Cancellation of ELF/VLF Electric Fields From CRT Displays .

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Abstract

Cancellation can provide a reduction in ELF and VLF electric fields from CRT displays, replacing other methods such as shielding, particularly in the front of a display. Some electric field probes only measure the scalar quantity, electric potential, posing a potential source of measurement error that is exacerbated if cancellation is carelessly applied. VLF Cancellation signals may be obtained from the horizontal flyback transformer. ELF cancellation signals can be obtained by sensing and amplifying the unwanted ELF field.

Introduction

Though little, if anything, is known about possible health effects of ELF and VLF electric fields[1] , reduction of these fields has become of interest to those who are involved in the design, evaluation, purchase, and use of displays. As a result, many manufacturers are evaluating methods of reducing the amplitude of these fields. When the source of the field cannot be eliminated, it usually is shielded.

Shielding in itself is incompatible with current display design trends. Lower cost and lighter weight require a reduction in the amount of sheet metal used. Today's smaller packaging and higher operating frequencies impose more stringent cooling requirements, and the call for a larger portion of the display to be recyclable entails a reduction in the use of metalized plastic.

Shielding is particularly problematic in the front of the display. The use of low resistivity transparent coatings (<10 KΩ/sq) usually will reduce the field in front to an acceptable level, though it is expensive and forces the designer to make tradeoffs involving visual performance, shielding effectiveness, and cost.

Magnetic fields radiated from deflection yokes and practical cancellation methods were described by Sluyterman[2], and such practice has become the main-stay of low magnetic field display designs. It was later realized that it should be possible to cancel the AC electric fields much as AC magnetic fields from displays are canceled, thus realizing the benefit of shielding without the attendant drawbacks[3]

Cancellation

Point Charge Model

Sluyterman noted that, at the frequencies present in modern CRT displays, the magnetic fields can be treated as quasistatic, greatly simplifying analysis. This is true because the wavelengths are very large compared to the distances involved. This is also true for electric field at the same frequencies.

For further simplicity, an AC electric field source inside a CRT display can be treated as a point charge. Taking this as the nominal case, from Coulomb's law, we can find the electric field intensity at a point of interest[4], *P*, by

$$E = \frac{1}{4\pi\varepsilon_o}\frac{q}{r^2}$$

Where

E is the electric intensity at the point, P,
q is the point charge in Coulombs,
r is the distance from the q to P, and
ε_o is the permittivity of free space

When multiple charges are present, the electric intensity at P may be calculated by finding the vector sum of the electric intensities caused by the individual charges[5].

$$E = \frac{1}{4\pi\varepsilon_o}\sum\frac{q\hat{r}}{r^2}$$

Where

$\hat{r}$ is a unit vector in the direction of the individual charges, q.

In Figure 1, two charges of opposite polarity are considered, the charge due to the unwanted field, *q1*, and the charge due to the cancellation field, *q2*, which form an electric dipole. Note that in Figure 1(a), *q1* and *q2* cancel completely because the intensity vectors converge on *P* from the same angle. In Figure 1(b), the horizontal component of the intensities from *q1* and *q2* will cancel, but their vertical components will reinforce at *P* because the intensity vectors from *q1* and *q2* converge from different angles.

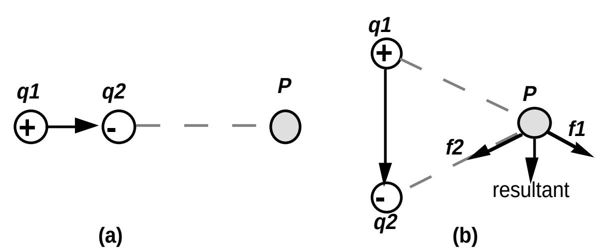

Figure 1 (a) The intensities for *q1* and *q2* exert force on *P* from the same angle, and thus cancel. In (b), the horizontal component of vectors f1 and f2 (from *q1* and *q2,* respectively) cancel at *P,* but the vertical components add.

The MPR[6] and other standards currently being formulated use grounded displacement current electric field probes to sense the electric potential field, V, a scalar resulting from the electric intensity, E. The electric potential at a point resulting from multiple charges is the algebraic sum of the individual potentials, and is found by[7]

$$V = k_o \sum \frac{q}{r}$$

Where k_o is 8.897 X 10^9 N-m^2/C and V is expressed in V/m.

