INTRODUCTION

The purpose of this note is to provide an overview of the alternatives available for communication of WeatherLink data and control commands between a field weather station and the base computer. The emphasis is on radio communications.

COMMUNICATION OPTIONS

Because the WeatherLink bus uses standard RS-232 conventions operating at 1200 or 2400 Baud, half-duplex, (see below for details) many communication modes may be used. The following four are presently supported by Davis Instruments' products:

Short-range Modem. A pair of Short-range Modems can transmit over a two-twisted-pairs cable for distances of four miles or more, depending on wire gauge. The Davis model 7875 is an example.

Telephone (POTS). The conventional "plain old" telephone system may be used to "dial up" a weather station from the base computer to transmit commands and receive data. Davis supplies a model 7870 Adapter to enable the connecting of the WeatherLink's modular cable to the DB-25 connector of a standard external telephone modem. The WeatherLink software supports entry of telephone numbers, automatic scheduled dialing, and maintenance of databases for multiple stations.

Cellular Phone. A cellular phone modem-transceiver may be installed at the weather station, enabling it to be called from any telephone for transferring of data. The Davis model 7652-003 includes an antenna and all necessary components for connection of a Motorola CTM2400 3-Watt Cell-phone Transceiver to the WeatherLink module. If the station is solar-powered it will be necessary to use a Timer, model 7690, or an Alarm Output Module, model 7736, to control power to the transceiver. The Davis Instruments 7708/7711 solar-panel/battery combination provides sufficient power to support a small number of relatively short calls per day under typical solar conditions.

Radio. Just about any radio modem/transceiver pair that can accept 1200- or 2400-Baud RS-232 data in a data-only mode is suitable for use with WeatherLink data. The alternatives supported by Davis products and the factors involved in selecting an approach are discussed below.

If there is a question regarding the selection or installation of communications equipment, we recommend that the services of a communications consultant or technician be employed.

LINK CHANNEL DESCRIPTION

The WeatherLink data channel may be described as follows:

- Point-to-point, master-slave. The base station (computer with WeatherLink software) initiates all communications. The GroWeatherLink, working with YDI or RF Neulink radios, can address a network of field stations.
- RS-232, 1200 or 2400 Baud, switch-selectable.
- Half-duplex. The GroWeather and EnviroMonitor stations are true half-duplex. The Perception, Wizard, and Monitor are designed to operate full-duplex, but they will operate on a half-duplex channel if some limitations are accepted, the principal one being that if the user requests a long bulletin display it cannot be interrupted. It must be allowed to complete.
- Data-only. No RTS/CTS handshake. 20 msec allowed for turn-time.
- CRC error-check. Data are error-checked in all systems. Control commands are error-checked by GroWeather and EnviroMonitor stations.
- Power-conserving mode available.

COMMUNICATION PROTOCOL

A data transfer comprises the following sequence:

1. The master (base) station sends a control command or request for data (6 to 12 bytes, including CRC).
2. The field station responds with a single character: CRC ERROR or ACKNOWLEDGE valid request.
3. If data were requested, the field station then sends the data.

Any one of six types of data transfer may be requested. Example transfers and their typical lengths:

a. Read Archive Memory	32 data bytes + 2 CRC
b. Memory Dump	256 bytes + 2 CRC
c. Archive Dump	32k bytes in XMODEM blocks (128 bytes data + header & CRC).

If data are transferred at least once per Archive Interval, a single good Read Archive transfer each time is sufficient to convey all necessary data.

If power conservation is not an issue, the station may be requested to send data continuously for real-time display of the “bulletin.”

SELECTING A RADIO

In selecting a radio communication channel, the factors to be considered include cost, whether the transmitters will be licensed or unlicensed, the range required, the nature of the transmission path, and the frequency of data downloads versus the power available.

UNLICENSED, USA

Spread-spectrum. The frequency band of 902 to 928 MHz is available for unlicensed transmission in the U.S. and Canada. Power output must be less than 1 Watt; the maximum allowed antenna gain for a 1-Watt transmitter is 6 dBm.

At this frequency the transmission path must be line-of-sight: a completely unobstructed path between the antennas of the communicating radios. Even vegetation can affect the transmission. Hills or buildings will block transmission.

The spread-spectrum radio specifically supported by Davis Instruments is the YDI model *RM910-DAVIS*. The radio is available from YDI; Davis Instruments provides two kits, each of which includes an antenna and all necessary cables, connectors, and mounting hardware, plus power supply and programming disk. One kit includes a 3 dB omni-directional antenna, the other an 8.5 dB directional antenna. A 12 dB antenna is available from YDI (Model 918-10); if this is used the 7632-912 Installation Kit should be purchased from Davis. The higher-gain antennas are permitted because the output power of the transmitter is 20 mW. Information regarding antenna choice, model numbers, and procurement of radios is given below.

