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Appendices

Appendix A
RS232 Interface Standard

Data Transfer Modes

Logical data in microcomputers is represented as bits (binary digits). Bits are customarily explained through tables that illustrate each bit's contribution to some overall logical scheme. Although the bit is an intellectual construction, it is, nevertheless, physically a voltage whose magnitude gives the bit his value (i.e. 1 or 0).

When bits must be moved about within the computer itself, they are transmitted along wires. If the data to be transmitted is in 8-bits format bytes, then eight separate, discrete wires must simultaneously carry the eight representative electrical voltages between the two points. This simultaneous transmission of the eight bit-voltages that constitute a byte is referred to as ***"parallel transfer"***. Parallel transfer, then, is done byte-by-byte. Since all eight bits arrive at their destination at the same instant, parallel data transfer can be accomplished at extremely high speeds. These qualities make it the preferred method of data transfer whenever possible.

Data transfer, especially high-speed data transfer, demands a tightly controlled environment. The internal temperature of the computer must be regulated and the electrical properties of resistance, capacitance, and inductance carefully pre-calculated. As long as data is being moved about inside a computer, this environment is stable and predictable. But a great deal of computer data must be transported to the outside world. Microcomputers communicate with peripheral devices such as printers, terminals, modems, print buffers, etc. These processes are known collectively as input/output, or simply I/O.

The Interface

An interface is the point of contact between dissimilar environments; between the computer's circuitry and external devices. Since an interface is a sort of "door" to the computer's world, it is sometimes called an ***I/O port**, or* just a port.

The primary objective of any interface is to provide a medium for the transfer of data. Further more, self-protection and usability are also important goals for any interface. Once such an interface has been established, the transfer of data to external environments is possible.

When considering parallel transfer for the interface, two major problems arise. The first is the wire itself. At least nine wires - eight for the data bits, one for circuit common ("ground")- are needed. Still more wires are usually required to control the flow of data across the interface. Another problem lies in the very nature of the bits/voltages themselves. When a bit/voltage changes state from a one to a zero, or vice versa, it does so very rapidly -in the order of nanoseconds (one billionth of a second).This abruptness is itself an essential part of the process of data transfer. Slow changes between zero and one are not even recognized as data. As a cable gets longer, its electrical properties (capacitance & inductance) restrict the abruptness with which a bit can change between zero and one, and data corruption or loss becomes likely. Because of this, the speed inherent in parallel data transfers makes transmission over long cables problematic.

Therefore, its use is restricted to a few peripheral devices (such as printers) that are likely to be used in close proximity to the computer, or that must be operate at very high speeds.

The obvious alternative to sending all bits simultaneously on multiple wires is to send them singly, one after the other. At the receiving end, the process is reversed and the individual bits are reassembled into the original byte. With just one bit to transmit at a time, data can be transferred with a simple electrical circuit consisting of only two wires. This scheme - known as ***"Serial Transfer"*** - reduces the bulk and much of the expense of the parallel technique.

This saving is offset by a decrease in efficiency: it takes at least eight times longer to transmit eight individual bits one after the other than to transmit them all simultaneously in parallel. This speed limit is insignificant for many typical applications. Serial peripheral devices are slow, at least in comparison to the internal speed of microprocessors. Each involves some time-consuming, sometimes mechanical process that greatly limits its speed: printers are limited by the speed of their print-heads, modems by the frequency restrictions of the telephone lines, and disk drives by their slow rotational speed. So the speed inherent in the process of parallel data transfer is largely wasted on such peripheral devices. The serial method, therefore, can afford to sacrifice some speed while still adequately servicing the peripheral devices. In such cases, the sacrifice in speed is inconsequential in comparison to the increased reliability and transmission range.

Standard Interfaces

There are always several ways to design any circuit "correctly", any number of perfectly functional interfaces for an application are possible. In this diversity lies a problem fundamental to all interface circuitry: compatibility with other interfaces.

