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VHF-FM RADIO BROADCASTING:
Tests to compare horizontal, vertical and mixed polarizations

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THE BRITISH BROADCASTING CORPORATION

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Summary

The BBC is re-engineering its VHF-FM radio networks from horizontal to mixed polarization. This Report describes tests carried out to monitor this change and which confirm the advantages of mixed polarization. Tests from the BBC transmitting station at Wenvoe to compare vertical and horizontal polarization are also described.

It is concluded that mixed polarization is the best choice for re-engineering the UK VHF-FM networks. For new networks the optimum polarization would be vertical, with the option of adding a horizontal component for areas where interference to fixed installations could be lessened by the use of the additional directivity available with horizontally polarized receiving antennas.

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1. Introduction

The BBC Band II VHF-FM broadcasting networks are being re-engineered from horizontal to mixed polarization.

Earlier Reports described tests to assess the advantages of mixed polarization in Nottingham[1] and from Crystal Palace, London[2] (also see Refs. 3 to 8). This Report describes work carried out which confirms these advantages, comparing reception from Wrotham, (the BBC's high-power VHF-FM transmitter for the London area) before and after its re-engineering to mixed polarization.

Further experiments comparing horizontal and vertical polarization, with particular reference to multipath propagation and to reception in cars, using test transmissions from the Wenvoe transmitting site in south Wales are also described.

2. Types of polarization

It is important to clarify the terms used to describe polarization. Linear polarization is the basic form and is usually termed 'Horizontal Polarization' (HP) or 'Vertical Polarization' (VP) to describe the direction of the electric field in the plane at right angles to the direction of propagation. This orientation also corresponds to the optimum orientation of the receiving dipole for the corresponding transmitted polarization.

If the transmitted power is divided (usually equally) between the horizontally and vertically polarized components, no importance being attached to the phase difference, then the transmitted polarization is called 'Mixed Polarization' (MP).

Special cases are 'Slant Polarization' where the two components are equal and in phase and 'Circular Polarization' where the components are equal but differ in phase by 90 degrees. Slant polarization is another form of linear polarization where the electric field lies in a plane at 45 degrees to the horizontal. With circular polarization the electric field rotates with time.

3. Transmitting antennas for circular and slant polarization

It is useful to understand the problems of designing transmitting antennas for circular and slant polarization.

Taking the simple case of a slanted dipole (Fig. 1), it can be seen that although in a broadside direction the antenna is obviously slanted, when viewed from the side the antenna appears to be vertical and indeed radiates vertical polarization in that direction.

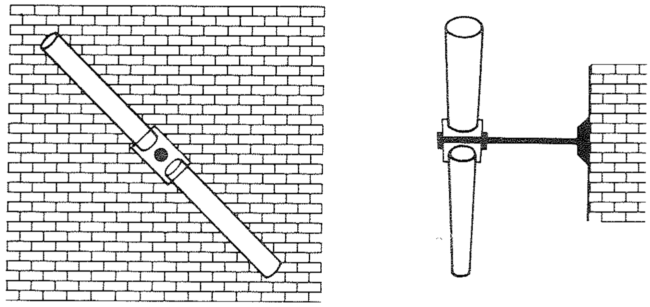

Fig. 1 – A slanted dipole viewed from the side appears to be vertical and radiates vertical polarization in that direction.

The same type of problem occurs with nominally circularly polarized antennas: it is not practical to maintain the exact phase and amplitude characteristics over a wide arc. Fig. 2 shows part of the nominally circularly polarized antenna at Wrotham[9]. It consists of tiers of crossed dipoles fed in quadrature. Fig. 3 shows typical polar diagrams of its HP and VP components. Even with this carefully designed high power antenna the ratio between the HP and VP components varies by up to 4 dB. Similarly the phase relationships vary by up to 45 degrees.

Thus the angle of slant from a slant polarized antenna varies with direction and the actual polarization of a nominally circularly polarized antenna can best be described as elliptical with the parameters of the ellipse varying with direction. In practice, this is of no consequence as we are seeking only to excite HP and VP receiving antennas and do not expect listeners to attempt to match the radiated polarization with their receiving antennas. Hence the use of the more general term, 'Mixed Polarization'.

4. Tests from Wrotham

4.1. General

The new mast, antenna and transmitters were brought into service at Wrotham in December 1981, replacing those used since the introduction of VHF-FM radio in 1953. With the introduction of the new antenna, the polarization of the transmitted signals was changed from horizontal to mixed. The change

also involved a doubling of the transmitter power to maintain approximately the same level of HP component together with an additional VP component of similar amplitude.

The opportunity was taken to compare reception of Wrotham before and after the change. The tests included some overnight periods when both new and old systems were available simultaneously allowing direct comparisons.

The new MP antenna at Wrotham is 29 metres higher than the old HP antenna and the mast position has changed by about 100 metres. Fig. 4 compares the polar diagrams of the HP components of both antennas (for comparison with the HP and VP patterns of the new antenna again see Fig. 3). The radiation pattern of the new antenna is not as omnidirectional as the original slot antenna, and because of this, bearing in mind that the maximum e.r.p. is restricted by internationally agreed limits, the mean e.r.p. of the horizontal component of the new antenna is 1.3 dB lower.

4.2 Reception at rooftop height – 10 metres a.g.l.

4.2.1 Equipment used

Measurements of the old HP transmissions were made using a two element yagi receiving antenna mounted on a 10 metre extendable mast (see Fig. 5). When the MP transmissions were measured the mounting was modified to incorporate an electrically controlled rotator which enabled the yagi to be rotated axially from horizontal through vertical to horizontal. There was no significant interaction between yagi and mast.

4.2.2 Horizontal components

Fig. 6 compares the field strengths of the HP components received from the old HP and new MP transmissions at the same locations. The results shown are based on the average field strengths of all three radiated programmes (Frequencies 89.1, 91.3 and 93.5 MHz).

The average reduction in HP field was 1.2 dB which compares with the reduction calculated from the theoretical patterns of 1.3 dB. At 94% of the locations measured the reduction was less than 6 dB. Much of the scatter in the field-strength results shown on Fig. 6 is due to the change of antenna height and mast position. The increased signal on bearings between 260 and 290 degrees ETN demonstrates the advantage of the increased height in directions where receiving antennas are screened by hills.

4.2.3 Polarization of received signal

At each point at which field strengths were recorded, the field strengths of the HP and VP components were measured by rotating the receiving antenna between HP and VP. The antenna was also rotated to the angles at which maximum and minimum values of the signal were obtained and these values and angles were noted.

Even in those directions towards which Wrotham radiated truly circular polarization, the received polarization was elliptical rather than circular. This was due to ground reflections and obstacles along the propagation paths altering the the phase and amplitude of the received signal components.

Taking into account the propagation paths and variation between the radiated HP and VP components with direction, it would be expected that on average the received polarization would be elliptical with maxima in random directions. Examination of the results showed that although this tended to be the case there was a bias towards the maximum field being near the horizontal. The maxima were within 10 degrees of horizontal at 28% of points measured: at only 12% of points were the minima near horizontal.

The average improvement a listener could gain by rotating his receiving antenna from horizontal to the maximum was only 1.6 dB. At only 16% of the points measured was the ratio of maximum relative to the horizontal signal more than 2.5 dB. The received HP components were, on average, 0.6 dB stronger than the VP components.

4.2.4 Discussion

The received signal from the nominally circularly polarized transmission was rarely truly circular and thus any advantage to be gained by the use of circularly polarized receiving antennas is minimal. Only in exceptional circumstances is it worth mounting a fixed linearly-polarized rooftop receiving antenna other than horizontally (perhaps when screened by buildings where there may be standing wave effects, or to null out horizontally polarized interference). The great majority of fixed installations with external HP antennas will have experienced negligible change to their received signal.

