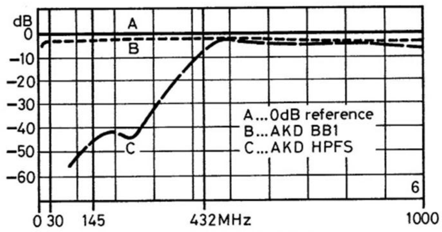


Fig A3.6. AKD BB1 and HPFS, 1000MHz

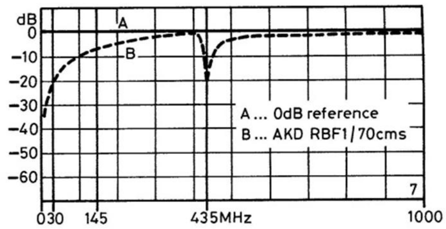


Fig A3.7. AKD RBF1/70cm, 0–1000MHz

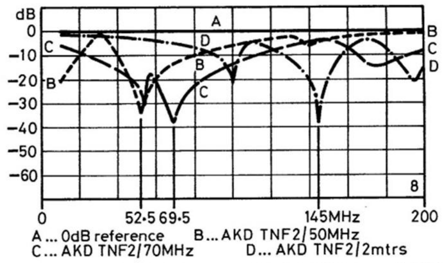


Fig A3.8. AKD TNF2/2m, TNF2/70MHz and TNF2/50MHz, 'floating' source, 0–200MHz

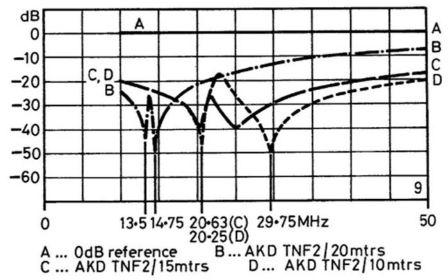


Fig A3.9. AKD TNF2/10m, TNF2/15m and TNF2/20m, 'floating' source, 0–50MHz

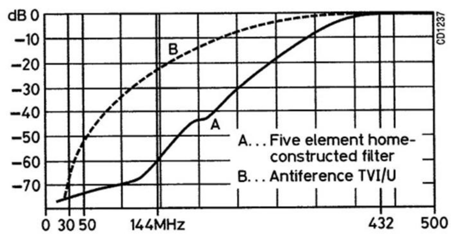


Fig A3.10. Five-element home-constructed high-pass filter and Antiference TVI/U, 0–500MHz

Filter pass-band loss

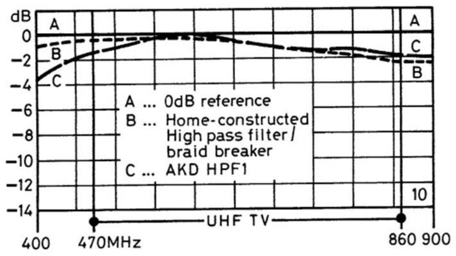


Fig A3.11. Home-constructed high-pass filter/braid-breaker and AKD HPF1, differential mode pass band, 2dB/division, 400–900MHz

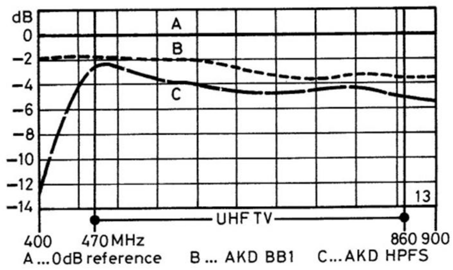


Fig A3.14. AKD BB1 and HPFS, differential mode pass band, 2dB/division, 400–900MHz

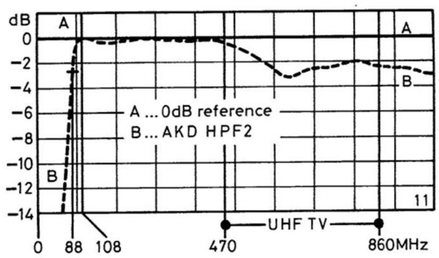


Fig A3.12. AKD HPF2, differential mode pass band, 2dB/division, 0–1000MHz

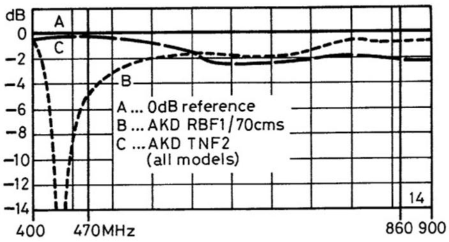


Fig A3.15. AKD RBF1/70cm and AKD TNF2 (all models), differential mode pass band, 2dB/division, 400–900MHz

