THE EFFICIENT METHOD OF AMBIENT SIGNALS CANCELLATION IN EMC INTERFERENCE MEASUREMENTS

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SUMMARY

The paper deals with some aspects of EMC interference signal measurements in the presence of undesired ambient signals that appear mainly by an open field test site measurement. The method for efficient ambients cancellation is described, and discussed in the article from theoretical, as from practical point of view. The method, which is in the form of special hardware/software utilities already implemented in some modern electromagnetic interference (EMI) receivers, is based on ambient signals storing in an internal receiver memory and then on their "subtracting" from actual measured signals. Results of this concept depend first of all on the character of actual ambients signals, and on their time and frequency stability. After the theoretical background of the concept is stated, its effectiveness was checked in series of EMI measurements by using the EMI Spectrum Receiver from the Seaward Ltd. in the frequency range from 9 kHz to 1000 MHz. By this, we have used various types of simulated as well as real existing ambient signals and various modes of EMI receiver. The cancellation of ambients was tested for continuous harmonic signal, for continuous square wave ambient signal, and for signal of broadband white noise character. The simultaneous treatment of these types of signals was also investigated. All tests were executed under the Peak-Detection mode of the EMI receiver, some of their also by using the Quasi-Peak detection mode. Our measurement demonstrated, that the "subtraction" effect is more effective in Quasi-Peak mode measurement, as in Peak detector mode. Simultaneously, the accuracy of the cancellation increases with decreasing of the measuring frequency span. Thus, our practical experiences show, that by taking a proper measuring process, the obtained results are very good, and the cancellation of undesired ambients can be made very effectively.

Keywords: *interference measurement, ambient signals, EMI receivers, cancellation of ambients, ambient noise signals*

1. INTRODUCTION

The electromagnetic (EM) emissions measurement presents one of the main EMC practical tests. By all measurement of the radiated and/or conducted emission generated from the equipment under test (EUT) is very important unambiguously to distinguish between emissions from the EUT and ambient electromagnetic signals, i.e. signals from other EM sources. Thus, ambient signals can cause a problem by both radiated and conducted emissions measurement and they are the major cause of inaccurate measurements.

EM ambients can be continuous or transient, broadband or narrowband. Examples of continuous narrowband ambient signal sources in the frequency bands up to 1000 MHz are some UHF radio and TV broadcast stations, pager and mobile phone stations. The typical continuous broadband ambient sources are some local industrial plants, switching energy systems and devices, as computer networks. A typical ambient trace measured by a spectrum analyzer or EMI receiver from 9 kHz to 1000 MHz on an open test field site is shown in Fig. 1. Here, broadcast, pager, and mobile phone transmissions are evident. Their comparatively high level can therefore exceed the measurement limits by several tens of dB and thus, the ambients can make the measurement results incorrect and unusable.

By practical EMI measurements, we can realize certain steps to mitigate effects of some ambient signals. Examples of mitigation measures are:

- Doing the testing at the weekend or in the evening, when usual industrial continuous and/or transient broadband noise is lowest.
- Performing the measurement with the narrowest bandwidth over a narrow span, to distinguish the EUT emission from narrowband ambients.

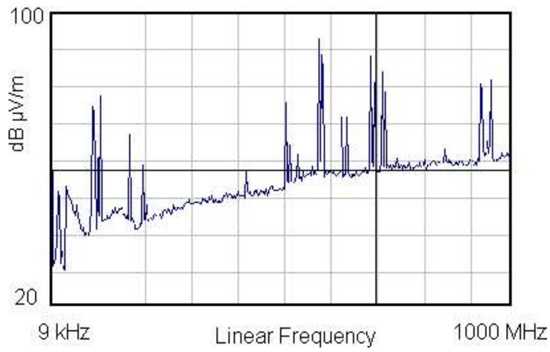


Fig. 1 Typical trace of ambient signals in an OFTS in MHz frequency range

If the radiated emission of the EUT should be tested, we can realize also additional steps:

- Orienting the measurement range to be at right angles to the worst offenders, taking advantage of the antenna's null on-axis.
- Reducing the antenna–to–EUT distance below the 3 m standard value to increase the EUT signal contribution. By this, the emission limits should be checked and the comment should be noted in the test record.

