Electronics and Telecommunication

Antenna, RF feeder and RF connector topics

RF antennas (or aerials) are an essentialelement of any radio communications link, whether it is for a high power transmitter like those used for broadcasting, or low power ones like those used wireless technologies such as WLAN or remote control and sensingapplications.
Apart from the power levels, RF antennas are used across the whole radio spectrum, from ELF right up to the microwave bands. Whatever the power, and the frequency, the basic RF antenna design theory remains the same, although the practical approach has to change to meet the differenting mechanical requirements.

Although RF antenna design and theory can involve a considerable amount of involvedmathematics, there is much that can be achieved with only a minimum of mathematics, and most RF antenna engineers do not need a Ph.D in advanced calculus.

RF Antenna Basics
Electromagnetic waves and basic antenna operation
Polarisation
impedance - including radiation resistance, loss resistance and efficiency
Resonance and bandwidth
Directivity and gain

Feeders
The ideal position for an antenna is rarely in the optimum position for the transmitting or receiving equipment. As a result a form of transmission line or feeder is required to transfer the signals and power to and from the antenna.

Coaxial feeder
Coax cable loss or attenuation the reasons for it and how to minimise it.
Coax cable power rating
Coax cable velocity factor
RF coax cable data and specifcations
Environmental factors relating to coax cables
Balanced feeder
Waveguide basics
Waveguide data
Antenna RF diplexer - although not a feeder, a diplexer is sometimes included in the feed system of an antenna.

RF coax cable connectors

A wide variety of RF connectors are available for making connections to coaxial cable. These connectors including BNC, C-type, N-type, UHF (Amphenol) connector, SMA, SMB, SMC and many more are able to be used in a variety ofapplications.

Coax cable connectors - general overview
BNC connector
TNC connector
C-Type connector
N-Type connector
SMA connector
SMB connector
UHF connector

The dipole antenna

The dipole antenna is one of the most basic forms of antenna available. It is widely used on its own, and it is also used as the "driven" element in many other types of antenna.

The dipole antenna
Folded dipole

The vertical antenna

Vertical antennas are widely used in many areas, and are particularly widely used formobile applications because they radiate all around them in the horizontal plane. This means that they do not need redirecting as the mobile station moves. The quarter wave vertical is the simplest, but there are many other designs that provide improved performance and gain.

Quarter wave vertical
Five eighths wavelength vertical
J pole vertical antenna

Directional antennas

There is a good variety of different types of directive antenna that can be used. Althoughthe yagi antenna is the most popular, it is by no means the only one, and other designs and approaches are more applicable in many instances.

Yagi
Log periodic beam antenna
Parabolic reflector
Horn antenna

Wideband antennas
Most antennas are only able to operate over a narrow bandwidth. There are some techniques that enable the bandwidth of an antenna to be increased considerably, and also some desgigns that are able to operate over very wide bandwidths.

Discone
Log periodic beam antenna

Loop antennas

Where directivity and small size are required, loop antennas may often provide an answer.Although different types of loop have slightly different properties, they are able to provide a good antenna solution in many circumstances.

Loop antenna overview
Ferrite rod antenna

Applications

Antennas can be used in many applicationsfrom reception of terrestrial and satellite television to point to point radio, short wave radio and much more.

Satellite antennas for satellite television and other satellite applications

Antenna installation

When installing an antenna many points must be considered. Location, type of antenna, method of installation and many other items all affect the antenna installation. Safety is also a crucial element because if the antenna is not installed correctly the antenna may collapse.

Antenna height
Antenna installation materials - choosing the correct materials to minimise corrosion
How to install coax cable - some key points to note.

Cellular Telecommunications and Cell Phone Technology

There are many mobile or cell phone systemsthat are in use all over the world and there is a considerable amount of equipment ranging from the cell phones themselves to cellular base stations, antennas and the network infrastructure. In addition to the basicequipment there is new cell phone technology to provide the many new services that are now available, enabling cell phone users to enjoy many new applications

from games, andringtone downloads to picture and videodownloads. With technologies ranging from GSM, GPRS, EDGE to UMTS or W-CDMA and cdmaOne (IS-95) to CDMA2000 1X, EV-DO and EV-DV and mobile TV technologies such as MediaFLO, DMB, and DVB-H, there are plenty of technologies in use.

There is plenty of terminology associated withcellular telecommunications and cell phone technology. Our terminology glossary explains the most commonly used terms associated withcellular telecommunications / cell phone technology:

The technology behind cellular systems and cell phones has developed from the first generation (1G) systems to the second geenration (2G) systems and then to the third generation (3G) systems. At each stage the performance improved and further facilities were available, from SMS messaging to video downloads.

Major Mobile Phone Systems (a tabular overview)
Mobile phone or cell phone history

Cellular telecommunications basics.

There are a number of basic concepts behindcellular telecommunications systems. These include the idea of cells themselves as well as how the networks are set up, what is in a mobile phone and how some of the transmission technologies such as CDMA, TDMA and the like operate.

The basic concepts of a cellular telecommunications system
The multiple access schemes used by mobile phones
The duplex schemes used by mobile phone networks FDD and TDD
The operation and electronics within a mobile phone
The basics of a cellular network
The way in which a mobile phone registers onto a network
Handover or handoff, the way in which cellular calls are transferred from one cell to another
For articles on CDMA, MIMO, OFDM, etc, see our new RF Technology and Design section.