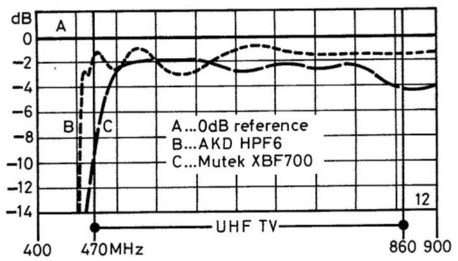


Fig A3.13. AKD HPF6 and Mutek XBF700, differential mode pass band, 2dB/division, 400–900MHz

Filter stop-band loss – common mode

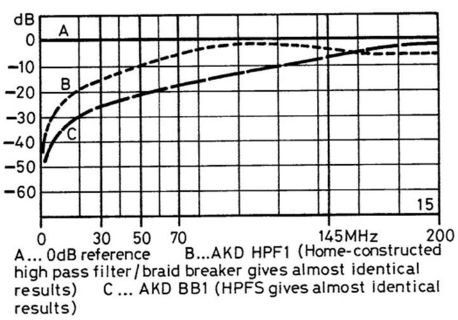


Fig A3.16. Home-constructed high-pass filter/braid-breaker and AKD HPF1, BB1 and HPFS, common mode, 0–200MHz

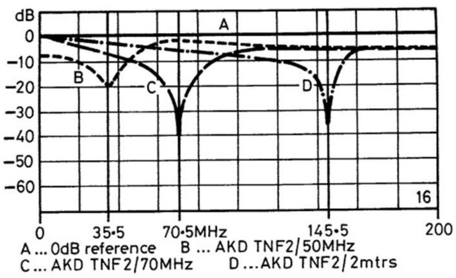


Fig A3.17. AKD TNF2/50MHz, TNF2/70MHz and TNF2/2m, common mode, 0–50MHz

Filter stop-band loss – common mode *(continued)*

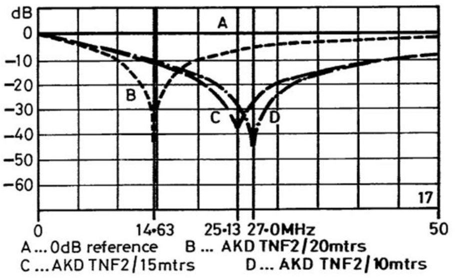


Fig A3.18. AKD TNF2/20m, TNF2/15m and TNF2/10m, common mode, 0–50MHz

Equivalent circuits, appearance etc

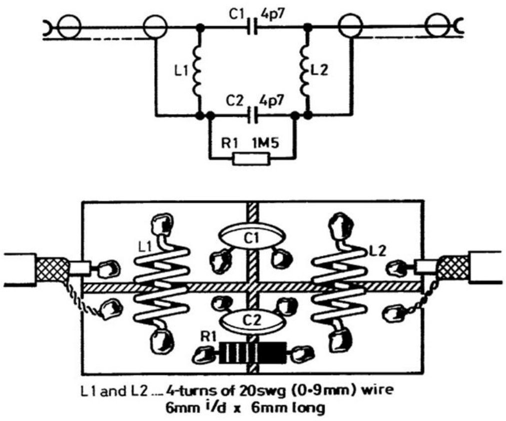


Fig A3.19. Home-constructed high-pass filter and braid-breaker circuit diagram and layout. PCB is single-sided 50 x 25mm. Scrape grooves approx 1.5mm wide in copper to leave four areas as shown. (From the DTI booklet *How to Improve Television and Radio Reception*.)

