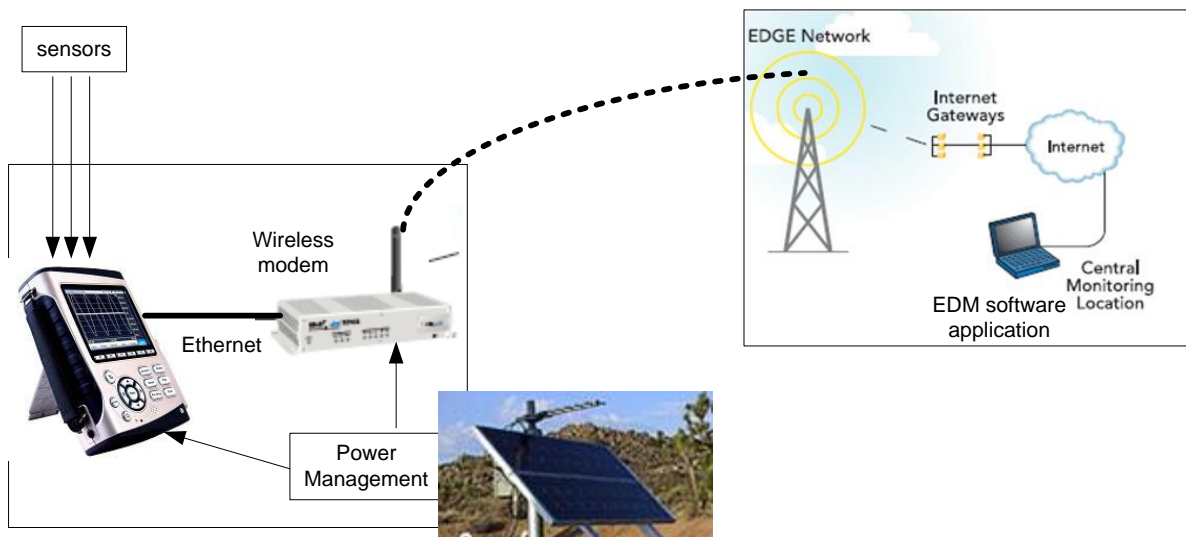


## Long Distance Remote Monitoring with Wireless Technology

### Introduction

More and more real world applications require accurately monitoring shock, vibration, noise, strain and other physical signals in remote or inaccessible locations such as runways, mines and wind turbines. The monitoring systems may also be subject to extreme environmental conditions. The user may be hundreds of miles away from multiple monitoring sites, yet needs to look at the data in real time, make adjustments to measurement parameters, and capture and download the complete recorded signals. The compact form factor of the CoCo-80/90, with its superb dynamic signal analysis capability and real-time recording, along with advances in wireless communication technology make this possible. The quick acceptance of 2.5G and 3G wireless networks have increased the cost-effectiveness of deploying remote monitoring systems worldwide.

While the user can fully take the advantage of CoCo's graphical user interface on site, CoCo is also a standalone network based device. When CoCo is connected with a wireless modem, it communicates with the user through a secure internet connection. This simple integrated solution is far more cost-effective than PC-based solutions. The complete remote monitoring system can be described in the following diagram as an example:



Here are a few typical applications for remote monitoring:

### Bridge and Building Structural Monitoring

The CoCo-80/90 can be used for applications ranging from simple beam-fatigue analysis, to structural mechanics research, to continuous monitoring of large complex structures. Highway overpasses, roads, buildings, retaining walls, suspension bridges, and amusement park rides are some types of structures for which our systems provide remote, unattended, and portable monitoring. Sensors used include strain gauges and accelerometers that are sensitive to the low frequency excitation and very low input signals.

