REPORT 1067

IMPROVEMENT OF THE RECEPTION QUALITY IN AUTOMOBILES FOR FREQUENCY MODULATION SOUND BROADCASTS IN BAND 8 (VHF)

(Question 49/10)

(1986)

1. Introduction

There are major difficulties in achieving high-quality reception of FM sound-broadcasting signals in a moving automobile. Severe signal drop-outs may be experienced by the receiver as the vehicle encounters a continously changing multipath receiving environment. At high vehicle speeds, these drop-outs appear as short staccato-like bursts of noise. At lower speeds, losses of programme are replaced by noise created by two completely different effects. In cases of non-selective fading caused by short-distance multipath propagation, the receiver attempts to compensate for a diminished signal level. In cases of selective fading, caused by long distance mulipath propagation, the distortions appear similar to a strong modulation-dependent noise. The rate of drop-out occurrences is usually random, with the greatest incidence occurring in urban areas where numerous buildings may shadow or reflect the transmitted radio signals. The incidence of the selective fade-out is additionally dependent upon topography.

2. Non-selective fading

2.1 *Diversity reception*

Theoretical studies and field measurements were carried out in the United States of America in order to determine the multipath characteristics for band 8 (VHF) sound-broadcast transmissions. As a result of these studies two major conclusions were reached. Firstly, it was determined that the probability of a signal drop-out occurring during the itinerary of a vehicle may be represented approximately by the well-known Rayleigh probability distribution. Secondly, it may be possible to achieve a considerable improvement in quality of reception by mounting two antennas on the vehicle to provide space diversity reception in a selection combining mode.

A classical technique for dealing with the problem of audio reception of fading signals is the use of diversity reception. Diversity is typically achieved by the combined (or alternate) use of two or more receiving elements. Any of several diversity modes may be employed: frequency (more than one channel), polarity (antenna with different polarization), or space. The last mode is especially attractive for automobile reception since it promises great benefit with no change of broadcasting standards.

Typically, space diversity systems have utilized antennas placed many wavelengths apart, usually ten wavelengths or more. Such spacing is not possible on an automobile where the overall length of the vehicle may be typically less than 1.5 wavelengths at band 8 broadcast frequencies. However, for correcting a drop-out, it has been observed that the movement of a vehicle over only a short distance (approximately 1 m) usually results in a completely adequate improvement in reception. This observation provided the rationale for investigating how effectively space diversity reception might be employed in an automobile.

The theoretical study based on actual field measurements and computer processing of the data has confirmed that significant improvement of FM radio reception can be achieved; Fig. 1 illustrates this. The upper chart shows a representative plot of relative field strength along a line in space from 0-14 m. The downward fluctuations are of varying severity and may or may not result in audible drop-outs, depending on station power, distance of the vehicle from the transmitter, and receiver sensitivity. The lower chart illustrates the degree of signal uniformity which would be achieved if a 2.8 m space diversity antenna system were used. (The vehicle shown is drawn to the distance scale of the chart.) It is easy to perceive how a radio receiver, automatically selecting the better output from one of the two antennas, can maintain an optimum signal level as both antennas are moved in tandem along the distance scale.

2.2 *Measurements and analysis*

A number of measurements were made on various streets and highways in New York City and surrounding suburban areas. A test vehicle with a single antenna connected to a data recorder was used to monitor the changing RF signal envelope as a function of vehicle speed. Computer sampling and processing of the data was later accomplished to predict what degree of improvement might be achieved by the use of two receiving antennas instead of one. Figure 2 represents the average system performance of the diversity reception for an antenna separation of 2.6 m for a constant value of probability, arbitrarily chosen to be 1.0%. Included in this chart is the reference curve for Rayleigh fading which appears as a diagonal line for the case of a single antenna ($m = 1$).

