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Narrow-band f.m. system for television links: tests of performance under conditions of multipath propagation

N.H.C. Gilchrist, B.Sc., C.Eng., M.I.E.E.

Research Department, Engineering Division
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NARROW-BAND F.M. SYSTEM FOR TELEVISION LINKS: TESTS OF PERFORMANCE UNDER CONDITIONS OF MULTIPATH PROPAGATION

N.H.C. Gilchrist, B.Sc., C.Eng., M.I.E.E.

Summary

Mobile transmitters have a number of uses in television outside broadcasts; examples are found in the coverage of horse-racing, where a television camera mounted on a moving road vehicle provides close-up pictures of competitors, and also at golf tournaments and boat-races, where helicopters have been used to carry cameras. Multipath propagation can often result in severe distortion of the received signal, and, with mobile applications, it is not always possible to avoid multipath problems at all the locations to be visited by the mobile unit during any particular event. It is thus important that any modulation system for use with mobile links should be tested under the multipath conditions which it may encounter.

This Report, one of a series of four, describes tests conducted using an experimental narrow-band f.m. system developed for use with Band V television links. The tests were carried out using a mobile transmitter and a stationary receiver in a location which has given severe multipath distortion when used for outside broadcasts in the past. It was concluded that the performance of the narrow-band system in respect of multipath susceptibility is at least as good as that of the conventional wide-band system.

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G.G. Gouriet

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1. Introduction

In order to try and reduce problems of mutual interference between television f.m. link equipment and television a.m. broadcast signals in Band V, experimental work has been conducted on a narrow-band or v.s.b. (vestigial-sideband) f.m. television system to replace the existing d.s.b. (double-sideband) system which is used for Band V links. The earlier experimental work has shown[1] that it is possible to restrict the bandwidth of the f.m. television signal to 8 MHz, using a vestigial-sideband technique, with only a small increase in non-linear distortion, compared with that of the existing double-sideband system operating in a bandwidth of 16 MHz. It has also been established[2,3] that the narrow-band (v.s.b.) f.m. system is less sensitive to adjacent-channel interference than the conventional full-bandwidth (d.s.b.) system.

The work described in this Report was conducted in order to compare the performance of the narrow-band (v.s.b.) and full-bandwidth f.m. systems under conditions where severe multipath distortion is experienced. This involved operating a mobile radio link at Newbury Racecourse, where the appropriate severe conditions have been found during outside-broadcast events.

2. Experimental arrangement

The tests were conducted with the Band V transmitter in the Colour Roving Eye vehicle (a modified Citroen Safari) operating at full bandwidth, with a carrier rest frequency of 849 MHz. At the receiving site, a helical Band V aerial on the roof of the grandstand was panned to follow the transmitting vehicle and the signal received was fed by cable down to a radio link vehicle containing receivers and monitors. Two receivers were fed with the signal from the aerial; one was a conventional, full-bandwidth (d.s.b.) receiver, and the other was modified for narrow-band (v.s.b.) operation. The two received pictures were displayed on adjacent colour and monochrome picture monitors.

The modifications to the receiver for narrow-band use consisted of inserting an 8 MHz bandpass filter in the i.f. channel (together with an equaliser to compensate for some of the group-delay distortion introduced by the filter) and following this with a limiter. An amplitude limiter was already built into the receiver, but the extra limiter was included to ensure full limiting, as the success of the v.s.b. technique depends upon good limiter action. Fig. 1 shows a block schematic diagram of the equipment added to the receiver i.f. section, and also the extra units added after demodulation to correct for frequency-response distortion of the video signal. A spectrum analyser was used to check the action of the filter and limiter modifications, and the spectra obtained are shown in Fig. 2. At (a) is shown the spectrum obtained at the output of the receiver's i.f. amplifier. For conventional (d.s.b.) operation, this signal would be applied directly to the input of the limiter/demodulator unit. After v.s.b. filtering, the signal shown at (b) was obtained. The action of the extra limiter restores, to a large extent, the sidebands removed by the filter so that the spectrum shown at (c) is obtained, and this signal is returned to the receiver for further limiting and demodulation. As the limiter regenerates the higher-order sidebands at a rather lower level[1] than was present in the original full-bandwidth signal, a loss of amplitude occurs at the higher video frequencies and video amplitude equalisation is necessary to compensate for this.