### **Wind Turbine Monitoring**

A unique area of machine conditioning monitoring is the remote monitoring of wind turbines. Vibration monitoring is an important aspect in wind turbine monitoring. Other quantities including electrical power quality, torque, strain and temperature are also monitored with CoCo. Vibration analysis can detect and determine the severity of wear in the electrical generating equipment and rotating components of the turbine. This equipment consists of the main bearings, gearbox, and the generator. Vibration sensors are mounted to the bearings, gearboxes and the rotor hub and return an analog signal proportional to the instantaneous local motion. Data acquisition requires a high sampling rate, very high dynamic range and anti-aliasing. Wireless technology allows CoCo to be installed in the turbine without costly cabling to ground level.

### **Airport Noise Monitoring**

A typical airport noise monitoring system includes a number of CoCo instruments placed strategically around the airport, a central computer system and one or more workstations. CoCo is typically configured as a noise level analyzer mounted in an all-weather cabinet and set up with multiple weatherproof microphones. Correlated noise monitoring - where noise events are correlated with flight tracking data as well as weather and demographic data - is used as an integral part of a comprehensive environmental monitoring policy for airports.

### **Construction Noise and Vibration Monitoring**

Ground vibration and noise from construction activities affect infrastructure projects in several ways. Within the general vicinity of a construction site, vibration can result in damage to existing structures, disturbance to people, hearing damage, damage to sensitive machinery, and degraded performance of precision instrumentation or motion sensitive equipment. The vibration level and its effects on the surrounding neighborhood can be monitored and evaluated, ensuring compliance with local ordinances and preventing vibration contamination of nearby facilities or businesses.

Current practices for monitoring the conditions in the vicinity of construction sites typically consist of measuring acoustic signals, vibration signals with accelerometers, or free field or structural motions using velocity transducers. In addition to recording and monitoring the noise and vibration, CoCo can also be configured to generate alarms and notify engineers of excessive levels.

## **CoCo-80/90**

CoCo-80/90 is a multi-channel portable data recorder, dynamic signal analyzer and vibration data collector that is ideal for a wide range of industries including machine conditioning monitoring, automotive, aviation, aerospace, electronics and military that demand easy, quick and accurate data recording and real-time processing in the field. CoCo-80 is a low-cost, lightweight, battery powered system with unparalleled dynamic range and accuracy. CoCo-80 is equipped with 2, 4 or 8 input channels and accurately measures and records both dynamic and static signals on each channel simultaneously. The mass flash memory records 8 channels of streaming signals simultaneously up to 102.4 kHz while simultaneously computing real-time time and frequency-based functions. An embedded signal source channel provides various signal output waveforms that are synchronized with the input sampling rate. Sensor types that may be used with CoCo include microphones, accelerometers, displacement sensors, velocity sensors, tachometers, strain gauges, temperature, pressure, and many others.

CoCo-90 is equipped with an additional 8 channels for a total of 16 input channels and accurately measures and records both dynamic and static signals. The mass flash memory can record up to 16 channels of streaming signals simultaneously up to 51.2 kHz while simultaneously computing real-time time and frequency based functions.

The CoCo-80/90 system is equipped with two USB ports, 100 BaseT Ethernet, SD-card interface, audio input/output, a 5.7 inch color LCD display and a keypad.

The CoCo utilizes a new signal processing method, Configurable Signal Analysis (CSA). CSA provides unique flexibility for real time analysis including filtering and spectral analysis. Data can also be downloaded to a PC using EDM software from Crystal Instruments. EDM is a powerful tool for managing the large amounts of data generated by these systems and for further data analysis offline. The software includes database tools, analysis tools and report generators and is invaluable for working with multiple CoCo units in the field.

## ***CoCo as a Remote Monitoring Solution***

CoCo is an Ethernet based device designed for use in scientific and industrial applications. It is very compact and reliable compared to a PC-based instrument with similar capabilities. When CoCo is connected to the wireless modem, it becomes a remote monitoring system. With the inclusion of a solar power source, a CoCo monitoring solution can be installed almost anywhere. Here are the main items that must be addressed in this type of project.