Cellular testing
With vast numbers of phones and cellularsystems deployed and new ones beong launched all the time, it is essential that newequipment is thoroughly tested ebfore it is launched ontoth e market. Additionally ones systems are deployed it is essential to esnure that they are operating to their best.

Cellular conformance testing overview
Conformance testing for GSM and UMTS
cdma interoperability test

Global System for Mobile Communications (GSM).
GSM is the system that was developed in Europe and is now the most popular system in use around the globe.

The development of the Global System for Mobile communications GSM
GSM technical overview (6 pages)
General Packet Radio Service, GPRS, tutorial (5 pages)
Enhanced Data for GSM Evolution (EDGE) UMA unlicensed mobile access and GAN generic access network
UMA / GAN conformance testing

CDMA System including cdmaOne (IS-95) and CDMA2000 (IS-2000)

The CDMA family of technologies including cdmaOne (IS-95) to CDMA 2000 were the first technologies to use CDMA technology.

What is CDMA cdmaOne / CDMA2000? A Guide to the CDMA system and its evolution.
IS-95 (cdmaOne)
CDMA2000 1xEV-DO
CDMA Band Classes and Frequency AllocationsUMB Ultra-Mobile Broadband the 3.99G evolution for cdam2000

Universal Mobile TelecommunicationsSystem (UMTS) / Wideband CDMA (W-CDMA)

UMTS / W-CDMA Tutorial (5 pages)
High Speed Downlink Packet Access (HSDPA)
High Speed Uplink Packet Access (HSUPA) The companion to HSDPA.
UMTS TDD The scheme being used for mobile broadband.
3G LTE Long Term Evolution an overview of the developments being undertaken for the next generation cellualr systems The scheme being used for mobile broadband.

Miscellaneous sytems and features
Pacific or Personal Digital Cellular (PDC)
i-mode for e-mails and internet surfing
TD-SCDMA the 3G system being developed in China

Location services:
Assisted GPSMobile video:
Mobile video broadcasting video to phones using T-DMB and DVB-H
DVB-H Digital Video Broadcasting Handheld
DMB Digital Multimedia Broadcasting

Private Mobile Radio PMR

Private or Professional Mobile Radio (PMR), or Public Access Mobile Radio (PAMR) is used in many countries around the world, and new technology is being developed to ensure it keeps up with today's needs. It is widely used by the emergency services, and this is particularly true of the new Tetra system that is being widely deployed.

An overview of private mobile radio (PMR) the various standards that are available to use.
An overview of the basic "local" PMR system
Trunking using the MPT1327 system
An Overview of TETRA private mobile radio (PMR)

Electronic Circuits and Designs

A potpourri of basic electronic circuits, circuit ideas, and formulae for anyone undertaking electronic circuit design

The exact configuration of an electronic circuitis not always easy to remember, and even then there are associated electronic circuit designformulae to calculate the various circuit values.

This section of the Radio-Electronics.Com website contains information about basicelectronic circuits, building blocks, along with the relevant formulae to provide a unique reference on the web for anyone undertaking electronic circuit design.

This section is organised by the chief component in the circuit. Thus a filter using anoperation amplifier would come under the operational amplifier section, and a transistor radio frequency amplifier would come under the transistors section and a pin diode attenuator would be found in the diodes section.

Resistor circuits
Resistors are the most widely used components in electronic circuits. Although very simple in concept they are key to the operation of many circuits. They can be used in a variety of ways to produce the requried results.

Resistors in parallel
Resistor attenuator circuits

Resistor capacitor (RC) circuits
RC or resistor capacitor circuits are used in a number of applications and may be used toprovide simple frequency dependent circuits.
Twin T notch filter

LC filter circuits
Using inductors and capacitors a whole variety of filters can be designed and made. These include low pass, high pass and band pass filters

A basic filter overview
Low pass LC filter
High pass LC filter
Band pass LC filter

Diode circuits
The diode is one of the most elementary semiconductor devices. It essentialy allows current though the device in one direction. Using this facet of the diode there are many uses, but there are also other facets of its nature that enable to to be used in otherapplications as well.

Simple PIN diode attenuator and switch
Constant impedance pin diode attenuator
Power supply current limiter
Diode voltage multiplier
Single balanced diode mixer
Double balanced diode mixer

Transistor circuits
Two transistor amplifier circuit with feedback
Transistor active high pass filter
Transistor current limiter for power supplies
Transistor crystal oscillator

SCR, Diac and Triac Circuits
SCR overvoltage crowbar circuit

Operational amplifier circuits
Operational amplifiers are one of the mainbuilding blocks these days used in analogue electronics. They are not only easy to use, but they are plentiful, cheap and offer a very high level of performance.

Operational amplifier basics
Inverting amplifier
High input impedance inverting amplifier
Non-inverting amplifier
High pass filter
Low pass filter

Band pass filter
Variable gain amplifier
Fixed frequency notch filter
Twin T notch filter with variable Q
Multivibrator oscillator
Bistable multivibrator
Comparator
Schmitt trigger

Digital logic circuits
Logic circuits consisting of building blocksincluding AND and OR and NAND and NOR gates for the basis of today's digital circuitry that is used in widely in electronics. Trigger, bistables, flip flops,etc, are also widely sued and can be made up from the basic building blocks.

