

# TEM Waveguides for EMC Measurements

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**Abstract**—An overview of TEM waveguide electromagnetic compatibility (EMC) test facilities applicable to radiated emission and immunity measurements is given. Measurements of the field homogeneity in two TEM waveguides of different style are discussed. A statistical weighting of the measured electrical field is used to compare the results with standards requirements.

**Index Terms**—Field homogeneity, generalized telegraphist's equations, higher order modes, TEM cells.

## I. INTRODUCTION

THE open area test site (OATS) is the reference for many standard measurement procedures which assume far-field conditions. This paper considers OATS alternative electromagnetic compatibility (EMC) test facilities for radiated immunity and emission measurements. OATS emission testing can be difficult due to poor EM environments. A shielded enclosure can be used to isolate the test area from the environment. Wall reflections must then be suppressed over the desired frequency range to simulate a free-space environment. This can be achieved by covering the walls with absorbing material. However, absorption is typically less than ideal for wavelength large compared to the absorber size and absorber material can be costly. Thus, in order to reduce the expense of EMC, testing alternatives such as TEM waveguides are of interest.

## II. TEM WAVEGUIDES

The TEM mode can be used to approximate a free-space plane wave. TEM wave propagation is possible in waveguides consisting of at least two separate conductors. The transverse field distribution of the TEM mode is identical to the transverse electrostatic field between the two conductors. In order to approximate a linearly polarized plane wave as would exist in ideal free-space, two infinite parallel plates give the desired field structure. Parallel plates of finite width can be used to approximate a linearly polarized plane wave over some limited volume.

### A. Open TEM Lines

Open parallel plate structures or strip lines can be problematic as they are open. They radiate to the outside environment. To avoid radiated emissions and ambient noise, they need to be located inside a shielded room. Coupling between the shielded

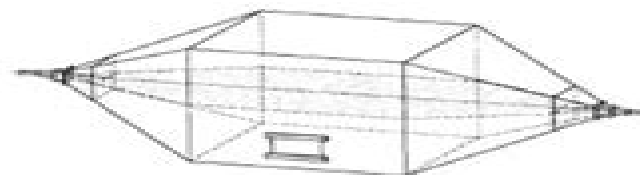


Fig. 1. Crawford cell.

room and the open TEM line can significantly degrade the intended TEM line performance. This disadvantage led to the development of enclosed TEM lines, also known as TEM cells.

### B. Enclosed TEM Lines

TEM cells for EMC applications are usually given a rectangular cross section. The TEM mode field structure between the wide flat inner conductor and the outer wall resembles that of a parallel plate line. Such TEM waveguides are closed and do not couple to the outside environment.

### C. Double-Port Waveguides

Enclosed TEM lines can be separated into single- and double-port waveguides. This criterion deals with the termination of the waveguide. An example for a double-port waveguide is the Crawford cell [10], which is depicted in Fig. 1. It consists of two tapered sections and a homogeneous middle section. In these cells, the location of the septum is normally *symmetric*. Cell impedance is usually designed to be  $50\ \Omega$  to facilitate connection to standard measurement equipment. Both ports may be used for measurements, excitation, or resistively loaded.

### D. Single-Port Waveguides

Single-port waveguides typically feature some sort of broadband termination. One realization is to combine distributed resistors with an absorber wall as is done in gigahertz TEM (GTEM) cells [8], as shown in Fig. 2. The location of the septum in a GTEM cell is *asymmetric* to achieve a larger test volume.

Fig. 3 shows the asymmetric cross section of a GTEM cell, together with the coordinate system used in the section that follows.

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# Emc Measurements Guide

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*A Handbook for EMC Testing and Measurement* David Morgan, 1994-06-30 This major reference book is aimed at engineers and technical managers concerned with EMC electromagnetic compatibility It explains why EMC testing is necessary what standards must be met how such testing is carried out and therefore how to prepare for it what accuracy and repeatability can be expected and when to test

*Electromagnetic Compatibility in Railways* Ade Ogunsola, Andrea Mariscotti, 2012-08-14 A railway is a complex distributed engineering system the construction of a new railway or the modernisation of a existing one requires a deep understanding of the constitutive components and their interaction inside the system itself and towards the outside world The former covers the various subsystems featuring a complex mix of high power sources sensitive safety critical systems intentional transmitters etc and their interaction including the specific functions and their relevance to safety The latter represents all the additional possible external victims and sources of electromagnetic interaction EMC thus starts from a comprehension of the emissions and immunity characteristics and the interactions between sources and victims with a strong relationship to electromagnetics and to system modeling On the other hand the said functions are achieved and preserved and their relevance for safety is adequately handled if the related requirements are well posed and managed throughout the process from the beginning The link is represented by standards and their correct application as a support to analysis testing and demonstration

