Asymmetric Artificial Networks (AAN) for Balanced Telecommunications Cables Conducted Common Mode Emissions Testing

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Abstract—The Artificial Asymmetrical Network (AAN) defined in CISPR 16-1-2 Edition 1.2 (2006-08) is used primarily for the measurement of Common Mode (Asymmetric) conducted emissions on balanced telecommunications cables. In CISPR 22 (now CISPR 32), these AANs are referred to as Impedance Stabilization Networks (ISN). The AAN is intended to control several parameters when installed between the Equipment Under Test (EUT) and the Associated Equipment (AE) including the Common Mode Impedance, the Longitudinal Conversion Loss (LCL), and the decoupling of conducted Common Mode signals originating from the AE. While the LCL parameter receives the most attention, it is only 1 of 4 possible contributors to the conducted Common Mode emissions the AAN can respond to. These contributors will be discussed in the paper along with some general AAN information. The possible impact to the conducted Common Mode voltage and current by the insertion of the AAN between the EUT and AE will be discussed.

Keywords—AAN; ISN; Conducted Common Mode Emissions; CISPR 22; CISPR 16-1-2

I. INTRODUCTION

The Asymmetric Artificial Network (AAN) is used in Electromagnetic Compatibility (EMC) testing when assessing the conducted Common Mode (CM) emissions on a balanced telecommunications cable connected to the Equipment Under Test (EUT). CISPR 16-1-2 Edition 1.2 (2006-08) [1] defines the required characteristics of the AAN. The AAN requirements originated in CISPR 22 [2] and were defined in CISPR 22 as Impedance Stabilization Networks (ISN). CISPR 22 has now been incorporated in CISPR 32 [3].

When installed between the EUT and the Associated Equipment (AE), the AAN is intended to control several electrical parameters of the telecommunications cable under test. These include the CM impedance, the Voltage Division Factor (VDF), the Longitudinal Conversion Loss (LCL), and decoupling of any CM emissions from the AE. AANs are defined only for telecommunications cables having 1 pair, 2 pairs, or 4 pairs.

This paper discusses some of the basic characteristics of an AAN to provide some background. A variety of stimuli can contribute to the CM conducted emissions measured by the AAN – not just the LCL that is often assumed to dominate. These stimuli are discussed. The installation of the AAN between the EUT and AE can rearrange the distribution of CM conducted voltages and currents on the telecommunications cable and possibly impact the CM conducted emissions measured by the AAN. These possible impacts are discussed in general terms. A discussion about AAN calibration uncertainties is also presented.

II. AAN CHARACTERISTICS

Fig 1 shows the basic block diagram of the AAN along with the associated terminology. The AAN is intended to control the CM impedance of the telecommunications cable under test (with respect to the local test setup ground) to be 150 ohms (+/- 20 ohms). The conducted CM voltage at the input to the AAN is measured at the RF output port of the AAN with a receiver via the AAN coupling circuit. The specified VDF is defined as the ratio of the CM voltage at the AAN input to the AAN RF output port. The decoupling network removes the large majority of any conducted CM signals propagating from the AE to prevent it from contaminating the EUT conducted CM emissions measurement.

The LCL circuitry within the AAN is intended to simulate the balance of the network that the EUT is intended to operate with. The network is typically described by the type of telecommunications cable being used on the network such as Category 3, Category 5, and Category 6. CISPR 16-1-2 defines 3 levels of LCL balance, but does not tie them to these cable Categories: CISPR 22 (now 32) however does tie them together. While the specified LCL varies with frequency, the LCL are best known by their value at 150 kHz: 55 dB for Cat 3, 65 dB for Cat 5, and 75 dB for Cat 6.
III. CONDUCTED CM SIGNALS MEASURED BY THE AAN

The LCL is probably one of the most widely known parameters associated with the AAN and is often thought to dominate the measured conducted CM emission. The LCL circuit converts part of the desired differential (symmetric) signal to a common mode signal which is the parameter that the AAN measures. The lower the LCL, the more differential to common mode conversion there is. A LCL of 55 dB will convert more signal than a LCL of 65 dB.

While it may be true that the LCL sometimes dominates the measured conducted CM signals, there are 3 other potential contributors to the conducted CM emissions measured by the AAN as shown in Fig 2. The interface circuitry between the EUT and the telecommunications cable may generate conducted emissions directly (VcmI/O in Fig 2). Circuitry internal to the EUT may radiate electromagnetic fields which can couple to the telecommunications cable and induce CM conducted signals (VcmI/C in Fig 2). This is also true for nearby cabling that is part of the test setup – CM signals on those cables may radiate and couple to the telecommunications cable under test (VcmO/C in Fig 2). The contribution from the LCL is shown in Fig 2 as VcmLCL. Common mode currents introduced on the telecommunications cable interact with the very low CM impedance of the AAN decoupling circuit to create a CM voltage. Note these CM voltages and currents can add or subtract from one another due to frequency and phasing variations.