Precautions

Displacement current electric field probes are not able to differentiate between the conditions shown in Figures 1(a) and (b). Therefore, it may be prudent to ensure that the electric intensity, E, is canceled as well. In actual application, this is accomplished by locating the cancellation field radiator as close as practical to the source of the unwanted field.

The MPR protocol requires the measurement of AC electric potential in only four locations around the display. With field cancellation, some designs may produce (and in laboratory experiments, have produced) acceptably low potentials at the four locations specified by the MPR, while at the same time, producing unacceptably large potentials at intermediate points (Figure 2). With careful design, such circumstances can be prevented.

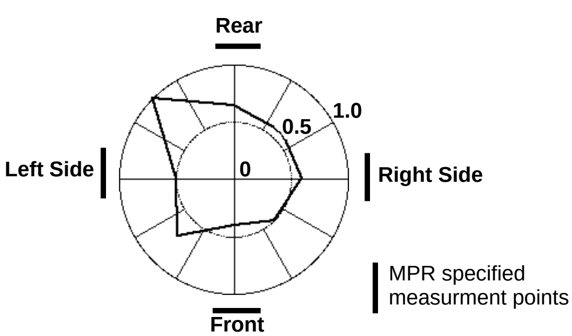

Figure 2. Possible field profile that may be excessively large at other than MPR specified measurement locations. Amplitudes are normalized.

Methods of Cancellation

General

In practice, to accomplish electric field cancellation, a cancellation field is introduced from a suitably located radiator. The radiator can be in the form of a dedicated structure similar to a shield, or it can be a secondary function of of a device with another primary function, such as a heatsink or mounting bracket.

The best way to obtain a cancellation signal depends upon the source of the unwanted field. The most common sources of significant electric fields from displays are the horizontal deflection circuit, high voltage power supply, vertical deflection circuit, power supply, mains wiring, degaussing coil, and fluctuations of the CRT anode voltage.

Cancellation of VLF Fields

Cancellation signals for the horizontal deflection and high voltage power supply are usually periodic and of consistent wave shape and amplitude. They are best obtained from a winding on the horizontal feed choke and/or high voltage flyback transformer (Figure 3).

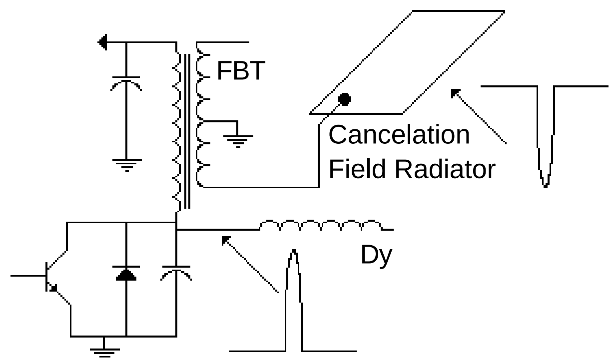

Figure 3. A radiator plate connected to a negative going pulse on the flyback transformer can radiate a field to cancel the field for the positive pulse radiated from the deflection yoke.

The area and shape of the radiator plate can be adjusted to provide maximum cancellation, allowing the designer to make use of whatever output of the appropriate polarity happens to be available.

This method was recently demonstrated when the VLF electric field from a prototype display was measured according to the current MPR protocol, and was found to have undesirably large VLF electric fields, particularly in the rear and on the left-hand side.

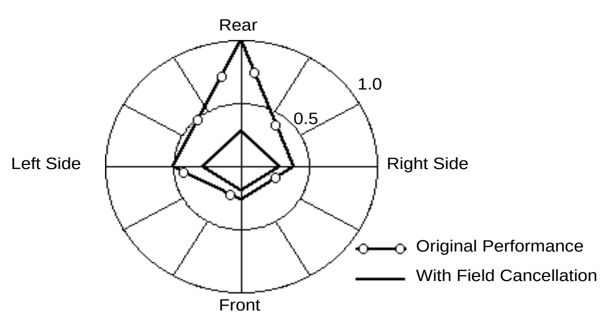

Figure 4. VLF electric field strength at 50 cm was greatly reduced by the introduction of a cancellation

signal in the left-rear area of the chassis. Amplitudes are normalized.