Nevertheless it is clear, that even with these steps, we cannot eliminate the majority of the real existing ambient signals.

2. ELECTRONIC CANCELLATION OF AMBIENT SIGNALS

Modern EMI measuring receivers, e.g. Spectrum Receiver from Seaward Electronic Ltd., HP 8542 and HP 8546 EMI receivers' family or HP E7404A Spectrum Analyzer include a facility, which allows effective cancellation of majority of ambient interference signals from the measured ones. This DSP based function of the receiver is often marked as *<Difference>*, *<Normalization>*, or *<<Mark All Duplicate>* and *<Delete Marked>>* mode.

2.1. Ambient signal cancellation concept

The basic concept of ambient (i.e. undesired) signal cancellation by a "subtracting" means may be illustrated by Fig. 2. Its operation is as follow:

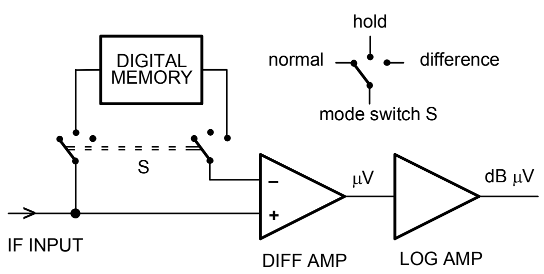


Fig. 2 Basic setup for ambient signal cancellation

After the test site is properly prepared to the emission measurement, the EUT is switched OFF. Thus, the input of the EMI receiver consists of ambients (i.e. undesired) signals only. The mode switch S in the IF block of EMI receiver (Fig. 2) is in the "normal" mode position, so that the ambients are now checked in the required frequency range. The trace of ambients as whole or at some selected frequencies will be then digitized and stored in the internal memory of the receiver by switching S to the "hold" mode position (Fig. 2). After that, the EUT (worked in the contingent worst case mode or oriented to the worst case position) is switched ON and the "difference" mode position of switch S is selected. Now, the input of EMI receiver contains the measured (i.e. from EUT emitted) signal $S(t)$ and actual ambient signals $A_d(t)$. In this mode, the required emission test (i.e. ambients plus EUT emission) is performed, while the differential amplifier DIFF AMP in the receiver (Fig. 2) realizes the subtraction the stored noise trace from the actual measurement. Thus, the resultant output signal $U(t)$, following the subtraction, may be written as

$$U(t) = [S(t) + A_d(t)] - A_h(t) \quad , \qquad (1)$$

where $A_h(t)$ denotes the primary ambient signals stored in the "hold" mode position of the switch S. Squaring both sides of equation (1) yields

$$U^2 = S^2 + (A_d - A_h)^2 + 2 \cdot S \cdot (A_d - A_h) \quad . \qquad (2)$$

Taking the expectation of both sides of Eq. (2) and defining that S is uncorrelated with ambient signals A_d and A_h, so that the expectations of $S \cdot A_d$ and $S \cdot A_h$ are zero, one obtains

$$E\left[U^2\right] = E\left[S^2\right] + E\left[(A_d - A_h)^2\right] \quad . \qquad (3)$$

From the previous equations, it is seen that the output signal $U(t)$ becomes equal to $S(t)$ only if the stored ambient signal $A_h(t)$ is identical with the actually received ambients $A_d(t)$. In this situation, the measured signal power $E[U^2] = E[S^2]$ and it will be unaffected from disturbing ambient signals.

