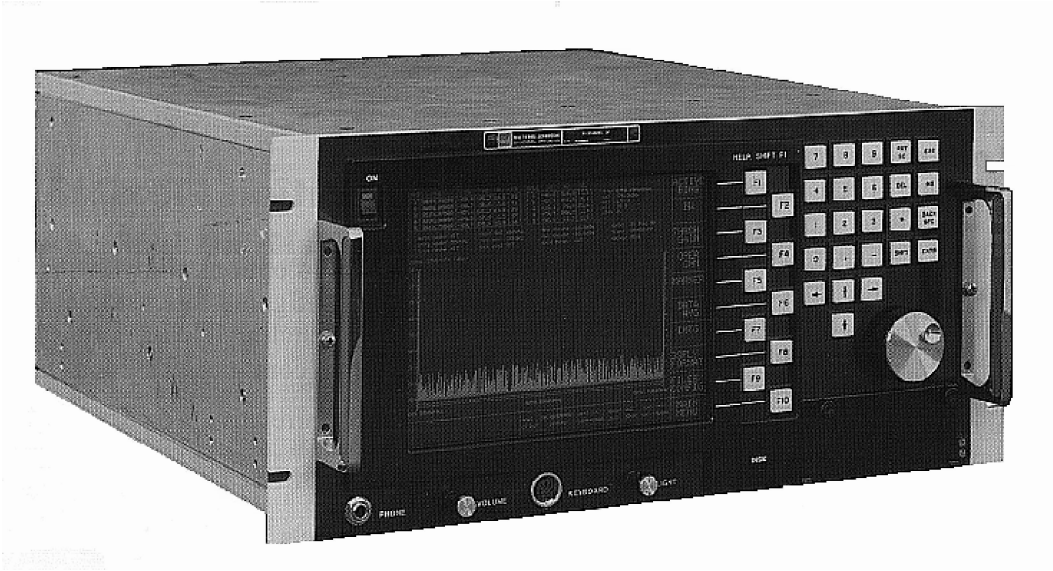
Technical Data

WATKINS-JOHNSON

May 1996

Correlative-vector DF System
WJ-8986A N-Channel



The WJ-8986A is a low-cost compact Direction Finding (DF) system. By combining advanced digital signal processing (DSP) techniques with state-of-the-art hardware, WJ presents a DF system with outstanding across-the-board performance. New synthesizer techniques provide a fast tuning rate, while parallel A/D Converters simultaneously digitize signals. This combination allows for a high probability of intercept and accurate lines of bearing (LOBs) for short duration signals. Specialized DSP and parallel computation techniques considerably reduce the time needed for LOB calculations. In addition, graphical data-processing options provide a powerful tool in applications such as resolving co-channel signals and DF of low-power signals.

These features allow the WJ-8986A to perform three major communications intercept system functions:

- High-quality DF
- Signal acquisition and monitoring
- RF/IF PAN display using high-resolution spectral FFTs

Features

- ❑ *DF, acquisition, display & monitoring capability*
- ❑ *High-accuracy antenna versatility*
- ❑ *3- to 5-channel simultaneous signal processing*
- ❑ *High-processing gain/DF sensitivity*
- ❑ *50-MHz/second scan rate (with DF)*
- ❑ *Effectiveness against frequency agile & PTT-type signals*
- ❑ *DFs on 10-microsecond pulses (monopulse-type design)*
- ❑ *Graphical front-panel displays*
- ❑ *Single rack-mountable unit with EL display*
- ❑ *Full remote control via IEEE-488 interface*
- ❑ *PC/AT-based design*

HEIGHT	8.75in(22.23cm)	**DEPTH**	20in(50.80cm)
WIDTH	19in(48.26cm)	**WEIGHT**	66lbs(29.86kg)

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With all of its performance, the WJ-8986A is a practical, easy-to-use box. The system consists of an 8.75-inch (22.23 cm) high rack-mountable chassis. The front panel of the DF contains a lighted keypad and EL display, as well as jacks for optional keyboard and headset. The DF antenna and accompanying cables are the only additional hardware. Options install internally in a modular fashion. Typical system power is less than 250 watts, making it ideal for vehicular applications.