Logic truth table
Hints and tips on designing and laying out digital or logic circuits
Using inverters to create other functions
A divide by two frequency divider using a D-type flip-flop
An R S flip flop using two logic gates
An edge triggered R S flip flop using two D types
An electronically controlled inverter using an exclusive OR gate

Design principles and processes:

Overviews and tutorials about the processes and concepts required for electronics design

The pages in this section of Radio-Electronics.Com are aimed at providinginformation about the hardware design ofelectronics circuits. Topics from design conceptsand methodologies, through to more practicalelements of PCB layout, ESD, EMC, verificationand validation testing, etc.

ElectroMagnetic Compatibility, EMC

EMC or ElectroMagnetic Compatibility is of great importance in any circut design these days. In order to meet the requirements to pass EMC test it is necessary to take accont of it from the early stages of design.
Design techniques for EMC tutorial
EMC filter design

Electrostatic Discharge ESD

Electro Static Discharge (ESD) is important for anyone involved with electronics. Even small discharges that would go unnoticed in everyday life can cause large amounts of damage to electronic circuits. Find out all about it and how to ensure electronic circuits are not affected in our three page tutorial.
Electrostatic Discharge ESD

PCB design

With printed circuit board design and layout becoming an ever more integral and important part of the overall circuit design process, technology is moving forward and anabling the PCB to meet the demanding requirements of high frequency operation, smaller components, and higher component densities.

PCB design process overview
PCB layout tutorial
Schematic capture
Signal integrity for PCB and circuit design
PCB design and layout guidelines

Circuit simulation

EMC or ElectroMagnetic Compatibility is of great importance in any circut design these days. In order to meet the requirements to pass EMC test it is necessary to take accont of it from the early stages of design.

Electronic Components

Electronics and radio components

- including capacitors, resistors, inductors, semiconductors, diodes, transistors, crystals .....

There is a very wide range of electronics components available from passive components such as resistors, capacitors, inductors and quartz crystals to active components includingsemiconductors such as diode and transistors. Thermionic valves or tubes are also used in some specialist applications as well. These and more are all used in electronics and radio circuits today.

Surface Mount Technology (SMT)
In recent years there has been a drammatic change from the use of leaded components to surface mount technology. These SMT components make the manufacturing process much easier and faster.
Introduction to surface mount technology SMT
Surface mount technology (SMT) component packages
The Ball Grid Array, BGA, package used forintegrated circuits

Capacitors

The capacitor may appear to be simple device at first site, there is more to them than meets the eye. The choice of capacitor can enable the circuit to work correctly... or not.

- Capacitor marking codes
- Conversion chart to convert pF to nF to uF
- SMD capacitors
- Summary of capacitor types
- Electrolytic capacitor overview
- Tantalum capacitor overview
- Ceramic capacitor overview
- Silver mica capacitor overview

Resistors

Resistors come in an enormous variety of sizes. Their markings are known as the resistor colour code and this normally tells their value, and other parameters about them.
Resistor colour code
Standard or preferred resistor values and the E series
Thermistor - the temperature dependent resistor
Light dependent resistor, LDR, or photo resistor
SMD resistor - the surface mount resistor

Semiconductors
Transistors and diodes are in widespread use today. Many millions are used each day apart from those that are incorporated in integratedcircuits.
Basics of semiconductors
Semiconductor numbering or coding systems - the Pro-electron and JEDEC systems for diode, transisor and FET codes.

Diode types:
Introduction to the PN junction and the basic diode
Gunn diode
IMPATT or IMPact Avalanche Transit Time diode
Laser Diode
Light emitting diode (LED)
Photodiode
Avalanche photodiode
PIN Diode

Schottky barrier diode
Tunnel diode
Varactor or varicap diode
Zener or Voltage reference diode
Diac

Active devices:

The bipolar junction transistor (BJT)
Photo transistor (phototransistor)
The High Electron Mobility Transistor (HEMT)
The Thyristor or Silicon Controlled Rectifier (SCR)
Triac
Charge coupled image sensor CCIS
FPGA - Field Programmable Gate Array
ASIC - Application Specific Integrated Circuit
Semiconductor Memory Technologies
Flash memory
MRAM - Magneto-resistive Random Access Memory
DRAM - Dynamic Random Access Memory
EEPROM
SDRAM

Quartz Crystals

Quartz crystals are widely used in many areas of electronics. Their unique properties make them an ideal choice in many applications
Quartz crystals - What are they and how the can be used as a resonator
The effects of ageing on the frequency stability of quartz crystals
Oven controlled crystal oscillator (OCXO) for greater temperature stability
Temperature Compensated Crystal Oscillator (TCXO)
Voltage Controlled Crystal Oscillator (VCXO)
Quartz crystal specifications and how to specify them for radio oscillator and filter applications

Quartz crystal filters:

Quartz crystal bandpass filter - filters using discrete crystals
Monolithic crystal filter