In reality, the actual ambient signals may be very variable: continuous and/or transient frequently with random time variation in magnitude and/or frequency. For this reason, the output signal $U(t)$ will contain the desired signal $S(t)$ and some undesired signal, although substantially reduced in magnitude. At all events, the subtraction A_d and A_h maximizes the measured output signal-to-undesired noise ratio and the most of the common ambient signals will be removed from the actual measuring.

2.2. Evaluation of the measurement

Many EMI receivers enable a simultaneous indication of all traces during each measuring steps. The first measured and then stored "hold" trace of the ambients $A_h(t)$ will still be displayed on the receiver screen, which will now allow a comparison to be made between the two traces $A_h(t)$ and $U(t)$. The Fig. 3 shows a trace of the "hold" ambients $A_h(t)$ before selecting the "difference" mode (upper trace). The lower trace in Fig. 3 shows the typical effect of canceling out the ambient noise by selecting the "difference" mode of receiver.

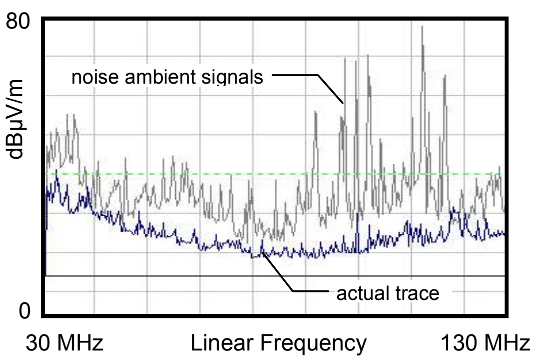


Fig. 3 Effect of the „subtraction" of ambient signals from the measured trace

From the theoretical point of view, as from the practical experiences is clear that the success of ambient signals cancellation will be due - first of all - to the character of the cancelled (ambient) signals. To obtain good and veracious results by using this cancellation function of EMI measuring receivers, it should be especially pointed that:

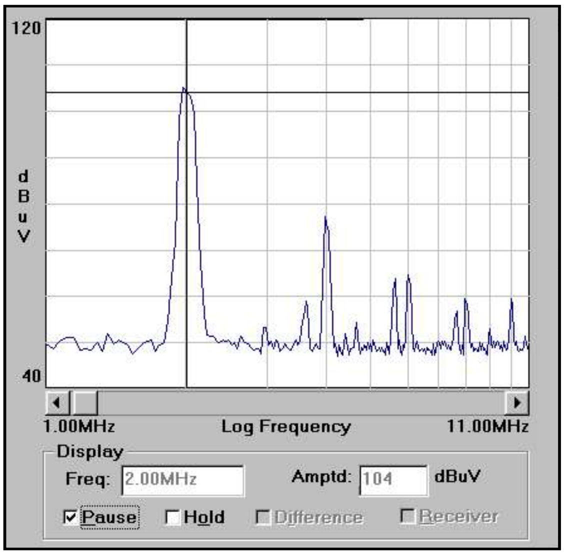
- The ambient noise signals should be continuous, i.e. time and frequency stable. Transient signals from aircraft transmissions, arc welders, mobile phones etc. may not be effective cancelled out by the subtracting function. The transients are often appeared during only one of the measurements, i.e. they are not present in the same form both in ambients (normal mode), as in ambients plus EUT signals (difference mode) measurements.
- For the same reason, the actual EUT emission measurement should be created always immediately after the ambient noise mapping and the "subtraction" of the EM noise background from the measured trace should be several times repeated. When both measurements are realized in large time distance, the actual ambient noise A_d can change indispensable from its stored course A_h and the cancellation will be disturbed.

