Getting the right response

Phased aerial arrays can provide a tailored polar response. Bill Wright shows how it's done, using DAB reception as an example

The DAB networks in the UK are not well co-ordinated, with the result that some locations have various DAB muxes (multiplexes) available at widely differing signal strengths.

Not every DAB transmission site broadcasts the BBC mux, for example, so anyone near one of these sites might find that the BBC mux is 40dB or more below the ones from the nearby transmitter. DAB tuners can't always cope with this, and often will not find the weaker mux when scanning or, if they do find it, will only decode it erratically. The weaker mux is, *per se*, strong enough, but the receiver is 'swamped'.

When DAB reception is via a communal aerial system the signal level at the head-end has to be set so that the strongest signals do not overload any of the amplifiers. This will often leave weaker signals up to their necks in amplifier noise. It's no good distributing DAB signals with the BBC mux, for instance, in an unusable condition.

The solution is to attenuate, or weaken, the very strong signals so there is less of a difference between them and the rest. Notch filters are no use here; the solution is to use a directional aerial. We need, ideally, more-or-less equal gain in all directions except across one small angle, where we would like minimum gain. A conventional Yagi or log periodic DAB aerial can help a bit, but there's a better way. It involves connecting two aerials together to produce a specific polar response, or directional characteristic. There are 101 ways of doing this, with an equal number of outcomes. The variables are the spacing between the aerials, whether or not one aerial is inverted (producing a 180° phase shift), and the relative lengths of the feeders from each aerial to the combiner. Certain basics apply to any configuration. The combiner should be an ordinary fully screened inductive splitter with 'f' connectors (CPC: AP00304; DAS: 0604; Taylor: TD2-4F; Labgear: WBS402). Since any signal picked up on the cable will make nonsense of this technique, the aerials must have baluns, and the cable must be CT100 or equivalent.

The quick and easy way

Almost any polar response is possible but the simplest way is best, so I'll start with a straightforward configuration.

Mount two dipoles 0.5λ (0.5 wavelength) or1.5λ apart. The feeders from dipole to combiner can be any length but must be exactly equal. Both dipoles should be the same way up. This is vital, but it's impossible to tell with some makes ('Vision', for instance) other than by trial and error! The polar response will have two deep nulls 180° degrees apart and in line with the dipoles. This is because the two dipoles receive signals from that direction exactly out of phase, so they cancel out. One null should be carefully aligned with the unwanted transmissions, using an analyser. With a bit of luck, the opposite null won't coincide exactly with a wanted signal (if it does use a Yagi or a log). Nearby reflective objects will greatly reduce the apparent depth of the null. The distance between the dipoles (centre to centre) for the maximum rejection at the top, middle, and bottom of the UK DAB band is given in Table 1.

The closest spacing (0.5λ) is the easiest to rig and has the most stability.

You might think that discriminating against the strong signals like this would result in their reception being distorted, but DAB doesn't work like that. With the direct signal strongly attenuated much of the received signal will be from reflections, and unlike FM or analogue TV, DAB uses these multipath signals quite happily. Many DAB networks, in fact, have all the transmitters on the same channel, so if you null out a very strong one a more distant one will start to make a contribution. But if you do create an unacceptably deep response notch in a mux and the BER suffers, a minute rotation of the array will move the notch out of the way. This array has maximum gain (+3dBd) at 90° to the nulls, so align it at a compromise angle if you are after one particular weak mux, using BER rather than signal strength as the criterion.