![Fig 2. The 4 potential conducted CM coupling contributors. Total Vcm measured at receiver equals sum of VcmI/C + VcmI/O + VcmO/C + VcmLCL.](image)

IV. POSSIBLE TOPOLOGY IMPACT OF ADDING A AAN

Fig 3 shows a simplified layout of a EUT and AE with and without an AAN inserted between them. If either the EUT and/or the AE are generating conducted CM emissions, viewing them as a CM Thevenin voltage source and source impedance is convenient for this discussion. There is likely no way to characterize the magnitudes of these CM voltage sources and impedances, but it is reasonable to expect they can vary from low to high.

![Fig 3. Generic topology layout with and without an AAN inserted between the EUT and AE.](image)

Without the AAN present, the conducted CM emissions present on the telecommunications cable under test will be subject to the relative magnitudes of these sources and the source impedances, relative phasing between these emissions (they may and or cancel) and standing waves may be present on the telecommunications cable.

When the AAN is inserted between the EUT and the AE, several effects may occur. The AAN now locks in the CM impedance presented to the telecommunications cable under test to 150 ohms instead of that of the AE. The AE now sees the very low CM impedance of the AAN decoupling circuit instead of what the EUT presented. Standing waves that may have been present without the AAN may now be rearranged. The addition and/or subtraction from the mixing of the EUT and AE conducted emissions may be altered.

Fig 4 shows a block diagram example of the AAN impact when both the EUT and AE CM source impedances are relatively low compared to 150 ohms. Without the AAN, the conducted CM voltage is relatively low and the conducted CM current is relatively high. When the AAN is inserted, the conducted CM voltage could increase and the conducted CM current could decrease.

![Fig 4. Topology when both EUT and AE have CM impedances low compared to 150 ohms.](image)

While it is difficult to accurately estimate or quantify these potential impacts, it can be seen that such impacts are possible on the conducted CM voltage and current.
Fig 5. Topology when both EUT and AE have CM impedances high compared to 150 ohms.

V. AAN CALIBRATION CONSIDERATIONS AND RELATED UNCERTAINTIES

CISPR 16-1-2 provides general setups for calibration of the various specified AAN parameters, but no guidance is provided on how to execute these calibrations to minimize the calibration uncertainties. Formal calibration with minimized uncertainty requires the use of controlled calibration fixturing.

Calibration of an AAN typically is performed with a Network Analyzer in a 50 ohm system. However, the AAN has a 150 ohm CM input impedance. The AAN is typically equipped telecommunications connectors (RJ45 style) that are mechanically incompatible with 50 ohm systems. The combination of these problems mandates that small, precise calibration fixturing and adaptors be used to optimize uncertainty and repeatability of the calibration.

CISPR 16-4-2 [4] provides guidance on the Uncertainty budget that is reasonable for various EMC test setups. For the conducted CM emissions testing, the budgets (for K=2) for the AAN are stated as:

- VDF: +/- 0.2 dB
- LCL: +3, -6 dB (worst case depending on LCL value and frequency)
- CM Impedance: +2.5, -2.0 dB

With careful calibration fixturing, it is quite feasible to meet these CISPR uncertainty budgets.

The CISPR specifications for the AAN do not include transmission quality requirements for the AAN. It is possible for an AAN to meet all of its CISPR requirements, but degrade the high speed digital signal to the point where secondary problems may be introduced. It is recommended that the user of an AAN contact the AAN manufacturer to verify the high speed digital transmission qualities of the AAN prior to use.

VI. CONCLUSION

When performing EMC conducted common mode emissions testing, use of the AAN provides a means to place a balanced telecommunications cable running between the EUT and AE into a more known and controlled configuration by fixing the CM impedance, the balance of the telecommunications pairs via the LCL, and decoupling CM conducted emissions from the AE. However, the introduction of the AAN may rearrange the conducted CM voltages and currents.

The AAN will respond to any conducted CM emissions present on the telecommunications cable under test. This includes emissions generated by the EUT as well as emissions induced from external sources and the LCL of the AAN.

Meticulous, controlled calibration fixturing can reduce calibration uncertainties associated with the AAN parameters to levels below the CISPR uncertainty budgets.

REFERENCES