The range of the YDI radio is one-half to four miles, depending on the antennas used, as discussed below.

Unlicensed spread-spectrum transmission is also permitted in the U.S. and Europe at 2.4 GHz. Transmissions at this frequency are even more demanding in their requirement for a line-of-sight path.

Low Power. Other frequency bands are available for low-power (10 to 20 mW) unlicensed transmission. Davis Instruments does not directly support any of these at this time.

LICENSED, USA

To prevent interference between radios, the Federal Communications Commission (FCC) requires that a specific frequency be assigned and a license issued before a narrow-band higher-power transmitter is placed in operation. The license process takes two to six weeks. The FCC fee is $60; a fee of $160 is required by the Personal Communications Industry Association, which assigns a recommended frequency and submits the application to the FCC. In addition you may wish to use a consultant to handle the details and type the forms. We used Josie Lynch, of Professional Licensing Consultants, Inc. (see page 9).

Before seeking a license you will need to know the emissions characteristic of your transmitter (see data section, page 8) and the latitude, longitude, elevation, and planned antenna height of your base station.

VHF. Frequency bands of 129 to 174 MHz and 220 to 222 MHz are often used for data transmission. These lower frequencies do not require line-of-sight paths, but the antennas are larger and more expensive.

UHF. The frequency band of 450 to 470 MHz is often used for agricultural and industrial data transmission. Older radio types use a crystal to set the carrier frequency, so the frequency must be known at the time the radio is ordered. Newer radios often use a synthesized frequency, so radios can be shipped off-the-shelf and frequencies can be set through the data I/O port by a computer at any time.

The radio modem/transceiver recommended by Davis is the RF Neulink 9600 operating in the 450 to 470 MHz band. Davis supplies two Antenna Kits, each of which includes an antenna and all necessary cables, connectors, and mounting hardware, plus a power supply and a programming disk for setting the frequency and other characteristics. One Kit includes a 2 dB omni antenna and one a 10 dB directional antenna.

The range of the Neulink 9600 is typically up to 25 miles, depending on terrain and antenna height and type. The range can be extended by installing a Neulink 9600 in repeater mode. It should be ordered in this configuration from RF Neulink; Davis software does not support configuring of repeaters.

In some circumstances RF radiation from the Neulink's omni-directional antenna can affect the weather station's measurement of temperature and barometric pressure. If data are being averaged over an interval that is long with respect to the duration of radio transmission from the station, the effects will be negligible. If radio transmission is continuous (as in the case of displaying the Bulletin), the data may be affected. In this case it may be necessary to raise the antenna to a height of three feet (1m) or so above the console or 1.5 feet (0,5m) above the Sensor Mounting arm (mast-mount hardware is included in the Antenna Kit), or in some other way place it at a distance from the station (see Site and System Configuration section). An Industrial weather station has better immunity to such RF noise than does a Standard station.

ANTENNAS

In selecting antennas the principal considerations are transmission distance (range) and whether an omni-directional or directional type is needed.

ANTENNA GAIN

An antenna's "gain" is a measure of its ability to focus its transmitting energy and its receiving sensitivity. Gain is measured in terms of decibels (dB), the logarithm of the factor of increase; every 6 dB added to the total of antenna gains at both ends doubles the transmission distance (if factors such as antenna height and propagation path characteristics permit).

OMNI-DIRECTIONAL ANTENNAS

As the name implies, an omni-directional antenna transmits and receives signals in all directions (in the horizontal plane). Its usual form is essentially a vertical wire. If the station is a Base Station which must communicate with Remote or Field Stations located in different directions, its antenna probably should be omni-directional.

Omni (or "whip") antennas tend to be lower in cost, have lower gain (lower range), and be more compact -- less subject to damage by vandalism, ice, and wind. They do not need to be aimed.

DIRECTIONAL ANTENNAS

Directional antennas focus their transmitting energy and receiving sensitivity in one direction. This can have two benefits: the effective range is longer, and the receiving antenna is less sensitive to interference coming from other directions. The most common form is called a Yagi-Uda or just Yagi, after its inventors. The antenna lobe, or focussed beam, lies in the direction in which the antenna boom is pointed.

The Yagi antenna's beam width is expressed in degrees of angle between the two directions at which the signal strength has fallen to –3dB compared with the center value. For example, the Davis 8.5 dB 900 MHz antenna has a beam width of 65º when vertically-polarized. This means that the range will be reduced to 71% at angles of 32º either side of the aimed direction.

The antenna focus is not perfect, so it is possible for a Yagi antenna to communicate with antennas that lie outside its main beam, but the effective range will be much lower.

Polarity. A Yagi antenna may be mounted in either of two orientations; the choice determines the polarity of the transmitted signal:

a. If the antenna elements are vertical, the E-plane and the Polarity of the antenna are Vertical.
b. If the antenna elements lie in the horizontal plane, the E-plane and Polarity are Horizontal.