Getting more gain

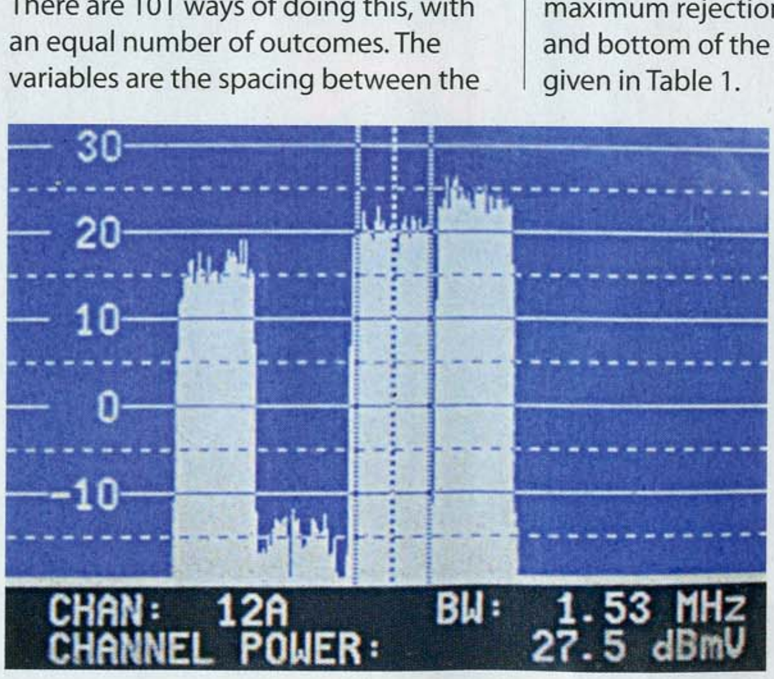
The same basic method can be used with a pair of Yagis or logs to achieve further tailoring of the polar response.

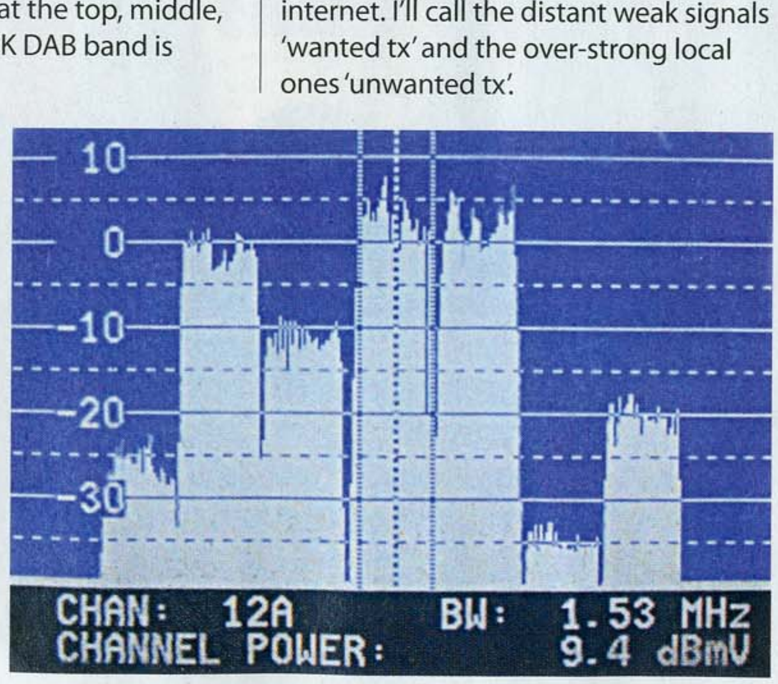
At the same time the performance of the array can be refined still further by ensuring that both aerials receive the distant DAB signals exactly in phase 'This', I hear you lament, 'is getting complicated. We have to ensure that the signals from the local station are exactly out of phase, and at the same time get the signals from the distant station exactly in phase! How, Bill?'

Actually, it's easy with the help of the internet. I'll call the distant weak signals 'wanted tx' and the over-strong local ones 'unwanted tx'.

Bill Wright

Bill grew up with a TV aerial in his hand, helping his aerial installer dad. In 1971 he seized the reins and has never looked back. Nowadays he concentrates on distribution systems, leaving everything else to his son Paul





The muxes on channels 11C, 12A, and 12B come from a nearby transmitter and when received on a normal aerial are far stronger than any other.