### **Wireless Modem**

A wireless modem is a device that communicates to a wireless network instead of the local telephone system. When you connect with a wireless modem, you access the Internet via your Internet Service Provider (ISP). Many wireless modems offer GSM/GPRS or CDMA standards-

based quad-band capability. A standalone modem provides high speed wireless data communication and integrates seamlessly with remote EDM software. Wireless modems are available with a broad range of interface options including RS-232, USB and Ethernet. This application requires the speed of an Ethernet connection.

The built-in routing capabilities of a wireless modem usually provide DHCP services and firewall security utilizing Network Address Translation. The modem can be configured for one of three network connections: always-on, wake-up on ring, or dial-on demand. The always-on network connection automatically establishes a wireless data connection and allows for around the clock surveillance, monitoring or real-time data acquisition of any remote Ethernet device such as a Web camera. If the data link is dropped in the event of poor reception or a complete loss of service, it will automatically re-establish the data link. The wake-up on ring configuration allows the modem to "wake up" and initiate a connection when it detects an incoming ring. For security reasons, you can setup the modem to wake up based on the caller ID. This configuration is ideal for reducing the costs associated with the modem being online and available 24/7. When configured for dial-on demand, the wireless modem only accesses the Internet when data is present. This configuration is ideal for sharing Internet access among networked PCs.

### **Solar Power Supply**

Very often, AC power may not be available in the remote area. Solar electric power becomes a possible and viable solution. We will have to consider following factors when a solar panel and power system is chosen:

- High Efficiency Photovoltaic Modules
- Solid State UL Listed Control Systems
- Sealed Maintenance-Free Batteries
- Weatherproof, Aluminum Battery Enclosures
- Extra Room for your Equipment
- Highest Quality Hardware Accessories



There are many websites talking about calculating the total power capacity of the solar power system. The consideration factors are:

- Solar zones: this is the geophysical factor describing the average solar energy available
- The total power consumption of CoCo, wireless modem and accessories in a day

For example, a 4 channel CoCo with wireless modem that runs continuously for 24 hours, 7 days a week, requires about 15 watts. If the monitoring site is within California, you probably need to budget for a solar panel with power of 160 watts. The budgeted power of solar panel is much larger than that of the power consumption of the CoCo. This is understandable because of the lack of solar energy during nighttime hours and the angle of incidence early and late in the day. CI will provide assistance to determine the power budget based on configuration and location.

### **Packaging**



### **Special Software Functions**

The CoCo has a long list of dynamic signal analysis functions that can be used for remote monitoring, including long waveform recording, transient capture, trigger, auto-power spectrum analysis, FRF, octave analysis, sound level meters and real-time filters. A new technology, CSA, Configurable Signal Analysis, allows the user to upload various processing algorithms to the hardware and execute it in real time.

Besides the signal processing and data acquisition functions mentioned above, the following items are commonly required in the remote monitoring system:

1. Flexible data recording functions that can be started and stopped by timers, external events or through manual operation by the user remotely
2. Remote login and display the running status, such as input signal RMS, peak value etc..
3. Download the data files remotely
4. Delete the data files remotely

5. Send out alarms when certain signals exceed preset limits
6. Send alarm signals automatically through email or pager
7. Power management functions to save power, or to put the system into sleep mode
8. Wake up from the sleep mode
9. The host software at the user's site must be able to view and operate on multiple CoCos through wireless connection at the same time
10. Operator reset of the system remotely

A remote monitoring system must be designed to accept a remote reset command. Any computerized system can hang up due to unexpected software glitches. Although rarely used, this function is necessary if the operator is a long distance from the monitoring system.

Two software methods are available to monitor the CoCo-80 remotely. One is a dedicated user interface that CI developed based on its EDM (Engineering Data Management) software. The EDM is Windows application that can be installed and launched on a PC. A special option can be enabled in the EDM so it can be connected to one or multiple CoCo-80s remotely by using static IP address identification.