If two Yagi antennas are communicating with each other, either polarity may be used, but both must have the same polarity. If another signal source is interfering, it may help to change the polarity. If a Yagi is communicating with an omni, the polarity must be vertical.

ANTENNA HEIGHT

915 MHz signals (and, to a lesser degree, 450 MHz signals) tend to travel like visible light, in a straight path. So there should be a line-of-sight unobstructed path between antennas of communicating stations. Because the earth's surface is curved, antennas must be elevated above the ground if they are to communicate at a significant distance. A formula for estimating required antenna height above level ground is given in References 1 and 2: $H = D^2/2$, where D = Distance in miles and H = height in feet. This formula gives the following estimates:

Transmission distance		Antenna Height	
3 miles	4,8 km	4.5 feet	1,4 m
4	7,3	8	2,5
8	14,6	32	9,8

Alternatives for antenna placement are discussed in the Site and System Considerations section.

RANGE

Table 1 gives estimated ranges for combinations of Davis-supplied antennas with line-of-sight paths between them. Range estimates for other antenna gains may be found by using Figure 4 on page 11.

Table 1. Transmission distance, line-of-sight, vs. antenna type

		Estimated Range					
		Omni-to-Omni		Omni-to-Yagi		Yagi-to-Yagi	
YDI RM910	8.5 dB Yagi	0.9 mi	1.4 km	1.6 mi.	2,6 km	3 mi.	4,8 km
	12 dB Yagi			2.3	3,7	7	11,2
Neulink 9600		4 mi.	6,5 km	10 mi.	16 km	25 mi.	40 km

POWER

AC POWER

If AC "mains" power is available at the field and base stations, the radios may be on continuously and the WeatherLink operated in its normal modes.

SOLAR POWER

If the field station is operating on solar/battery power, it is necessary to switch power to the radio so it is off most of the time in order to conserve the charge drained from the battery. The radio's power is switched on by the Timer or the Alarm Output Module for brief pre-determined intervals to allow communication.

The AOM enables the modem at 5 minutes past each even-numbered hour (according to the time clock in the Console) and keeps it enabled for four minutes. When a communication is received, the modem remains enabled during the data transfer and for two minutes thereafter; no communication is interrupted.

The Timer can be set to any intervals the user selects. Any radio communication in progress when the Timer switches OFF will be interrupted. (Exception: a cell-phone call will not be interrupted.)

The "Charge Budget, " discussed below, is one means of determining the amount of time that the radio may be on each day.

CHARGE BUDGET

When using the radio in a solar/battery-powered station, one must limit the power drawn by the radio. This means limiting the time that the radio is ON, enabled to receive messages, and -- in most cases -- limiting even more severely the duration of transmissions.

The Charge Budget table (on page 10) gives a worksheet and an example of a charge budget, used to calculate the daily battery drain for various ON and TRANSMIT durations. The sheet is also used to estimate the daily charge available to the battery from the solar panel.

Charge Drain per Day

Lines A, B, C, and D of Table 2 sum up the current drains over the day.
A: A Monitor II station with Link draws 16 mA, a GroWeather or EnviroMonitor station draws 18 mA.
B: The Alarm Output Module, when in Power-Save mode, draws 2.4 mA continuously. The Timer current may be considered zero when the relay is not energized; it draws 12 mA when the relay is closed.
C: This is the current drawn by the radio when on (see the equipment data section). The Neulink 9600 Modem/transceiver, for example, draws 100 mA when on. The YDI draws 180 mA.
D: This is the additional current drawn by the radio when transmitting. The Neulink draws an additional 800 mA. The YDI draws essentially zero additional current.

The total current drawn, in Amps (mA/1000), multiplied by the ON time in minutes gives the charge drain in Amp-minutes.

The Example in Table 2 is for a GroWeather station using the Timer to turn the Neulink 9600 radio ON for four six-minute periods each day. It assumes that two three-minute calls are made each day to read out the data.

Charge Gain per Day

Lines E, F, G, and H provide parameters for calculation of the average charge that the solar panel provides to the battery each day.
E: The charging current provided by the solar panel when solar irradiance is 1000 Watts per square meter. The panel included with the Davis solar Power Kit provides 0.6 Amp.
F: The solar irradiance at solar noon at the station site, in W/m^2.
G. The length of the day, in hours.
H. A multiplier to account for cloudiness or other factors which may limit the average sunlight reaching the panel throughout the day. Note that even during cloudy conditions at least 20% of the radiation usually gets through.

The total charge gain is then --
(Rated Panel Current) x (Peak Irradiance/1000) x 0.55 x (Day Length in minutes) x "Cloud Factor."

The factor 0.55 includes battery efficiency and the integration of the solar cosine effect over the day.
The charge GAIN/DRAIN ratio gives the number of days of operating charge accumulated on an average day.