3. PRACTICAL VERIFICATION OF THE CANCELLATION CONCEPT

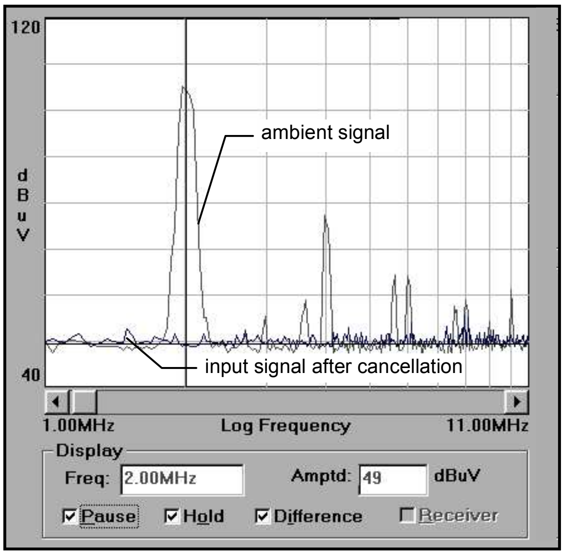
To verify the cancellation concept described above for various types of possible ambient signals, we have realized a set of practical emission measurement in the EMC pre-compliance test laboratory at the Institute of Radio Electronics Brno University of Technology. The EMI Spectrum Receiver from Seaward Ltd. with in-build "subtracting" function was used in the frequency range from 9 kHz to 1000 MHz.

The verification was treated as a "null emission signal" measurement, i.e. with the "desired" emission signal $S(t) = 0$. From equation (1) it is seen that in this case if the ideal cancellation condition $A_h(t) = A_d(t)$ occurs, the displayed signal should be $U(t) = 0$. To approach this "ideal" level can be taken as criterion of a "perfect" cancellation effect.

First, we have investigated a situation, when - from the view of cancellation success - a "near ideal" ambient is occurred, i.e. the ambient signal is continuous, time, and frequency stable. We have use a sine wave 2 MHz signal from a laboratory signal generator. The displayed frequency trace (frequency spectrum) on EMI Spectrum Receiver in the range from 1 MHz to 11 MHz is show in Fig. 4.a. It can be seen that the used "ambient" signal is not perfect; except the first harmonic component (2 MHz), it contains also some higher harmonics, e.g. 2nd, 4th etc. The "ambient" trace on Fig. 4.a was stored in the EMI receiver memory ("hold" mode), and then the "difference" measurement was realized. The result is show in Fig. 4.b, in which the lower curly trace states for actual input signal after the cancellation effect. It is evident, that the cancellation of ambients may be 50 dB or more. Residual deviations from the ideal trace are very small and due to frequency instabilities of measured signal, as to limited digitizing accuracy and resolution of EMI receiver. The "null" trace level (approx. 49 dBμV in Fig. 4.b) is due from adjusted amplifier gain, and from own noise level of the receiver.



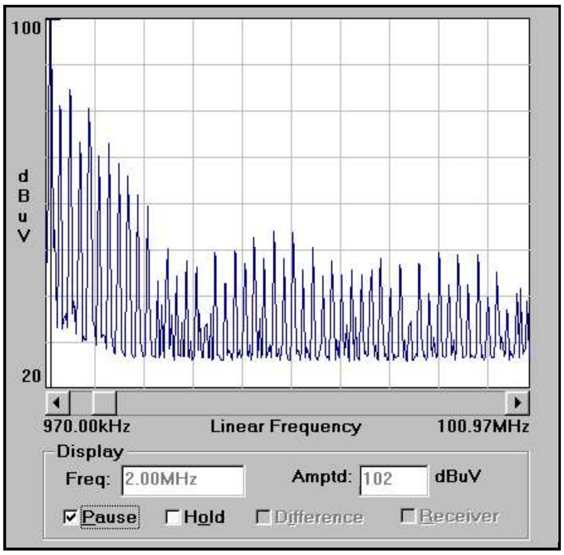
a)