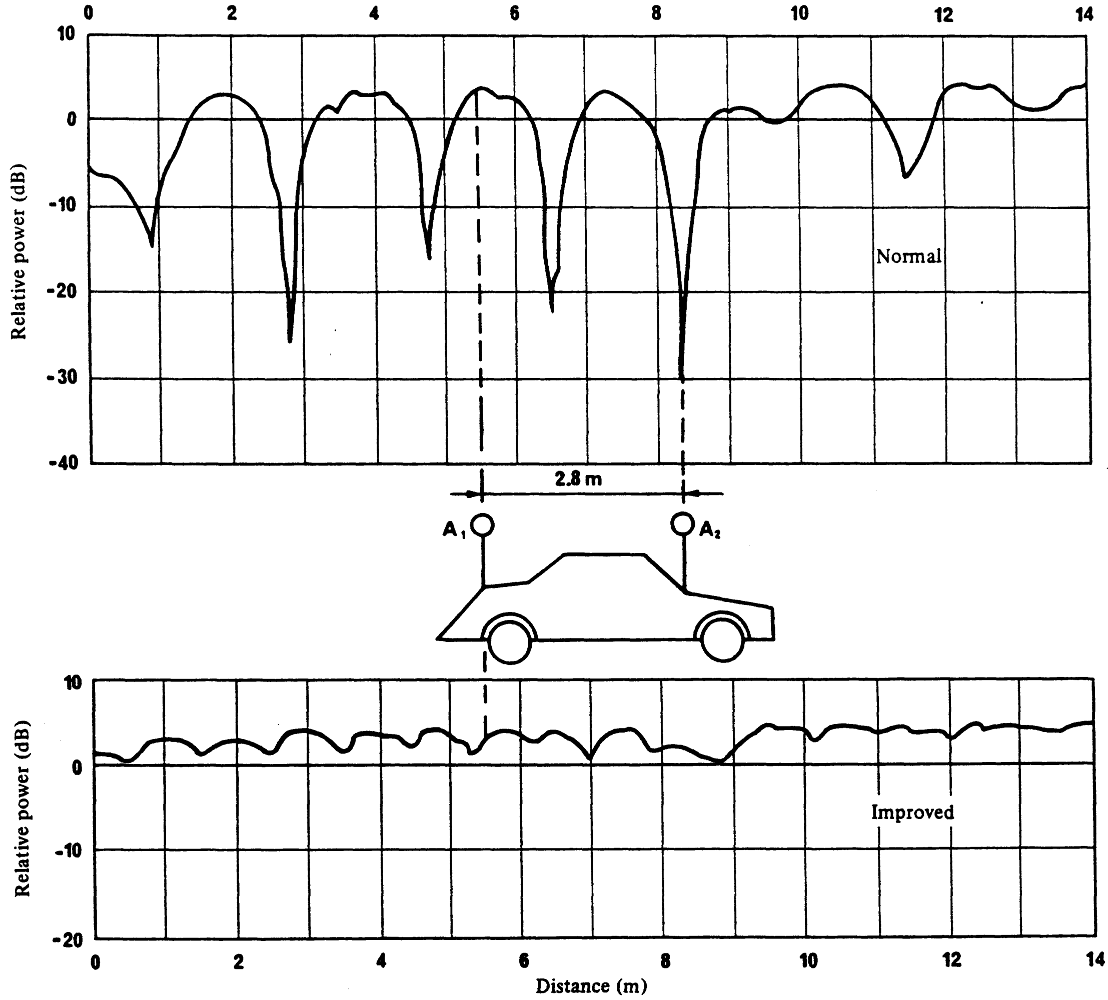

FIGURE 1 – *Fading of FM carrier as a function of distance (above) and resultant FM carrier using space diversity and selection combining*