4.3 Reception in cars

4.3.1 Equipment used

The car receiving antenna used for the tests was a normal offside wing mounted telescopic whip

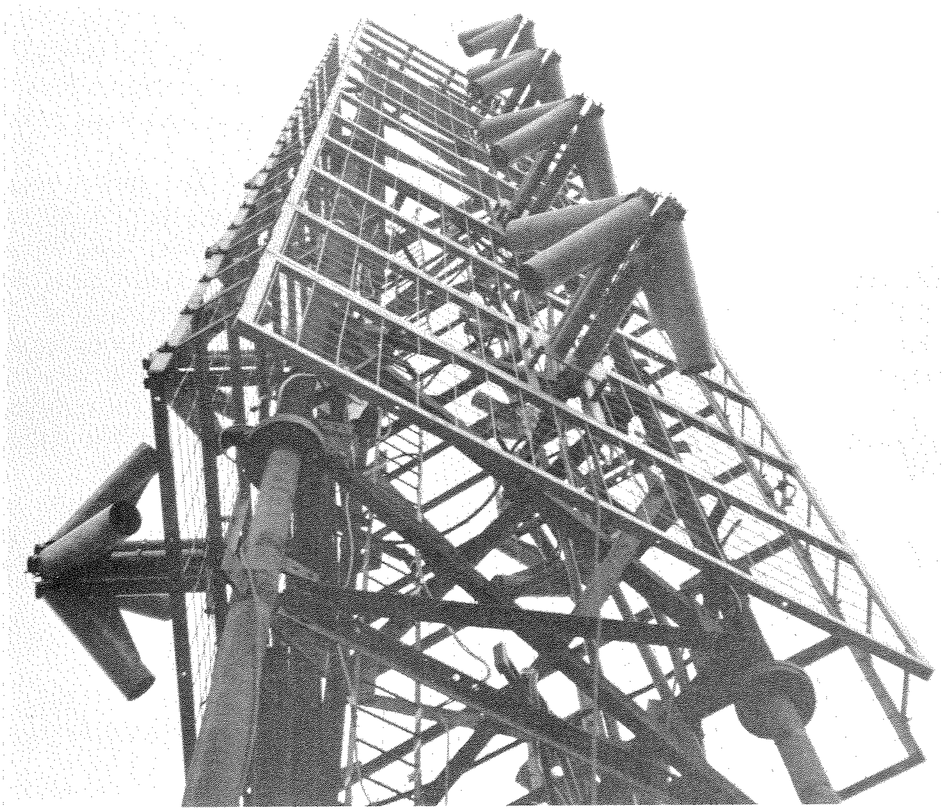

Fig. 2 – Four tiers of the Wrotham mixed polarized antenna under test at works.

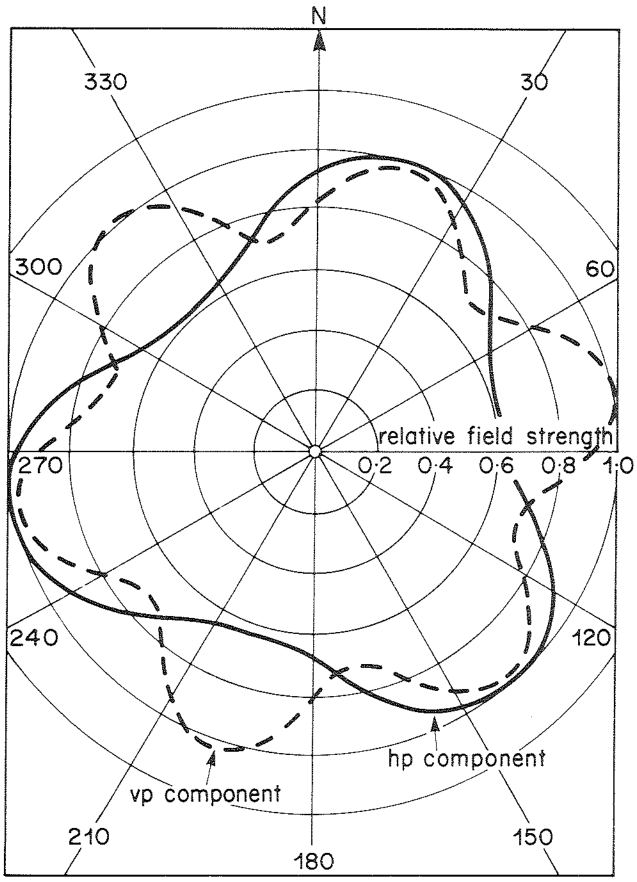

Fig. 3 – Polar diagram of the mixed polarized antenna at Wrotham (89.1 MHz) showing the difference between the HP and VP components.

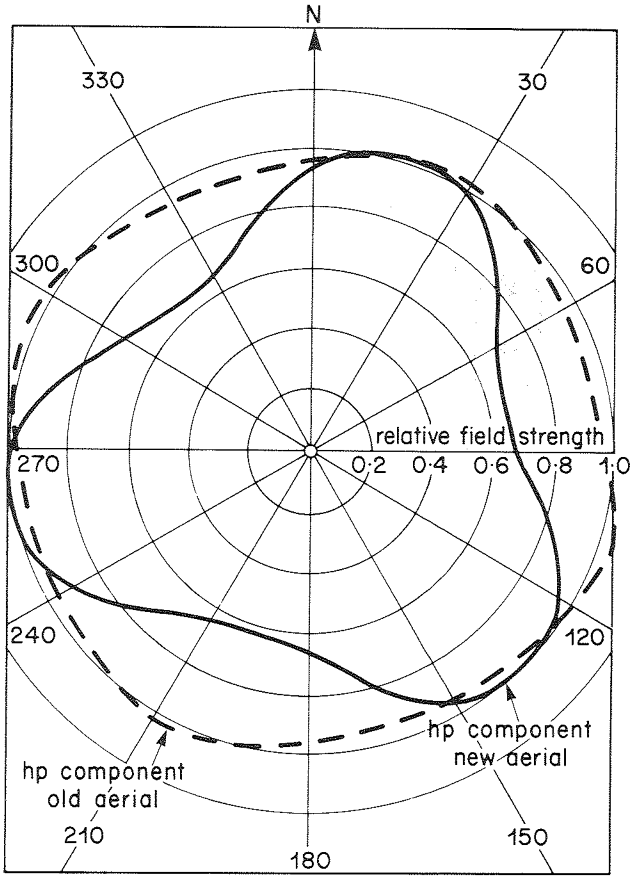

Fig. 4 – Horizontally polarized polar diagrams at 89.1 MHz of the old HP and the new MP antennas at Wrotham.

antenna. Reception was compared with that of similar antennas on different cars and it was considered to be typical of its type. Polar diagrams of the antenna, measured by rotating the car on a turntable illuminated with appropriately polarized signals are shown in Fig. 7: there was significant variation with frequency, particularly for the HP case.

A continuous recording of the signal strength could be made with a chart recorder and the signals were also recorded on an automatic statistical analyser which produced output data in the form of signal strength for percentage distance.

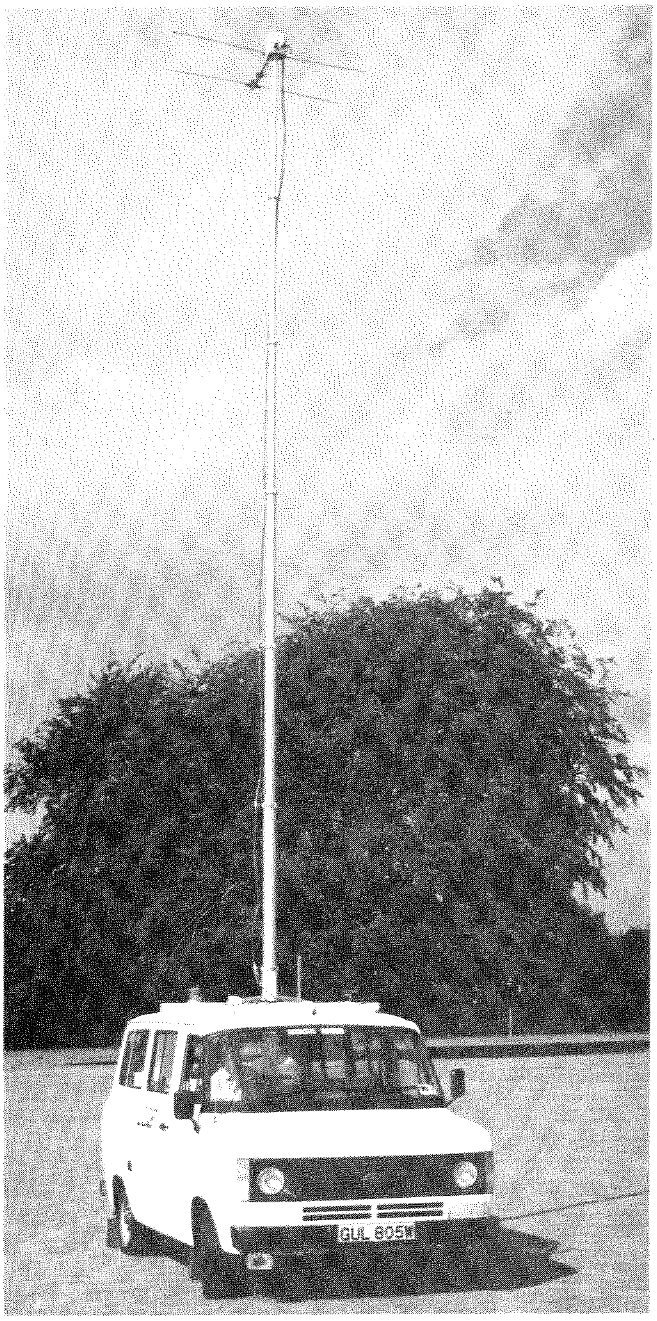

Fig. 5 – Measuring vehicle with two-element yagi mounted on 10 m extendable mast.

