MULTIPLE ACTIVE RECEIVING ANTENNA SYSTEM FOR FM BROADCAST SCANNING DIVERSITY INTEGRATED IN A CAR WINDOW

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1. Distortions by multipath effects

With increasing demands for high fidelity reception in cars and for data transmission reliability with RDS (radio data system) the requirements with respect to the signal to distortion ratio on the fm broadcast channel have been increased remarkably. The typical distortions with fm radio reception with a single antenna are caused by signal fadings and are of similar character and extent with all known types of receiving antennas such as whip antennas, active wind screen antennas, and short active rod antennas. These distortions also occur in service areas of broadcasting stations with sufficient field strength level and are not restricted to the fringe of the service area. This problem can be solved by means of antenna diversity utilising a multitude of antennas.

2. External diversity processor

The multipath reception with small differences in delay time causes deep fadings of the received signal level. Therein noise, adjacent- and co-channel interference and intermodulation distortion are found if the instantaneous level of the rf-carrier is below the distortion level. In contrary to this, distortions caused by multipath reception with great delay times between incident waves occur if the amplitude level of an echo wave is in the same order of magnitude as the main wave. As shown in /1/ the various kinds of distortions described above form sharp erroneous peaks of the instantaneous frequency deviation from the frequency modulated rf-carrier and even in a standing car the envelope of the carrier forms sharp notches with deep level minima generated by the fm-modulation of the rf carrier. The simultaneous appearance of erroneous level notches and short pulses of erroneous frequency deviation serves as a criterion for an extremely fast operating distortion recognition. In fig. 1 the intermediate frequency (if)-signal before being limited in amplitude is fed to the external diversity processor for distortion detection. The if-signal represents the image of that rf-signal at one of the inputs E1..EM, which is connected to the rf-input of the receiver by the electronic switch. In a more general case the signals E1 to EM are linear combinations of the antenna signals A1 to AN generated in the matrix circuit. The operation principle of the diversity processor is discussed in detail in /2/. A system of this kind will be implemented in cars by the companies Philips, Fuba and BMW.

3. Increase of performance versus the number of antennas

As described in /3/ the signal quality Q_e of an antenna can be defined as the logarithmic ratio of the duration of a drive to the sum of time segments of distorted reception during this drive. Using a main antenna A_1 and N-1 auxiliary antennas the gain in signal quality G_q with a diversity system with reference to a single antenna by theoretical approximation can be described by

$$G_q=Q_e*(N-1) \text{ in dB.}$$

The measured results represented by the black columns in fig.2a and 2b in an urban area and in a mountain area respectively are in accordance with this formula and show the relevance of the theoretical assessment. Therefore the signal quality is considerably improved by application of additional antennas. However with car production the implementation of a too great number of antennas is restricted as far as practicability is concerned. Therefore the improvement of the signal quality by additional use of linear combinations of the output signals of a limited number of fm-antennas is investigated. In this respect for example the sum and the difference of the N output signals of the antennas are generated in a matrix with M signal outputs to feed the inputs E of the electronic switch. In fig.2 3 antenna signals are used to form 3 linear combinations. These combinations are especially effective in mountain areas where the likelyhood of multipath distortions as a result of linear distortions due to great delay time differences between superimposed waves is high. By matrix combined signals different directional pattern are obtained reducing the likelyhood of distortions of this kind. In urban areas however the gain of signal quality by means of linear combinations is less, since in such regions noise, adjacent- and co-channel interference during the deep level fadings due to the Rayleigh field are dominant and the linear combination during the deep fading of the signals does not help to improve the reception. Therefore in most cases even with closely packed antennas the gain in signal quality per an additional antenna is greater than per an additional linear combination.

4. Multiple antenna system in a car window

It is obvious that antenna diversity can not be utilised on the basis of standard whip antennas due to optical, esthetical and aerodynamical aspects. In the past active AM and FM antennas have been developed as front and back window antennas. New investigations have shown that even a number of 4 active antennas can be arranged on the small space of a car window for example in the rear window. These antennas have different receiving signals caused by different antenna structures and different rf-loads at the heater opposite the amplifier. In the following the receiving performance of a car equipped with 4 rod antennas as shown in fig.3 is investigated in comparison with an integrated 4 antenna system in the rear window. In fig.5a the signal level of a single rod antenna is plotted versus time and fig.5b shows the level of one of the active window antennas of the antenna arrangement of fig.4. Below the plots of the signal levels in fig.5 the corresponding audio distortions are displayed. Fig.6a shows the signal level and the distortion by use of the 4 rod antenna system and fig.6b describes the 4 antenna system implemented in the window. Both antenna arrangements deliver comparable results. The probability for a simultaneous occurance of an interference on all 4 closely packed screen antennas is not greater than with the 4 rod antennas being considerably spaced apart.