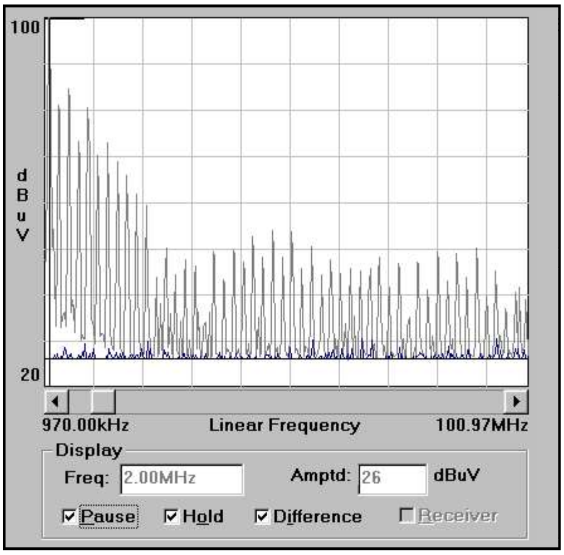
b)

Fig. 4 Measurement with continuous ambient signal: a) initial trace of ambient signal; b) displayed result in "difference" operating mode

The next verification measurement was realized by using the ambient signal in the form of a continuous square wave with the frequency rate of 2 MHz and the duty cycle of 50 %. The achieved results are approximately the same as with previous (harmonic) ambient signal and they are displayed in Fig. 5. Due to the "subtraction" effect in Fig. 5.b, the "ambient" signal is nearly completely cancelled with the suppression of some tens of dB.



a)



b)

Fig. 5 Measurement with square wave continuous ambient signal: a) initial trace of ambient signal; b) displayed result in "difference" operating mode

The conclusions from the above discussion and practical verification can be extended from the deterministic ambient signals to the case when the ambients have the form of additive noise or - of course - to the superposition of both.

Thus, in the next measurement, the ambient was created through a stochastic signal in the form of broadband white noise signal. A laboratory noise generator with IMPATT noise diode was used with an additional broadband amplifier with 30 dB gain. Its resulting frequency trace is due to the upper trace in Fig. 6. In the same figure, the lower trace state for the actual input signal (i.e. zero signal in our measurement) after the difference mode of the receiver is selected.

The Fig. 6 shows that in the frequency band about 100 MHz some other ambient EM signals appear as the white noise signal only. Probably they are broadcast signals from some broadcast stations, which reached the input of the test EMI receiver. Their cancellation seems by far not sufficient (see the lower trace in Fig. 6). To check this impression, we realized next ambient noise signal measurement in a narrowed frequency band from 50 to 150 MHz. The result in Fig. 7 shows, that also the additional broadcast ambients are enough cancelled by using the "difference" mode of measurement.