Note that in GroWeather and EnviroMonitor stations the battery voltage is measured by the weather station and reported via WeatherLink, so you can monitor the voltage and reduce or cease communication if it drops too low. It is suggested that communication be limited whenever the battery voltage is less than 12.5 Volts; if the voltage drops below 12.0V, it is suggested that no communication be initiated until there is reason to believe that the station has received charging sunlight for an hour or more.

SITE AND SYSTEM CONSIDERATIONS

This section provides a brief discussion of some of the alternatives for the physical design of the radio communications link.

PROPAGATION PATH

The radio path between antennas should be unobstructed. Spread-spectrum 915 MHz transmissions require a clear line-of-sight path. Such a path is highly desirable for UHF (450-470 MHz) signals. Achieving the clear path may require positioning the antennas at a considerable height (as discussed above) or horizontal distance from the weather station or base station computer. If this proves necessary, two alternatives are available:

a. Use a long coaxial cable between the radio and the antenna. This may not be particularly desirable, because signal strength is lost at the rate of 0.1 to 0.16 dB per foot of cable length.
b. Place the radio close to the antenna, and use a long data cable between the Weather Station (or the Base Station Computer) and the radio. The RS-232 interface will drive a cable up to 50 feet in length; a longer cable will require use of a short-range modem pair.

The 6-foot cables attached to Davis-provided antennas permit the antenna to be mounted up to two feet (0,6m) above a Sensor Arm and System Shelter. Greater elevation can be obtained by using a 50-Ohm co-ax extension cable (BNC female to BNC male). The connection should be protected from weather. The 12-foot cable provided for the YDI 12-dB antenna permits a height of eight feet (2,4m) above the Arm.

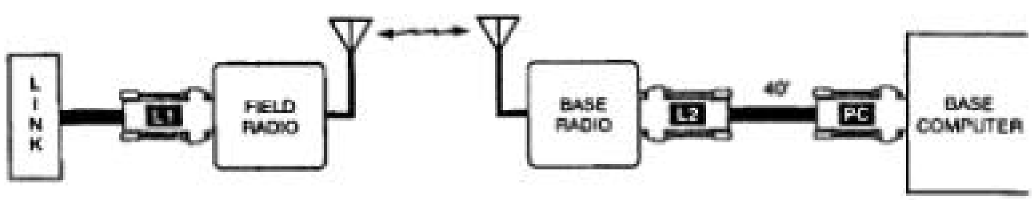

Figure 1a. Schematic of "compact" field and base stations.

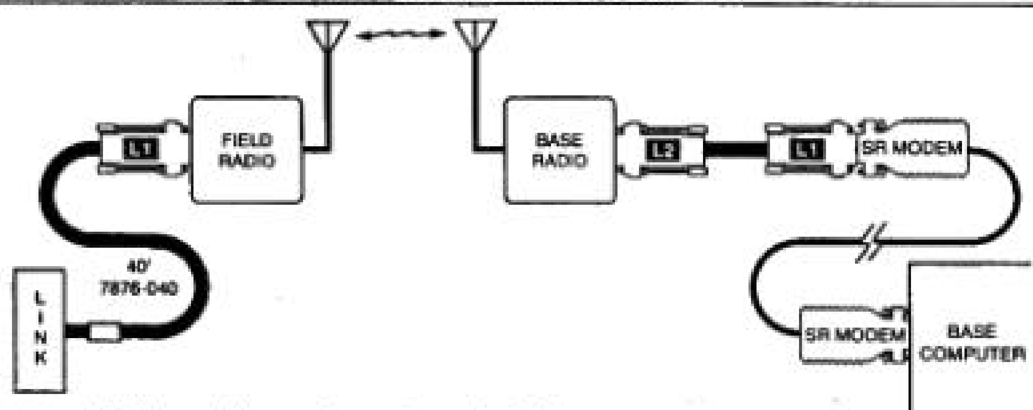

Figure 1b. Stations with greater antenna height.

SYSTEM CONFIGURATIONS

Figure 1 illustrates two possible radio links. In Figure 1a, the Field Station radio is within 8 feet of the weather station console. The WeatherLink's attached data cable plugs into the radio via an Adapter. At the Base Station the radio is connected to the computer by a 40-foot modular cable.
In Figure 1b, the Field Station radio is located well above the console (at the top of a mast or tower or at the peak of a barn roof, for example), connected by a 40-foot extension to the data cable. Similarly, the Base Station radio is located some distance from the computer, in the attic of the office building or outbuilding or on a tower. Short-range modems span the distance.

SHELTERS

A barn, shed, or other outbuilding may be used to house the Sensor Interface, Console, WeatherLink logger, and radio of a field station. Similarly the base station radio may be installed in a residence or office building. In such cases, no special equipment enclosures may be required. If no existing structures are available, however, Davis provides two shelters for housing the radios and optional surge protectors.