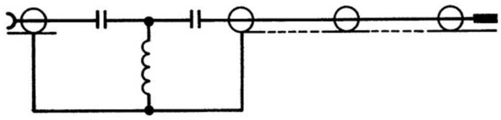


Fig A3.21. AKD HPF2 equivalent circuit

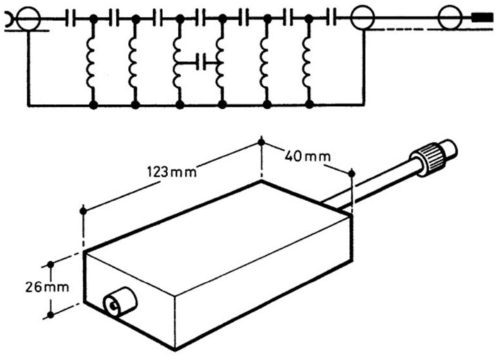
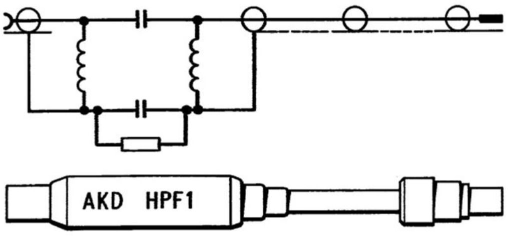
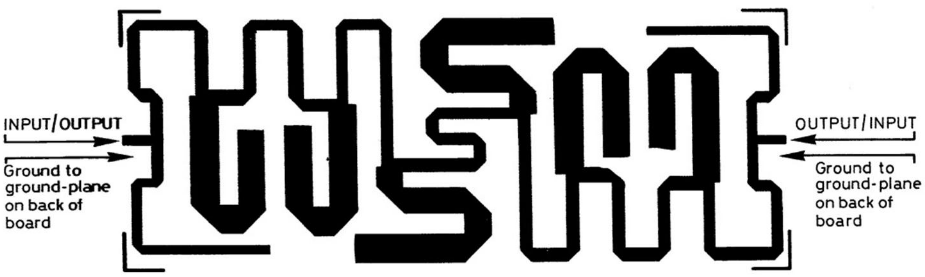