In the late 1960's a need surfaced for remote access to mainframe computers. It becomes desirable for the end-users to access computers from remote locations. Short distances- a few hundred feet, perhaps within the same building- could be spanned by the addition of extra wires. For truly distant remote access, telephone lines were considered. For many reasons computer data cannot be injected directly into the telephone network. A translating device - the Modem - is required.

When computerized telecommunications was in its infancy, the Bell System supplied most of the data equipment to its lines. Bell naturally exercised strict control over the modem interface. But as activity in the telecommunications field increased, and more and different kinds of equipment began to appear, Bell surveyed the hodgepodge of equipment that the computer industry was threatening to connect to its lines. It saw little that it liked and much that it felt would compromise and complicate the delivery of communications service to the public. The telephone companies predictably prohibited the connection of most of these devices.

Interfacing Basics

In its simplest form, the RS-232-C interface consists of only two wires-one to carry data, plus a ***"circuit common"***. The circuit common is the absolute voltage reference for all the interface circuitry, the point in the circuit from which all voltages are measured.

A typical DTE device is an ordinary video terminal with a keyboard and a video display. Data on pin 2 of the DTE is transmitted, while the same data on pin 2 of a DCE (modem) is received data.

Bidirectional Data

Terminals and modems are not usually one-way devices- each may also perform the opposite function. For example, modems usually fetch characters from the telephone line and output them to the terminal. Similarity, the terminal receives the characters output from the modem and displays them on the video screen. Bidirectional interchange between the two devices is directly analogous to the connection of two telephones. The difference between the DTE and DCE is: DTEs transmit on pin 2 and receive on pin 3. DCEs transmit on pin 3 and receive on pin 2.

Handshaking

There remains only the straightforward matter of interactive device control, i.e ***handshaking***. Handshaking is the way in which the data flow across the interface is regulated and controlled. Two distinct kinds of handshaking are described in Software Handshaking and Hardware Handshaking.

An important distinction between the kinds of signals of the interface is between ***data signals*** and ***control signals***. Data signals are simply the pins which actually transmit and receive the characters, while control signals are everything else. If a modem can automatically answer the telephone, for example, it must be able to *report an incoming call* to the computer and not start transferring data to the computer without first *receiving a "OK, I'm ready to receive now" confirmation* from the computer.

There are generally two or three such inquire-confirm pairs on an interface that allow one device to "talk" to the other. There is in practice no guarantee that a modem and/or terminal will implement any or all of these handshaking features. The manufacturers of equipment may arbitrarily decide to apply some of the standard handshaking, no handshaking at all, or to invent a scheme of their own.

The RS-232-C Interface Standard

RS-232-C interface was developed for a single purpose, unambiguously stated by its title:

"Interface Between Data Terminal Equipment and Data Communications Equipment Employing Serial Binary Data Interchange."

The interface standard document consists of four parts:

- **Electrical Signal Characteristics**
- **Interface Mechanical Characteristics (Connectors)**
- **Functional Description of Interchange Circuits**
- **Standard Interfaces for Selected Communications System Configurations**

RS-232-C equipment "Compatibility"

While some of the signals on the RS-232-C interface are implemented almost universally on microcomputers, others are applied liberally without regard to any established practice. What can be expected from any device claiming to be "RS-232-C compatible"?

Areas of RS-232-C Compatibility:

- *The prescribed electrical characteristics (voltage, etc) of the interface are, by necessity, closely observed.* If a device claims to be "RS-232-C compatible" it means that you can connect it to another such "compatible" device without damaging either. This guarantees that they will match well enough electrically to permit the exchange of data.