4.3.2 Signal strength

Fig. 8 summarises the results of the measurements made before and after re-engineering using the offside wing mounted whip antenna.

The routes were graded in terms of median signal strengths which were measured over distances of about 1 km. The limit of service signal strength was taken as 30 dB rel. 1 microvolt measured across the receiver input. This signal strength gave just adequate monophonic reception on the car radio receiver used to monitor audio quality bearing in mind that the receiver had to cope with signal flutter above and below the mean value.

The average signal increase due to re-engineering from HP to MP, noting that the transmitter power had been almost doubled (+ 3 dB), was as follows:

Rural areas	11 dB
Suburban areas	8 dB
Urban areas	7 dB

Thus the advantage gained by the change of polarization alone is between 4 and 8 dB for mobile reception in cars.

5. Multipath interference measurements in the Wrotham area

5.1 General

Multipath interference occurs when a reflected signal interferes with the direct signal from the same transmitter[10-17]. Its subjective effect is related to both the difference in amplitude between the two signals and the time delay between them. The latter is of course related to the difference in path length between the signals.

Following the re-engineering of Wrotham from HP to MP, despite generally much-improved reception, a few reports were received of increased multipath interference to car radio reception. Initial checks revealed that the problems were limited to fairly restricted areas. Tests were therefore carried out to assess the causes of this increased multipath and to locate the sources of the reflections.

5.2 Equipment used

The Band II measuring receivers used are fitted with a cathode ray tube which displays received signal amplitude variation against frequency deviation. Using this, it is possible to measure the path delay and the relative amplitudes of the direct and

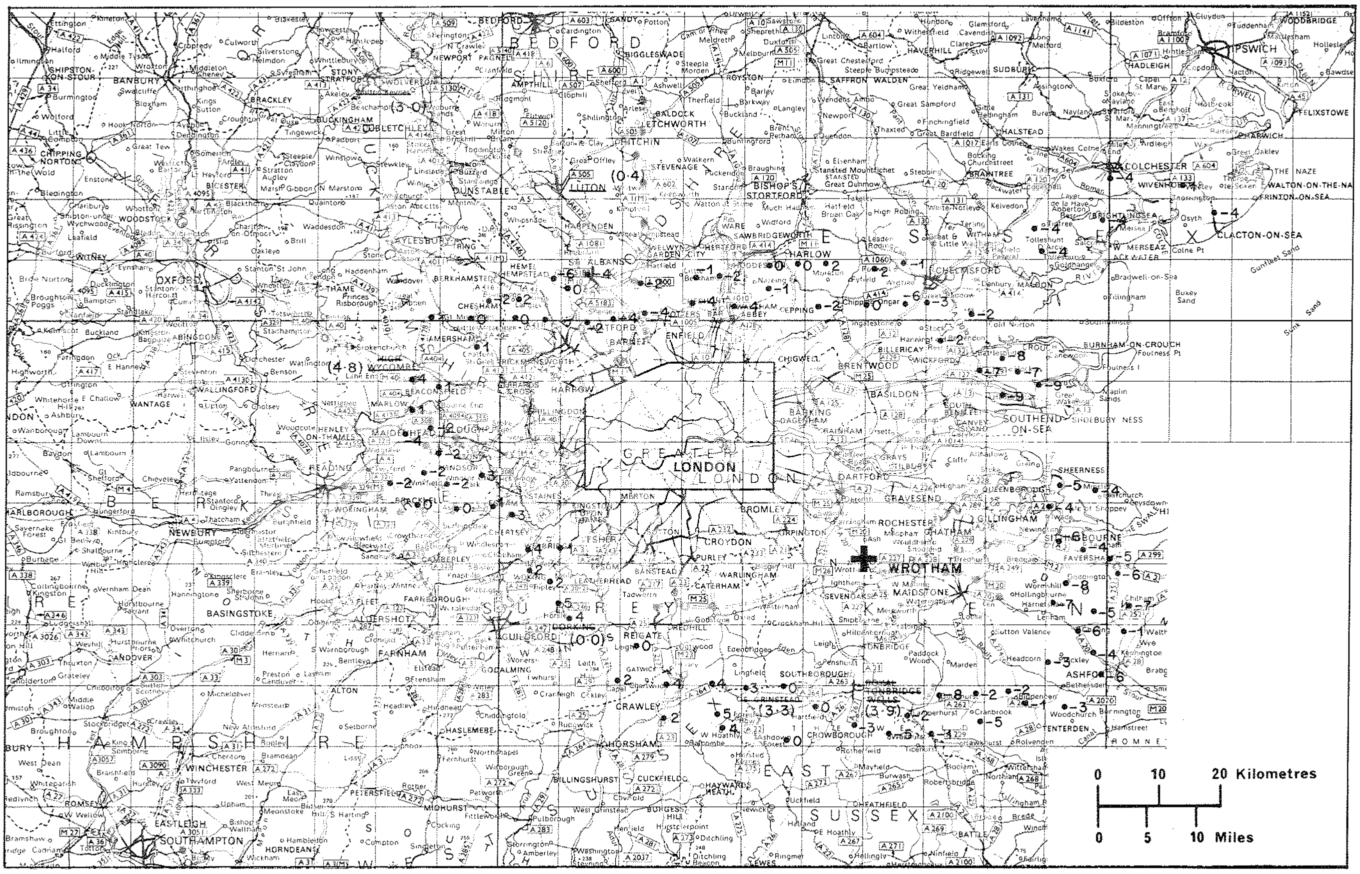

Fig. 6 – Increase in level of received HP component from Wrotham following re-engineering (measured at 10 m a.g.l.).

Map Key

● –2	Ratio of received horizontally polarized components, after : before re-engineering (dB) (Average of all three radiated frequencies)
Town (3·9)	Overall average of the town (dB)

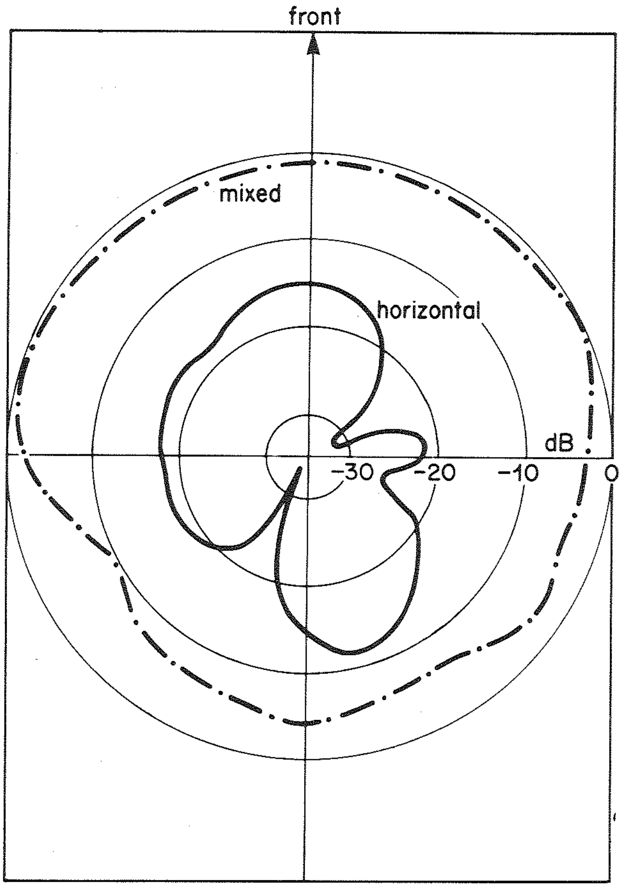

Fig. 7 – Polar response of wing mounted car radio antenna to horizontal and mixed polarizations.

