

# 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

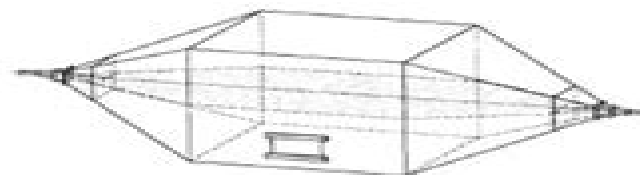


Fig. 1. Crawford cell.

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.

Manuscript received April 2, 1999; revised September 2, 1999.

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Publisher Item Identifier S 0018-9375/99/090440-2.

# Emc Measurements Guide

**Ernest R. Freeman, Michael Sachs**

A red circular graphic with a gradient, appearing as a stylized arrow or a partial circle, located to the right of the authors' names.

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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 (EMC).** Standards Australia Limited,2007

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

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**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

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**Electromagnetic Compatibility (EMC) - Part 4-7: Testing and Measurement Techniques -**

General Guide on Harmonics and Inteharmonics Measurements and Instrumentation, for Power Supply Systems and Equipment Connected Thereto (IEC 61000-4-7:2002) Polska. Polski Komitet Normalizacyjny,2004      **Electromagnetic Compatibility (EMC).** Standards Association of Australia,1999      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      A Practical Guide to EMC Engineering Levent Sevgi,2017-03-31 This practical new resource explores the fundamentals of EMC engineering and examines the concepts and underpinnings of electromagnetics This book highlights the procedures from design to market for both technical and non technical issues including market control accreditation calibration EMC tests and measurement and EMC protection Basic electrical engineering theories Maxwell equations EM scattering diffraction and propagation in the electromagnetic model are presented The circuit model including lumped parameter circuit elements two port circuit definitions grounding common and differential model currents and microstripline circuits are explored This book also covers antennas and antenna calibration including communication antennas normalized site attenuation NSA loop antennas and loop antenna calibration LAC Noise and frequency analysis on fundamental electromagnetic signals noise and transforms is explained Readers find insight into EMC test and measurement environments and devices Time saving MATLAB code is included in this resource to help engineers with their projects in the field      **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

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*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      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

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