Interference-reducing antennas for the BCB

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There is probably little of value which has not already been researched or patented as a way of improving reception on the BCB: the main problem is finding it! Over the last two years I have been looking at the early radio literature in my attempt to understand the problems better. One of the most useful findings were references to 'anti-interference' antennas in literature of the 1930s. Since I have seen few post-war references to such arrangements, it seems well worth repeating this experience, especially because the reception improvements can be quite startling.

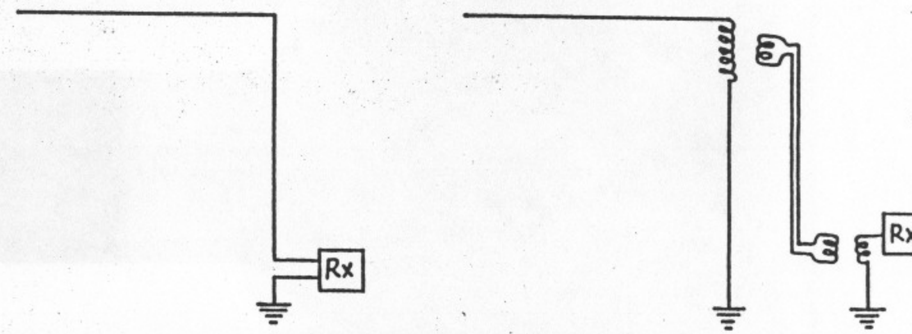
The aim of most radio reception can be simply stated: to hear the desired station-and nothing else! Discrimination against unwanted stations or distant noise sources is often achieved with directional reception, either with loops alone, or with phased and combined loop and omnidirectional antennas. The vertical whip or inverted L antennas often used in phasing combinations are more susceptible to the interference from household appliances, than screened or balanced loop antennas. Thus, the directional omni + loop array is often 'contaminated' by interference received by the omnidirectional antenna and ways must be found of reducing this interference if the effective system noise floor is not to be determined by nearby interference.

A possible confusion must be avoided at the outset: "anti-interference" or "anti-static" antennas are sometimes referred to as "noise-reducing" antennas, which could be misleading. The background "noise" on the BCB is produced by distant thunderstorms or man-made electrical interference and will not be reduced by an "anti-interference" antenna; it only deals with interference in the vicinity of the antenna (up to about 90m on the BCB), since the principle strategy is that of reducing electrostatically-induced interference.

The interference to be combated is mostly generated by household appliances, fluorescent lighting, and TVs, but the presence of interference may not be audibly obvious unless one happens to hear the moment when an appliance is switched off and the received "noise" drops suddenly: other interference has a distinct signature. Local interference on the BCB is mostly vertically polarized and generated with respect to ground, thus, any antenna which is balanced with respect to ground should be able to reject some of this interference. Screened, or balanced loops do not respond to the electrostatic wave and have a well-known reputation for being relatively insensitive to nearby interference, compared with vertical (capacitive) antennas which respond mostly to the elctrostatic component. At a distance from the interference source where the electrostatic amd magnetic components are of equal strength (a distance of about 30m and 90m at the high and low ends of the BCB respectively), the advantage of the screened or balanced loop over vertical or inverted L antennas will not be great. If, in the presence of nearby interference, a vertical antenna sounds about as "noisy" as a screened or balanced loop, then "anti-interference" techniques can be probably judged successful, or unnecessary.

Interference-reducing antennas can be roughly divided into two categories: those which depend for their effect upon being placed away from the interference, and those which attempt to balance it out, regardless of their position.

The best introduction is to be found in Terman (1) and a number of articles (2-9) show the interference-reducing antennas known in the 1930s, a time when, before the enforced suppression of appliances, interference was a considerable problem for BCB reception. Although any improvement of the antenna/receiver grounding in fig. 1 will increase interference rejection, further improvement is possible when the antenna or its feeder is near a source of interference. Strafford (2), who patented several details of anti-interference antennas for his company, Belling Lee (UK), which marketed the antennas, gives an arrangement as shown below.