Vacuum tubes
Vacuum tubes or thermionic valves are still used today and many can be found in vintage radio sets. (For information about the history of valves and their development see the Radio History section of this website - see side menu). Many audio enthusiasts prefer the sound that comes from a tube amplifier. Additionally there are many valve radios or wireless sets in use, and vacuum tube or thermionic technology continues to be used in some specialist areas of electronics.
Basic concepts behind the vacuum tube
Descriptions of the cathode, anode and grid used in the vacuum tube.
Vacuum tube or thermionic valve numbering systems
Vacuum tube or thermionic valve equivalents for replacements and substitution.
Vacuum tube or thermionic valve pin connections - pin connections for some popular valves.
Travelling wave tube (TWT) - used for high power microwave amplifiers.
Photomultiplier - used for image capture in very low light levels

Wire and cables
Wire and cable are an important part of any electronic system. While wire and cables may not attract the same attention as other components, wire and cables are nevertheless an important topic.
Wire and cable Metric / AWG conversion chart

Electronics production and manufacture

Production Process Overview
There are many processes involved in producing a surface mount, of any otherelectronic circuit board. These processes all need to be combined so that they operate together and provide the highest quality output.
Overview of an electronics assembly / production process.
Overview of the PCB manufacturing processdetailing how PCBs are designed and manufactured.

Component placement
One of the major elements in the manufactureof electronic circuit boards is the placement of the components onto the boards. While some printed circuit boards may have only a few components, some of today's electronic circuitboards may use several thousand. This is clearly not suitable for manual assembly and therefore automated techniques must be used.
PCB Pick and place systems

Soldering
Basic soldering processes
Solder
Solder paste and how to use it
Lead free solder and soldering techniques

Solder resist
Manual or hand soldering
Soldering irons and soldering stations - the key points to note about them
SMT soldering - soldering processes applicable to surface mount technology.
Infrared reflow soldering
Wave soldering
BGA solder process

Standards and Lgislation

There are several standards and some legislation covering the manufacture of electronic equipment.
RoHS - Restriction of Hazardous Substances - the EU directive to reduce the levels of hazardous substances in electronic equipment
What is the WEEE Directive? - for Waste Electrical and Electronic Equipment

Radio and Electronics Formulae

There is a huge number of formulae, formulasor calculations that appear in radio and electronics circuits and other areas of radio and electronics. Everything from calculating the capacitors in series and parallel, through the charge on capacitors, and flux in inductors through
to calculations about signals in feeders and the like. They are all important and often difficult to remember. This section of Radio-Electronics.Com aims to provide a quick and easy reference for them.

Resistors
- Resistors in series and parallel and a table of resistors in parallel
- Table of resistivity and temperature coefficient of resistance for various materials

Capacitors and capacitance
- Dielectric constant and permittivity

Decibels
- Table of decibel values for power, voltage and current
- Conversion table for dBm dBW and power measured in watts

Radio Frequency
- Voltage Standing Wave Ratio (VSWR)
- Return loss
- Return loss / VSWR / Voltage reflection coefficient conversion table

Mathematical Functions
- Trigonometrical functions
- Hyperbolic functions
- Mathematical series

Physical constants and other data
- Fundamental physical constants
- Derived physical constants

Radio operation
- Morse code
- Phonetic alphabet

Radio Broadcast Technology

Radio broadcast technology and radio broadcasting including analogue radio digital radio, analogue television and the many forms of digital television for terrestrial television, satellite television and mobile or handheld television.

Radio broadcasting is an established use of radio technology. The first organised broadcasts taking place in the 1920s.
Now there are many radio stations broadcastingall over the world using a variety of differernttypes of transmission. Today, radio broadcastequipment from transmitters and receivers to antennas, studios and relay links are widely available, although with the new standards fortransmission including DAB Digital Radio and DRM, new equipment is required. Nevertheless AM as well as FM with its RDS capability are still the most widely used.

AM broadcasting
C-QUAM system for broadcasting AM stereo

VHF FM broadcasting

VHF FM is the most widely used form ofbroadcasting in areas of the world where the population is relatively high. Its bandwidth enables it to carry high quality transmissions, stereo, and other services such as RDS.
Broadcast VHF FM
RDS - Radio Data Service

Digital Radio Broadcasting

DAB digital radio is now widely deployed in many countries around the globe, and now that the cost of radios has fallen, listener figures are rising. Although not available in many countries, it is certainly making a significant impact where it has been deployed, adding more flexibility and the possibility of near CD quality.

What is DAB, Digital Audio Broadcasting
DAB digital radio Band III channel numbers and frequencies
HD Radio - the new digital radio system for the USA
Digital Radio Mondiale (DRM) - the new standard to replace AM broadcasting

Television

There are many way in which television can be distributed these days. From the old analogue television radio broadcasts, through the new digital methods of radio delivery to IP based delivery over wired networks such as the Internet.