A small cancellation field was introduced by connecting a pulse from the horizontal flyback transformer to an existing metal part, causing the field to the rear to be reduced by more than a factor of three (Figure 4). When the size of the cancellation field radiator was optimized, field potential decreased by more than an order of magnitude.

<u>Cancellation of ELF Fields</u>

The anode voltage of displays without a regulated anode supply can vary several hundred volts peak-to-peak because of video signal current and blanking; thus resulting in up to several hundred Vrms/m in the ELF band when measured according to the MPR protocol. Changing video content and user's adjustment of the brightness and contrast controls makes the field from the CRT anode unpredictable. Similarly, the AC mains wiring is sometimes found to be reversed in homes and offices, resulting in increased ELF electric fields from the degaussing coil.

For cases such as these, the cancellation signal is generated best by capacitively sensing the unwanted field, inverting, amplifying, and reradiating the signal as a cancellation field. Figure 5 shows a circuit that performs this function.

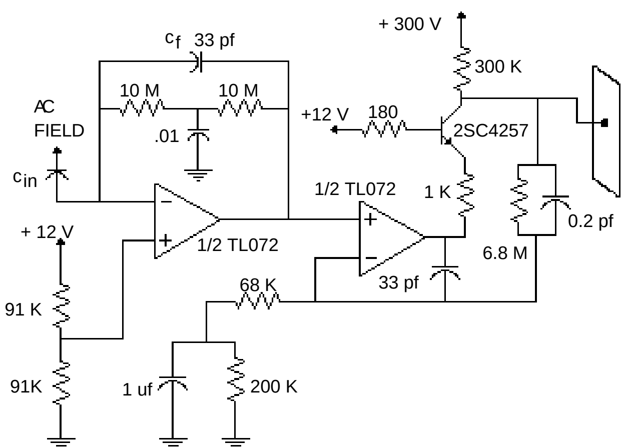

Figure 5. The current sensed through the capacitive coupling to the anode (Cin) is integrated in Cf to obtain an inverted replica of the anode voltage waveform.

Capacitive coupling to the CRT anode may be by way of a small conductive strip positioned near the CRT or attached directly to the back of the CRT bell.

The radiator area required to cancel a given field is inversely proportional to the amplitude of the cancellation signal. High voltage, low current transistors recently developed for use in focus modulation circuits make it possible to economically generate ELF compensation waveforms of 1 KV P-P or more, thus minimizing the area of the radiator.

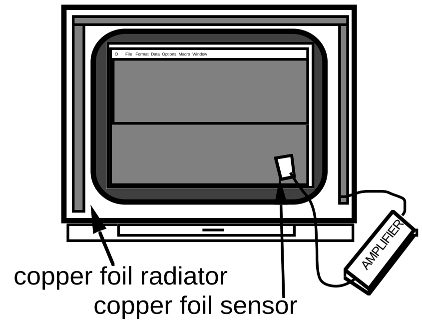

Figure 6. Test setup including the image used to generate electric field fluctuations for tests.

To demonstrate this method, a commercially available 14-inch display was externally fitted with a field sensor, cancellation amplifier, and cancellation field radiator as illustrated in Figure 6. In actual application, the entire electric field cancellation subsystem would be located within the enclosure. The image depicted in Figure 6 generated large fluctuations of the anode voltage to produce the distinctive waveforms shown.

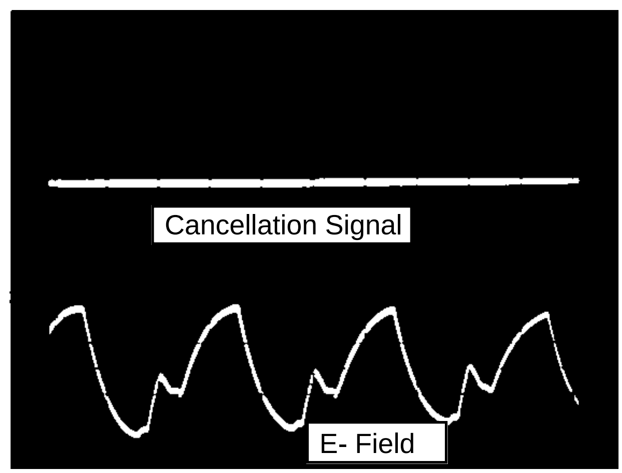

Figure 7. The upper trace is the cancellation signal (off).
Lower trace is the ELF Electric field sensed 50 cm in front of a display.