The second method is one step further in using the Internet technology. The EDM software can act as a website portal and it will post the data graphs to a dedicated website address. This method will allow the users viewing the live data that CoCo is acquiring on the Internet anywhere in the world.

### **Bandwidth Limitation**

In general, the wireless data transfer rate through a modem is much lower than when the unit is running on a local area network (LAN). For example a GPRS Class 10, Quad-band wireless modem can transfer the data up to 85 K bps. The actual transfer rate can be only a fraction of the ideal speed. This is much lower than a 100Mbits Ethernet LAN. To deal with low bandwidth, the software must be specially designed to be very bandwidth-conscious. For example during the normal operation, the user might want to see some very basic measurement status, such as min/max of the time signals, but not the time signals themselves. If necessary, such as during an alarm state, the time signals can be downloaded for analysis.

### **Advantages of the CoCo Remote Monitoring Solution**

Previously, it has been necessary to construct such a remote monitoring solution based on a PC architecture with add-on cards. There are many problems associated with the PC-based solution. It is expensive, personal computers typically are not rugged tend to fail in the outdoor temperature and humidity environment, and such as system consumes too much power. CoCo is an Ethernet based integrated solution, small and lightweight, designed for industrial use, more reliable, and consumes only a fraction of the power of a PC-based instrument.

The keypad and LCD of CoCo also come handy when the operator wants to look at the real-time data on-site. When the instrument is setup and used for on-site test, the user interface of CoCo can provide a great deal of information. When it is set in the remote monitoring mode, LCD will be turned off to save the power and its life.

**All Components**

In summary, the remote monitoring system can be constructed by using following elements:

<b>Categories</b>	<b>Description</b>
CoCo-80/90	CoCo Hardware, 2/4/8/16 channels
	CoCo application software
	Host PC EDM monitoring software
Power Supply	Solar Panel
	Deep Cycle Marine/RV Battery
	Power Regulator
	DC to DC Converter
Enclosure	Stainless enclosure with Tripod Mounting
Wireless	Wireless Modem with Ethernet port
	Antenna for Wireless Modem GPRS
	Carrier service, monthly paid
Sensors	Outdoor Microphones, IEPE, cable, pole mount
	Outdoor accelerometers, IEPE, cable, mounting accessories