Here a phased pair of dipoles is used to attenuate the local muxes by about 20dB, allowing amplifier gain to be increased and making the reception of three or four other muxes far easier. Note the different reference levels in these two screenshots

Channel	Frequency (MHz)	0.5λ spacing (mm)	1.5λ spacing (mm)
11B	218.640	686	2058
12A	223.936	670	2009
12D	229.072	655	1964

Table 1: spacing between DAB dipoles to give two nulls 180° apart

The angle of the dangle

Essentially, you need to find the angle between the two signal paths because that will tell you the spacing between the two aerials.

First, find the azimuth of the wanted tx. You need the National Grid Reference (NGR) of the receiving site, which you can get from an Ordnance Survey map or from Multimap. Zoom in and click on the exact location, then read off the accurate NGR under 'Map Information.' Go to either Wolfbane, Megalithia, or the UK TV alignment calculator (see the list of websites in the boxout) and feed in the NGR for the receiving site and the name of one of the transmitters and this will give you the azimuth. This is the bearing in degrees of that transmitter as seen from the receiving site. These sites list TV transmitters, many of which also broadcast DAB, but if you are using a DAB-only site Megalithia and the UK TV alignment calculator will accept NGRs for the transmitter location.

Next, find the azimuth of the unwanted tx, which you might be able to do in the same way. If it's very close, use Megalithia's map, zoom in, check that both locations are exactly correct, then read off the 'beam heading' or azimuth. Alternatively, import a large-scale OS map into a graphics programme and measure the azimuth there. The clockwise angle between vertical and the line to the tx is the azimuth. Don't mix OS grid North and true North for these calculations. Subtract one azimuth figure from the other to get the angle subtended at the receiving site by the two signal paths. Table 2 gives you the physical spacing between the two aerials that will give a sharp null in exactly the right direction. 0.5λ (half wavelength) spacing can be inconvenient when two Yagis are used, so I've given the figures for 1.5λ spacing too. The aerials aren't necessarily 0.5λ or 1.5λ apart; that is the distance by which one is closer to the unwanted tx than the other. The extra half wave in the path length results in the signals at the aerials being 180° out of phase, so when they are combined complete cancellation occurs. The aerials can be any physical distance apart – it just depends on the angle of the signals that are to be discriminated against. But at the same time the two aerials have to be an exactly equal distance from the wanted tx, so that the signals are exactly in phase from that direction and are thus added at the combiner. If you do this carefully you will get a useful increase in gain of 2.5 to 3dB.

Alignment

Use the spacing figures given in the table to build the array, using either the 0.5λ or 1.5λ path delay as is most practical. Leave a little extra length on the cross-arm for the time being. Fix one aerial permanently at one end of the cross-arm and mark the theoretically correct spacing, which will be near the other end, and temporarily mount the second aerial there.

Align the array for maximum signal on the wanted signals, ignoring for the time being the unwanted signals. If you have built the array correctly the aerials will now be pointing exactly at the

Angle between the signal paths (degrees)				Spacing for ch 11B (cm)		Spacing for ch 12A (cm)		Spacing for ch 12D (cm)	
				0.5λ	1.5λ	0.5λ	1.5λ	0.5λ	1.5λ
05	175	185	355	791	2374	794	2318	6799	2266
10	170	190	350	394	1181	375	1154	3384	1128
15	165	195	345	265	796	259	777	253	760
20	160	200	340	201	604	196	590	192	576
25	155	205	335	161	484	158	473	154	462
30	150	210	330	137	412	134	402	131	393
35	145	215	325	107	358	117	350	114	342
40	140	220	320	107	320	107	312	102	305
45	135	225	315	96	289	94	283	92	276
50	130	230	310	89	267	87	261	81	244
55	125	235	305	83	248	81	242	79	237
60	120	240	300	79	236	77	230	75	225
65	115	245	295	76	228	74	222	72	217
70	110	250	290	73	219	71	214	70	210
75	105	255	285	70	211	69	206	67	202
80	100	260	280	69	208	68	204	66	199
85	95	265	275	69	207	67	202	66	198
90		270		68	206	67	201	65	196