Operator interface is via the front-panel keypad of the processor or an IEEE-488.2 remote control. An optional keyboard can also perform all DF operations. System output is by a multiple grey-scale, high-resolution EL display located on the front panel. This display provides the operator with system configuration, LOB results, and various graphical displays such as angle of arrival (AOA) versus signal strength and AOA versus frequency. An optional external CRT adds enhanced color graphics.

LOBs are calculated using a correlation algorithm on signals obtained from monopulse antenna arrays. This technique easily adapts to a wide variety of DF antennas. Dipole antenna arrays primarily provide DF coverage in the VHF/UHF ranges. Other compatible antenna configurations include:

- Crossed-loop antennas for HF ground waves
- Large baseline arrays for HF sky waves
- Annular slot or ferrite loops for covert applications

In general, the WJ-8986A uses arbitrary antenna arrays for DF applications.

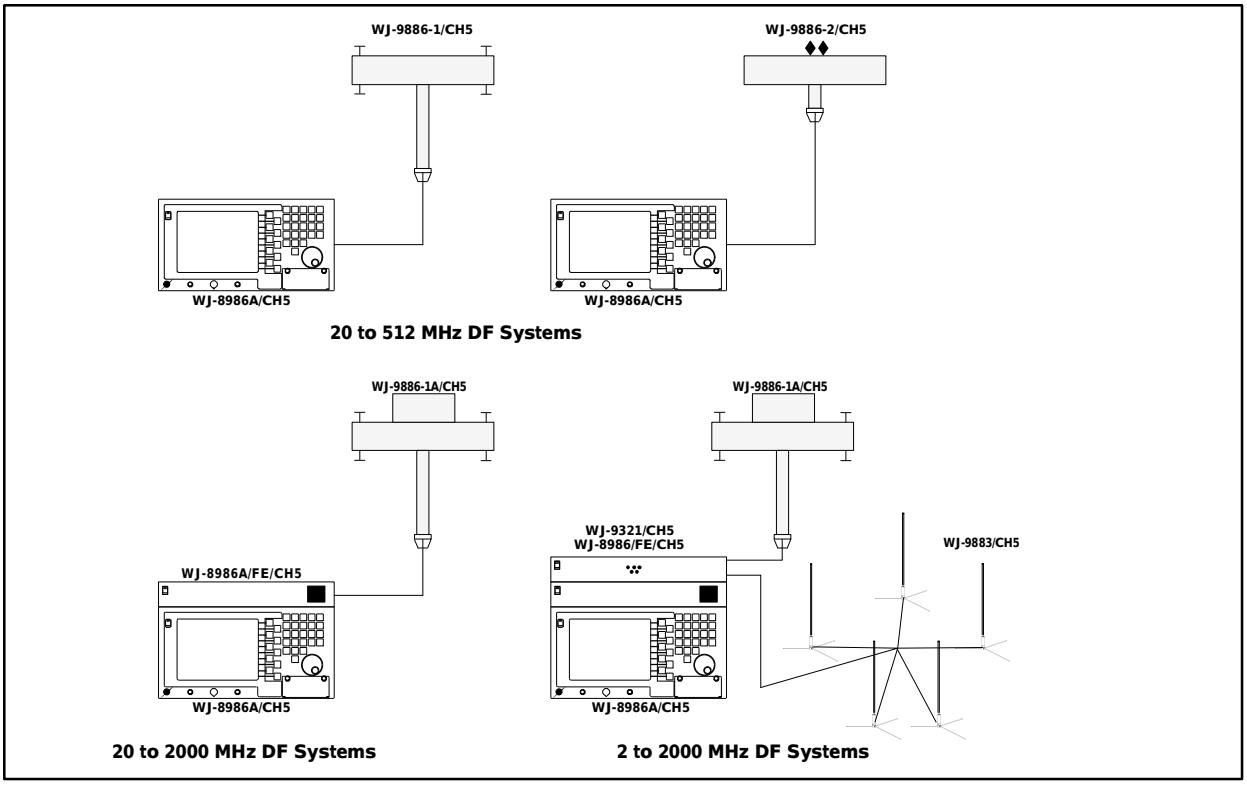
The WJ-8986A uses graphics data-processing software to enhance its operation. Standard software includes a basic simplified display, plus the displays shown on page 3.