***Application Example***

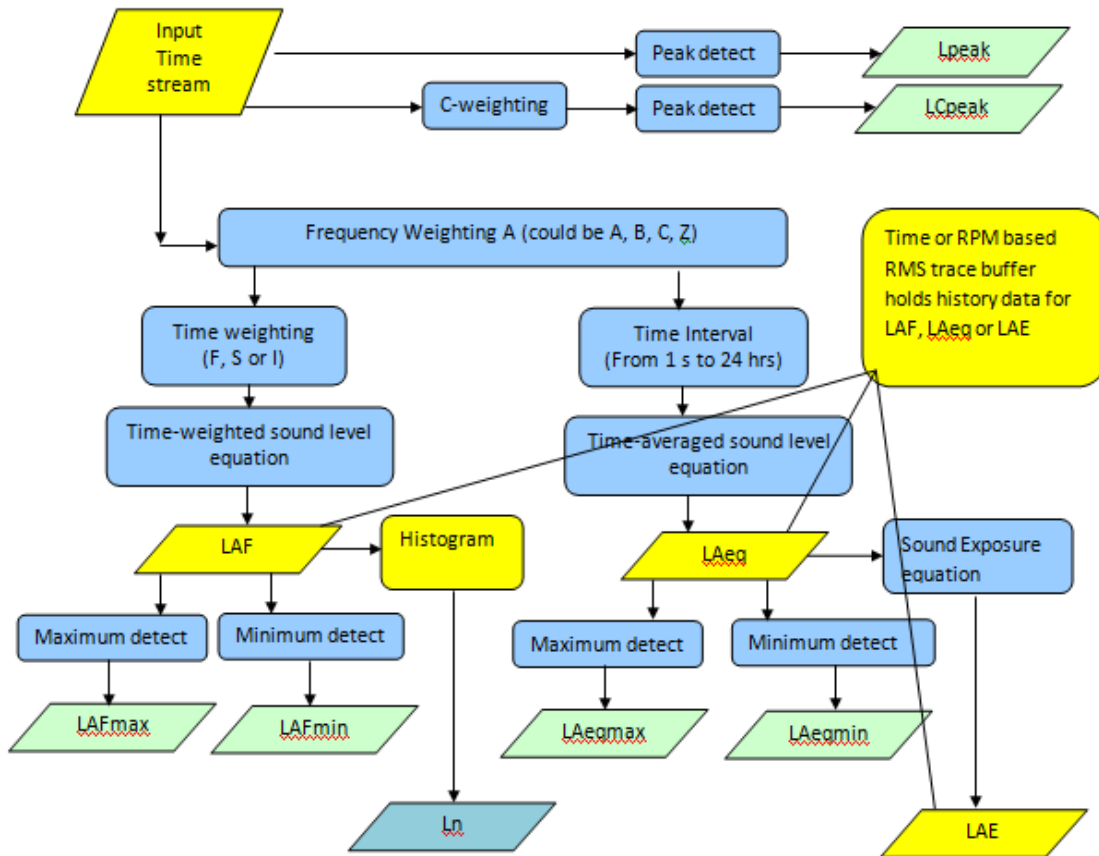
**Measurement Quantities**

In this application example, the CoCo will measure following quantities in a typical construction site:

1. Tonal noise: Noise containing a prominent frequency and characterized by a definite pitch.
2. CNEL: Community Noise Equivalent Level.
3. Hourly energy mean noise levels (Leq): See definition in Sample Noise and Vibration Control and Monitoring Plan attached to this Section.
4. Maximum Noise Level (Lmax): See definition in Sample Noise and Vibration Control and Monitoring Plan attached to this Section.
5. Peak Particle Velocity (PPV): Peak Particle Velocity.

**Measurement Description**

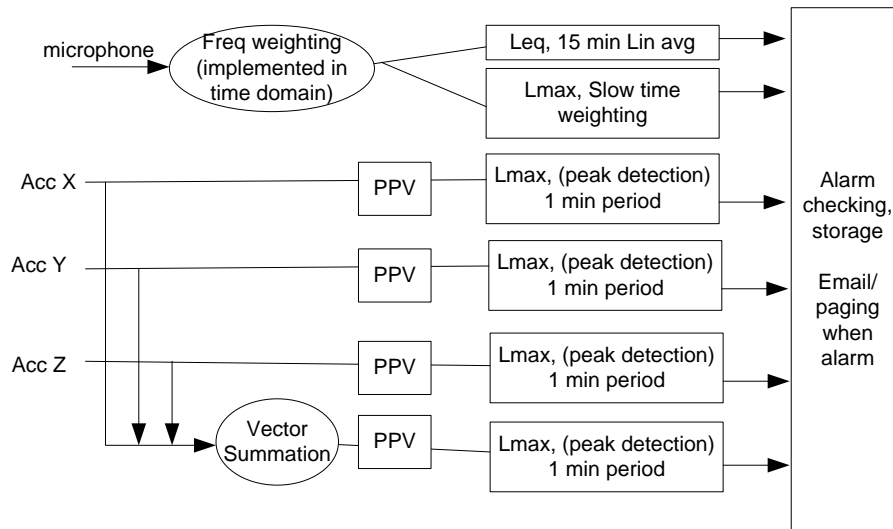
Following picture shows the data processing diagram for ONE input channel of CoCo for all the sound level meter measurements when A-weight is applied.



Sound level meter computation diagram.