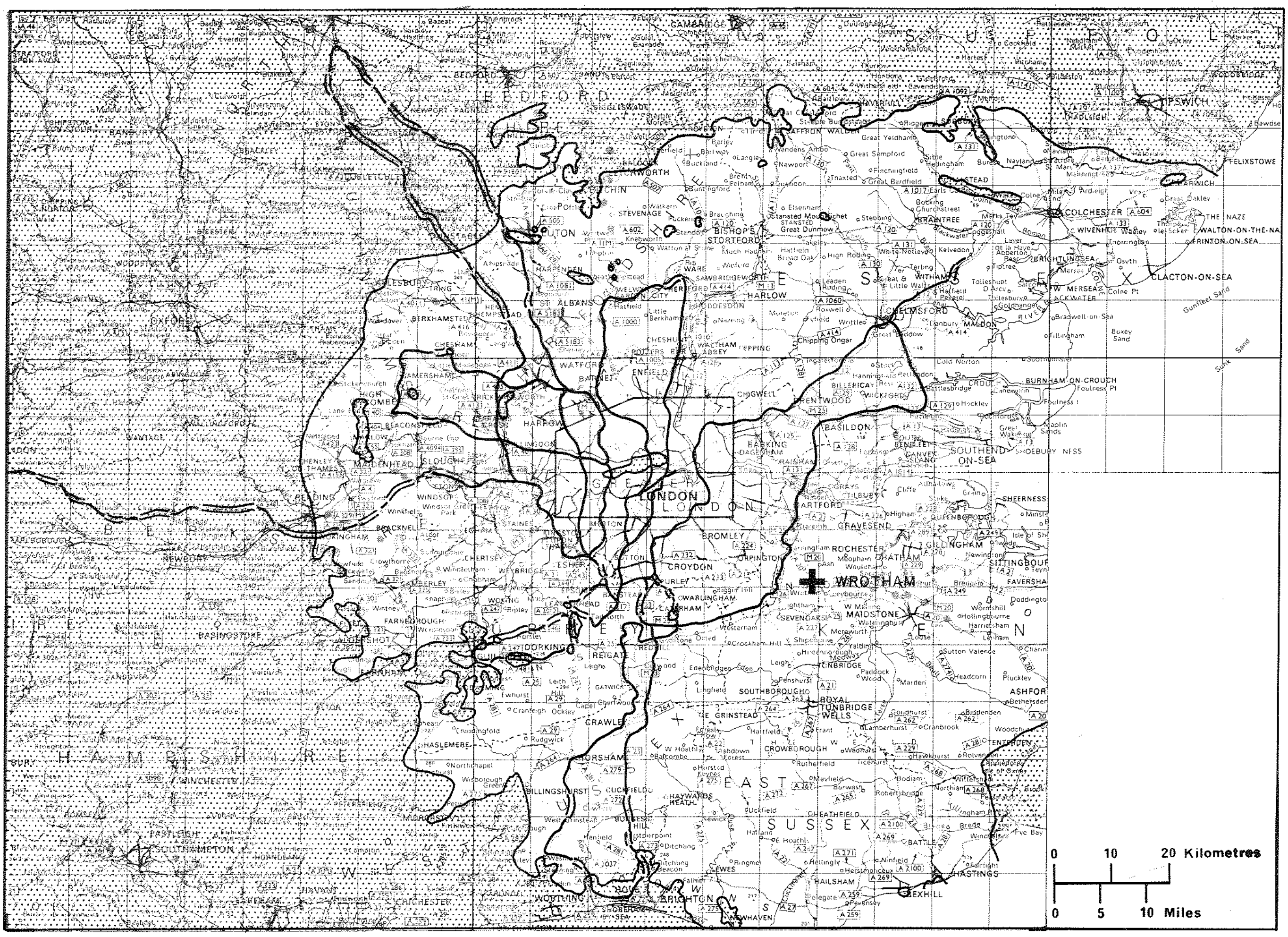

Fig. 8 – Route covered during the car radio reception tests. The sections of road, shown as double lines, illustrate the extension of car radio coverage brought about by the re-engineering of Wrotham to mixed polarization. The unshaded area is the area in which good stereo domestic reception can be obtained using a rooftop antenna.

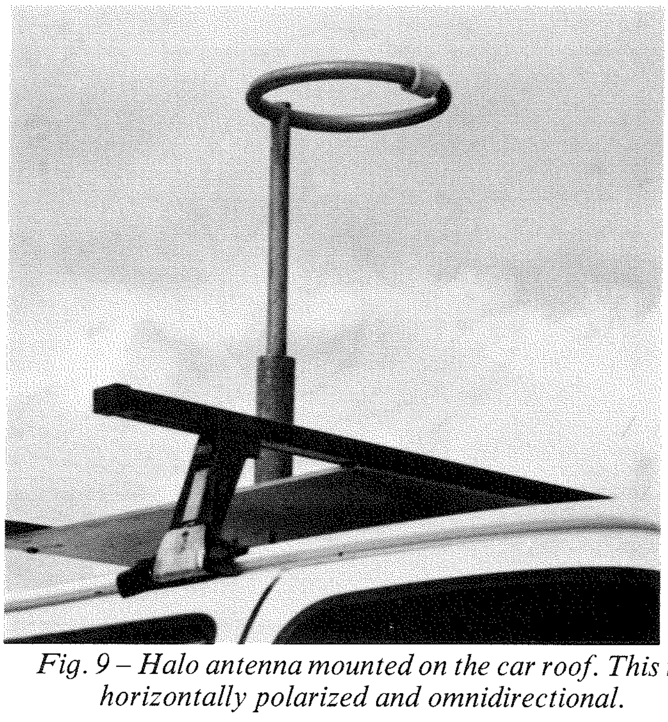

Fig. 9 – Halo antenna mounted on the car roof. This is horizontally polarized and omnidirectional.

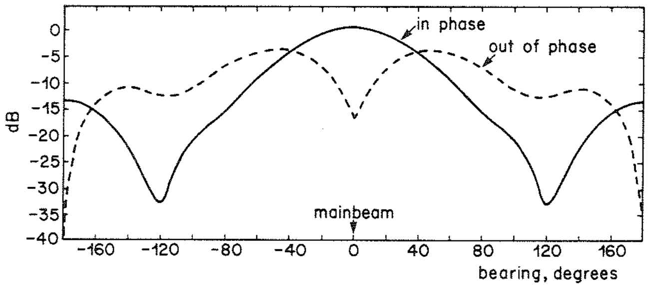

Fig. 10 – Horizontal radiation pattern of receiving antenna consisting of two, two-element yagis, operated in and out of phase (93.5 MHz). The anti-phase condition introduces a notch in the centre of the main lobe.

reflected signals. Better accuracy is obtained if the transmission is modulated to a high deviation with a low frequency tone, or better still, a low frequency sawtooth waveform, rather than normal programme. 130 Hz tone was optimum for the receivers used and in the later tests 130 Hz sawtooth waveform modulation was found to provide the most satisfactory trace on the receiver display.

Measurements were made outside programme hours with the Radio-3 transmitter feeding Wrotham's old HP antenna, whilst the Radio-4 transmitter fed the new mixed polarized antenna.

Both directional and omnidirectional receiving antennas were used. The omnidirectional antennas were a car roof mounted halo (see Fig. 9) and a quarter wave whip, also mounted on the car roof.

The directional antenna consisted of two, two-element yagis spaced 1.8 metres apart on a horizontal boom. The two yagis could be rotated between horizontal and vertical polarization. Their outputs could be combined together either in phase or in antiphase. The antiphase condition produced a deep notch which could be used to null out a signal from a particular direction (see Fig. 10).

With the directional antenna it was possible to measure the path difference and direction but, because of the complex polar diagram, not the relative amplitudes of the signals. The omnidirectional antennas could be used to measure path difference and relative amplitude, but not of course, direction.

5.3 Reflection points

Fig. 11 shows the locations from which reflections appear to originate in the London area. The measurements were made with the omnidirectional antennas and the plots are ellipses of equal path delay.

Fig. 12 shows ray paths derived using the directional antennas to determine the incident direction and path difference.

The ellipses clearly converge on the tall buildings of central London, and the position of this convergence is backed up by the results from the directional antenna.

The buildings reflect both HP and VP components. In most, but not all cases, the VP components were the stronger. It is interesting to note that tests carried out later on individual isolated tall buildings were unable to distinguish differences in reflection between polarizations.

The accuracy of the path delay measurements was equivalent to about 1 km path difference and hence it was not possible to resolve reflections from specific buildings. However there was no evidence to suggest that any one specific building was a dominant source of reflections, but more that the source was the general mass of buildings in central London.

A maximum of the VP component from the new MP antenna at Wrotham (Fig. 3) points towards central London (About 315 degrees ETN from Wrotham). This has the effect of increasing the relative strength of the reflections, particularly when they are received in locations where the direction of the direct ray is in a minimum of the antenna's VP polar diagram. Whilst this problem must be considered when designing MP transmitting antennas, in the specific case of London the antenna orientation maximises the VP component along some of the more important motorway routes out of London, and of course in central London, to give much improved reception in the area.

In contrast Fig. 13 shows multipath reflections in the Horsham area. This time the main reflections were from the surrounding hills rather than from buildings. The reflection points and the level of multipath changed with polarization and receiving point. But this time neither polarization was worse than the other.

5.4 Discussion

Multipath problems are not due to a single cause but are due to a number of factors in combination.

Firstly, there must be significant attenuation of the direct signal. For example, the worst areas of multipath interference in southern London are screened from Wrotham by hills.

Secondly, the problem areas must be exposed to reflections from buildings or hills which themselves must be illuminated by a strong signal from the transmitter. The worst areas in London have an unobstructed view of tall buildings in the city centre and the VP polar diagram of the Wrotham antenna has a maximum towards central London over an unobstucted path.