1. Normal antenna 2. 'anti-interference'

The difference between the two types is in the use of a balanced line feeder and the point where the line is connected to the antenna. The fig. 1 antenna picks up interference, and the downlead may contribute substantially. Although different explanations of the 'anti-interference' mechanism were offered in the 1930s, practical experience showed that a substantial reduction of the pickup of nearby interference resulted when connection 2 is used. The balanced feeder is practically unaffected, since interference voltages cancel out in the receiver transformer. Furthermore, it permits the antenna to be placed away from the interference field of the house. In fig. 2 an element of balance may also be involved in the antenna's rejection of interference.

It is no exaggeration to expect reduction of nearby, electrostatically-induced interference of the order of 30dB-40dB, as compared with an indoor antenna or badly constructed outside antenna. The reduction in comparison with a reasonably-sited outside antenna will not be so large, but even 10-15dB can make the difference between receiving weak signals and only interference.

It is also possible to connect a vertical whip as fig. 2 and I have my 10m whip with the transformer 6m from the ground. Contrary to expectation, there was no measurable loss of signal voltage (i.e. ± 3dB) on groundwave stations, as compared with the transformer at ground level. If a vertical whip is mounted on the house structure, the upper part of the antenna should be above roof level, where the interference will be weaker. An existing CB-band whip could form the upper part of such an "anti-interference" antenna.

Thus, there are three cardinal rules for antenna placement:
1. Put it as far away from any house and mains wiring as possible. 2. Make it as high as is feasible. 3. Use a balanced feeder. This may even require that the downlead from an inverted L be at the end furthest from the house. Even if one is using a battery-powered radio, there will still be electrostatic coupling of the antenna and antenna feeder to the mains wiring, and one can expect local interference to be re-radiated by your own house-mains wiring. It is important to recognise that a good signal-to-interference ratio is more important than the highest possible signal input, since the feeder arrangements described below cause a signal loss of about 6dB due to transition loss and capacitive shunting.

In order that the antenna-receiver signal transfer be made without introducing interference, a balanced line is better than coaxial cable and any residual unbalance can be compensated (16,17). Use zipcord for the line, which is cheap, easy to obtain, durable and has no significant loss at BCB frequencies (14). A screened, balanced line was found to give only marginally better rejection of signal ingress and is hardly worth the extra effort and expense. The antenna transformer should have a high degree of coupling to minimise signal loss (wind the secondary over the primary) and an inductance of about 5mH ensures operation with low loss down to 150kHz; 2-3mH is sufficient for use down to 500kHz (10). My antenna transformer was wound on a Siemens B64290-K618X830 25mm ferrite toroid with 37:7 turns, which ratio was determined empirically (11). A toroid gives good coupling, but is not obligatory, and ferrite rod can be used. Reference 3 stresses the importance of low capacitive coupling across the electrostatic screen, for which reason the windings are separated by 1.6mm (on a cylindrical iron dust core). It also advises that an electrostatic screen at the antenna transformer (connected to antenna ground) may do more harm than good. Antenna transformer ratios in the range from 1:4 to 1:7 will be roughly correct, but optimum voltage transfer will depend on your antenna/feeder, and can be adjusted when receiving steady, daytime groundwave signals. The step-down ratio is necessary in order to reduce the capacitive shunting by the line of the antenna voltage. Both windings of the balanced-to-unbalanced transformer (on the same Siemens toroid type) at the receiver have 8 turns, for use down to 150kHz. The inductive reactance of this transformer in a 50 Ohm circuit should be roughly 200 Ohms at the lowest frequency of interest. Other toroids or ferrite rods can be used. Although a 1:1 balun could be used at the receiver I have used a conventional transformer, which permits the use of an electrostatic screen (use copper, aluminium foil, or p.c.b.) should this give an advantage, but centre-tapping the balanced side of the transformer and grounding it to receiver ground will cause current to flow, probably inducing some noise and is not recommended. The best possible, independent ground connections for the antenna and the receiver should still be used. At least a single ground stake should be used, as deep as is practicable and the connection to the antenna/receiver should be of low inductance. The mains ground is NOT suitable and even house water pipes may be unsatisfactory.