A map of the race-course site is shown in Fig. 3. The Roving Eye vehicle was driven, for these tests, along the normal route used during race meetings. This consists of a straight run along the south side of the course, outside

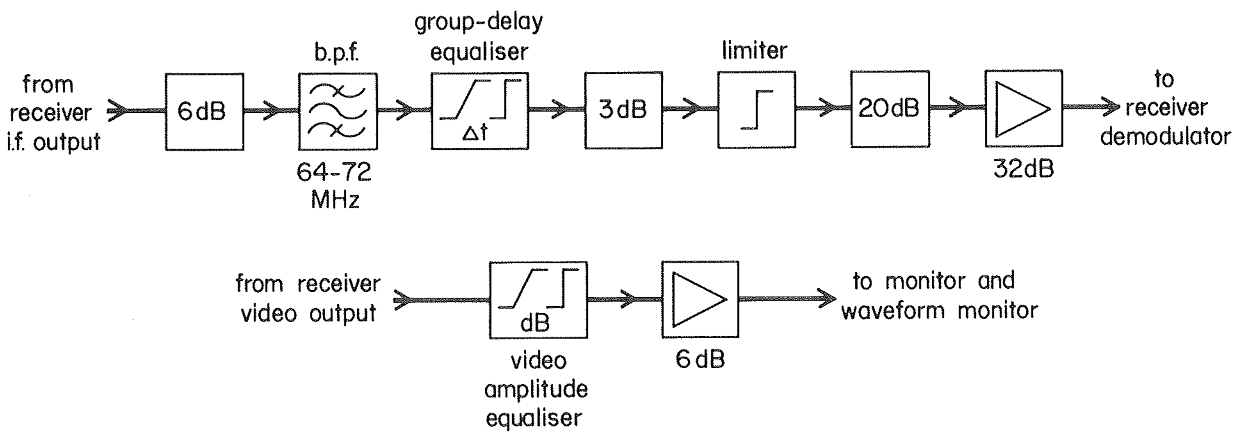
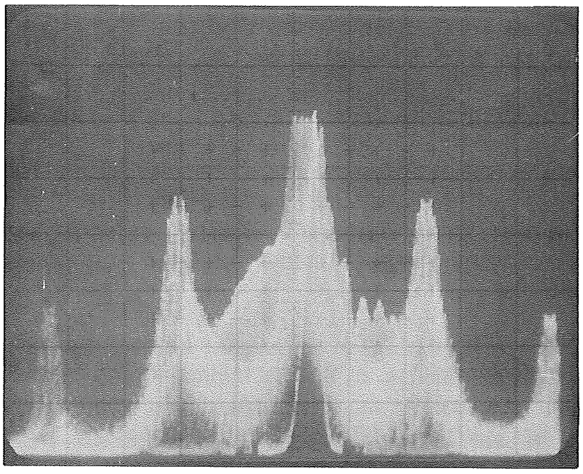
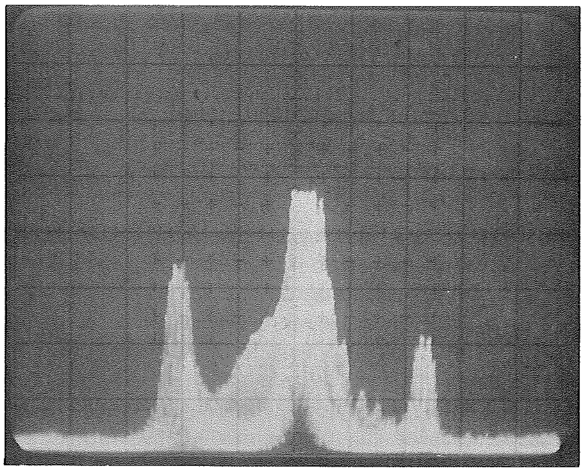