What is DVB - Digital Video Broadcasting - an overview or tutorial about the basics of DVB
IPTV - Internet Protocol Television

History of Radio and Electronics

Morse Telegraph System The introduction of the Morse telegraph system brought about one of the largest revolutions in communications the world has ever seen, arguably more important than the internet. Read about its inventor, Samuel Morse and its history:- - Samuel Morse
- Development of the Morse Key
- The Story of the Morse Telegraph System

Great Names

Read about the great names in the history of radio and electronics:-
- Andre-Marie Ampere
- Edward Victor Appleton
- Edwin Armstrong Inventor of the regenerative radio, superset radio and wideband FM
- Ambrose Fleming Inventor of the diode valve
- Michael Faraday
- R A Fessenden
- Johann Gauss
- Oliver Heaviside
- Hedy Lamarr Hollywood actress and inventor of frequency hopping
- Sir Oliver Lodge
- Nikola Tesla
- Thomas Alva Edison
- James Maxwell

- Guglielmo Marconi
- Hans Christian Oersted
- Captain H.J. Round
- Alessandro Volta
- Georg Ohm The man who discovered the link between resistance, voltage and cirrent in a circuit

History of Radio

Radio has been an accepted part of everyday life for many years. Its development is stillongoing, and has taken it from an interesting curiosity to a means of communication on which today's world relies. Read about the essential milestones in its development.
- The Story of Radio
- History of the Radio Receiver

The discovery and development of the thermionic valve or vacuum tube

There is a great nostalgia about the gently aroma that rises up out of a vacuum tube radio that is operating. The first tubes appeared at the beginning of the 20th Century and heralded the beginning of electronics as we know it today. Find out about their development.

History of the vacuum tube

- or to give it its Eupoean name - the thermionic valve

The invention of the vacuum tube or thermionic valve brought the dawn of the age of electronics. Its invention enabled the wireless technology of the day to move forward. Many new and exciting applications were found for these devices, first as telephone repeater amplifiers and then many other applications that were not always linked to wireless and as a result the new area of electronics was born.

Beginnings
The first vacuum tube was not made until the beginning of the 20th Century, but the foundations for its discovery were laid many years before. Professor Guthrie made one of the first discoveries in 1873. He was investigating effects associated with charged objects and he showed that a red-hot iron sphere that was negatively charged would become discharged. He also found that the same did not happen if the sphere was positively charged.

The American inventor named Thomas Edison took the next major step in 1883. Edison was developing electric light systems and one of the major problems that he was facing was their short life. Although the filament life was a problem, the main limiting factor was that the bulbs

quickly became blackened. Initially it was thought that this was caused by atoms of carbon from the element hitting the glass. As it was known that the particles leaving the element were negatively charged, experiments were carried out to prevent them hitting the glass. One method that Edison tried involved placing a second element into the envelope. He reasoned that if he placed a positive charge on the second electrode, particles could be attracted away from hitting the glass of the bulb. Edison experimented with the polarity of the charge on the second electrode and he noticed that when the second element was made positive with respect to the filament then a current flowed in the circuit. When the potentials were reversed he noticed that this did not happen. Edison was fascinated by the effect but uncharacteristically he did not find a use for it. Even so it became known as the Edison Effect.

Over the years Edison demonstrated the effect to many other leading scientific personalities including Preece, a well known British electrical engineer and more importantly to Ambrose Fleming, the professor of electrical engineering at University College London. Although no developments were made for a number of years the seed had been sown for later discoveries.

More Developments

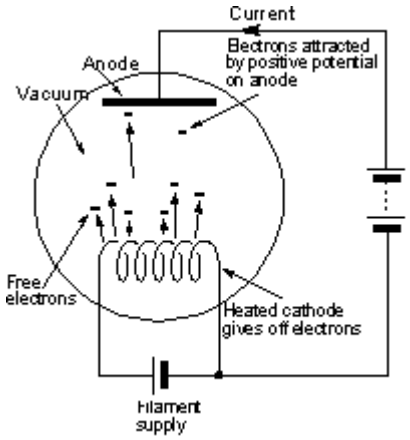
Like Edison, Fleming was also fascinated by the effect and performed some experiments around the idea. For example in 1889 he had some bulbs made up for him by the Ediswan Company in the UK. Using these bulbs he reproduced the Edison Effect, although again this was performed using a steady state charge. It was not until a few years later that he observed that if an alternating current with a frequency between 80 and 100 Hz was passed through the bulb, then only one half of the cycle was passed. In other words it was rectified to produce a direct current.

At this time there was a lack of understanding about the operation of the device and this prevented further progress from being made. However the situation improved when Sir Joseph Thomson discovered that atoms were made from even smaller particles, one of which was a negatively charged particle, an electron. Accordingly it was quickly realised that it was electrons that were being emitted from the heated filament in the bulb, and it also provided the reason why they were attracted to an electrode with a positive charge.

Fleming's oscillation valve

In addition to his work at University College London, Fleming also acted as a consultant to the Marconi, who at this time was rapidly increasing the distances over which wirelesssignals could be used for communication. For example, in 1901 he made the first transatlantic transmission, and then sought to improve the performance that could be achieved. Fleming rightly saw that the major limitation in the sensitivity of the receiving equipment was caused back the lack of sensitivity of the detector. At the time coherers and magnetic detectors were used, and both of these instruments were very inefficient.

Fleming decided that he needed to seek ways of improving this situation, and in November 1904 whilst he was walking along Gower Street in the West End of London, he had what he called "sudden very happy thought". He wondered if the Edison Effect could be used to rectify what he called the "feeble to and fro motions of electricity from an aerial wire". Fleming instructed his assistant to set up an experiment and to their great exhilaration they were quickly able to prove that the idea worked.