Fig A3.22. AKD HPF6 equivalent circuit and appearance



Left: **Fig A3.20. AKD HPF1 equivalent circuit and appearance**

Below: **Fig A3.23. Mutek XBF700 stripline filter**



Equivalent circuits, appearance etc *(continued)*

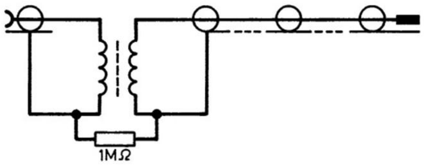


Fig A3.24. AKD BB1 equivalent circuit

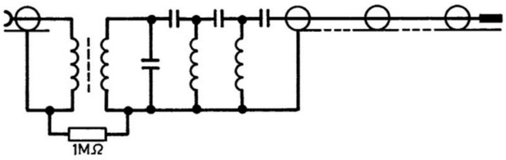


Fig A3.25. AKD HPFS equivalent circuit

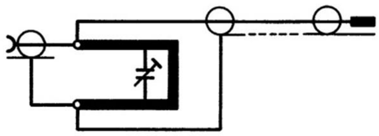


Fig A3.26. AKD RBF1 equivalent circuit

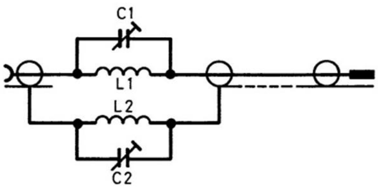


Fig A3.27. AKD TNF2 tuned notch filter range (all models) equivalent circuit

Ferrite chokes – common-mode loss

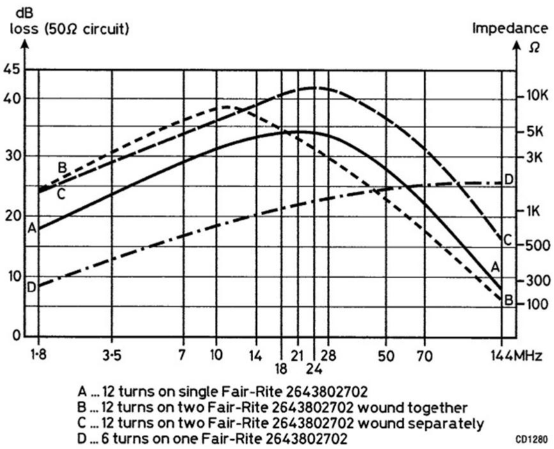


Fig A3.28. Impedance of various ferrite ring chokes from 1.8–144MHz

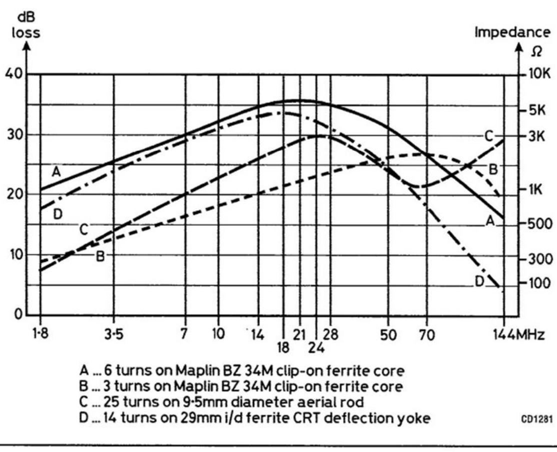


Fig A3.29. Impedance of other types of ferrite core from 1.8–144MHz

Ferrite core details

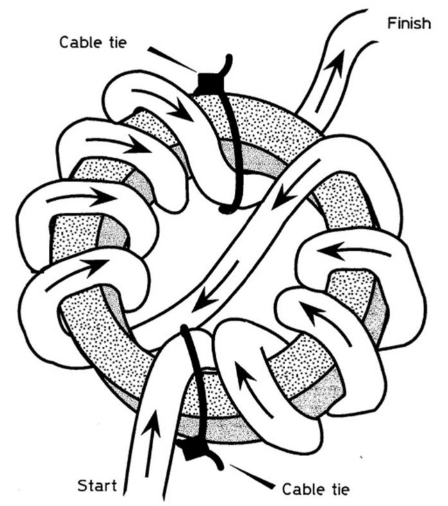


Fig A3.30. Recommended winding for ring cores

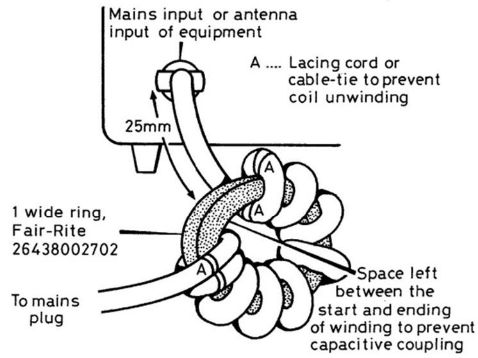


Fig A3.31. Ferrite rings on mains lead or coaxial cable

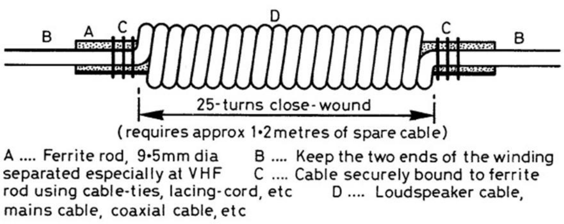


Fig A3.32. Common-mode choke using ferrite rod

Test methods etc

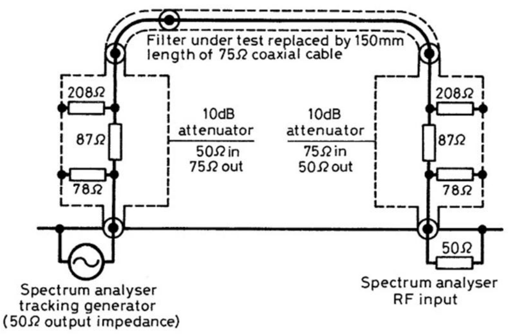


Fig A3.33. Differential-mode 75Ω filter test, grounded source and load, 0dB reference