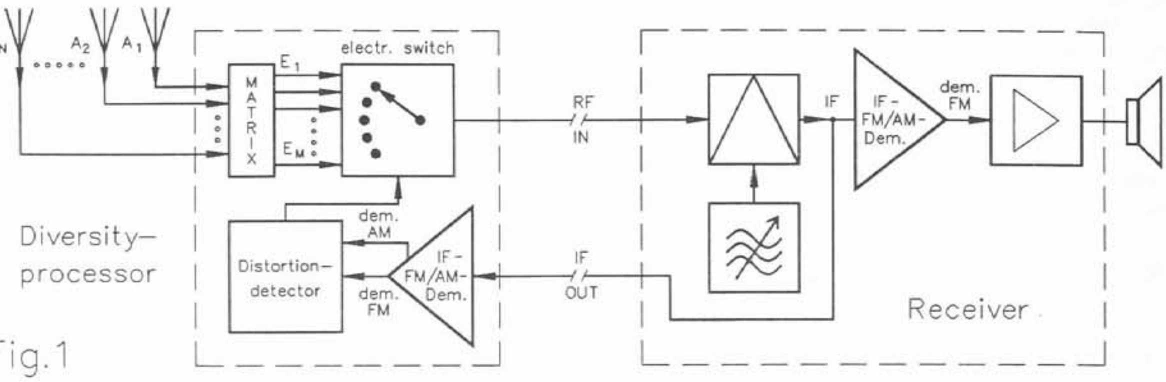

Fig.1

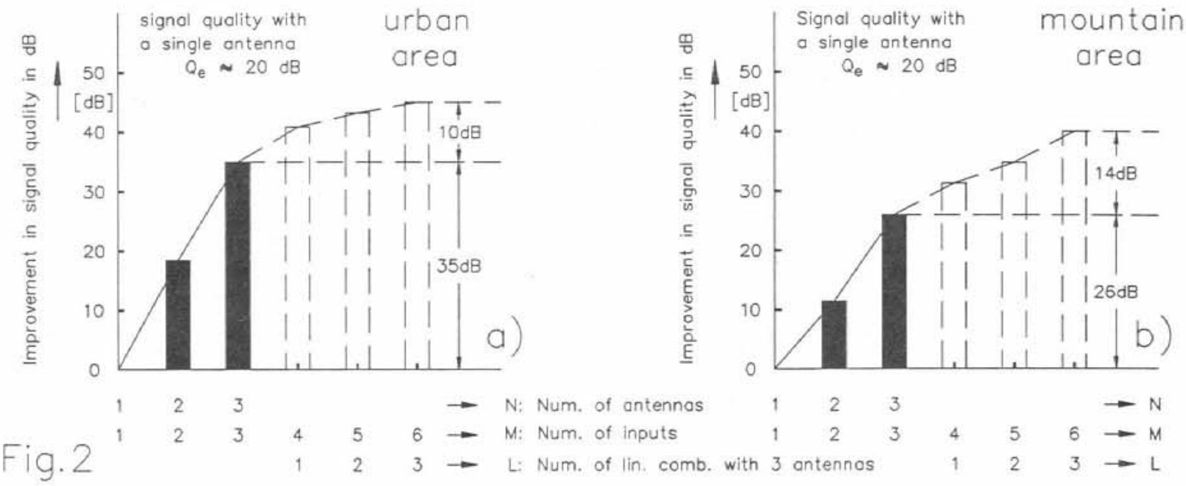

Fig.2

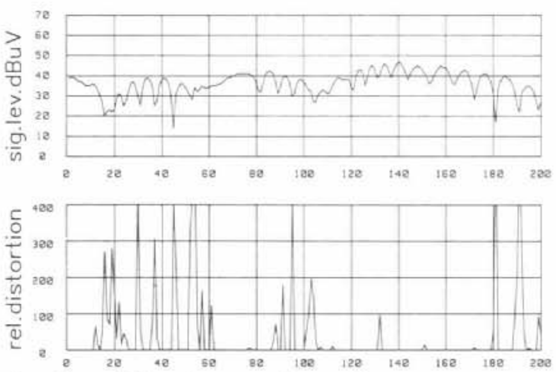

Fig.5a Single rod antenna

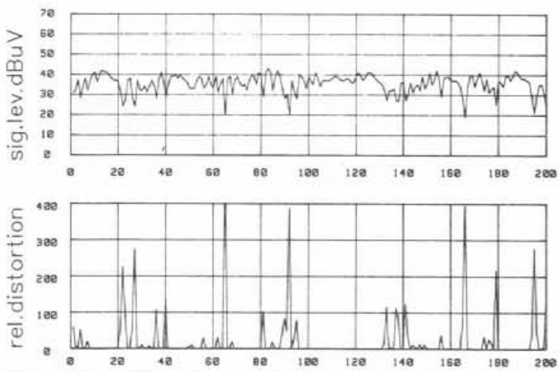

Fig.5b Single window antenna

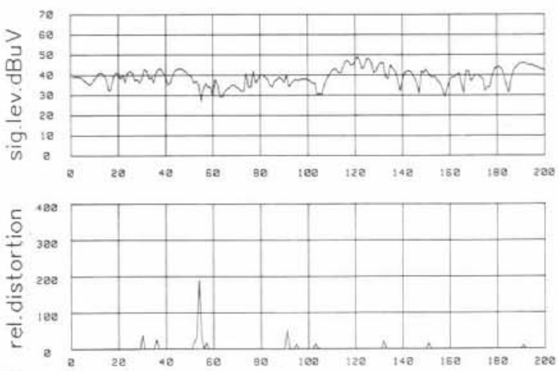

Fig.6a 4 rod antenna system

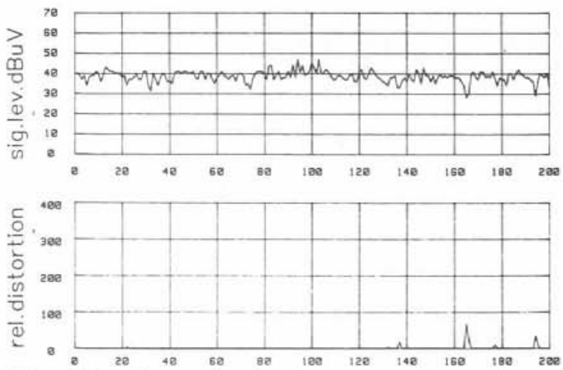

Fig.6b 4 act.window ant.system

4. Significance of the correlation factor between the signals of different antennas

As a criterion for judgement of the capability of an antenna diversity system in mobile communication techniques usually the correlation factor of the time dependent output signal levels of the various antennas is regarded. This caused the working group of the CCIR to recommend a distance of 2.8m between the antennas for FM antenna diversity /4/. The above documented results are in contrary to this recommendation. In /4/ a time invariant noise level is assumed and a distortion occur, if the noise threshold exceeds the instantaneous signal level. With mobile broadcasting reception however the interference due to time variant intermodulation, adjacent and co-channel interference and multipath distortion is of importance. For the reduction of audio distortions by means of antenna diversity the correletaion factor between the actual distortions in the received signals is most significant. In fig.7 the correlationfactor c_{ij} expressed by