Concept of the diode vacuum tube

Fleming called his new invention an "oscillation valve" because it acted in a similar way to a valve in a pump that allows gas or water to move in only one direction. He patented the idea that was clearly a major step forwards inwireless technology. Even though the vacuum tube was still in its infancy it was still a major improvement over the coherer or magnetic detectors that were available at the time.

Despite its clear advantage over other detectors, Fleming's oscillation valve or vacuum tube was not widely used. Valves or tubes were difficult and expensive to make and their heaters consumed large amounts of power and this had to be supplied by expensive batteries. Additionally some cheaper devices were discovered in 1906. Devices that were forerunners of the Cat's Whisker detectors that were used in crystal sets until the mid-1920s were discovered. In fact two different patents were filed, one by Ferdinand Braun for a crystal detector using hydrated crystals of manganese oxide and the other by H. Dunwoody for a crystal detector using carborundum. These devices had many limitations but they were very much cheaper than Fleming's oscillation valve and as a result they were quickly adopted.

The Audion

Even though crystal detectors were very successful, several people continued to investigate whether they could develop thermionic or vacuum tube technology whilst avoiding any infringement of Fleming's patent. It was de Forest, an American who had been working on

a variety of areas associated with wireless who made the next and crucial vacuum tube development. He had been researching Fleming's diode valve and having investigated the idea he took out some patents for improvements in 1905 and 1906 where he introduced a third electrode. However in 1907 he took out a patent for a three-electrode device where the additional electrode which was placed between the anode and cathode had a fine grid structure. He called this device his Audion which he used as a leaky grid detector, not realising its full potential.

It was not until 1911 that the vacuum tube was used as anamplifier. After this discovery people were quick to try to exploit it. De Forest built an amplifier using three Audions and demonstrated it to the telephone company A.T & T. Althoughthe performance was poor they saw its potential and soon started to build repeaters using vacuum tubes which they had improved. Naturally as soon as the tube was used as anamplifier, people were quickly able to use it as an oscillator. Indeed, one of the problems soon encountered was difficulties in preventing oscillations in view of the high values of grid anode capacitance.

Radio Signal Propagation

Concise guides, information and tutorials to radiowave propagation including topics such as HF radio propagation, VHF propagation, microwave radiowave propagation, the ionosphere, ionospheric propagation, etc. Also overed is the effect or radiowave propagation on general radio communications, two way radio communications, mobile radio communications, radio broadcasting, cellular telecommunications coverage and Wi-Fi propagation.

The way in which radio signals travel or propagate it is prime importance to anyone associated with radio communications, be itcellular telecommunications, HF radiocommunications, two way radiocommunications, maritime or general mobilecommunications and much more. From radiocommunications users of the short wave or HF bands through to those using the VHF and UHF bands. Radiowave propagation is also of great importance to those using satellites, whether for TV reception, GPS or for any other purpose.Although satellites use frequencies well above the limits normally though to be affected by the atmosphere, there are still radio signalpropagation effects that are noticed. Additionally radiowave propagation is very important to those planning radiocommunications networks, from cellulartelecommunications or PMR networks, through to those using WiFi and other wireless technologies including Bluetooth, Zigbee, and Wimax.

Radio signal propagation basics

Radiowave propagation changes with frequency, and also with a number of other aspects. Whatever the frequency, radio waves are a form of electromagnetic wave and obey the basic laws that govern this type of wave. In order to understand how radio waves propagate it is necessary to look at the basic properties ofelectromagnetic waves and also the medium in which they travel, i.e. the atmosphere.

Electromagnetic waves and the electromagnetic spectrum
Reflection, refraction and diffraction of radio signals
Polarisation of electromagnetic waves - and their importance in radio wave propagation
Areas of the atmosphere that affect radio signals
An overview of the different types of radio propagation

Ground Wave

The ground wave is an important form of radio signal propagation. It is used by radiocommunications and broadcast stations on frequencies below about 2 MHz and enables them to provide local coverage.
Ground wave radio signal propagation

Ionospheric radiowave propagation - types of propagation and basic principles

Signals in the LF, MF and HF portions of the radio spectrum can travel over great distances using ionospheric propagation:
The Ionosphere
Ionospheric propagation
Ionospheric radio signal absorption
Critical frequency, MUF and LUF
Sporadic E
Transequatorial propagation
Near Vertical Incidence Skywave, NVIS, propagation

The Sun

The Sun has an enormous effect on ionospheric radiowave propagation and radiocommunications in general. The energy the Sun generates creates the ionisation that enables radio communications signals to be refracted by the ionosphere. As a result an understanding of its structure and nature helps provide a wider understanding of ionospheric propagation.
How the sun affects radio signal propagation
Solar disturbances
Sunspots

Ionospheric propagation - predictions, disturbances, etc

Ionospheric propagation is subject to many changes. Understanding the effects that may arise and predicting conditions is of great importnace to those using ionospheric propagation.
Sudden ionospheric disturbance, SID
Radio propagation prediction using solar indices
Radio propagation prediction software

Radiowave propagation in the troposphere

For frequencies at VHF and above different modes of propagation prevail. Although some ionospheric modes may be experienced, the main effects are caused by changes in the troposphere.
Tropospheric propagation
Troposcatter

Special forms of radiowave propagation

There is a variety of specialized forms of radio signal propagation that can be used to good effect for specialised applications. These include such forms of propagation as meteor scatter, troposcatter, "Moon bounce" and others.
Meteor scatter or meteor burst communications

Satellite Technology

Satellites are now an essential part of today's technology. The world has now come to rely on them in many ways. From satellite television (satellite tv) or direct broadcasting (DBS) of radio and television to the Global PositioningSystem (GPS) and the new Galileo system, as well as communications satellites such as Inmarsat and surveying and weathermonitoring satellites. Today we rely on satellites for many functions and they have become a part of everyday life that we take for granted. However it was only back in 1957 that the first satellite, Sputnik was launched. This ground breaking achievement set the pace for an enormous rate of development that sawcommunications and many other areas of life revolutionised.