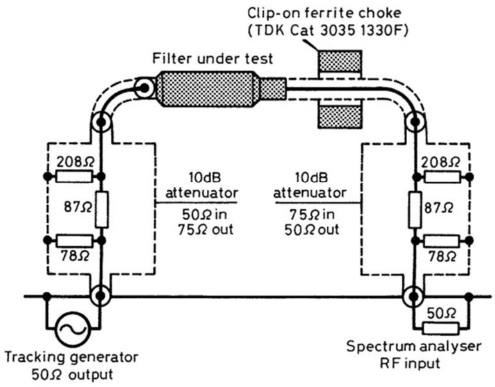


Fig A3.34. Differential-mode 75Ω filter test, grounded source and load, measurement of filter loss

Test methods etc *(continued)*

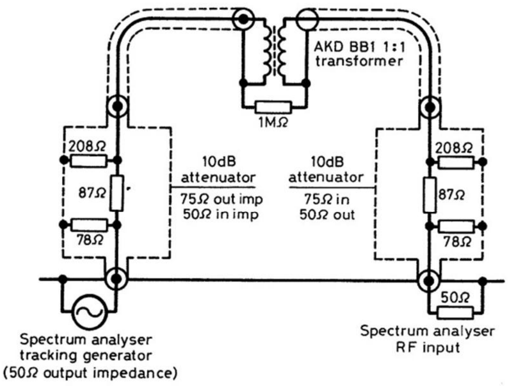


Fig A3.35. Differential-mode 75Ω filter test, floating source, 0dB reference

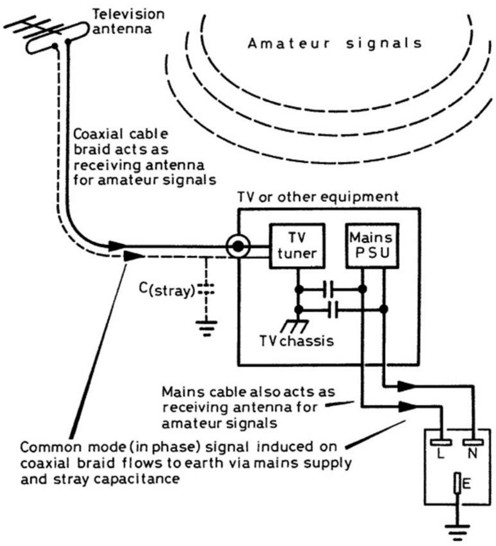


Fig A3.37. Illustration of common-mode signal pick-up

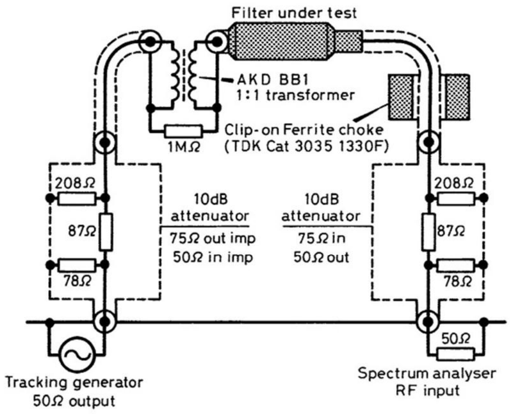


Fig A3.36. Differential-mode 75Ω filter test, floating source, measurement of filter loss