Multipath causing audible distortion to the received signal is normally from reflections having a path difference of several kilometres. Multipath received from much shorter distances produces standing waves in the received field. These produce

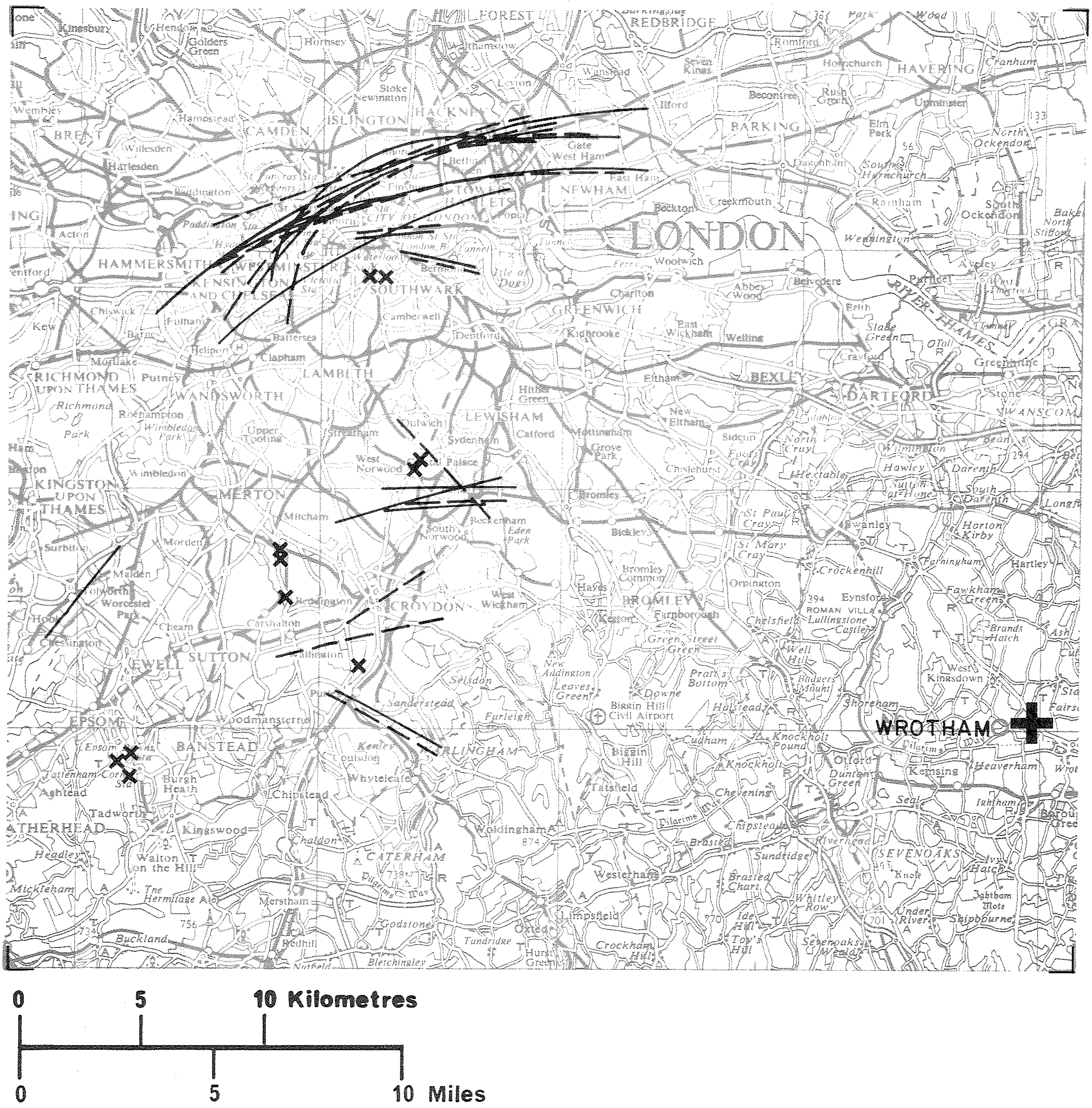

Fig. 11 – Reflections from London; derived from results measured with an omnidirectional antenna and plotted as ellipses of equal path delay.
Receiving locations are marked with an 'X'.

Map key

———	Horizontally polarized transmission: vertically polarized omnidirectional receiving antenna
— — —	Mixed polarized transmission: vertically polarized omnidirectional receiving antenna
✖	Receiving locations

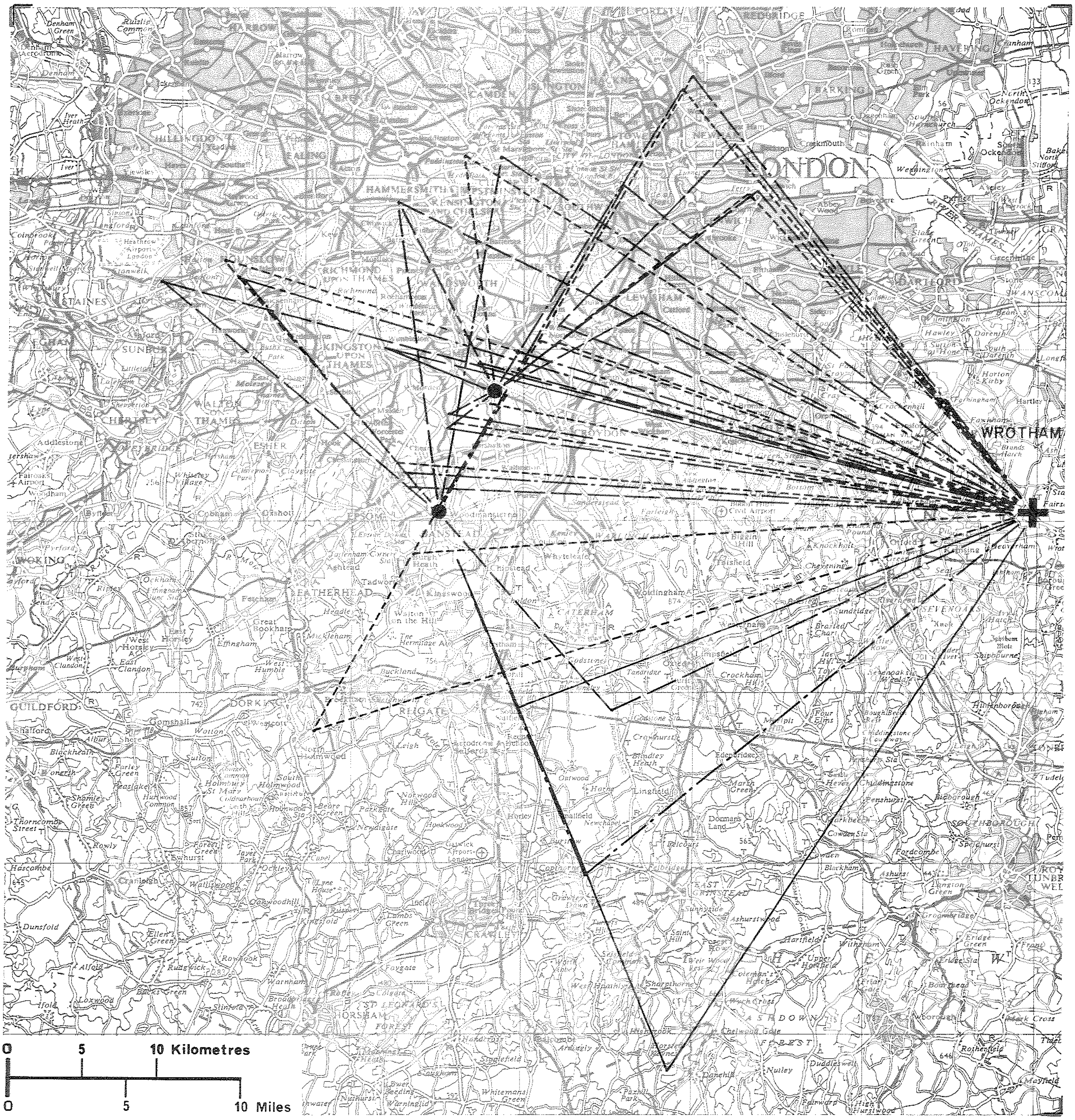

Fig. 12 – Reflections from London **using** *a directional receiving antenna and plotting ray paths.*

Map key

— —	Horizontally polarized transmission: horizontally polarized receiving antenna
———	Horizontally polarized transmission: vertically polarized receiving antenna
—·—	Mixed polarized transmission: horizontally polarized receiving antenna
- - - - -	Mixed polarized transmission: vertically polarized receiving antenna