$$c_{ij} = \frac{\int_0^{t_0} (u_i(t) - \overline{u_i}) \cdot (u_j(t) - \overline{u_j})\, dt}{\sqrt{\int_0^{t_0} (u_i(t) - \overline{u_i})^2\, dt \cdot \int_0^{t_0} (u_j(t) - \overline{u_j})^2\, dt}}$$

of the distortion levels u_i of the i-th and u_j of the j-th antenna are plotted for measured values of u_i and u_j. This corr. factor of the distortion level is presented by the shaded columns in fig.7. The unshaded columns for a comparison show the corr. factor of the appertaining signal level which with fm-broadcasting reguarly is much greater than the corr. factor of the distortion levels. Therefore with broadcast reception the corr. factor of signal levels is not a valid criterion for judgement of the capability of an antenna arrangement.

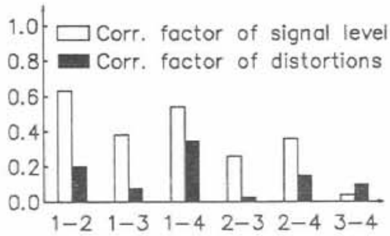

Fig.7 Antenna combinations

Fig 3: 4 rod antenna system

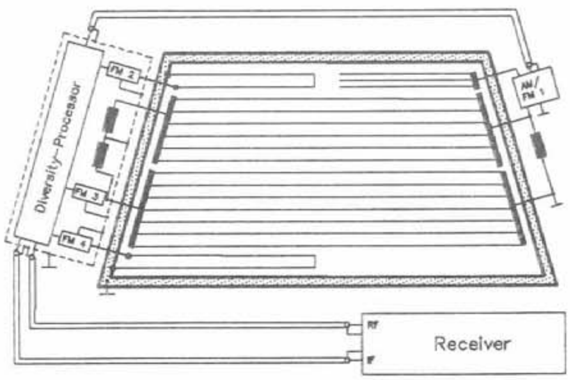

Fig 4: 4 ant. in a rear window

5. References

/1/ Lindenmeier: Advances in FM car radio reception; Proceed. of ISAP 1985, Kyoto, Japan
/2/ Lindenmeier, Reiter: Multiple antenna div. for fm carradio rec.; IEEE Antennas and Prop. 1987; Blacksburg, Virginia, USA
/3/ Lindenmeier, Hopf, Reiter: Mehrantennenanordnung in einer Fensteröff..; ITG Fachbericht 106 Hörrundfunk 1988, Mainz, FRG
/4/ CCIR Working group 10-B: Diversity Rec. in Automobiles for frequency modul. sound broadcasts in Band 8 (VHF). Doc 10/160-E