**Modern Measurements** Alessandro Ferrero, Dario Petri, Paolo Carbone, Marcantonio Catelani, 2015-09-03 This book is a collection of chapters linked together by a logical framework aimed at exploring the modern role of the measurement science in both the technically most advanced applications and in everyday life Provides a unique methodological approach to understanding modern measurements Important methods and devices are presented in a synthetic and easy to understand way Includes end of chapter exercises and solutions

*EMC for Product Designers* Tim Williams, 2011-04-01 Widely regarded as the standard text on EMC Tim Williams book provides all the key information needed to meet the requirements of the latest EMC Directive Most importantly it shows how to incorporate EMC principles into the product design process avoiding cost and performance penalties meeting the needs of specific standards and resulting in a better overall product As well as covering the very latest legal requirements the fourth edition has been thoroughly updated in line with the latest best practice in EMC compliance and product design Coverage has been considerably expanded to include the R New chapter on military aerospace standards of DEP STAN 59 41 and DO1 60E New chapter on systems EMC

**Electromagnetic Compatibility (EMC).** Standards Australia Limited, 2007

*Electromagnetic Compatibility (EMC).* SABS Standards Division, 2009

*EMC Shielding Materials* John W. Molyneux-Child, 1997 Effective and efficient shielding is essential for the control of electromagnetic emissions and this guide provides a survey of techniques and materials This edition examines in detail the consequences of the EMC Directive

**Electromagnetic Compatibility (EMC).** South African Bureau of Standards, 1999

Electromagnetic Compatibility David A. Weston, 1991 This totally revised and expanded reference text provides comprehensive single source coverage of the design problem solving and specifications of electromagnetic compatibility EMC into electrical equipment systems including new information on basic theories applications evaluations prediction techniques and practical diagnostic options for preventing EMI through cost effective solutions Offers the most recent guidelines safety limits and standards for human exposure to electromagnetic fields Containing updated data on EMI diagnostic verification measurements as well as over 900 drawings photographs tables and equations 500 more than the previous edition **Electromagnetic Compatibility Principles and Applications Second Edition** **FCC Record** United States. Federal Communications Commission, 2018 *Electromagnetic Compatibility Design Guide for Avionics and Related Ground Support Equipment* Ernest R. Freeman, Michael Sachs, 1982 Summary Laurel Hardy work in a horn factory where the noise drives Hardy to a nervous breakdown and ends with them taking a sea voyage that doesn't quite go as planned

**Electromagnetic Compatibility (EMC).** SABS Standards Division, 2009 **Electromagnetic Compatibility (EMC).** Standards South Africa, 2005 **Electromagnetic Compatibility (EMC) - Part 4-7: Testing and Measurement Techniques - General Guide on Harmonics and Interharmonics Measurements and Instrumentation, for Power Supply Systems and Equipment Connected Thereto (IEC 61000-4-7:2002)** Polska. Polski Komitet Normalizacyjny, 2004

**Handbook of Electromagnetic Compatibility** Reinaldo Perez, 1995 This text offers readers an understanding of the fundamentals of EMC from basic mathematical and physical concepts through present computer age methods used in analysis design and tests Fortified with information on how to solve potential electromagnetic interference EMI problems that may arise in electronic design practitioners should be better able to grasp the latest techniques trends and applications of this increasingly important engineering discipline **Electromagnetic Compatibility (EMC).** Standards Association of Australia, 1999 Symposium Record, 2004 Electromagnetic Compatibility (EMC). Testing and Measurement Techniques. General Guide on Harmonics and Interharmonics Measurements and Instrumentation, for Power Supply Systems and Equipment Connected Thereto British Standards Institute Staff, 2003-01 Electromagnetic compatibility Electromagnetic radiation Electromagnetic fields Electric power system disturbances Noise spurious signals Harmonics Electric distortion Electrical wave measurement Electrical measuring instruments Electrical testing *The useful knitter*, by E.M.C. Elvina Mary Corbould, 1887 **Electromagnetic Compatibility**, 1990

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