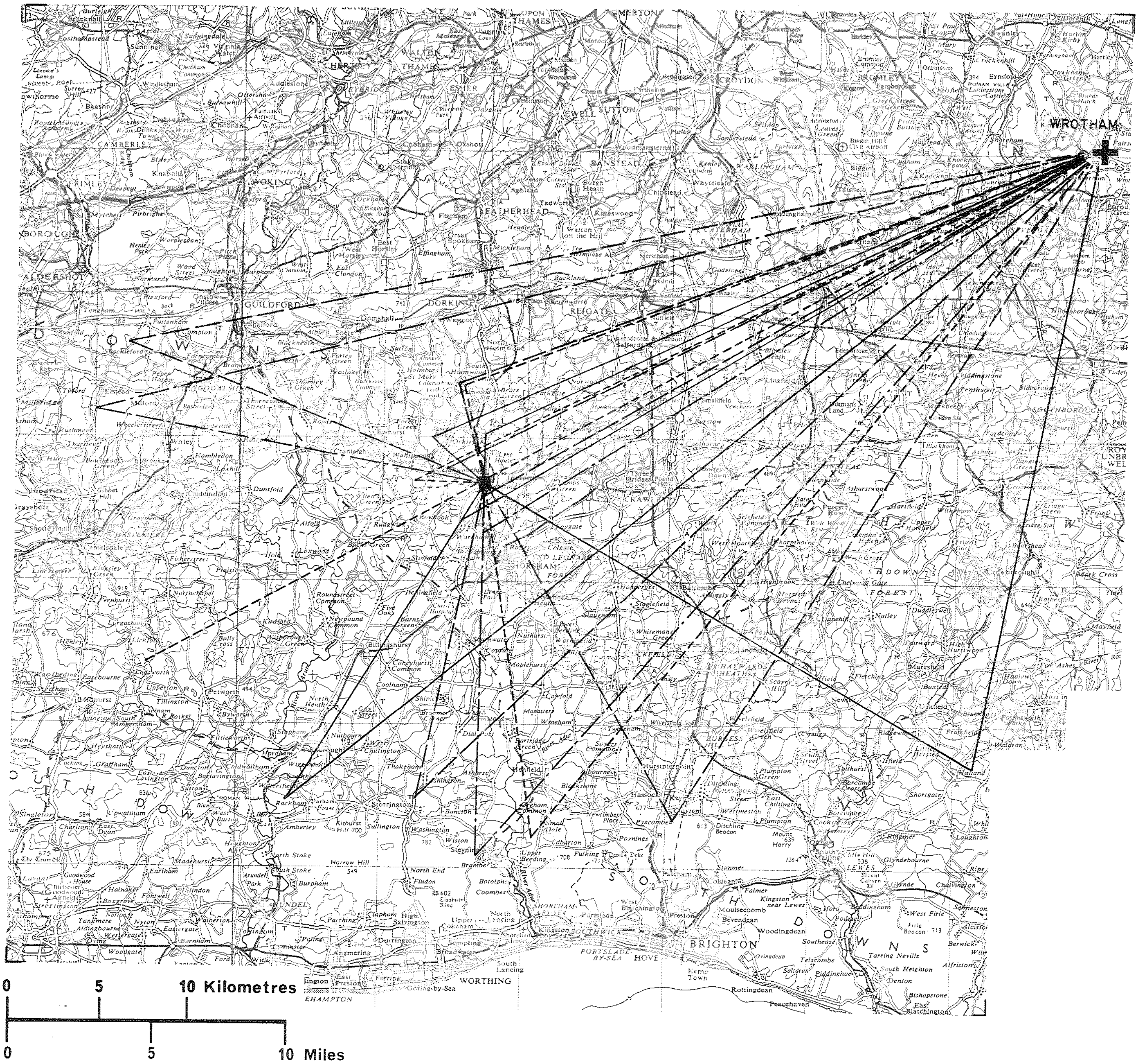

Fig. 13 – Reflected ray paths in the Horsham area.

Map key

— —	Horizontally polarized transmission: horizontally polarized receiving antenna
——	Horizontally polarized transmission: vertically polarized receiving antenna
—·—	Mixed polarized transmission: horizontally polarized receiving antenna
-----	Mixed polarized transmission: vertically polarized receiving antenna

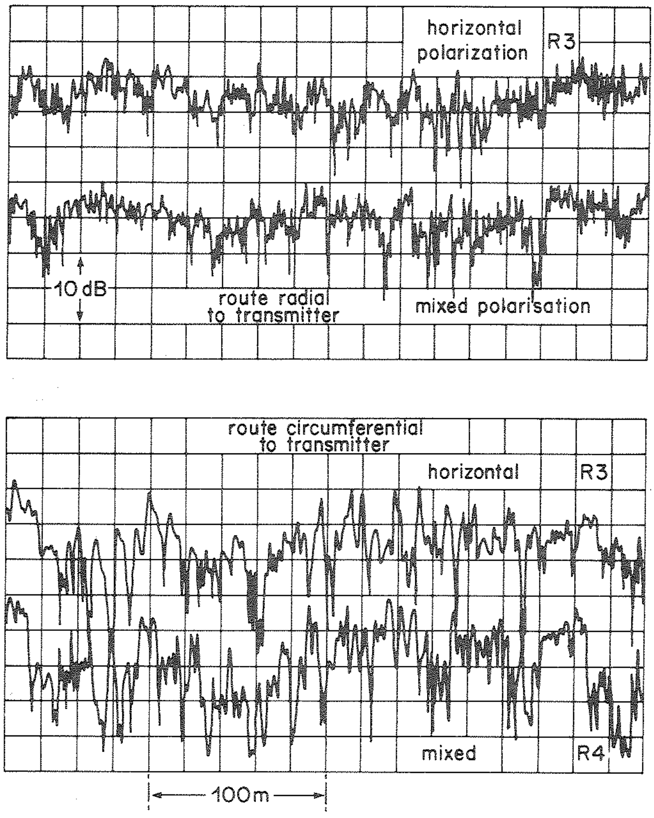

Fig. 14 – Flutter in urban areas received on HP Halo antenna.
Note how the frequency of the flutter is higher on radial routes.
To separate the two traces the level of the mixed polarized signal was attenuated by approximately 15 dB.

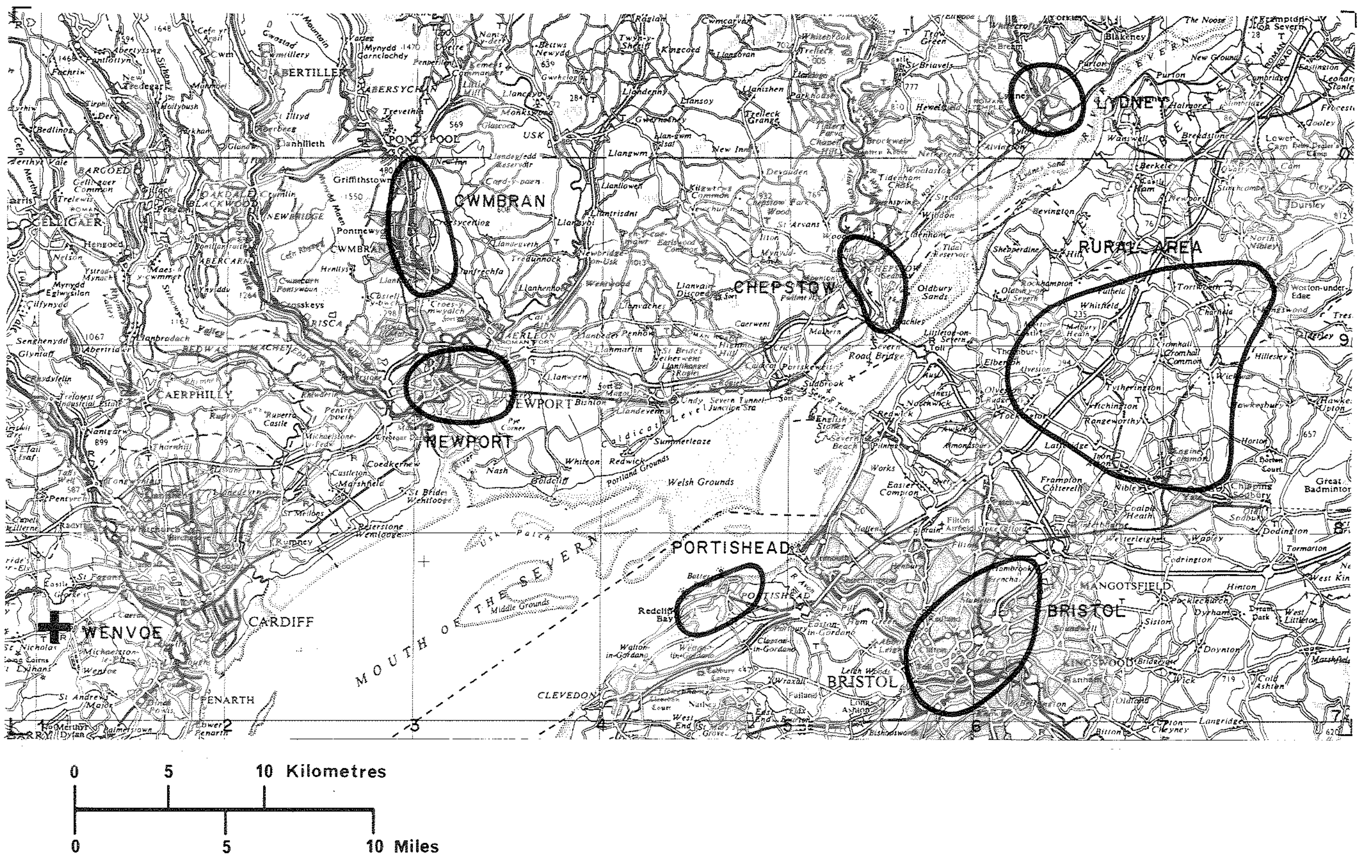

Fig. 15 – Areas in which measurements were made during the Wenvoe tests.