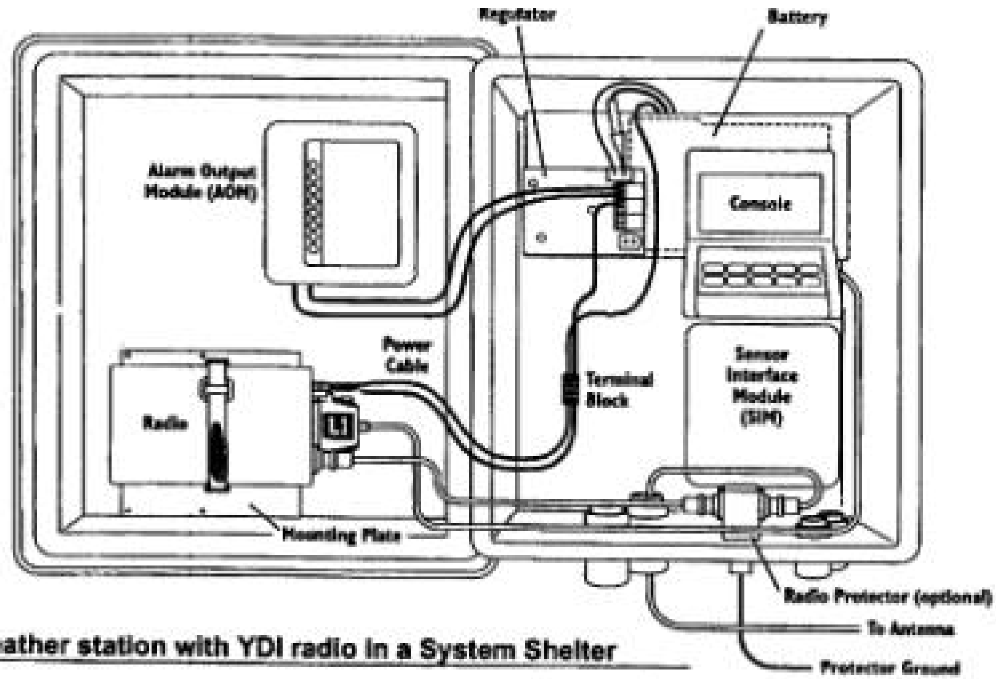

Figure 2. Weather station with YDI radio in a System Shelter

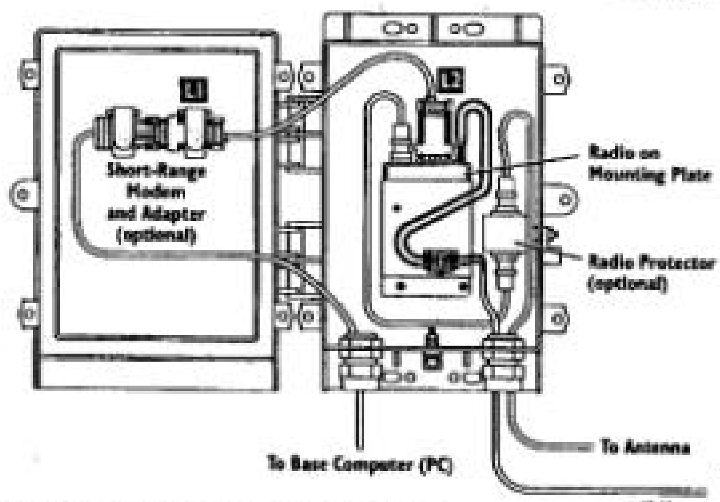

Figure 3. Base station UHF radio in a Multi-Purpose Shelter

System Shelter. The Complete-system Shelter is designed to provide weather protection for a complete weather station, including the optional solar power regulator and battery and a radio. Figure 2 illustrates the mounting in a System Shelter of a solar-powered station with YDI radio and an Alarm Output Module providing the power conservation control.

Multi-Purpose (MP) Shelter. The MP Shelter is a smaller enclosure suitable for housing a Sensor Interface and Console or a radio and its protector. The MP Shelter is useful when the radio must be located on the antenna mast, exposed to weather. Figure 3 shows an RF Neulink radio mounted in an MP Shelter at the base station with a Short-range Modem and Protector.

Small Surge-protector (SSP) Shelter. If it is necessary to add an extension co-ax antenna cable to a Davis-supplied antenna with BNC connector, weather-proofing is necessary. The SSP Shelter will shield the connection from rain or spray. Black electrical tape should not be used. Type N connectors are watertight.

DAVIS-SUPPORTED EQUIPMENT

The following radio and cell-phone products are specifically supported by the listed antenna kits and options from Davis Instruments. Other products may well be suitable for a wireless communications need. For more complete specifications see the individual product data sheet.