Configuration Flexibility

A variety of options allow system configurations for customer-specific applications, including HF and airborne DF. The standard system consists of:

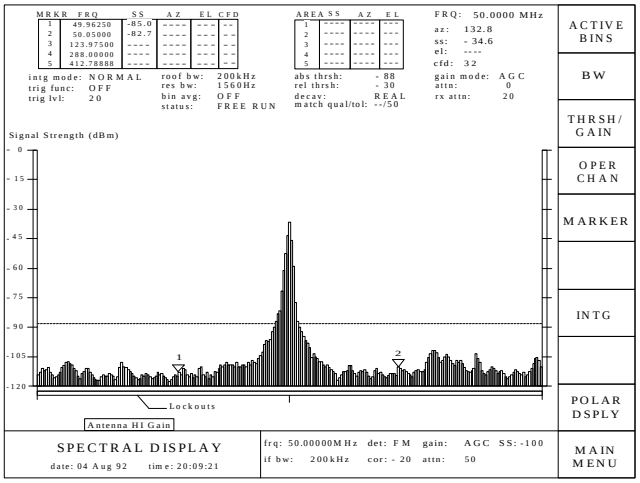
1) WJ-8986A Correlative-vector DF Processor
   - 2 to 512 MHz DF unit
   - 3 channels
   - Front-panel keypad/IEEE-488 bus
   - EL front-panel display

2) WJ-9886-X 20 to 512 MHz DF Antenna

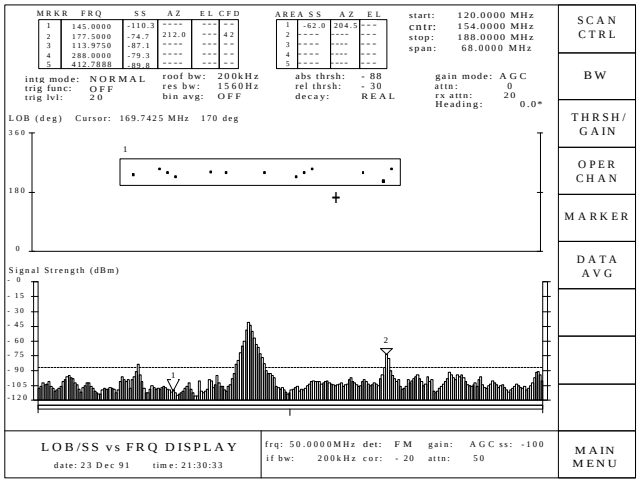


Typical System Configurations

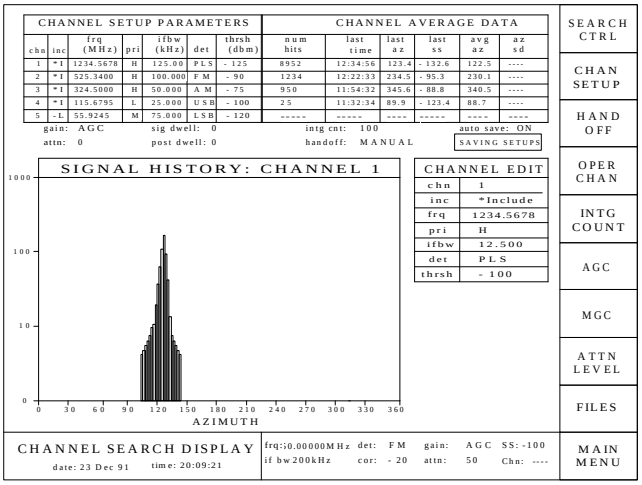
Samples of some available Displays.