- *The voltage levels assigned for zero and one will correspond to those described in the standard.*
- *A few pins on the connector are absolutely predictable:* * pin 2 & pin 3 are transmitted /received data * pin 7 is Circuit Common.
- *A terminal is a DTE.* When the standard was written, terminals were usually printing terminals; there were no video displays like those in use today. Instead, the computer responded to all commands by printing them. Printer interfaces therefore are traditionally configured DTE.
- *A modem is a DCE.* Because the RS-232-C standard was intended to standardize this interface, modems are nearly always DCE; however a few modem manufacturers - mindful that computer manufacturers can't decide if their serial ports should be DTE or DCE - have begun to include switches inside their equipment to permit the user to rearrange the traditional DCE pin assignments to DTE. Thus, even the holy distinction that the modem is, by definition, Data Communication Equipment, is beginning to blur.

HISTORIC OVERVIEW

The RS-232-C was originally set to standardize the interconnections of terminals and host computers through public telephone networks. Modems were used to translate the digital data signals from the computer equipment to analog audio signals suitable for transmission on the telephone network, and back to digital signals at the receiving end.

In the mid- to late 1960's, nearly all serial links for remote access to computers were through a telephone line. Remote access to the large mainframes of the time was accomplished almost exclusively by using the telephone network.

At that time, each manufacturer of equipment used a different configuration for interfacing a DTE (Data Terminal Equipment) with a DCE (Data Communications Equipment). Cables, connectors and voltage levels were different and incompatible, thus the interconnection of two pieces of equipment made by two different companies required the use of voltage level converters, and the manufacturing of special cables and connectors.

In 1969, EIA with Bell Laboratories and other parties established a recommended standard for interfacing terminals and data communications equipment. The object of this standard was to simplify the interconnection of equipment manufactured by different firms.

The standard defines electrical, mechanical, and functional characteristics. The electrical characteristics include parameters such as voltage levels and cable impedance. The mechanical section describes the pin number assignments and plug. The connector itself, however, is not specified. The functional description defines the functions of the different electrical signals to be used.

This standard shortly became RS-232-C (Recommended Standard number 232, revision C from the Electronic Industry Association), and a similar standard was available in Europe, developed by the CCITT (Comite Consultatif Internatinale de Telegraphie et Telephonie), and known as V.24 (functional description) and V.28 (electrical specifications). RS-232-C was widely adopted by manufacturers of terminals and computer equipment.

In the 1980's, the rapidly growing microcomputer industry found the RS-232-C standard cheap (compared to parallel connections) and suitable for connecting peripheral equipment to microcomputers. RS-232-C quickly became a standard for connecting microcomputers to printers, plotters, backup tape devices, terminals, programmed equipment and other microcomputers.

Since the standard only supported transfer rates up to 20 kbps (Kilobits per second), and distances of up to around 16 meters, new standards were adopted by EIA. The RS449 (mechanical) and RS423 (electrical) is upward-compatible with RS-232-C and can operate at data rates up to 10Mbps and distances of up to 1200 meters. Changing to a new standard, though, is a costly and long process. The RS-232-C is so widely available that it is certain to stay with us for some time to come.

RS-232 Signals

The number preceding each signal name correspond to the pin number defined in the standard

1. **Protective Ground**
2. **Transmitted Data**
3. **Received Data**
4. **Request to Send**
5. **Clear To Send**
6. **Data Set Ready**
7. **Signal Ground**
8. **Received Line Signal Detect (Carrier Detect)**
9. **+P (for testing only)**
10. **-P (for testing only)**
11. **(Unassigned)**
12. **Secondary Received Line Signal Detect**
13. **Secondary Clear To Send**
14. **Secondary Transmitted Data**
15. **Transmission signal element Timing**
16. **Secondary Received Data**
17. **Receiver Signal Element Timing**
18. **(Unassigned)**
19. **Secondary Request To Send**
20. **Data Terminal Ready**
21. **Signal Quality Detector**
22. **Ring Indicator**
23. **Data Signal Rate Selector**
24. **Transmitter Signal Element Timing**
25. **(Unassigned)**

RS-232 Signals Functional Description

General: The first letter of the EIA signal name categorizes the signal into one of five groups, each representing a different "circuit":

- *A - Ground*
- *B - Data*
- *C - Control*
- *D - Timing*
- *S - Secondary channel*

- **1 Protective Ground**
  - ***Name: AA***
  - ***Direction: -***
  - ***CCITT: 101***

  This pin is usually connected to the frame of one of the devices, either the DCE or the DTE, which is properly grounded. The sole purpose of this connection is to protect against accidental electric shock and usually this pin should not be tied to Signal Ground.