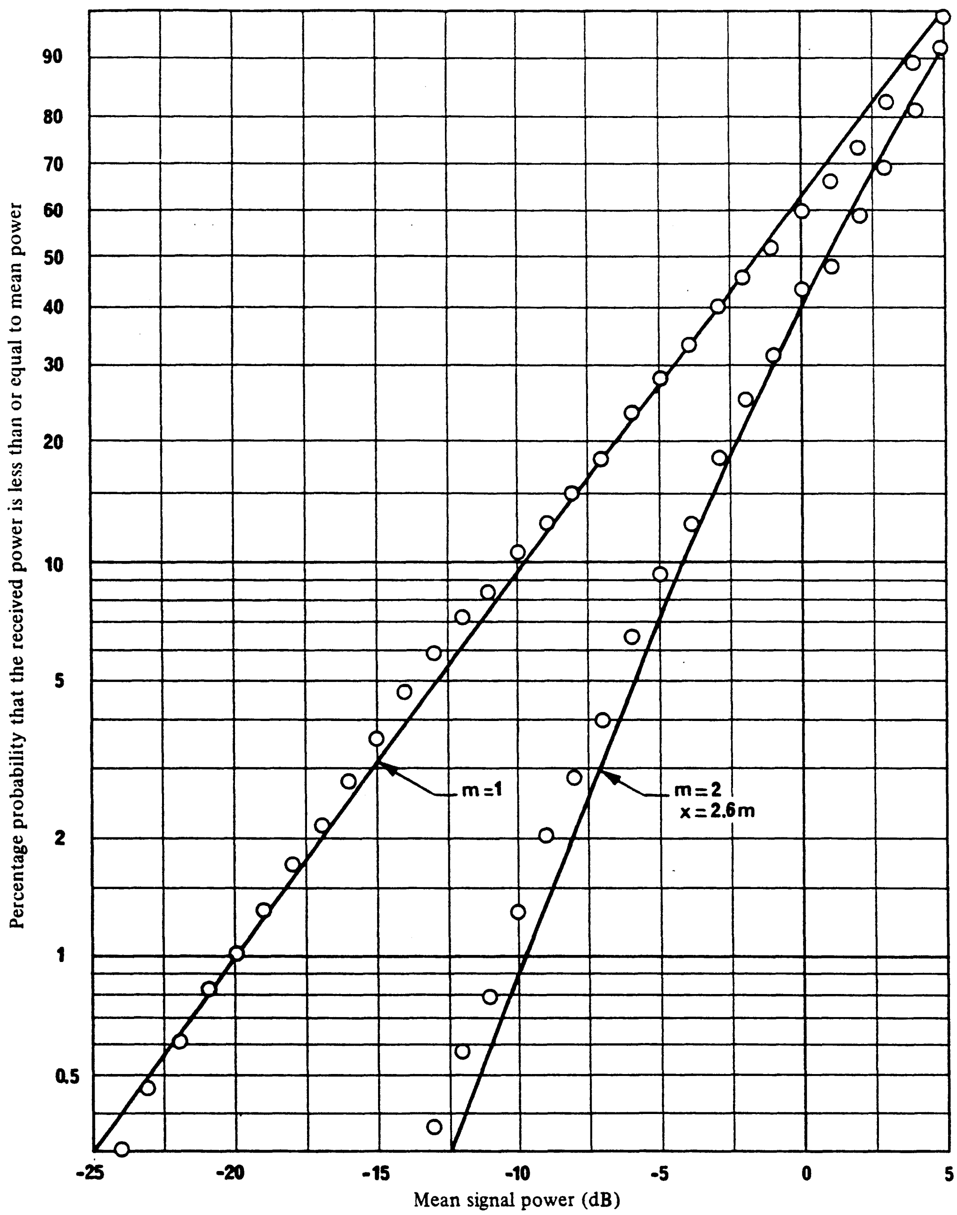

FIGURE 2 – *Cumulative probability distribution of m-branch selection diversity combiner*

m: number of car receiving antennas involved

x: separation between antennas

Figure 3 illustrates the effect of antenna separation on the performance of a selection combining system utilizing two antennas. The figure suggests that the diversity receiving system would achieve nearly theoretically predicted performance with antenna separation greater than 2.8 m. It also suggests that a single separation distance would be suitable for good reception across the entire FM broadcast band. Since the entire band extends only about ± 10% from the 101.1 MHz mid-frequency employed in the tests; it appears that any antenna separation greater than 2.8 m will be acceptable. Fortunately, this dimension can be realized on ordinary passenger automobiles.