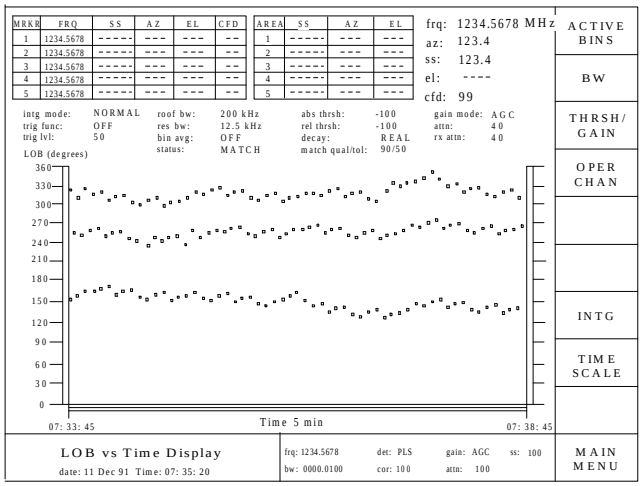
Spectral



LOB/SS vs. Frequency



Channel Search



LOB vs. Time

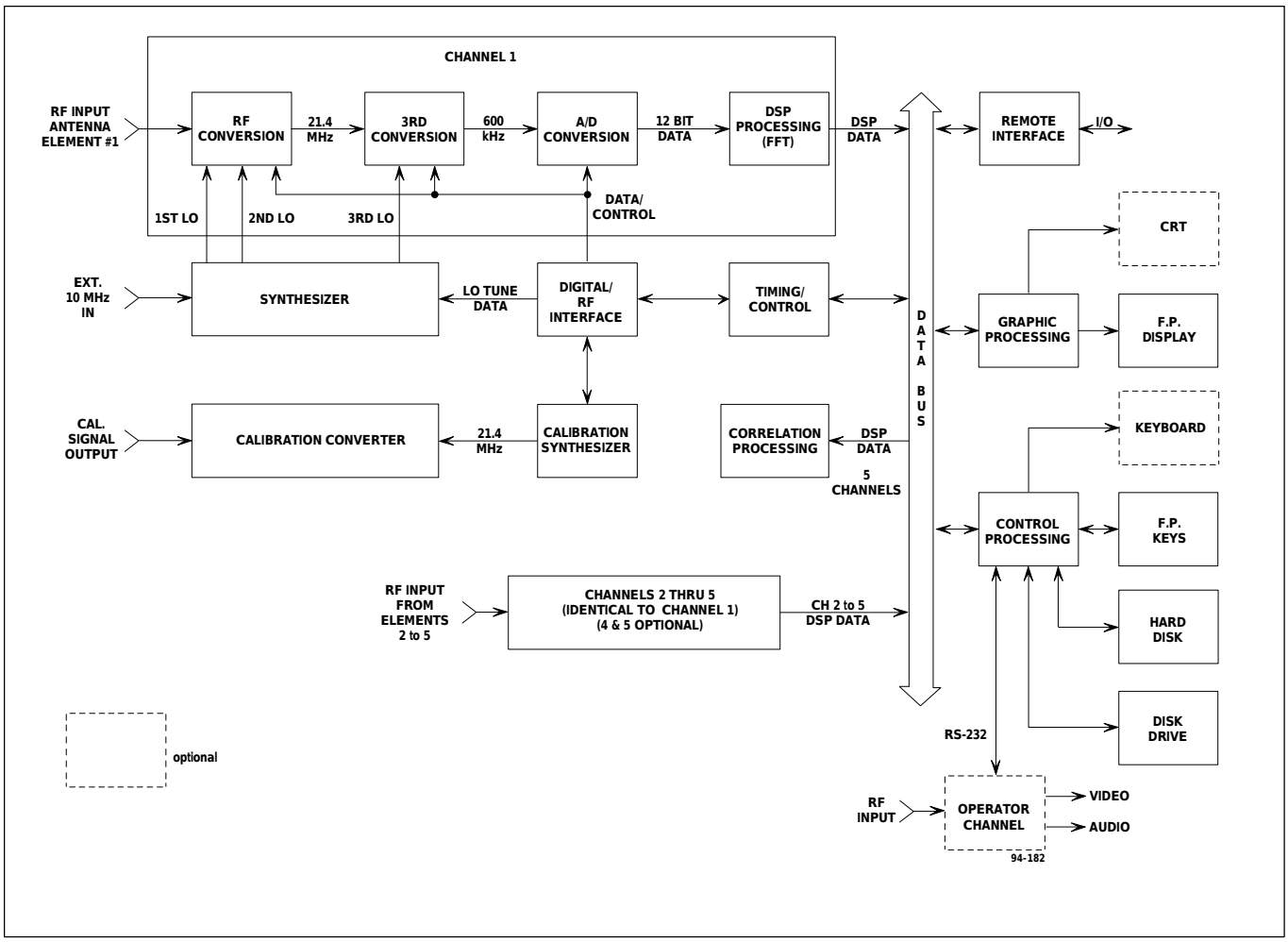
WPG104

Model # Matrix

		DF Processor	Frequency Extender	VHF/UHF Antenna[1]	HF Antenna[2]	Antenna Adapter/HF Preselector
Current Nomenclature	3-Channel	WJ-8986A/CH3	WJ-8986/FE3	WJ-9886-X	WJ-9883	WJ-9321
	4-Channel	WJ-8986A/CH4	WJ-8986/FE4	WJ-9886-X/CH4	WJ-9883/CH4	WJ-9321/CH4
	5-Channel	WJ-8986A/CH5	WJ-8986/FE5	WJ-9886-X/CH5	WJ-9883/CH5	WJ-9321/CH5

[1] See Separate Data Sheet.

[2] Must use WJ-9321 Adapter unit/HF preselector with this antenna. Standard cable length is 150 ft (45.72). Contact factory for different lengths.



Overall Block Diagram

Typical Applications

Resolving Co-Channel Signals

In many situations, two or more signals are located in the passband of the receiver. To accurately DF on a desired signal, an operator must identify and isolate it from any undesired signals. The operator uses the graphical processing software to obtain a high-resolution frequency spectrum display and to select the signal of interest. This eliminates the effects of other signals in the passband and calculates an LOB for the selected signal only.

DF on Low-Powered Signals

It is often desirable to DF on signals with poor signal-to-noise ratios (SNR) in order to obtain accurate LOBs. An operator can then use signal processing gain to improve the effective SNR. The noise figure of the WJ-8986A is typically less than 10 dB. In addition, the FFT algorithm used allows for narrow-resolution bandwidths, thus reducing the noise power. Averaging techniques allow a quick reduction of random noise to give accurate LOBs. The processing gain realized by this averaging becomes practical due to the fast processing time of the WJ-8986A. Conventional DF systems often require very strong signals to maintain a two- to three-degree rms accuracy.