The effects of cancellation of an ELF Electric Field can be seen in photographs taken from a dual trace oscilloscope (Figures 7, 8, and 9). In the photographs, the upper trace shows the cancellation signal that was applied to the cancellation field radiator. The lower trace indicates the ELF waveform sensed by an electric field probe, located 50 cm from the front of the display and designed to meet the requirements of MPR1990:8.

In Figure 7, The power supply for the cancellation amplifier was turned off so no cancellation took place. The lower trace shows the waveform of the ELF electric field which is 39.4 Vrms/m. This field is composed primarily of signals at the vertical refresh rate of the display.

When an approximately 250 VP-P cancellation signal was applied to the cancellation field radiator (Figure 8), the ELF electric field dropped to 4.6 Vrms/m. Incomplete cancellation occurred because of linearity and phase distortion in the cancellation amplifier.

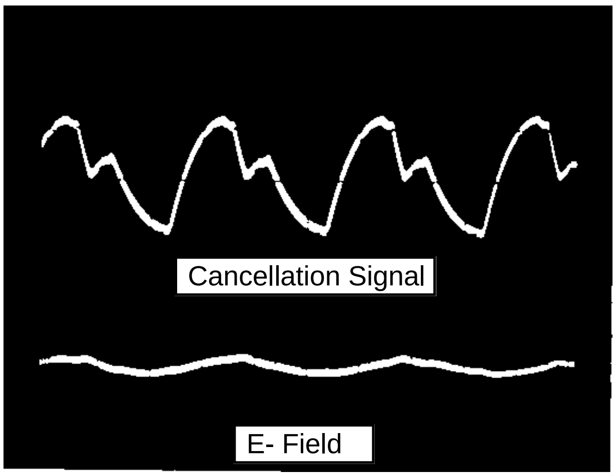

Figure 8. With cancellation applied, the resulting ELF electric field is reduced to 12% of its former amplitude.

As the video content changes and the brightness and contrast controls are manipulated, the output from the cancellation field radiator changes to maintain cancellation, even though the signal radiating from the anode may vary by a factor of 10 or more (Figure 9).

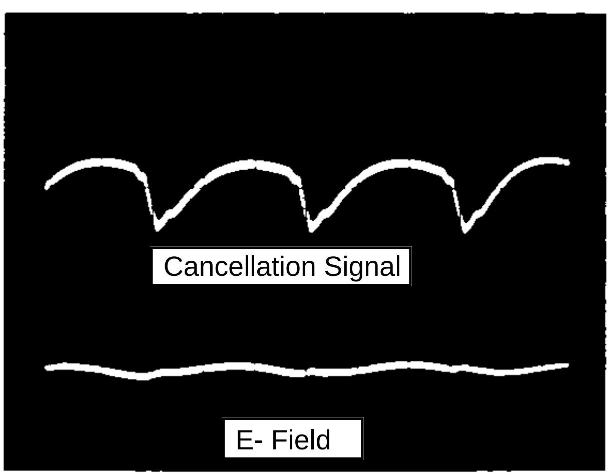

Figure 9. The cancellation signal is generated in response to the field generated when displaying a nearly flat field. Negative slopes in the cancellation waveform occur during vertical retrace blanking of CRT beam.

Summary

Cancellation of ELF and VLF electric fields has been shown to be a practical alternative to conventional methods such as shielding. Signals to cancel fields for highly variable sources, such as the CRT anode, can be obtained by sensing and amplifying the undesired field. Cancellation signals for more predictable fields, such as those arising from the horizontal deflection circuit, may be obtained directly from the deflection circuit itself.

When designing electric field cancellation systems, it is important to remain cognizant of the potential for serious measurement errors that may occur because commonly used instruments only measure the scalar quantity, electric potential, rather than the electric intensity vector. It is also important for the designer to be aware of the possibility of generating field profiles with undesirably large lobes that will be undetected when measured according to existing standards.

With care, effective ELF and VLF electric field cancellation systems can be designed that provide the benefits of conventional methods without their attendant drawbacks.

Notes and References

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