  This pin should connect the chassis (shields) of the two devices, but this connection is made only when connection of chassis grounds is safe (see ground loops below) and it is considered optional.

  Ground loops are low impedance closed electric loops composed from ground conductors. When two grounded devices are connected together, say by a RS-232 cable, the alternating current on the lines in the cable induces an electric potential across the ends of the grounding line (either Protective Ground or Signal Ground), and an electric current will flow across this line and through the ground.

  Since the loops impedance is low, this current can be quite high and easily burn out electric components. Electrical storms could also cause a burst of destructive current across such a loop. Therefore, connection of the Protective Ground pin is potentially hazardous. Furthermore, not all signal grounds are necessarily isolated from the chassis ground, and using a RS-232 interface, especially across a long distance, is unreliable and could be hazardous. 30 meters is considered the maximum distance at which the grounding signals can be connected safely.

- **2 Transmit Data**
  - ***Name: BA***
  - ***Direction: DTE -> DCE***
  - ***CCITT: 103***

Serial data (primary) is sent on this line from the DTE to the DCE. The DTE holds this line at logic 1 when no data are being transmitted. A "On" (logic 0) condition must be present on the following signals, where implemented, before data can be transmitted on this line : CA, CB,CC and CD (Request To Send, Clear To Send,Data Set Ready, Data Terminal Ready).

- **3 Receive Data**
  - ***Name: BB***
  - ***Direction: DTE <- DCE***
  - ***CCITT: 104***

Serial data (primary) is sent on this line from the DCE to the DTE. This pin is held at logic 1 (Mark) when no data are being transmitted, and is held "Off" for a brief interval after an "On" to "Off" transition on the Request To Send line, in order to allow the transmission to complete.

- **4 Request To Send**
  - *Name: CA*
  - *Direction: DTE -> DCE*
  - *CCITT: 105*

Enables transmission circuits. The DTE uses this signal when it wants to transmit to the DCE. This signal, in combination with the Clear To Send signal, coordinates data transmission between the DTE and the DCE.

A logic 0 on this line keeps the DCE in transmit mode. The DCE will receive data from the DTE and transmit it on to the communication link.

The Request To Send and Clear To Send signals relate to a half- duplex telephone line. A half duplex line is capable of carrying signals on both directions but only one at a time. When the DTE has data to send, it raises Request To Send, and then waits until the DCE changes from receive to transmit mode. This "On" to "Off" transition instructs the DCE to move to "transmit" mode, and when a transmission is possible, the DCE sets Clear To Send and transmission can begin.

On a full duplex line, like a hard-wired connection, where transmission and reception can occur simultaneously, the Clear To Send and Request To Send signals are held to a constant "On" level.

A "On" to "Off" transition on this line instructs the DCE to complete the transmission of data that is in progress, and to move to a "receive" (or "no transmission") mode.

- **5 Clear To Send**
  - *Name: CB*
  - *Direction: DTE <- DCE*
  - *CCITT: 106*

An answer signal to the DTE. When this signal is active, it tells the DTE that it can now start transmitting (on Transmitted Data line). When this signal is "On" and the Request To Send,Data Set Ready, and Data Terminal Ready are all "On", the DTE is assured that its data will be sent to the communications link. When "Off", it is an indication to the DTE that the DCE is not ready, and therefor data should not be sent.