SPREAD-SPECTRUM, 902-928 MHz

Radio — YDI *RM910-DAVIS*
RF Output Power: 20 mW
Current Drawn: 180 mA, 12 VDC, receive and transmit.
Order from YDI (see page 9).

Antenna Kits
- 7632-003: Antenna Kit with 3dB omni (6-foot antenna cable)
- 7632-008: Antenna Kit with 8.5 dB Yagi (6-foot cable)
- 7632-912: Installation Kit for YDI 12 dB Yagi antenna (12-foot cable)

Options
- 7683: Antenna Surge Protector and cable.
- 7708: Solar Power Kit: (requires AOM or Timer)

NARROW-BAND UHF, 450 to 470 MHz

Radio — RF Neulink *Neulink 9600*
RF Output Power: 2 Watts, typical
Emissions: 16K0F1D, 16K0F2D
Current drawn: 100 mA, receive; 900 mA, transmit, at 10 – 15 VDC.
Order from RF Neulink (see page 9)

Antenna Kits
- 7642-002: 2 dB Omni (6-foot antenna cable)
- 7642-010: 10 dB Yagi (6-foot antenna cable)

Options
- 7683: Protector and cable
- 7708: Solar Power Kit (requires AOM or Timer).

CELLULAR TELEPHONE

Transceiver — Motorola *CTM 2400*
RF Output Power: 3 Watts
Current drawn: 0.27 A, standby; 1.8 A, transmit.
Order from Motorola (see page 9). Requires service subscription.
Option: Handset. Permits voice calls to and from station.

Antenna Kit
- 7652-003. 3 dB omni (6-foot antenna cable)

Options
- 7681: Protector.
- 7708: Solar Power Kit (requires AOM or Timer).

The following shelters and accessories from Davis are compatible with the above products.

- 7724: Complete System Shelter
- 7728: Multi-Purpose (MP) Shelter
- 7768: Small Surge-protector (SSP) Shelter
- 7690: Timer
- 7736: Alarm Output Module
- 7875: Short-range Modem pair
- 7995: Omni Antenna Mast-mount Kit

SOURCES of COMMUNICATIONS EQUIPMENT and SERVICES

The list below identifies just a few of the many sources of equipment and services.

LICENSING SERVICES		
Personal Communications Industry Association	703-739-0300	
PO Box 25648		
Alexandria, VA 22313-5648		
Professional Licensing Consultants	301-309-2380	
PO Box 1714		
Rockville, MD 20849		
RADIOS		
YDI	703-237-9090	Model: RM910-DAVIS
103 Rowell Court	fax: 703-237-9092	
Falls Church, VA 22046		
RF Neulink	800-233-1728	Model: Neulink 9600
7610 Miramar Road	fax: 619-549-6345	450 – 470 MHz
San Diego, CA 92126-4202		
CELLULAR TELEPHONES		
Motorola Pan American Cellular Subscriber Sector		Model: CTM 2400
500 North State College Blvd., suite 1250	800-345-6864 ext 213	
Orange, CA 92868	fax: 800-897-1829 ext 213	
ANTENNAS and SURGE PROTECTOR		
Cushcraft Corporation	603-627-7877	
48 Perimeter Road, PO Box 4680	fax: 603-627-1764	
Manchester, NH 03108		
ANTENNA MASTS and MOUNTS		
Radio Shack	800-843-7422	5-foot mast: #15-842
CABLES and CONNECTORS		50-Ohm cable,
Pasternak Enterprises	714-261-1920	BNC male to BNC female:
PO Box 16759	fax: 714-261-7451	#PE3047-xx,
Irvine, CA 92623		xx = length in inches.
SURGE PROTECTORS		
PolyPhaser Corporation	702-782-2511	
PO Box 9000	fax: 702-782-4476	
Minden, NV 89423-9000		
LIGHTNING ARRESTORS and GROUNDING EQUIPMENT		
Harger Lightning Protection, Inc.	800-842-7437	
1066 Campus Drive	fax: 708-362-3519	
Mundelein, IL 60060		
Thompson Lightning Protection, Inc.	612-455-7661	
901 Sibley Highway	fax: 612-455-2545	
Saint Paul, MN 55118-1792		

SOLAR/BATTERY CHARGE BUDGET WORKSHEET

CHARGE DRAIN per DAY

	Current	**ON Time**		**DRAIN**
	(Amps)	(min/hour)	(min/day)	(Amp-min)
A. Station	_____	60	1440	______
B. AOM or Timer	_____	______	_____	______
C. Radio on	_____	______	_____	______
D. Transmit add	_____	______	_____	______

TOTAL **DRAIN**/DAY = A + B + C + D = ______ Amp-minutes

CHARGE GAIN per DAY

E. Solar Panel Current @ 1000 W/m^2 _____ Amps

F. Peak Solar Irradiance _____ $Watts/m^2$

G. Day Length _____ hours

H. Cloud Factor _____

TOTAL **GAIN**/DAY = E (F/1000) x .55 x 60G x H = _____ Amp-minutes **GAIN/DRAIN** = ____