In the sound level meter measurement, after the digitized data comes in, it is split into three paths: one goes to frequency weighting A, B, C or Z and one goes to C weighting or no weighting. The peak detection is computed from the output of C weighting or no weighting. The output of frequency weighting (A, B, C or Z) is further split into two paths. The first will go to a *time weighting function* which is more or less equivalent to an exponential averaging mode to calculate LAF; the second path goes to a time averaging function, which is equivalent to a linear averaging mode to calculate LAeq.

The general measurement block diagram can be described in the following picture:



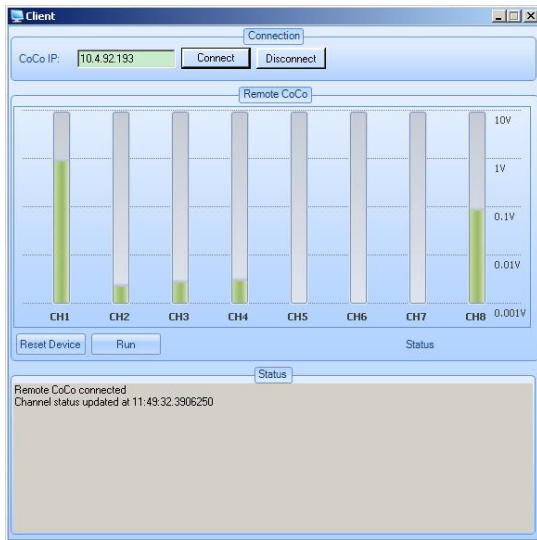
A CoCo with four channel IEPE inputs will be used for each monitoring device.

Ch1 will be connected with an outdoor microphone. The signal will be digitized and applied with A frequency weighting. This weighting function is implemented in the time domain. Then two signals will be computed. An Leq that uses 15 min averaging and an Lmax using slow time weighting.

Ch2, 3 and 4 will be connected to the X, Y and Z ends of a tri-axis accelerometer. The three vibration signals will be summed in vector and create the fifth channel. PPV will be applied to ch 2, 3, 4 and 5 (summed channel). Lmax over 1 min will be calculated. The actual peak detection rate will be much faster.

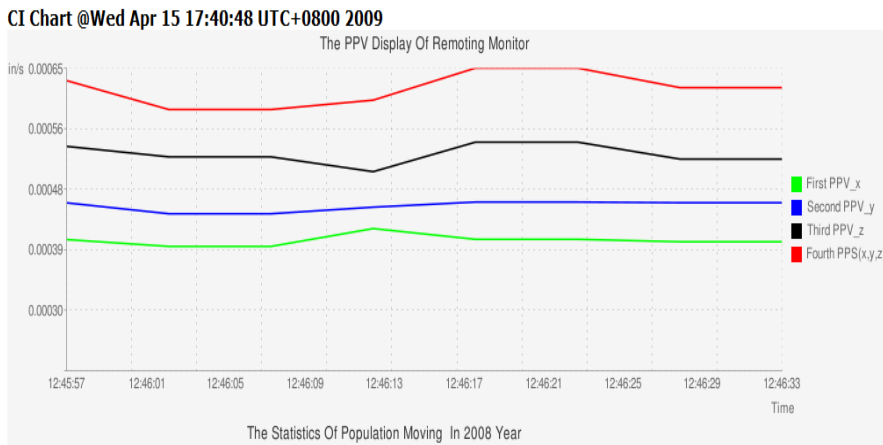
For this particular project the unit will only be active on certain days in a week. On every day the measurement time will be 7am to 5 pm, Mon-Friday. For general applications, the monitoring can be continuous and 24/7.

The picture below shows a screen capture of the EDM PC host software. It displays the input channel status of the CoCo hundred miles away.



When one or more signals exceed certain predefined limits, the email can be automatically sent to an email address.

The chart below is the live update display that remotely monitors the CoCo inputs.



From time to time, the user can then download the signals files from CoCo to PC. While the speed of data transfer is always a limitation, CoCo functions are very flexible to deal with various sophisticated tasks.