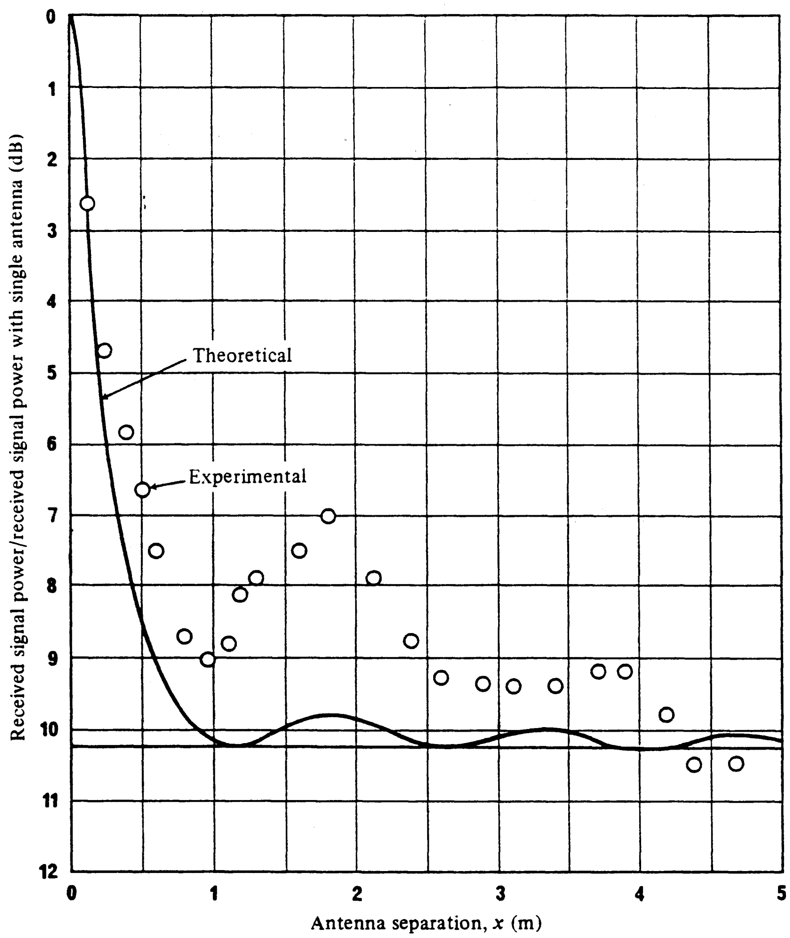

FIGURE 3 – *Effects of antenna separation on performance of two-branch selection diversity combiner over that for single antenna*

3. Selective fading

3.1 *Effects of long-distance multipath propagation*

Theoretical studies and field measurements were carried out in the Federal Republic of Germany in order to determine the effects of long-distance multipath propagation. From the result of these studies, two major conclusions can be drawn:

– sometimes the probability of noise bursts is much higher than that of level drop-outs and a relation cannot always be found between the instantaneous RF level and reception quality. Therefore, no level-sensitive diversity can completely solve the problems of selective fading;

– it may be possible to achieve a considerable improvement in reception quality by using new receiver techniques.

3.2 *Adaptive de-emphasis*

Selective fading causes incidental phase and amplitude modulation. When there is no level drop-out coincident with the selective fade-out, the unwanted amplitude modulation will be cancelled by the limiter. But there still remains the incidental phase modulation.

As shown in Figs. 4 and 5, there exists a relation between the envelope of the RF signal and the instantaneous value of interference in the baseband. The sharp extremes of the disturbance occur simultaneously with the zero crossing of the RF envelope. Therefore, a substantial part of the distortions may be eliminated by adaptive filtering in the baseband (Fig. 6). With an amplitude modulated-driven adaptive de-emphasis as shown in Fig. 7, the strong noise bursts caused by selective fade-out may be eliminated.

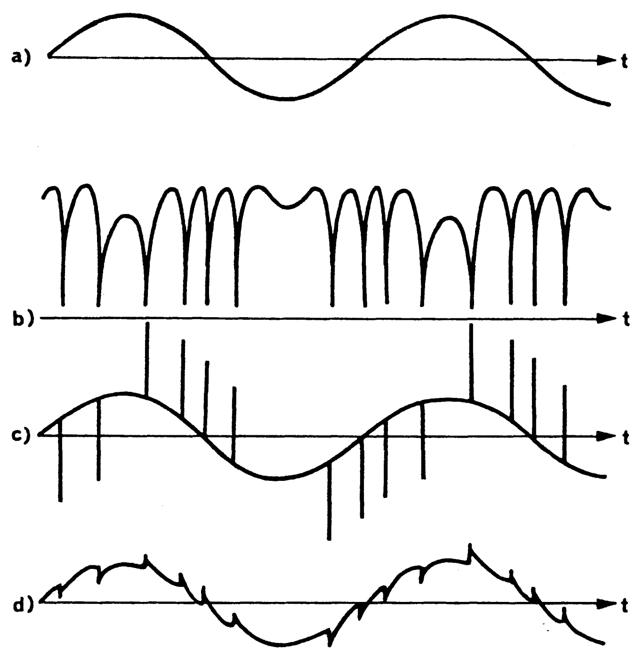

FIGURE 4 – *Disturbances to the audio signal caused by selective fading when the antenna signal level is high*