When the Data Set Ready and Data Terminal Ready signals are not implemented, in a local connection which does not involve the telephone network, the Clear To Send and Request To Send signals are sufficient to control data transmission.

- **6 Data Set Ready**
    - ***Name: CC***
    - ***Direction: DTE <- DCE***
    - ***CCITT: 107***

On this line the DCE tells the DTE that the communication channel is available (i.e., in an automatic calling system, the DCE (modem) is not in the dial,test or talk modes and therefor is available for transmission and reception). It reflects the status of the local data set ,and does not indicate that an actual link has been established with any remote data equipment.

- **7 Signal Ground**
    - ***Name: AB***
    - ***Direction: -***
    - ***CCITT: 102***

This pin is the reference ground for all the other signals, data and control.

- **8 Receive Line Signal Detect or Data Carrier Detect**
  - *Name: CF*
  - *Direction: DTE <- DCE*
  - *CCITT: 109*

The DCE uses this line to signal the DTE that a good signal is being received (a "good signal" means a good analog carrier, that can ensure demodulation of received data).

- **9 +P**

This pin is held at +12 volts DC for test purposes.

- **10 -P**

This pin is held at -12 volts DC for test purposes.

- **12 Secondary Receive Line Signal Detect**
  - *Name: SCF*
  - *Direction: DTE <- DCE*
  - *CCITT: 122*

This signal is active when the secondary communication channel is receiving a good analog carrier (same function as the Receive Line Signal Detect signal).

- **13 Secondary Clear To Send**
  - *Name: SCB*
  - *Direction: DTE <- DCE*
  - *CCITT: 121*

An answer signal to the DTE. When this signal is active, it tells the DTE that it can now start transmitting on the secondary channel (on the Secondary Transmitted Data line).

- **14 Secondary Transmitted Data**
    - *Name: SBA*
    - *Direction: DTE -> DCE*
    - *CCITT: 118*

  Serial data (secondary channel) is sent on this line from the DTE to the DCE. This signal is equivalent to the Transmitted Data line except that it is used to transmit data on the secondary channel.

- **15 Transmission Signal Element Timing**
    - *Name: DB*
    - *Direction: DTE <- DCE*
    - *CCITT: 114*

  The DCE sends the DTE a clock signal on this line. This enables the DTE to clock its output circuitry which transmits serial data on the Transmitted Data line. The clock signal frequency is the same as the bit rate of the Transmitted Data line. A "On" to "Off" transition should mark the center of each signal element (bit) on the Transmitted Data line.

- **16 Secondary Receive Data**
    - *Name: SBB*
    - *Direction: DTE <- DCE*
    - *CCITT: 119*

  Serial data (secondary channel) is received on this line from the DCE to the DTE. When the secondary channel is being used only for diagnostic purposes or to interrupt the flow of data in the primary channel, this signal is normally not provided.

- **17 Receiver Signal Element Timing**
    - *Name: DD*
    - *Direction: DTE <- DCE*
    - *CCITT: 115*

  The DCE sends the DTE a clock signal on this line. This clocks the reception circuitry of the DTE which receives serial data on the Received Data line.

The clock signal frequency is the same as the bit rate of the Received Data line (BB). The "On" to "Off" transition should indicate the center of each signal element (bit) on the Received Data line.

- **19 Secondary Request To Send**
  - *Name: SCA*
  - *Direction: DTE -> DCE*
  - *CCITT: 120*

The DTE uses this signal to request transmission from the DCE on the secondary channel. It is equivalent to the Request To Send signal.

When the secondary channel is only used for diagnostic purposes or to interrupt the flow of data in the primary channel, this signal should turn "On" the secondary channel un-modulated carrier.

- **20 Data Terminal Ready**
  - *Name: CD*
  - *Direction: DTE -> DCE*
  - *CCITT: 108.2*

When on, tells the DCE that the DTE is available for receiving. This signal must be "On" before the DCE can turn Data Set Ready "On", thereby indicating that it is connected to the communications link.