Fig. 1 - Experimental arrangement: v.s.b. conversion units for v.s.b. link receiving equipment



(a)

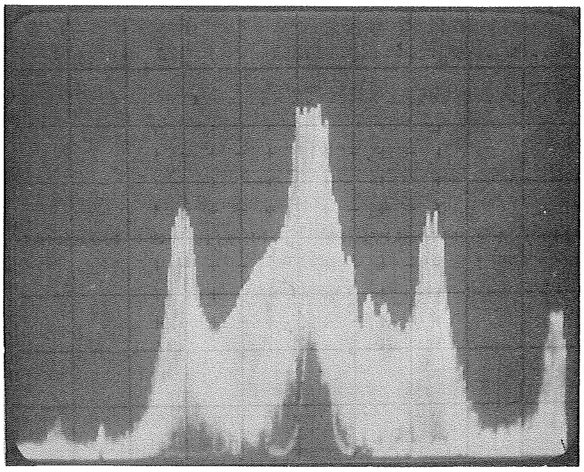


(b)

Fig. 2 - Spectrum of the f.m. signal at various points in the receiving equipment

(*a*) Spectrum at output of receiver i.f. amplifier
(*b*) Spectrum at output of v.s.b. filter
(*c*) Spectrum of v.s.b. signal after limiting

Vertical scale: 10 dB per major division
Horizontal scale: 2 MHz per major division



(c)

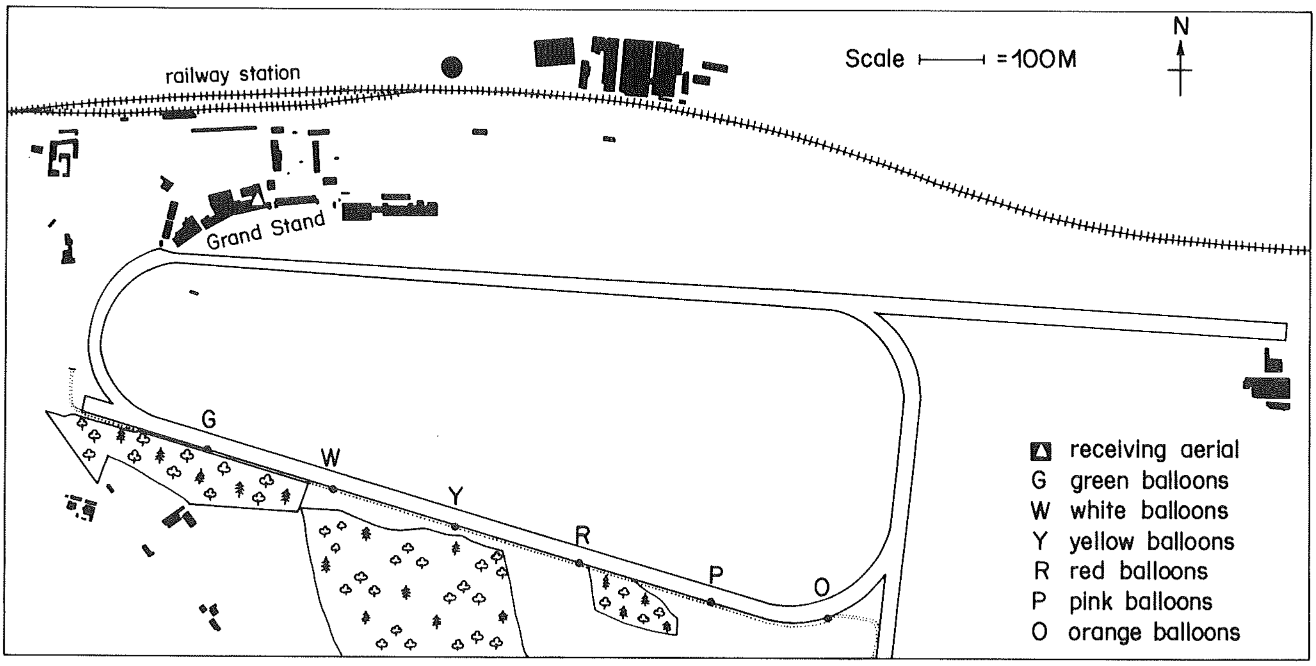


Fig. 3 - Map of the race-course

Fig. 4 - The Colour Roving Eye vehicle

the track. Coloured balloons were secured to the course rails at 200-metre intervals, and these were used by the observers in the radio link receiving vehicle to identify the location of the Roving Eye from the mobile camera pictures whilst tests were in progress.