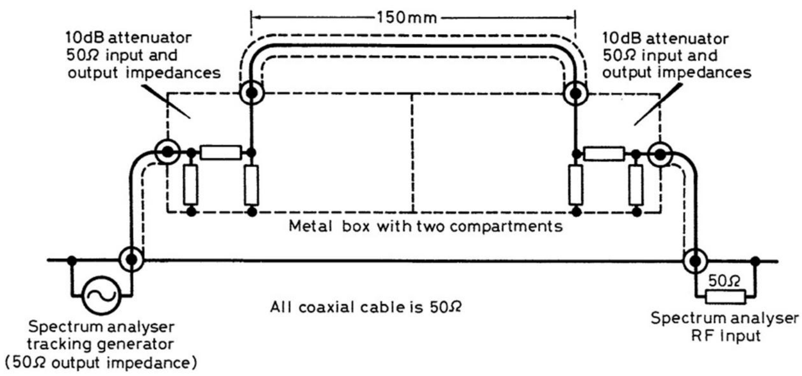


Fig A3.38. Common-mode filter test and ferrite choke test, 0dB reference

Test methods etc *(continued)*

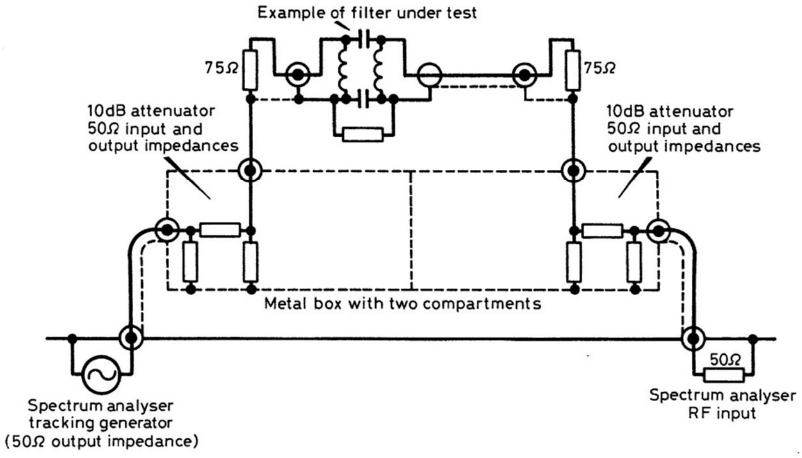


Fig A3.39. Common-mode filter test, measurement of loss in a 50Ω circuit

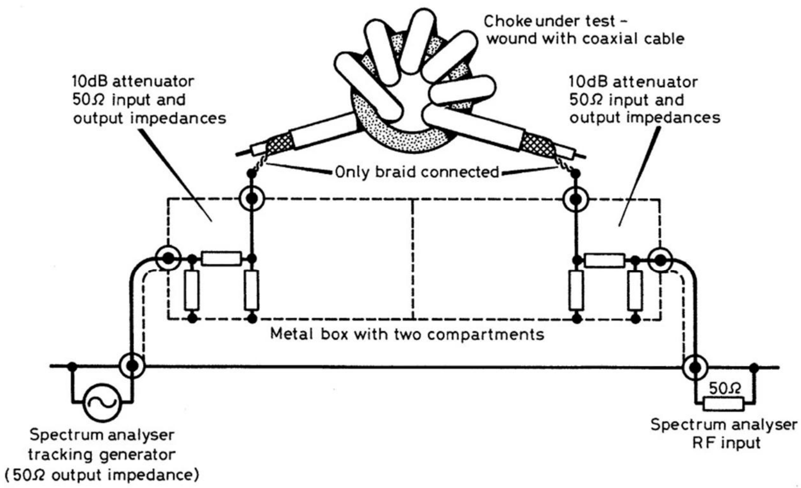


Fig A3.40. Ferrite choke test, measurement of loss in a 50Ω circuit

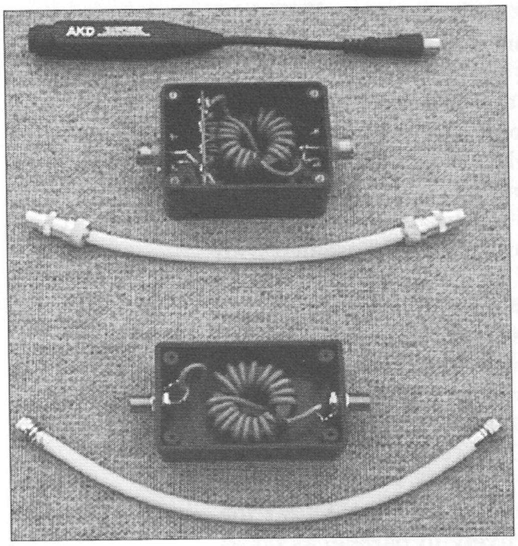


Photo A3.1. ***Top:*** **AKD HPFS filter.** ***Middle:*** **Boxed ferrite ring choke and high-pass filter with coaxial connectors for UHF TV.** ***Bottom:*** **Boxed ferrite ring choke with F-type connectors for cable TV**