- Satellite facts A potpourri of facts about satellites and their orbits.

Satellite basics
Whatever the form of satellite the basic concepts are still the same. The orbit, launch carriers and also the basic requirements for satellite must be met, whether the satellite is for communications, radio or television satellitebroadcasting, weather monitoring, or for navigation in the case of GPS.
- Satellite types and applications
- Satellite orbits
- Launching satellites and placing them into orbit
- Satellite design and construction
- The basics of satellite communications
- Satellite signal propagation - The effect of the troposphere and ionosphere on satellite signals
- Satellite frequency bands chart

Global positioning system (GPS)
The global positioning system (GPS) using the US DoD Navstar satellites is now well established and it is possible to buy GPS receivers very easily and cheaply considering the technology used. Additionally they are particularly accurate, enabling many cars to use SatNav systems inconjunction with stored mapto provide a very comprenesive navigation system. If this was not enough, Europe is to launch its own satellite navigation system under the name Galileo.
- A basic GPS introduction
- A technical summary of the Global Positioning System (GPS)

Satellite phone systems
Although terrestrial landline and mobile phone systems are widespread, satellite based systems are also available. Although more costly, these satellite phone systems provideessential services in several arenas.

Electronics Test and Measurement

Test methodologies
There are many ways in which electronicassemblies can be tested. Where they are forms of inspection to ensure that they havebeen built correctly, or functional tests that check the operation, each type of this form of electronics test and measurement has its ownadvantages and disadvantages.

In-Circuit Test (ICT)
Functional Test (FATE)
Automatic Optical Inspection (AOI) and X-Ray inspection
Boundary Scan (JTAG / IEEE 1149) Tutorial
- Boundary Scan Description Language, BSDL
- Designing for boundary scan test
- The JTAG specifications and the IEEE 1149 series of standards that define boundary scan
- The JTAG, boundary scan interface

Electronics Test and Measurement strategies

In order to ensure that an assembly can be properly tested it is necessary to develop a proper test strategy. Only in this way can any product be tested effectively and for the minimum cost.

Developing a successful test strategy for production test
Design for test (DFT)
The different types of test available for production testing
Selecting an In Circuit Tester

Test equipment technologies
There are a number of standards and technologies that can be used for controlling test equipment. GPIB, VXI and now PXI are some of the main ones that are available today.

GPIB What is it?
Pin connections for the GPIB connector
VXIbus for high speed integrated test systems
PXIbus an overview of PXI technology
PXI Express
LXI test technology basics

EMC, Electro-Magnetic Compliance
In recent years, Electromagnetic Interference, EMI, and Electromagnetic Compatibility, EMC, have become very important topics. As a result, testing for compliance with the EMC directive and other standards has become more important. With EMC compliance now an essential requirement before products can be launched onto the market, EMC testing is of interest to all electronic equipment developers and manufacturers.

Basics of EMC / EMI compliance test

Data acquisition
Techniques, equipment, and software used to acquire or collect data, process it, store and use it to provide essential data about processes and other conditions.

Basics of data acquisition
USB data acquisition
Data acquisition measurements the basics of the measurement techniques used and the precautions to be taken.
Thermocouples for data acquisition the basics of the measurement techniques used and the precautions to be taken.
Strain gauges for data acquisition the basics of the measurement techniques used and the precautions to be taken.
Flow meters for process control and data acquisition the basics of
the measurementtechniques used and the precautions to be taken.

Electronic test equipment summaries

There is a wide variety of electronic test equipment that is used within radio and electronics today. There is a large variety of electronic test equipment that is used in production, development, field test and general fault finding. Oscilloscope

- The different types of oscilloscope that are available
- Points to note when buying an oscilloscope
- Key tips for using an oscilloscope
- Oscilloscope probes and points to note about them

Spectrum Analyzer

- Using spectrum analyzers (analysers)
- The design of a spectrum analyzer and the way this reflects on its use

Frequency counter

- Frequency counter basics
- Frequency counter accuracy and resolution

RF power meter

- RF power meter basics

Logic analyzer

- Logic analyzer basics
- Key specifications for logic analyzers. Points to note when buying a logic analyzer.

Signal generators

- Radio frequency signal generators
- Function generator
- Arbitrary waveform generator

Test equipment calibration why and how test equipment is calibrated
Used test equipment advantages and disadvantages of buying second user test equipment

Environmental stress screening

Techniques to ensure that high quality product is produced are essential in today's development and production environments. Environmental stress screening is widely used with highly accelerated life testing (HALT) in development and highly accelerated stress screening (HASS) in production as part of an electronics test and measurement strategy.