Table 2. Spacing between the dipoles of two DAB aerials to produce a reception null from specific bearings relative to the main frontal lobe. 'Spacing' is the distance along the cross-arm between the aerials

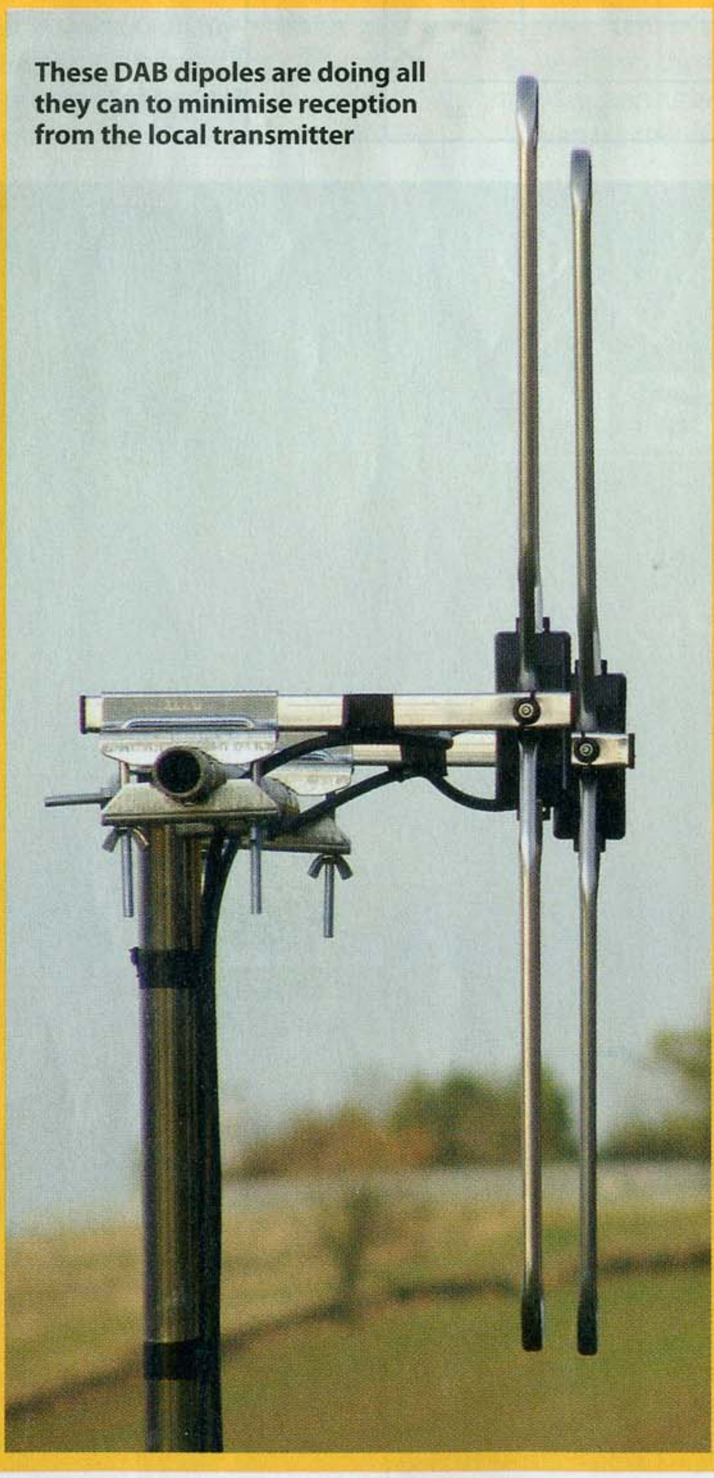
A versatile technique

The basic technique given here can be used for any job where there's a need to discriminate against signals from any specific off-axis direction except 180°.