The Data Terminal Ready and Data Set Ready signals deal with the readiness of the equipment, as opposed to the Clear To Send and Request To Send signals that deal with the readiness of the communication channel.

When "Off", it causes the DCE to finish any transmission in progress and to be removed from the communication channel.

- **21 Signal Quality Detector**
  - ***Name: CG***
  - ***Direction: DTE <- DCE***
  - ***CCITT: 110***

  This line is used by the DCE to indicate whether or not there is a high probability of an error in the received data. When there is a high probability of an error, it is set to "Off", and is "On" at all other times.

- **22 Ring Indicator**
  - ***Name: CE***
  - ***Direction: DTE <- DCE***
  - ***CCITT: 125***

  On this line the DCE signals the DTE that there is an incoming call. This signal is maintained "Off" at all times except when the DCE receives a ringing signal.

- **23 Data Signal Rate Selector**
  - ***Name: CH/CI***
  - ***Direction: DTE -> DCE***
  - ***CCITT: 111/112***

  The DTE uses this line to select the transmission bit rate of the DCE. The selection is between two rates in the case of a dual rate synchronous connection, or between two ranges of data rates in the case of an asynchronous connection.

  Typically, when this signal is "On", it tells the DCE (modem) that the receive speed is greater than 600 baud.

- **24 Transmitter Signal Element Timing**
  - ***Name: DA***
  - ***Direction: DTE -> DCE***

- *CCITT: 113*

The DTE sends the DCE a transmit clock on this line. This is only when the master clock is in the DTE.

A "On" to "Off" transition should indicate the center of each signal element (bit) on the Transmitted Data line.

- ## A note on signal travel direction

The pin names are the same for the DCE and DTE. The Transmit Data (pin number 2) is a transmit line on the DTE and a receive line on the DCE, Data Set Ready (pin number 6) is a receive line on the DTE and a transmit line on the DCE, and so forth.

• Electrical Signal Characteristics

Voltage levels defined in the standard

- **Data signals**

	"0","Space"	"1","Mark"
Driver (Required)	5 - 15	-5 - -15
Terminator(expected)	3 - 25	-3 - -25
Control signals	"Off"	"On"
Driver (Required)	-5 - -15	5 - 15
Terminator expected	-3 - -25	3 - 25

- ## Interface Mechanical Characteristics

The connection of the DCE and the DTE is done with a pluggable connector. The female connector should be associated with the DCE. The following table lists the pin assignments defined by the standard. The type of connector to be used is not mentioned in the standard, but the DB-25 (or on IBM-AT's, a minimal DB-9) connectors are almost always used.

- ## Pin designation for the 25-pin and 9-pin DB connector

Includes equivalent CCITT V.24 identification, and signal direction

DB-25 Pin #	DB-9 Pin #	Common Name	EIA Name	CCITT	DTE-DCE	Formal Name
1		FG	AA	101	-	Frame Ground
2	3	TD	BA	103	--->	Transmitted Data, TxD
3	2	RD	BB	104	<---	Received Data, RxD
4	7	RTS	CA	105	--->	Request To Send
5	8	CTS	CB	106	<---	Clear To Send
6	6	DSR	CC	107	<---	Data Set Ready
7	5	SG	AB	102	----	Signal Ground, GND
8	1	DCD	CF	109	<---	Data Carrier Detect
9		--	--	-	-	+P
10		--	--	-	-	-P
11		--	--	-	-	unassigned
12		SDCD	SCF	122	<---	Secondary Data Carrier Detect
13		SCTS	SCB	121	<---	Secondary Clear To Send
14		STD	SBA	118	--->	Secondary Transmitted Data
15		TC	DB	114	<---	Transmission Signal Element Timing
16		SRD	SBB	119	<---	Secondary Received Data
17		RC	DD	115	--->	Receiver Signal Element Timing
18		--	--	-	-	unassigned
19		SRTS	SCA	120	--->	Secondary Request To Send
20	4	DTR	CD	108.2	--->	Data Terminal Ready
21		SQ	CG	110	<---	Signal Quality Detector
22	9	RI	CE	125	<---	Ring Indicator
23		--	CH/CI	111/112	--->	Data Signal Rate Selector
24		--	DA	113	<---	Transmitter Signal Element Timing
25		--	--	-	-	unassigned