low frequency variations of the signal received in a moving vehicle. This effect is known as 'flutter'. Fig. 14 shows chart recordings of flutter recorded in the London area. The frequency of the flutter depends upon the change in path length between reflected and direct rays and thus flutter received along radial routes tends to be about twice the frequency of that received on circumferential routes. Note also the deep signal strength variations on the circumferential route as the car moved behind local obstacles.

The effects of flutter on distortion cannot be ignored. The audio distortion from longer distance multipath is much more noticeable in areas of greatest flutter because the effect of the long distance multipath is enhanced when the vehicle is in the minima of a standing wave.

The tall buildings of central London generally give the effect of reflecting VP more strongly than HP, although other measurements on isolated tall buildings showed no significant difference. In the more rural Horsham area both polarizations were reflected with equal intensity and mainly from the hills.

Overall, the benefits given by improved car reception and greater coverage considerably outweigh the slightly increased multipath found in some areas. It may be that antenna diversity receivers, now being produced by some manufacturers, will go some way towards eliminating these multipath problems, since there is a major asset of a much stronger signal with mixed polarization available in the multipath areas.

6. The Wenvoe Experiment

6.1 General

Whilst the overall results of the Wrotham tests were most encouraging, they left an area of doubt in terms of the effects of re-engineering to MP in other areas already known to be subject to severe multipath interference and with low field strengths.

The nature of the terrain in south Wales and the West Country makes VHF-FM reception, particularly at low antenna heights, highly variable. It was therefore decided to conduct further reception tests in part of this area covered by the Wenvoe transmitter near Cardiff. Fig. 15 shows the areas selected for measurement.

6.2 Equipment

Separate HP and VP transmitting antennas were provided, each fed by its own transmitter. The antennas were directional and had similar polar diagrams (see Fig. 16).

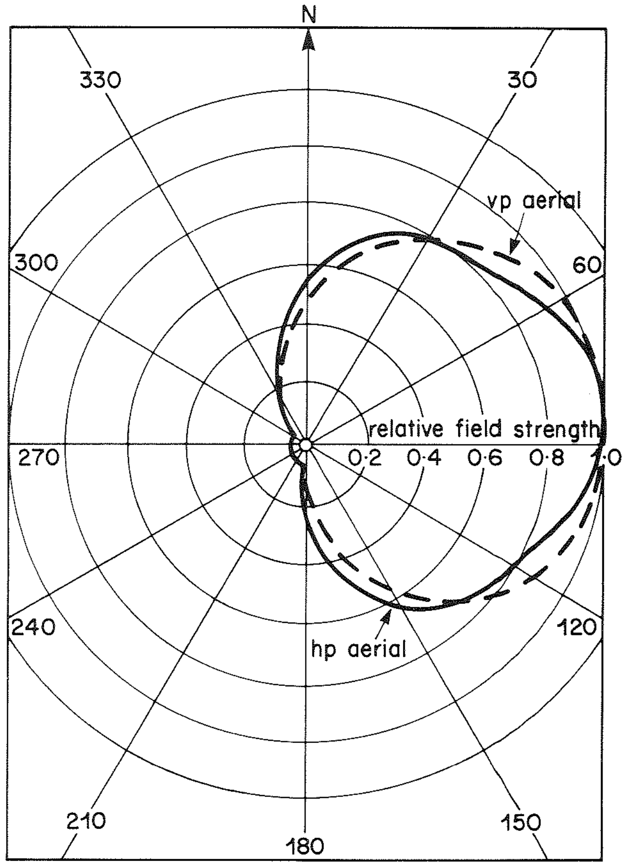

Fig. 16 – Polar diagrams of the HP and VP transmitting antennas used for the Wenvoe tests.

Transmissions on 103.1 MHz were frequency modulated by a low frequency sawtooth waveform to drive the multipath display on the receivers used. By alternately switching on and off the respective transmitter drives the polarization of the transmitted signals was switched between HP and VP at five minute intervals. This allowed effects due to radiating closely matched HP and VP components to be measured completely separately, which was not possible in the Wrotham tests.

Four different receiving antennas were available:

(i) Car wing mounted telescopic whip aerial.
(ii) Roof mounted halo aerial (omnidirectional).
(iii) Roof mounted quarter wave vertical whip (omnidirectional).
(iv) Two element yagi aerial mounted on a 10 metre mast and which could be rotated from HP to VP (see Fig. 17).

Measurements were made with a Hirschmann RPM 2000 A AM/FM test receiver. This receiver

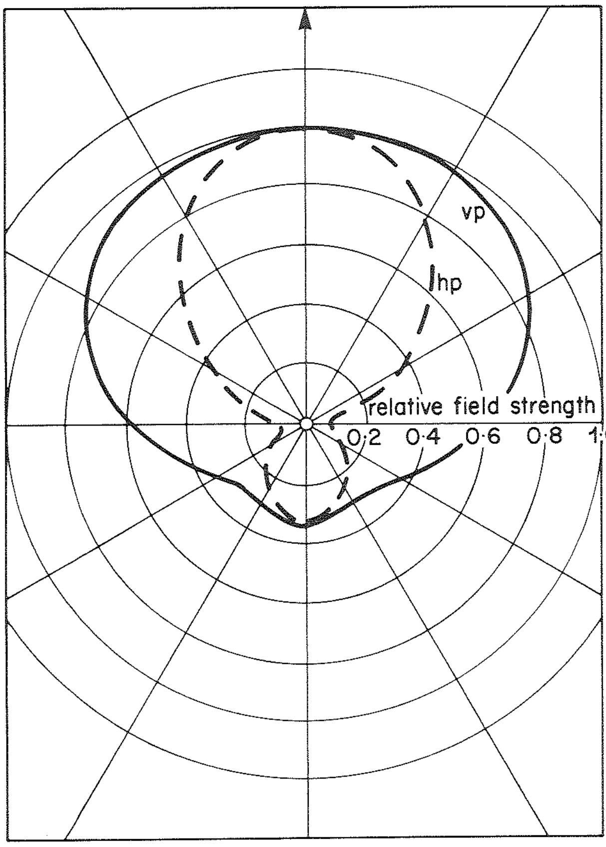

Fig. 17 – HP and VP polar diagrams of a two-element yagi antenna.

These are the patterns of the antenna used for the Wenvoe measurements at 10 m a.g.l. Note how the beamwidth of the HP pattern is about half that of the VP. The antenna is thus much better at rejecting interference when used for HP.

had not been available for the Wrotham tests: its main advantage is an improved method of measuring multipath interference (described later).

6.3 Field strength measurements

Table 1 lists the average field strengths in each area and the overall averages for the following four conditions:

(a) Two element directional antenna at 10 metres a.g.l.: HP transmitting and receiving antennas.
(b) Two element directional antenna at 10 metres a.g.l.: VP transmitting and receiving antennas.
(c) Omnidirectional (halo) antenna at 2 metres a.g.l.: HP transmitting and receiving antennas.
(d) Omnidirectional (whip) antenna with base at 1.6 metres a.g.l.: VP transmitting and receiving antennas.

The results for 10 metres a.g.l. show a difference between HP and VP of 2 dB, VP being the stronger.

	10 m a.g.l.		2 m a.g.l.	
	HP (a)	VP* (b)	HP (c)	VP* (d)
Cwmbran	56.4	60.0	48.5	52.2
Newport	70.8	73.2	56.4	60.5
Chepstow	62.9	63.0	52.1	53.8
Rural area	58.0	60.5	44.1	48.4
Portishead	62.1	65.0	51.3	55.3
Lydney	52.7	53.1	39.6	43.2
Bristol	52.2	53.8	38.1	43.5
Average**	58.5	60.5	45.8	50.0

Table 1: Averages of Measured Field Strengths dB (μV/m)

*The VP field strengths have been adjusted to correct for the small differences in the HP/VP transmitting antenna polar diagrams (see Fig. 16).
**The results are based on measurements at a total of 132 locations.