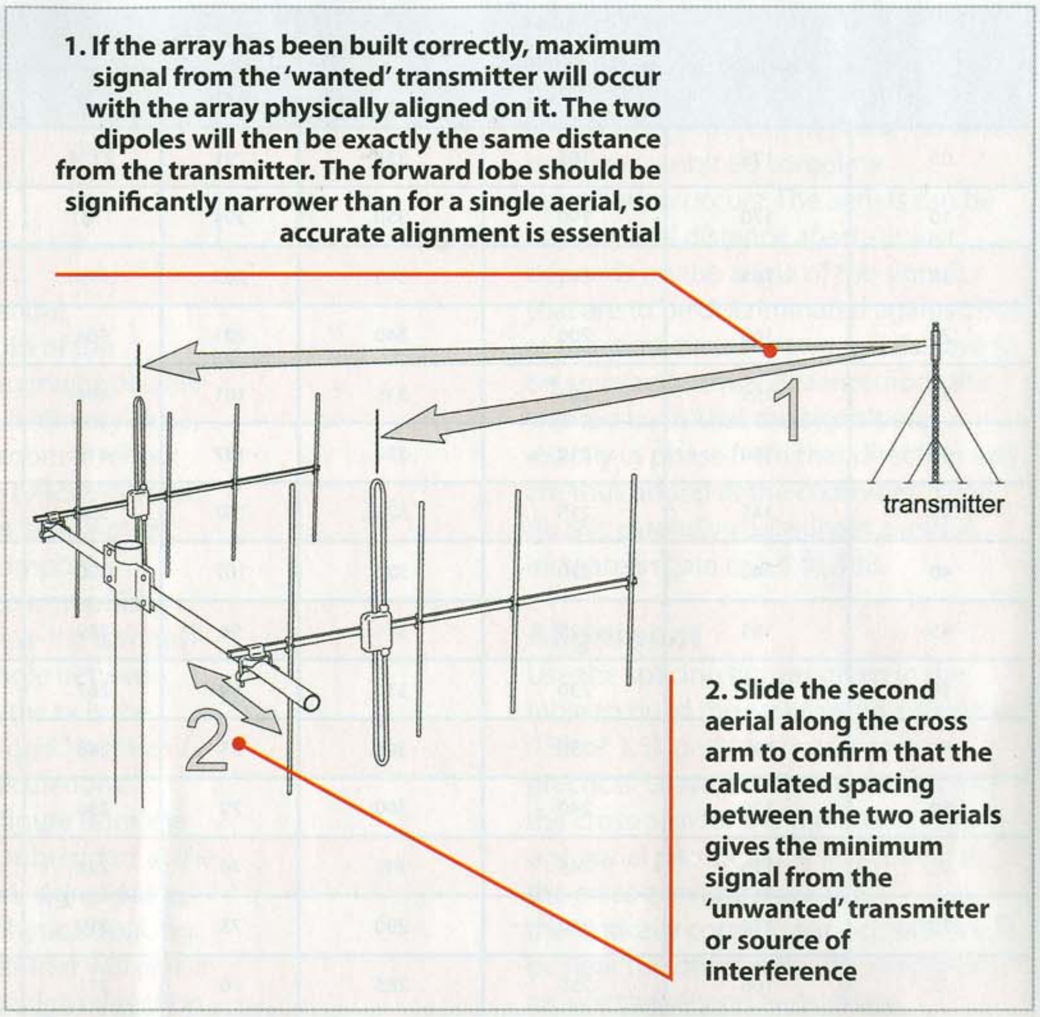
Because of DAB channel re-use in the UK, wanted multiplexes often have another mux competing with them. This can worsen BER (bit error rate) to the point where reception is impossible, but the phasing of two aerials can overcome this completely. The technique can also be used for VHF FM to eliminate co-channel interference, but is not suitable for reducing over-strong local signals when those signals are need for reception, because the resultant multipath causes distortion. It's better to use a notch filter or a tuned stub.