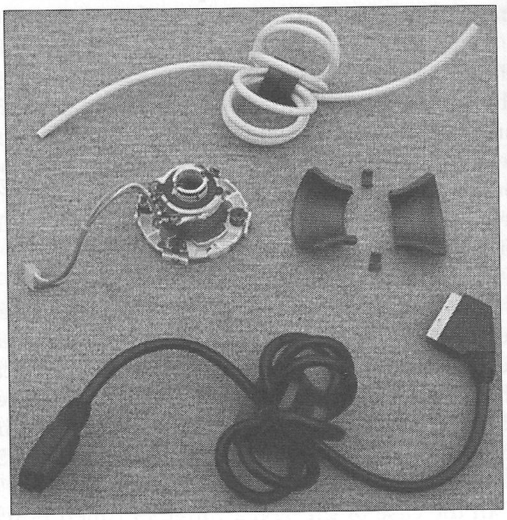


Photo A3.2. ***Top:*** **A length of 6.6mm diameter coaxial cable wound on to two Fair-Rite grade 43 rings.** ***Middle:*** **A scrap deflection coil assembly from a small CRT and a split ferrite yoke ring core from a larger CRT.** ***Bottom:*** **A SCART cable wound on to a ferrite ring core**

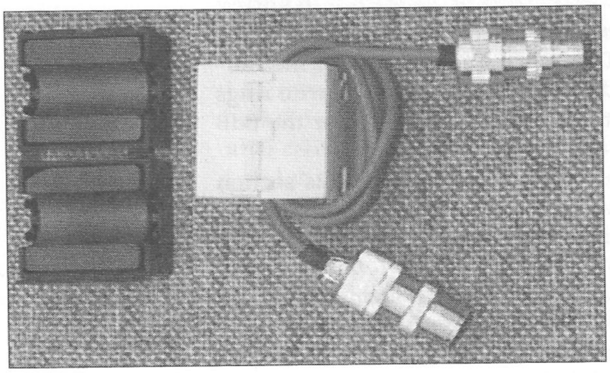


Photo A3.3. ***Left:*** **Maplin BZ34M clip-on ferrite core with 13mm diameter hole.** ***Right:*** **A length of miniature coaxial cable wound on to a clip-on ferrite core**