- ## Diagram of the DB-25 and DB-9 connectors

male connectors , front view

```
    1                           13         1         5
   ______________________________         _______________
   \ . . . . . . . . . . . . . /          \ . . . . . /
    \ . . . . . . . . . . . . /            \ . . . . /
     -------------------------              ----------
     14                     25               6       9

              DB-25                             DB-9
```

RS-232-C standard configuration

RS-232-C interchange circuit	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1 Protective Ground	-	-	-	-	-	-	o
7 Signal Ground	X	X	X	X	X	X	X
2 Transmitted Data	X	X		X	X	X	o
3 Received Data			X	X	X	X	o
4 Request to Send		X		X		X	o
5 Clear to Send	X	X		X	X	X	o
6 Data Set Ready	X	X	X	X	X	X	o
20 Data Terminal Ready	S	S	S	S	S	S	o
22 Ring Indicator	S	S	S	S	S	S	o
8 Received Line Signal Detector			X	X	X	X	o

X = required for any configuration
S = required for using PSDN (public switched telephone network)
o = specified by cable designer

Notice that only *one* circuit is *absolute requirement* for any such cable, this is the Signal Ground on Pin 7. That means that as long as Signal Ground is included on pin 7 this cable is "**RS-232-C compliant**"".

Appendix B
Wireless Connections

What you should know when starting a wireless project.

The reality is that wireless links work, and work well! They are providing economical, trouble-free links all over the world. Unfortunately, many businesses have installed wireless links that don't work. By following a few simple rules and dealing with a reputable vendor, you can make sure your wireless project works as advertised and provides that trouble-free link for many years. This discussion focuses on building - to - building links. Wireless LAN installations with all users in a single building are not covered by these rules. The rules are simple enough and easy to follow. But, many potential users of wireless links (and vendors) try to "bend" the laws of nature. They don't bend, they break! It's not rocket science. A good dose of common sense applied to what the vendors tell you goes a long way. These products are quite mature. When used within their limits, you should have no problems. The connection should not go down because it's raining, windy, or the third Thursday of the month. Simply use good judgment when applying these rules and you will have no problem. Also remember that wireless isn't the solution for every problem... there may be a mountain in the way or a more economical wired solution for a given application.

Now, *The Rules...*

Sight Surveys are Required!

There is no way to design a proper link (regardless of how simple it sounds) without looking at the geography involved. It's easy for an untrained person to perform a simple sight survey if they know what to look for. If the link is complicated, some expertise is required. Your vendor can help you decide how much of a problem the sight survey will be. As a minimum, the sight survey should cover...

- Length of the Path
- Matching Equipment to the Site Requirements
- Line of Sight

- Obstructions and the best way to deal with them
- Antenna mounting requirements, towers vs. pole, roof mounts, in-building mounts
- Cable routes between antenna and radio/LAN unit
- Power availability for the radio/LAN unit
- LAN environment... throughput requirement, protocol
- Any unusual situation, such as a building owner who doesn't allow outside antenna supports

Path Length

What is the length of the path? Do not over-extend the link. If a manufacturer states that the unit is good for 4 miles, don't try to make it work 6 miles or even 4.2 miles. In most cases, DCB de-rates the maximum path specified by manufacturers to allow for a more reliable link. Remember that all units in the USA must comply with the same Federal Communications Commission rules and regulations. They are all subject to the same maximum power limits. The laws of physics that govern path losses apply to all radios equally. If one manufacturer claims 50% more range than all the others, it's really suspect. Find out why they make that claim, and get references to prove it.