Although this article has been written around DAB reception, I first started experimenting with phased arrays for UHF TV use. The basic principles I've described here apply just as much to UHF, and can be very effective in combating co-channel interference and even good old-fashioned analogue ghosting. However, the phasing is, of course, frequency-dependent, so there is a compromise across even one channel group, and wideband use is a non-starter. Having said that, when wideband reception is required but the co-channel (etc) interference affects only a small part of the band, an array of two log-periodic UHF aerials can be remarkably effective.

- Multimap: http://www.multimap.com/
- UK TV alignment calculator: http://www.macfh.co.uk/Test/UKTerrestrialTVTest.html
- Wolfbane TV reception predictor: http://www.wolfbane.com/cgi-bin/tva.exe
- Megalithia: http://www.megalithia.com/elect/terrain.html



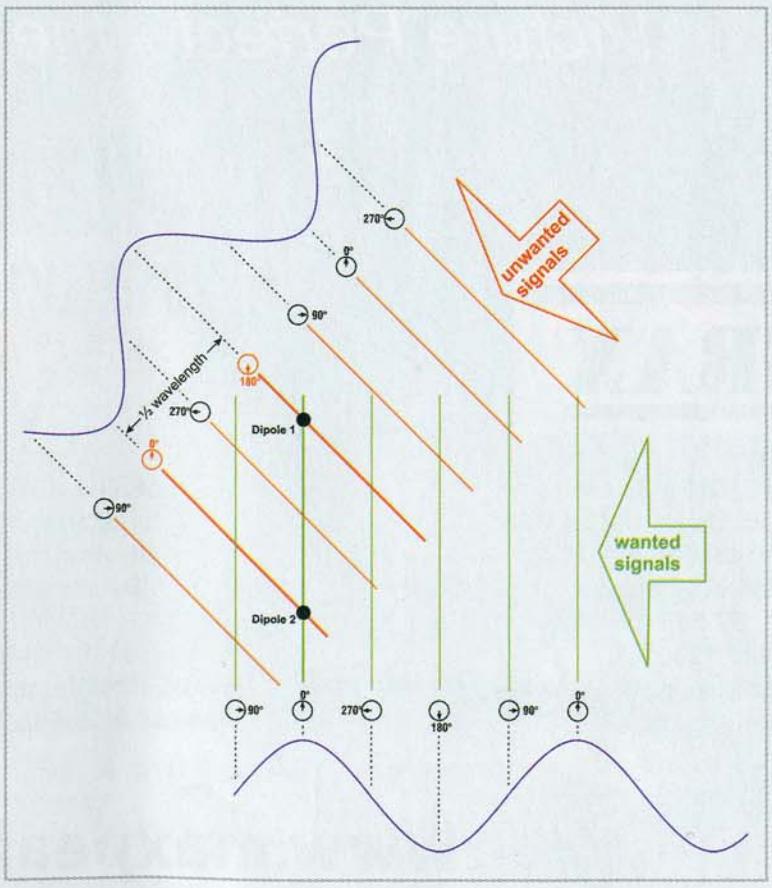
These DAB dipoles are doing all they can to minimise reception from the local transmitter



As the UK only uses a small part of the DAB band, a useful increase in gain can be obtained by the use of aerials that cover only the part of the band actually in use, such as the Triax 100171 five element

wanted tx and you should have a little more signal than with one aerial only. If maximum signal occurs 'off beam' or the combined signal is weaker than from one aerial alone check that both aerials are the same way up and that both feeders are the same length. If you still have strange results try a different combiner. Once you've got it right tighten the bolts so the array cannot rotate, then move the second aerial sideways along the cross-arm, keeping it pointing at the wanted tx. Keep your body to the rear of both aerials. As you move the aerial watch the level of the unwanted signals on the analyser. They should drop to a minimum at or very near the position marked on the cross-arm. If not, you've goofed! Maximise the null by fine adjustment and tighten the second aerial.

Visit Bill Wright's websites at www.wrightsaerials.tv and www.paras.org.uk.



The wanted signals are received by the two dipoles exactly in phase, so the signals will be added in the combiner to give about 3dB of extra gain. The unwanted signals, however, are received exactly out of phase, so they will cancel each other out in the combiner