Basics of environmental stress screening (ESS)
Highly accelerated life test (HALT) and highly acccelerated stress screening (HASS)

Wireless technologies

including Bluetooth, IEEE 802.11 (Wi-Fi), WiMax, Zigbee (IEEE 802.15.4), etc

Wireless technology in a variety of forms is anarea of electronics that is developing andgrowing particularly fast. Wirless LAN (WLAN) technology including Wi-Fi (IEEE 802.11), Bluetooth, Ultra-Wide Band (UWB), Wimax, Zigbee, and more are all growing and findingtheir own market areas. As a result wirelesstechnology is being more widely used and found in many new applications.

The development of wireless technologies

IEEE 802.11 / Wi-Fi

In recent years Wi-Fi has become increasingly popular. Enabling people to link computers towireless LANs either to give greater flexibility in offices, to reduce costs by not having to install wired networks, or just to access a computer network when using a "hotspot" in a cafe, hotel, airport lounge or wherever, this technology has become a major force in the wireless industry in recent months and years.

The IEEE 802.11 Wi-Fi standard for WLAN applications
IEEE 802.11 a providing 54 Mbps at 5 GHz
IEEE 802.11 b providing 11 Mbps at 2.4 GHz
IEEE 802.11 e providing Quality of Service enhancements and enabling applications such as VoIP and streaming video
IEEE 802.11 g providing 54 Mbps at 2.4 GHz
IEEE 802.11 n Wi-Fi standard providing speeds up to 600 Mbps

Bluetooth
Bluetooth is now a well established technology, providing wire-less connectivity for a widevariety of devices from headsets to mobile phones.
An overview of Bluetooth
Bluetooth version 2with enhanced data rate (EDR) and other new features
How to use Bluetooth

Wibree

Wibree is a new low power standard that is aimed at connecting small devices together.

Zigbee / IEEE 802.15.4
Zigbee is a relatively new standard that is aimed at the data collection, remote sensing and control applications. It has a particularly robust structure that enables it to operate reliably in harsh radio environments.

WiMax

WiMax is a standard that is of growingimportance offering high data rate communications over a wide or metropolitan area.

WiMax air interface / physical layer summary
Overview of 802.16 standard and the amendments including 802.16d (802.16-2004) and 802.16e (802.16-2005)
WiMax testing

Ultra-Wide Band (UWB)

Ultra Wide band is a technology that shows an enormous amount of potential. With data rates in excess of 1 Gbps being demonstrated, it may be ideal for many short range applications.

Ultra Wideband Technology
The development and applications of UWB technology
Direct Sequence Ultra Wideband
Multiband OFDM Ultra Wideband
Wireless USBa technlogy utilising UWB transmissions

Near Field Communications (NFC)

Near Field Communications (NFC) is a technology that uses local magnetic fields to communicate over short distances, providing easily, simple connectivity.

DECT Digital Enhanced Cordless Telecommunications phone system

DECT basics
DECT Specification Summary

HomeRF SWAP

Although the HomeRF working group was discontinued in January 2003, an overview is included for reference.

wireless networking in the home

The Home RF Shared Wireless Access Protocol (SWAP) was designed primarily as a wireless networking solution for home applications and aimed at a broad range of consumer devices. SWAP was an open industry standard for computers, their peripherals, cordless phones and a variety of other devices to communicate with each other around the home without the cost and inconvenience of having to install a wired network. To achieve this it was able to carry both voice and data. Unlike Bluetooth that is aimed primarily for use withcellular technology, or IEEE802.11 that is intended for business use, SWAP was intended for home use where the developers see a vast and growing market.

Unfortunately HomeRF did not catch a sufficiently large market and as a result the HomeRF working group was disbanded in January 2003. Nevertheless a short summary is included here for reference.

Capability

The system can support data rates of between 10 and 20 Mbps combined with sufficient range for most residential applications. If operating over slightly greater distances the speed can back off to 5 Mbps. Like 802.11b and Bluetooth, HomeRF operates in the 2.4 GHz ISM band. It uses frequency hopping with a hop rate of between 50 and 100 hops per second.

The system can be set up in either ad-hoc, peer to peer mode, or as a network with a Control Point (CP) giving access to a wired network within the house. In this respect it has many similarities to 802.11b.

When requiring to send data the CSMA/CS protocol derived from 802.11 is used. Here the unit wanting to send data listens to see if the frequencies are clear to send data. If it is clear then the data is sent, otherwise it waits for a random amount of time before trying to send the data again.

Data

The data within a HomeRF transmission is contained within repeating frames that are transmitted. Each one of these frames is either 10 or 20 mS long dependent upon the number of active voice calls at any given time. Within the frame, the bulk of the available capacity is used for asynchronous data transmission. However within the capacity reserved for this, priority is given to the streaming media sessions. Up to eight of these sessions are allowed, but when fewer than this number are present, the available capacity remaining can be used for ordinary data transmission.

The last part of the data frame structure is reserved for providing voice quality communications. These full duplex pairs of phone quality slots use the Digital Enhanced Cordless Telecommunications(DECT) system. The HomeRF protocolsmap directly onto this allowing an already well establishedsystem to be incorporated into the HomeRF technology. The full specification for HomeRF allows for a total eight of landlinequality links to be supported.