These arrangements will cover the BCB and longwave and also give usable signals on SW. There may be several dB loss on SW and those interested in making an all-bands antenna should consult reference 8. Lankford has reported satisfactory SW reception with an "anti-interference" inverted L antenna (20), but results must be tested experimentally at each location

While the connection of fig. 2 will reduce interference, there may still be a large residual level if the whole antenna is near a strong noise field. A balancing arrangement (7) is of interest where the antenna cannot be placed away from interference and provides a useful source of ideas for those restricted to indoor antennas. The operation depends upon a counterpoise antenna and a bridge, balancing circuit. Other references (15-18) indicate some of the circuits which have been devised for balancing the pickup of the antenna or of the line itself and which permit the remaining interference to be balanced out.

My first antenna at this QTH was an inverted L running up the side of the house and in under the roof. The daytime interference was terrible and only strong stations were audible. With the erection of a 10m whip some 15m away from the house as suggested by (13) came astonishing results: virtually no interference and a receivable station on most of the BCB frequencies during the day. When the whip was connected as an "anti-interference" antenna, with the transformer connection 6m from ground, it appeared to give extra protection from fluorescent lights, but this is difficult to test, unless one uses a standard interfering signal as described in (3) or (7). In cardioid mode, intelligible, atmospheric-noise-limited signals of less than -109dBm (1.6uV across 50 Ohms) can be routinely heard at midday in summer on 1215kHz from BBC Radio 3 (650km distant) even though 15 40W fluorescent lights are in operation only 16m away: fluorescent light interference is inaudible.

The bottom line: even with this 'anti-interference' antenna you will still be able to hear TV horizontal output and other RF nasties in your neighbourhood, which even special directional nulling techniques may not eliminate (12), but these will probably be at a level where they no longer prevent intelligible reception of even the weakest signals. Some experimentation will probably be required for optimum results.

My warm thanks go to Graham Maynard and Dallas Lankford, whose sharing of ideas and experience have helped develop my antenna system, and for reading a draft of this article

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Remote Tuning and amplified antenna signals

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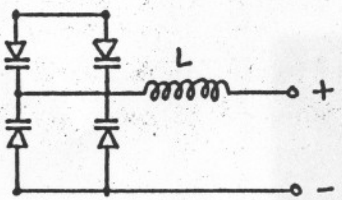
If one intends to implement remote antenna tuning, as recently described by Mark Connelly, the best engineering practice is to use varicaps back to back, and then add a second pair in order to achieve the capacitance of a single unit. When the signal voltage is more than about 1/10 of the tuning voltage, IMD may become noticeable. IMD is said to be lower when the tuning voltage is fed from a high reactance (large inductor) rather than a high value resistor (1). The out-of-band input power per diode should not exceed 25mW, but low-capacitance varicaps could be paralleled as a way of dividing the RF voltage between devices and lowering IMD.



X_L approx. 100K Ohms (e.g. 33mH for BCB)

When one is already committed to the use of an antenna amp with inadequate dynamic range, bandwidth limiting is the only way of reducing IMD without sacrificing signal level. Rohde & Schwarz make an active HF antenna (AK001) which switches (under microprocessor control) appropriate values of L and C in order to improve rejection at the antenna of very strong unwanted frequencies (of the order of V/m) and avoid the use of non-linear varicaps. This approach is feasible for a hand-switched design.

I believe the point has not been sufficiently appreciated in BCB listening circles (and some equipment manufacturers), that where active devices are used broadband in front of the receiver, these should be configured in a balanced mode in order to cancel 2nd order IMD by 20-35dB. I have had success feeding a 10m whip and 40 m^2 loop into balanced JFET grounded gate amps on the BCB in order to achieve adequate daytime sensitivity. Development of this approach is not completed, but ICP3 is about +30dBm and ICP2 about +60dBm which ensures inaudible daytime IMD products at this QTH. Furthermore, high-current, JFET source follower designs I air-tested for broadband use were only satisfactory when used in balanced mode.