Match the antenna to the path requirement

Simple links of a few hundred feet can be installed with small "rubber duck" type antennas mounted on the radios. Links of a few hundred feet to a few thousand feet are often made with "flat-plate" antennae attached to the side of buildings or inside windows. Multi-mile links require "yagi" antennae or reflector dish type antennae that may need a tower or metal pole mount for support.

Minimize Coax Cable Length

At these frequencies, signal loss in the cable between the radio and the antenna is significant. Minimize that loss by minimizing the cable length. Consider this when locating the radio and antenna. Use quality, low-loss cable. FCC regulations require unique connectors for many units, normally all units that are designed for installation by the general public. Make sure the coax connectors are appropriate.

Line of Sight is Everything

When using 2.4Ghz band license-free radios (and with a few exceptions, the 900Mhz band) the two antennae must be within line-of-sight (LOS) of each other. Read that literally...LOS means that you can see the remote site antenna from the other location. That is, assuming you have powerful enough eyes or a telescope. At these frequencies, if you can't see the other antenna, the radio signal can't. There can be no obstructions between the two. That includes buildings, water towers, billboards, LEAVES, mountains, and trucks. If you perform the site survey during the winter, will spring leaves and tree growth block the path? Sometimes you can move an antenna from one side of a building to the other to get around an object. At 23Ghz, there is a "fresnel zone", or clear area that must be maintained around the line of sight. For example, you can't "skirt" a hill in the middle of the path without giving some extra clearance.

Antenna mounting

The antennae must be mounted to a rigid structure. Do not use thin-wall pipe that will flex in the wind. The antenna is highly directional, and a wind or ice load that makes the antenna move a few degrees can ruin the link. We prefer 2" to 4" antenna mast pipe. Often a non-penetrating roof mount is used when LOS allows the antenna to be mounted 8' or less above a roof. Some links are short enough to allow a "flat plate" type antenna taped to a window pane, or to allow inside mounting of the antennae.

Deal with Obstructions and Long Path Length

Obstructions to LOS can be handled several ways. Moving an antenna can sometimes cure the problem of a building in the way. Adding a tower may be required for additional height to get over a tree. A repeater can be installed to allow the signal to go around an obstruction or extend the usable range to meet your path requirements. If repeaters are required, it's often better to have a professional perform the site survey and analysis. If long paths or obstructions are encountered, a wired link may be more economical.

Use the Most Appropriate Band

In urban areas, the 900 Mhz ISM band is becoming quite crowded and may be unusable for your application. Although units operating in the 900 Mhz band have greater range, the 2.4 Ghz ISM band is still quite open, and it's directional nature tends to keep it available. All ISM band units must tolerate interference... you don't "own" the frequency. If the requirements are more stringent, consider 23 Ghz licensed microwave units. They are more expensive, and require the time delay and expense of FCC licensing (or equivanent in other countries), but the frequency is guaranteed to be free of interference "forever".

Reliability

These systems should be as reliable as any wired link. To insure high reliability, use the lowest bandwidth that matches system needs. Lower speed links are more tolerant of external interference and path loss when used on long paths. The most reliable links use directional antennae instead of omni antennae. Use an omni antenna only when it is required for multi-drop systems or on very short paths. Unless you are using the frequencies in the 23 Ghz band (or higher), rain does not affect signal quality. When a system that uses these frequencies is designed, allowance is made for interference from the rain.

Again, the reality is that there are many reliable, economical, wireless data communications links. By following a few simple rules and working with a reputible vendor, a wireless link may be the best way for you to solve your communications problems. Although knowing these basics will help you discuss your application with our engineers, these rules are simply the beginning. When discussing the project with our engineers, you may be asked more questions to help determine best equipment for your project. Applying LNAs, bi-directional amplifiers, and FCC rules can quickly become complex. We're here to help!