Most of the measurements were made in areas where the signal had been diffracted and the results agree with earlier work[18] which indicates that VP signals are more readily diffracted over hills. However, Ref. 19 shows that this difference can vary widely, and the conclusion reached there, was that signals of both polarizations propagate equally well.

At 2 metres a.g.l. the results show an average difference of over 4 dB. This would be expected partly because of diffraction enhancement and partly from the enhancement of VP relative to HP near the ground. At 2 metres a.g.l. Ref. 20 predicts the latter enhancement to be about 2 dB.

The antennas used were calibrated relative to a dipole. It is therefore possible to derive height gain figures (see Table 2).

Area	HP	VP
Cwmbran	7.9	7.8
Newport	14.4	12.7
Chepstow	10.8	9.2
Rural area	13.9	12.1
Portishead	10.8	9.7
Lydney	13.1	9.9
Bristol	14.1	10.3
Average	12.3	10.1

Table 2: Average Height Gain (dB) 2 m to 10 m a.g.l.

The VP transmissions have less height gain because of the better VP/HP ratio near the ground (see Table 1).

It is important to know how reception on a typical wing mounted car whip antenna (mid-point 1.6 metre a.g.l.), compares with reception on the car roof antennas. Table 3 lists this comparison.

	Field/Signal Strength dB(μV/m)*			
	HP		VP	
Area	Halo (centre roof)	Car antenna*	Whip (centre roof)	Car antenna*
Cwmbran	48.5	38.6	52.2	51.3
Newport	56.4	49.7	60.5	58.6
Chepstow	52.1	43.7	53.8	51.6
Rural area	44.1	38.1	48.4	44.8
Portishead	51.3	43.3	55.3	52.7
Lydney	39.6	33.0	43.2	42.0
Bristol	38.1	34.1	43.5	41.2
Average	45.8	39.6	50.0	47.8

Table 3: Received Signal for HP and VP Transmissions

**The halo and whip antennas were calibrated on the vehicle with respect to a $\lambda/2$ dipole at the same height and the figures refer to the measured field strengths. On the other hand the wing mounted car antenna was uncalibrated and was not omnidirectional, particularly when receiving HP (see Fig. 7). For the purpose of these comparisons it was assumed to have the same gain and feeder loss as that of the roof mounted vertical whip.*

	Multipath %/kHz	
Area	HP	VP
Cwmbran	3.2	5.6
Newport	1.0	1.3
Chepstow	2.8	3.1
Rural area	1.6	2.3
Portishead	4.2	6.2
Lydney	2.7	5.0
Bristol	2.1	3.5
Average*	2.54	3.86
Standard deviation	2.6	3.2

Table 4: Average levels of multipath distortion at 10 m a.g.l.

**Total number of measurements 135.*

The figures show that, for VP transmissions, the signals from the $\lambda/4$ whip on the car roof were 2 dB stronger than those for the wing antenna. VP produced 8 dB more output from the wing antenna than did HP transmissions.

6.4 Multipath interference measurements

6.4.1 The measurement of multipath distortion

Measurements were made with the Hirschmann RPM 2000 A AM/FM test receiver. According to the manufacturers of this receiver tests have shown that the maximum rate of change of RF carrier amplitude during frequency deviation has a direct relationship to the subjective audio distortion caused by multipath interference. The receiver is designed and calibrated to measure this rate of change directly from a multipath display on a cathode ray tube, i.e. a display with f.m. deviation on the X-axis and received signal amplitude on the Y-axis. This rate of change is measured as % change of amplitude per kHz of frequency deviation (%/kHz).

Although further work is needed, listening tests during the Wenvoe experiment tended to confirm the relationship between %/kHz and multipath distortion. The approximate limits were 2%/kHz for acceptable stereo reception and 6%/kHz for mono.

6.4.2 Results – Multipath (10 metres a.g.l.)

Measurements were taken with the two-element yagi rotated axially to the correct polarization. Table 4 shows the multipath levels recorded.

Multipath was worse for the VP case partly because the polar diagram of the receiving antenna (Fig. 17) is much wider for VP than when the same antenna is mounted horizontally. These higher levels of multipath can be expected because of this lower antenna directivity.

6.4.3 Results – Multipath (car antennas)

The results of measurements made using omnidirectional car roof antennas are summarised in Table 5.

The VP multipath distortion was slightly higher. This suggests that the VP signals were more readily reflected than HP: but the effect is small.

Measurements made with the wing mounted car antenna are summarised in Table 6. In this case the average level of multipath distortion is slightly better for VP, but the difference is not significant.

Area	Multipath interference %/kHz	
	Halo (HP)	λ/4 vertical whip (VP)
Cwmbran	4.6	5.6
Newport	2.3	3.3
Chepstow	5.9	7.5
Rural area	3.4	3.7
Portishead	6.9	7.3
Lydney	7.2	9.1
Bristol	4.6	5.4
Average*	4.98	5.98
Standard deviation	1.66	1.95

Table 5: Car-roof reception with correctly polarized omnidirectional antenna
** Total of 135 measurements*

Area	Multipath interference %/kHz	
	HP transmission	VP transmission
Cwmbran	6.4	5.5
Newport	3.3	4.5
Chepstow	7.4	8.8
Rural area	5.8	5.3
Portishead	7.8	7.2
Lydney	9.5	9.3
Bristol	6.4	5.9
Average*	6.42	6.23
Standard deviation	3.99	3.82

Table 6: Wing mounted car radio antenna reception
**Total of 135 measurements.*

6.5 Summary and discussion of results of the Wenvoe experiment

(a) On average, at 10 metres a.g.l. the VP signal is 2 dB stronger than the HP signal. It is 4 dB stronger at 2 metres a.g.l. over a car roof.

(b) The average height gain between a car roof antenna at 2 metres a.g.l. and an antenna at 10 metres a.g.l. is 12 dB for HP, 10 dB for VP: a value of 11 dB would seem to be a sensible value to use for the general case.

(c) For VP transmission the signal output of the wing antenna is 2 dB less than that produced by the vertical whip on the car roof.

(d) For the same transmitted power, received with a car wing aerial, VP has an 8 dB advantage over HP.

(e) Multipath distortion is between 1%/kHz and 2%/kHz worse at 10 metres a.g.l. for the VP case when correctly polarized receiving antennas are used. Some of this difference is due to the wider polar diagram of the VP receiving antenna. With omnidirectional receiving antennas on the car roof, VP transmission also produced slightly more multipath than HP. No significant difference can be detected between the two polarizations with the wing mounted antenna. Overall VP signal reflections tend to be slightly greater than those which are HP, but the difference is small.

7. Conclusions – choice of polarization

To conclude it is useful to review and compare horizontal, vertical and mixed polarized transmissions.

Horizontal polarization (HP)

The main advantage of using horizontal polarization is the better directivity of rooftop receiving antennas and the consequent improved ability of these antennas to reject interference.

The important disadvantage is that HP is much less suitable than VP for most forms of car* and portable receiving antennas.

Vertical polarization (VP)

In the absence of interference, vertical polarization is undoubtedly the best choice for Band II broadcasting. Not only is it the optimum choice for low receiving antenna heights, cars‡ and portables, but for fixed installations VP works equally as well as HP.

The disadvantages become apparent when consideration has to be given to the effects of interference. In particular, fixed installations need to be able to provide stereophony of the highest quality

* However, rear window demisters which also act as receiving antennas have recently been introduced on some cars and these appear to respond much more effectively to HP signals than do wing-mounted vertical whips[21].

‡ The response of a car demister antennas to VP signals appears to be comparable to that of a wing-mounted whip.

and this brings greater demands for interference rejection. A VP receiving antenna has a much broader polar diagram in azimuth than the same antenna mounted for HP (a ratio of 2 : 1 for a two-element antenna) and is consequently less able to reject interference away from the direction of the wanted signal. Multipath interference is worse but rarely disastrously so in the United Kingdom.

Mixed polarization (MP)

Mixed polarization caters for both HP reception at fixed installations and reception of the VP component in cars and on portable receivers. Portables inside buildings tend to respond to a combination of partially depolarized HP and VP components.

The disadvantage of MP is the extra transmitter power required and the complexity of the transmitting antenna. This complexity is compounded when one considers the increased wind loading and the consequent mast strength requirements.

When, as in the UK, an existing horizontally polarized network is nearing the end of its equipment life and is being re-engineered, there is much advantage to be gained by changing to Mixed Polarization. This improves coverage and and encourages the growth of VHF-FM listening in cars and on portables, whilst retaining the horizontal component in those areas where interference (including multipath) to fixed installations could be lessened by the use of HP receiving antennas.

Where a VHF-FM network is being established for the first time, the optimum solution is vertical polarization with the option to add a horizontal component in those areas where interference to fixed installations could be lessened by the use of HP receiving antennas.

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