The Colour Roving Eye vehicle, a modified Citroen Safari, is shown in Fig. 4. Electric power for the technical equipment was provided by a petrol generator contained in the trailer.

3. Descriptions of tests and results

The initial tests involved carrying out several runs along the south perimeter track of the race-course in order to determine the worst areas for multipath propagation so that special attention could be given to the performance of the radio link in these areas. The most severe multipath effects occurred between the start (south-west corner of the course) and the green balloons. From the green balloon to the white balloons there was a progressive improvement, and then the pictures were substantially free from any serious disturbance up to the end of the run (by the orange balloons). For the most part, the path-differences between the direct and reflected signals were apparently very short, because the principle effect was one of deep carrier fades, rather than the appearance of discrete, displaced images.

A 2" quadruplex-head videotape recorder (type VR 3000) was available during the early part of the tests, and four of the test runs were recorded for subsequent study and demonstration. The Colour Roving Eye was fitted initially with a vertically-polarised omnidirectional transmitting aerial, and a test run carried out with a slow drive from the start to the green balloons and a normal speed run to the end of the track whilst the output of a full-bandwidth (d.s.b.) receiver was recorded on video tape. This test run was immediately repeated, but with a narrow-band (v.s.b.) receiver feeding the videotape recorder.* The omnidirectional transmitting aerial was then replaced with a horizontally-polarised 6-element yagi aerial which incorproated a mesh screen reflector behind the dipole to give improved front/back ratio in the radiation pattern, and the test run repeated firstly with the output of the v.s.b. receiver fed to the recorder, and then with the d.s.b. receiver feeding the recorder.

The results obtained using the omnidirectional aerial showed that both the d.s.b. and the v.s.b. systems suffered very severe impairment in the region of the start and green balloons. Loss of picture synchronism occurred repeatedly with both systems, although the v.s.b. system appeared to suffer slightly fewer complete collapses of synchronism, and the periods of picture loss appeared to be shorter. Loss of colour saturation occurred at times with both systems. Towards the end of the test runs, shortly after the Roving Eye passed the pink balloons, the signal received on the d.s.b. receiver appeared to fade down to the f.m. improvement threshold (corresponding to a carrier-to-noise ratio of about 10 dB at the input to the receiver's demodulator) and stay in this region for one or two seconds. The coarse, granular noise characteristic of the threshold condition was visible, but synchronism was retained and the videotape recorder remained locked so that the phenomenon was recorded. When the run was repeated using the v.s.b. system, there was no evidence of threshold noise.

When the omnidirectional aerial was replaced by a 6-element yagi aerial, multipath effects were greatly reduced. The v.s.b. system exhibited the symptoms of spasmodic threshold operation, with only one or two very brief instances of loss of synchronism in the worst area of multipath (from the start to the green balloons). In contrast, the d.s.b. system showed considerably more complete losses of synchronism in this area.

A number of test runs were conducted to try and identify the cause of the multipath propagation. The Roving Eye vehicle was driven along the south perimeter track with the camera pointing away from the receiving aerial, so that the television picture received at the grandstand showed the landscape directly behind the transmitting aerial whilst the test was in progress. It was difficult to draw any definite conclusions from this aspect of the tests, except that the worst conditions were obtained when the Roving Eye was passing a dense plantation of coniferous trees. Open fields and natural woodland (which was much less dense than the planted trees) did not introduce significant multipath. Reflections from houses behind the trees did not seem to be affecting results, either.