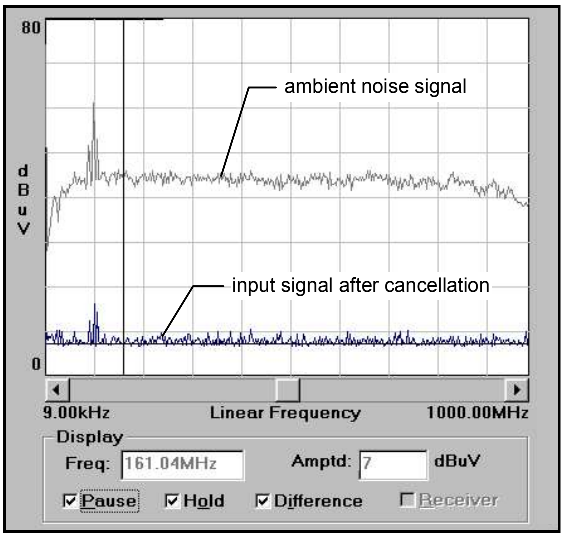


Fig. 6 Cancellation of white noise ambient signal in the range 9 kHz to 1000 MHz

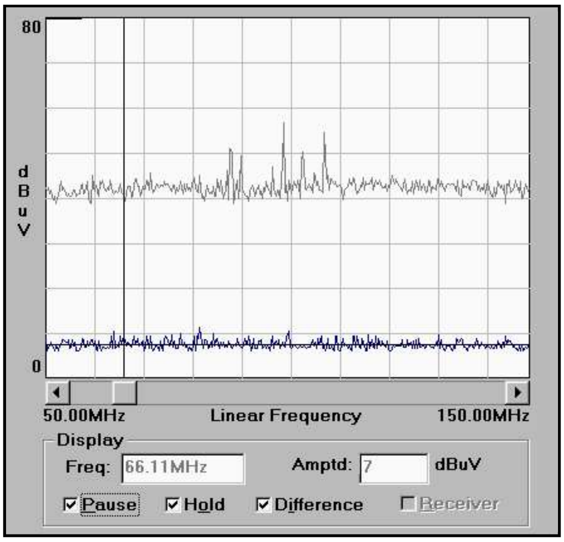


Fig. 7 Cancellation of additional broadcast ambient signal in the 100 MHz frequency band

Furthermore, our practical experiences with the described cancellation concept show, that the "subtraction" effect is more effective in Quasi-Peak receiver detector mode measurement, as in Peak detector mode. Simultaneously, the accuracy of the cancellation increases with decreasing of the measuring frequency span. This is documented in Fig. 8 by the "difference" measurement in Quasi-Peak detector mode in the narrow span from 95 to 105 MHz. The cancellation is nearly perfect.

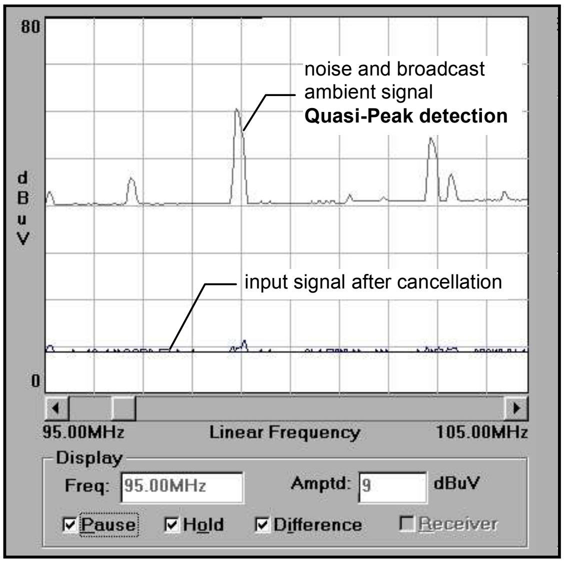


Fig. 8 Increasing of the cancellation effect of ambient signals by decreasing the sweep frequency range and by using the Quasi-Peak detection

4. CONCLUSION

The concept for efficient ambients cancellation is described, in detail discussed, and through series of practical tests verified. The cancellation method, which is in the form of special hardware/software utilities already implemented in many modern electromagnetic interference (EMI) receivers, provides an effective noise reduction facility thus eliminating the uncertainties caused in areas of high background EM noise. By taking a proper measuring process, the effectiveness of the method may be very good with high cancellation of as deterministic, as well as noise undesired ambients. Moreover, the "difference mode" measuring techniques could be successful used as for radiated, as well as for conducted emission tests.

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BIOGRAPHY

Jiří Svačina received the M.Sc., and Ph.D. degrees from Brno University of Technology, Brno, Czech Republic, in 1971, and 1978, respectively. Since 1983 he has been assoc. professor, and since 1995 he is a professor in Electronics and Communication at the Institute of Radio Electronics, Brno University of Technology. His research interests include theoretical and mathematical problems of special planar structures for microwave integrated circuits, and microwave measurements. He is also interested in specialized problems of EMC, EMI, and EMS. Prof. Svačina is the Head of the Institute of Radio Electronics at the Brno University of Technology, member of its Scientific and Pedagogical Boards, and also member of the scientific boards of Faculties of Electrical Engineering CTU in Prague, and West Bohemian University in Pilsen. He is the Senior Member of IEEE, U.S.A., and the Fellow of IEE, U.K.