a) modulating signal

b) RF envelope

c) audio signal before de-emphasis

d) audio signal after de-emphasis

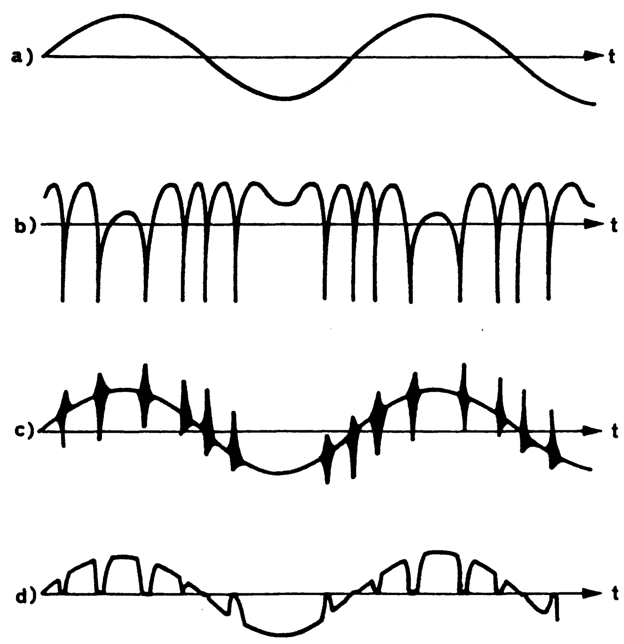

FIGURE 5 – *Disturbances to the audio signal caused by selective fading when the antenna signal level is low*

a) modulating signal

b) RF envelope

c) audio signal before de-emphasis with low limiting threshold

d) audio signal before de-emphasis with high limiting threshold

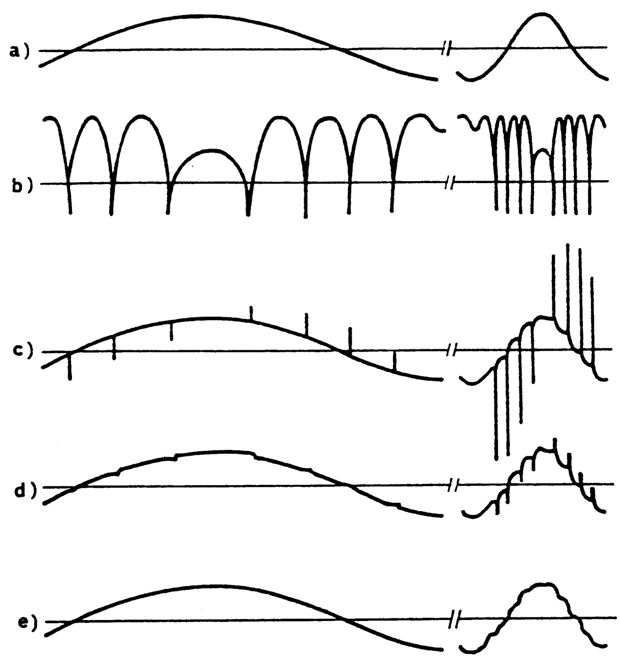

FIGURE 6 – *Differences in disturbances depending on the modulating frequency*

a) modulating signal

b) RF envelope

c) audio signal disturbances without de-emphasis

d) audio signal after sample and hold process

e) audio signal after adaptive low-pass filtering

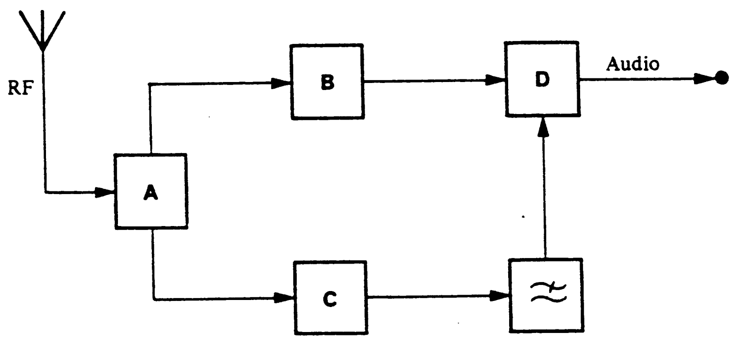

FIGURE 7 – *Control of the de-emphasis to eliminate disturbances caused by selective fading*

A: RF-IF stages

B: FM demodulator

C: AM demodulator

D: de-emphasis