SOLAR/BATTERY CHARGE BUDGET Example: GroWeather with Timer and UHF Radio

CHARGE DRAIN per DAY

	Current	**ON Time**		**DRAIN**
	(Amps)	(min/hour)	(min/day)	(Amp-min)
A. Station	0.018	60	1440	25.9
B. AOM or Timer	0.012		24	0.3
C. Radio on	0.100		24	2.4
D. Transmit add	0.800		6	4.8

TOTAL **DRAIN/**DAY = A + B + C + D = 33.4 Amp-minutes

CHARGE GAIN per DAY

E. Solar Panel Current @ 1000 W/m2	0.6	Amps
F. Peak Solar Irradiance	1000	$Watts/m^2$
G. Day Length	10	hours
H. Cloud Factor	0.75	

TOTAL **GAIN**/DAY = E (F/1000) x 0.55 x 60G x H = 148.5 Amp-min. **GAIN/DRAIN = 148.5/33.4 = 4.5**

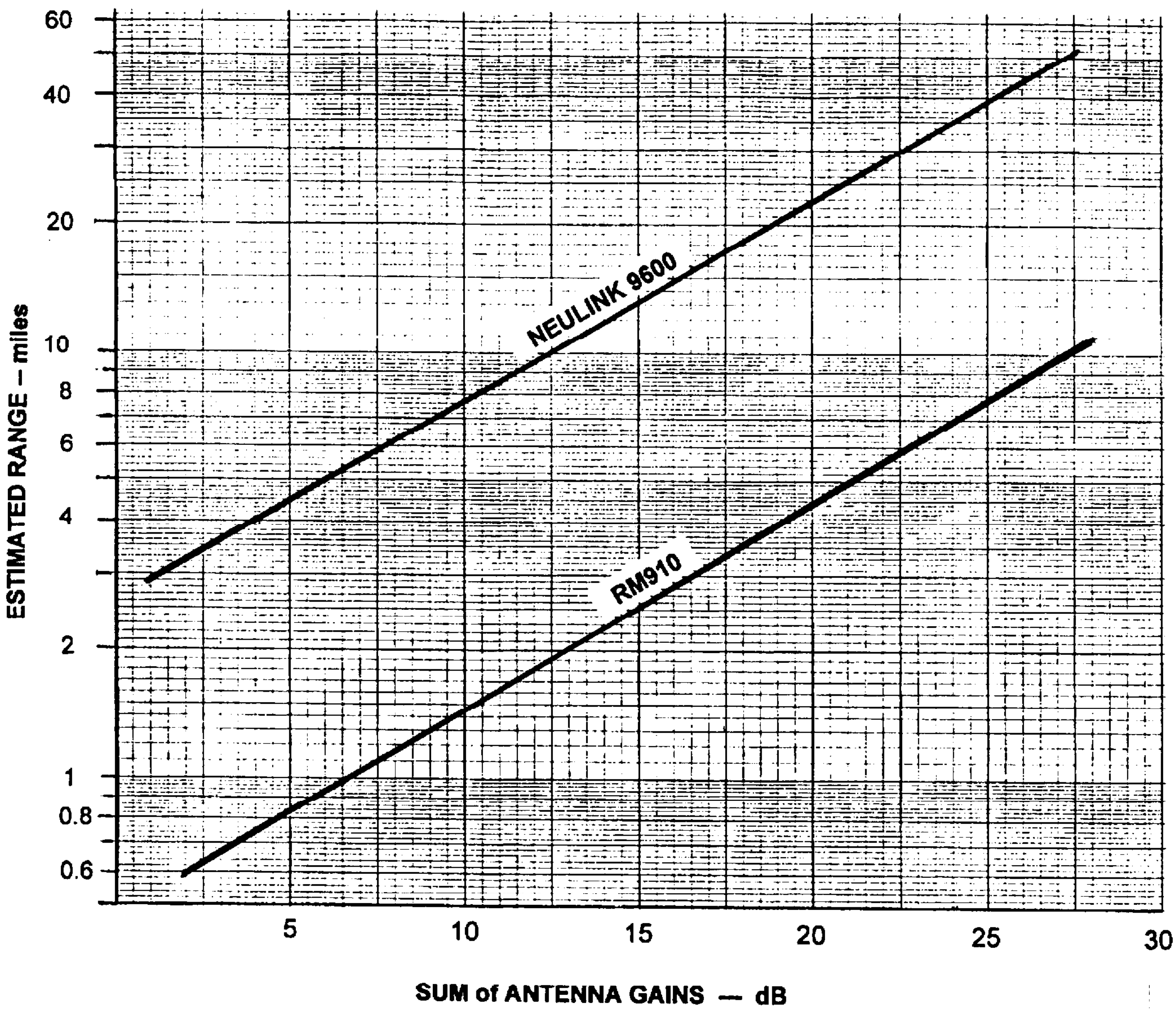

Figure 4a. Estimated transmission distance, in miles, line-of-sight, versus total antenna gain.