(1) W.E.Sabin and E.O.Schoenike (eds.) Single Sideband Systems and Circuits, McGraw-Hill 1987, pp 301-302.
(2) A.Burwasser, "How to design broadband JFET amplifiers", Ham Radio, Nov.1979, pp 12-19. (This article was kindly obtained for me by Dallas Lankford)

(1) F.E.Terman, Radio Engineers' Handbook, 1943. The essential reference book for every BCB DXer.
(2) F.R.W. Strafford, "Screened Aerials", Wireless World 1937 pp 516-518, and "Vertical or inverted L aerials", Wireless World 1939, pp 575-577. The arrangement shown was patented by E.M.Lee, F.R.W.Strafford and H.G.Stedman, UK Patent No. 505838, described in Wireless World, Aug. 1939, p 226.
(3) W.L.Carlson and V.D.Landon, "A new antenna kit design", RCA Review vol. 2, 1937 pp 60-68. Contains much practical information. This reference was kindly obtained for me by Dallas Lankford.
(4) J. van Slooten, "Ontvangantennes", Philips Technische Tijdschrift vol. 4, 1939, pp 333-337. Also in English and German editions.
(5) G.H.Browning, "Reducing man-made static", Electronics vol.5, 1932, pp 366-368. Mostly on the theory of matching the antenna to the line.
(6) K.R.Sturley, Radio Receiver Design, London 1949, pp 109-115. One of the standard works on radio design.
(7) V.D.Landon and J.D.Reid, "A new antenna system for noise reduction", Proc. Institute of Radio Engineers (Proc.IRE) vol. 27, 1939, pp 188-191. A synthesis of several patents including De Monge. Essential reading.
(8) H.A.Wheeler and V.E.Whitman, "The design of doublet antenna systems", Proc.IRE vol.24, 1936, pp 1257-1275. Discusses all-wave antennas and matching transformers.
(9) A.J.Cawthorne, "Curing TVI to MF/HF reception", Practical Wireless (London, UK) vol.80, Jan. 1984, pp 60-62. Advises placing antenna away from house; details on suppressing fluorescent lights.
(9) A.J.Gill and S.Whitehead, "Electrical interference with radio reception", Journal of the Institution of Electrical Engineers (London) vol. 83, 1937, pp 345-394. A substantial general survey of all types of interference and brief details of antennas.
(10) See E.E.Zepler, The Technique of Radio Design, London 1943, pp 41-44 for design equations and a discussion of problems. A very practical book.
(11) Dallas Lankford reports equivalent performance with 40:9 turns on an Amidon FT-87A-F for the antenna transformer and FT-114-75 43 turns trifilar as a transmission line 1:1 balance-to-unbalance transformer (see (20)).
(12) J.K.Webb, "Electronic steering of antenna nulls for interference reduction", Institution of Electrical Engineers Proceedings (London) vol. 130, 1983, pp 417-422. A more detailed version of the QST Oct. 1982 article by the same author.
(13) G.Maynard, 'Medium Wave, a practical approach', originally Medium Wave Circle, GB, also NRC reprint A60, IRCA reprint T63. The isolating amplifiers contributed more noise than the atmospheric background with my antenna and their use has been discontinued. There are also problems in obtaining low IMD from source or emitter followers on broadband use.
(14) The ARRL Antenna Book, 14th edition, Newington C.T., 1984 p13.10.
(15) UK Patent No. 506063, R.I.Kinross, reported in Wireless World, Sept. 1939, p306. Additional antenna with RC amplitude/phase balancing.
(16) UK Patent No. 504752, V.D.Landon, reported in Wireless World. Aug. 1939, p 114. Interference on transmission line is cancelled with phasing.
(17) E.M.D., "The prevention of interference between 'wired-wireless' circuits and wireless stations", Experimental Wireless and the Wireless Engineer, July 1924, 563-570. Similar arrangements to ref. 16.
(18) R.I.Kinross, "Reducing Interference", Wireless World, Nov. 1940, p 469-470. Experience with the De Monge balancing patent and variations.
(19) P. Hawker, Amateur Radio Techniques, 7th ed. 1980, p273. "Jones noise-balancing circuit" using additional "noise" antenna (RSGB publication).
(20) Private communication, July, 1991.