One interesting experiment, which was conducted with the Roving Eye vehicle stationary, consisted of rotating the receiving aerial to see whether any strong signals

* Although d.s.b. and v.s.b. reception was available simultaneously in the link receiving vehicle, the limiter performance of the d.s.b. receiver was inferior to that of the v.s.b. receiver. All recordings were therefore made from the v.s.b. receiver which was restored to d.s.b. operation, by removing the v.s.b. adaptor units and video equaliser, when required.

TABLE 1

	Transmitting Aerial	F.M. System	Description of Results
Line-up	Omnidirectional (v.p.)	D.S.B.	Colour Roving Eye stationary. Colour bars for checking equipment.
1	Omnidirectional (v.p.)	D.S.B.	Colour saturation errors and loss of synchronism at start. Threshold noise effects after passing pink balloons
2	Omnidirectional (v.p.)	V.S.B.	Colour saturation errors and loss of synchronism at start. No threshold effects after passing pink balloons
3	6-element yagi (h.p.)	V.S.B.	Occasional, brief losses of synchronism at start with some fading to threshold (without loss of synchronism) before reaching green balloons
4	6-element yagi (h.p.)	D.S.B.	Frequent losses of synchronism at start with severe patch approaching green balloon

could be detected coming from reflections behind the grandstand (e.g. from the gasholder just to the north-east of the receiving aerial). There did not appear to be any significant reflected signal from this direction, but it was found that, as the level of the received signal fell, the signal received on the d.s.b. receiver failed before that from the v.s.b. receiver. In fact, a recognisable picture could be received on the v.s.b. receiver when the d.s.b. receiver had lost the incoming signal below the f.m. threshold. When the v.s.b. receiver was converted back to d.s.b. operation, the picture was lost in noise, and was restored again by re-converting the receiver to v.s.b. operation.

4. The results recorded on videotape

This section is intended mainly as a guide for those able to view the pictures recorded by the videotape recorder during the early part of the tests, although the results are of wider interest. The ability to replay the recordings several times since the tests at Newbury has assisted greatly in the interpretation of results and the evaluation of the performance of the v.s.b. system. In particular, the fact that the d.s.b. system suffered from threshold noise effects during parts of the test run, in which the v.s.b. system was obviously above the f.m. threshold, was noticed during study of the recorded pictures after the field tests. From theoretical considerations, it would be expected that the carrier-to-noise ratio obtained with a system operating in only half of the bandwidth of the conventional system would be 3 dB higher, at the same field strength.

One undesirable feature of videotape recording, is that, as a result of momentary loss of synchronism during recording, periods can occur during replay when the machine has to regain synchronism before it can continue satisfactorily. The effect of this is to exaggerate the worst features of the multipath distortion somewhat. Neverhteless, the use of videotape for this work has proved invaluable.

Table 1 shows the contents of the videotape. Total running time is about 14 minutes, comprising 4 minutes of colour bars followed by 10 minutes of test recordings.

5. Conclusions

The tests of the narrow-band (v.s.b.) and full-bandwidth (d.s.b.) f.m. systems under conditions of multipath propagation have shown that the performance of the v.s.b. system is no worse than that of the conventional d.s.b. system. Observers in the radio-link receiving-vehicle were of the opinion that, in some of the conditions encountered, the v.s.b. system could give slightly better results than the d.s.b. system.

A study of the results recorded on videotape indicates that the reason for the slightly more favourable performance of the v.s.b. system lies in its reduced bandwidth. During deep fades (caused by the reflected u.h.f. signal tending to cancel the direct signal) the received carrier level drops to within a few decibels of the f.m. improvement threshold (sometimes known as the 'noise threshold'); with the narrow-band system, the threshold occurs at a carrier level 3 dB below that for the threshold in the full-bandwidth system. As the threshold represents the limit of operation for an f.m. system, the full-bandwidth system must fail at a receiver input level 3 dB higher than the narrow-band system. It should be understood that this extension of the threshold is the only respect in which the narrow-band system exhibits a noise advantage; the signal-to-noise ratio of the demodulated video signal when both systems are operating above the threshold is actually slightly worse for the narrow-band system.[1]

6. Acknowledgements

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link and vehicle facilities for the tests described in this Report.

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