<u>From Chapter 5 of RSGB Guide to EMC</u>

Five Element UHF TV Filter

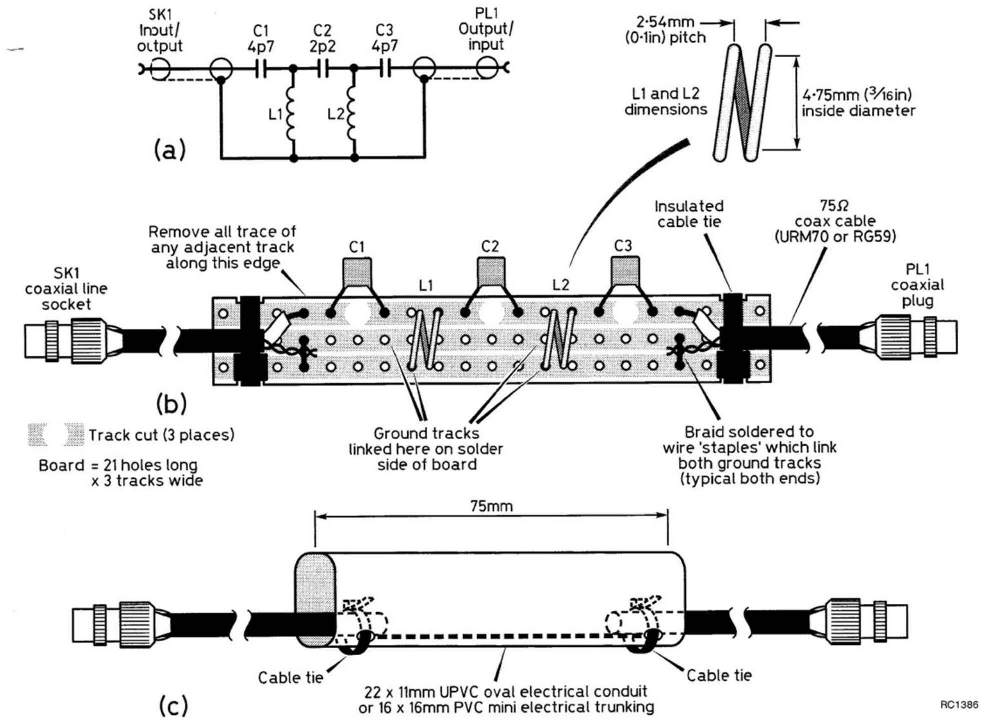


Fig 5.11. Construction of a five-element UHF TV high-pass filter. (a) Circuit. (b) Veroboard layout seen from component side. (c) Housing

The five element UHF TV high pass filter shown Fig 5.13 appeared in the EMC Column of Radio Communications, June 1997, accompanied by the following notes. *"A small offcut of Veroboard can be used if the layout is followed exactly. When cutting the board, it is important to remove all traces of any copper strip to minimise coupling between the input and output. The capacitors are the miniature ceramic plate type. L1 and L2 are self supporting coils mounted flush with the board. They consist of one and a half turns of 0.8 to 1mm diameter copper wire as shown. The solid inner core of a piece of TV aerial coaxial cable is ideal and the insulation from the inner can be used as a coil former . URM70 cable is preferable for the flying leads as normal TV aerial cable is rather thick and inflexible. The filter can be housed in a piece of plastic tubing about 75mm long with cable ties to secure the flying leads to the holes drilled in the sides of the tube."*

Extract from Chapter 5 of RSGB Guide to EMC

Checking ferrite cores

Ferrites are complicated materials and not easy to characterise, but as a quick check of whether an unknown core is likely to make a practical choke or not, the óseries-lossô test will be found useful. This circuit is also quite a good illustration of how the choke operates in practice.

Wind 10 turns of insulated wire on to the core, and connect the ends of the winding between a signal generator and some form of RF detector as in Fig 5.7.

The signal generator and the detector should have 50ohm output and input respectively. If there is any doubt about this, a 6dB attenuator should be inserted either side of the test circuit to define the source and load resistance. The switch and the terminals for the choke (and the attenuators, if required) can be mounted on a plastic box. Tune the signal generator to a frequency of about 3.8MHz and switch S1 from closed to open; the difference indicated on the detector between the two conditions should be at least 10dB. Repeat the test at 28MHz: the difference should be greater than 23dB. Measurements at 28MHz may be unduly optimistic due to resonance effects so it is worthwhile checking at other frequencies.

If a core with a known good EMC performance, such as a Fair-rite 2643802702 (see above), is available it can be used as a basis for comparison. If the test box is working correctly, results from a core of this type will be considerably better than the figures quoted above. If the detector is uncalibrated, the difference can be measured by re-adjusting the signal generator output so that the detector output returns to some pre-determined level.

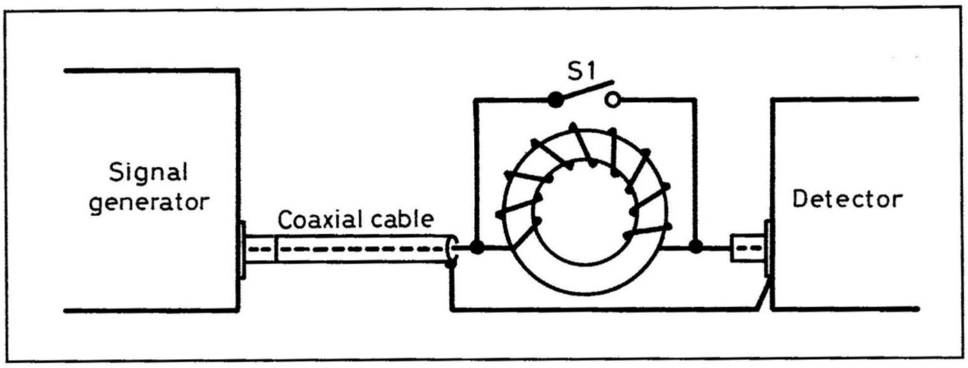


Fig 5.7 Ferrite choke test circuit