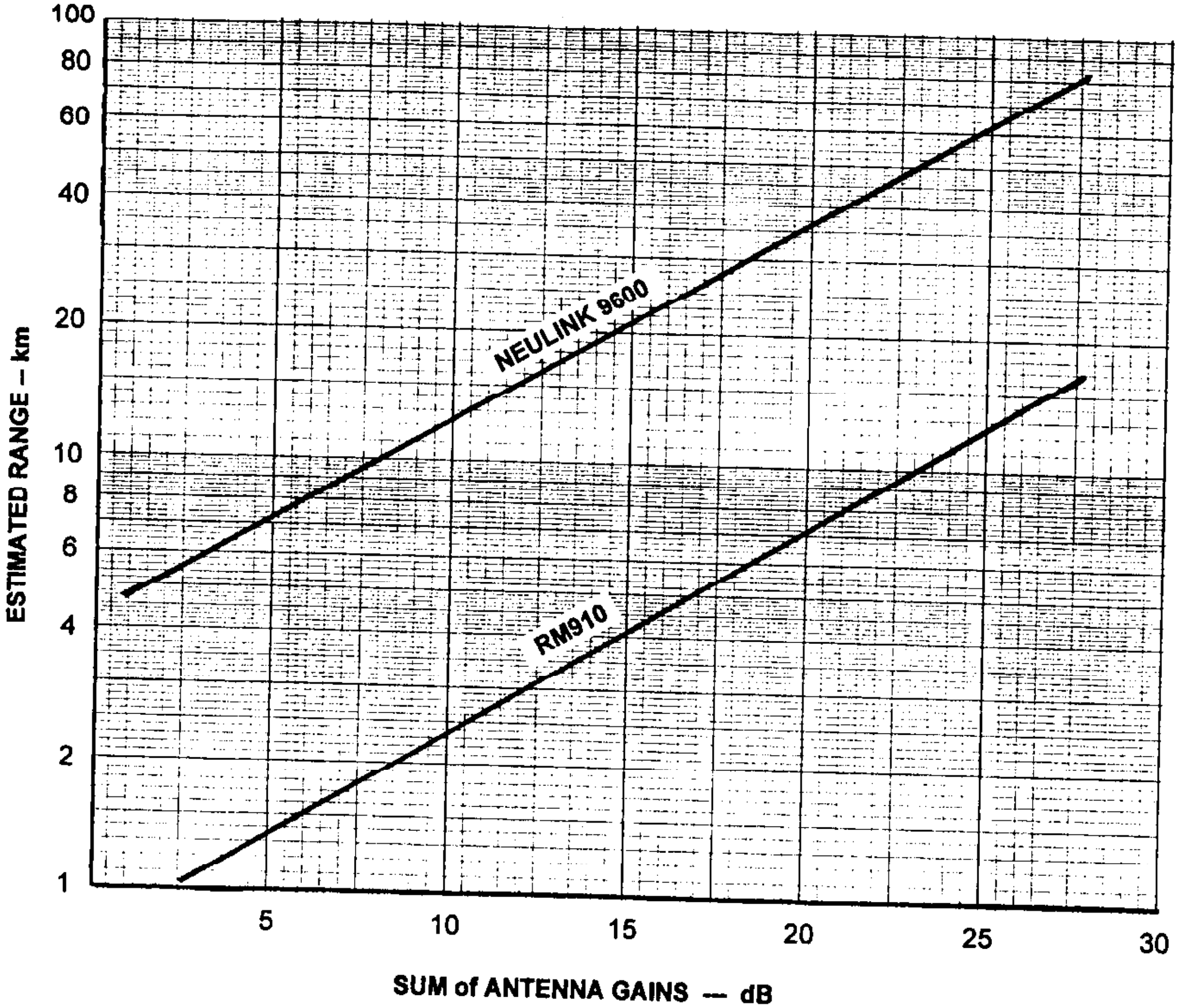

Figure 4b. Estimated transmission distance, in kilometers, line-of-sight, versus total antenna gain.

REFERENCES

1. NLR Series Technical Notes. Aerotron-Repco Systems , Inc., Orlando, FL (Spread-spectrum issues)
2. Carr, Joseph. Practical Antenna Handbook, TAB Books, 1989.

REFERENCES

1. NLR Series Technical Notes. Aerotron-Repco Systems , Inc., Orlando, FL (Spread-spectrum issues)
2. Carr, Joseph. Practical Antenna Handbook, TAB Books, 1989.

DAVIS

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