Large Systems

The three- to five-channel Correlative Vector DF technique eliminates antenna switching and allows a fast DF response or throughput time. This is critical in large system applications where the DF is tasked by a fast acquisition receiver, such as the WJ-9195C, WJ-8695, or compressive receiver units. Many current DF units require antenna switching that results in slow throughput. The DF then becomes too slow to keep up with the large queue of signals sent by the acquisition receiver. Short duration signals are often gone before the DF operation is performed. The low cost and high accuracy of the WJ-8986A DF unit makes it ideal for an emitter location in a netted configuration of two or three units.

Signal Acquisition

The WJ-8986A graphics software allows an operator to establish a target list of up to 100 different frequencies. Priorities are assigned to each frequency, and the DF continuously collects data on the targeted frequencies. The collected information is stored on disk, or displayed in a tabular or histogram format. The system also performs standard frequency (F1-F2) scans with DF at 50 MHz/second. The combination of scan rate, pulse response, and graphical displays allow the unit to DF on frequency agile signals. In these modes, the WJ-8986A is also effective as an acquisition unit for a typical collection system.

System Specifications

Contact WJ for exact sensitivity specifications

Frequency Range	**20 to 512 MHz, tunable to 2 MHz (512 to 2000 MHz optional)**
Required Minimum Signal Duration	**10 µsec (with trigger mode)**
Scan Rate	**50 MHz/second, typical (with DF & 25-kHz resolution bandwidth)**
LOB Response Time[1]	**35 msec plus integration time, typical**
FFT Bin Size	**3.2 kHz to 25 Hz (3.2-kHz roofing filter) 22 kHz to 86 Hz (22-kHz roofing filter) 200 kHz to 782 Hz (200-kHz roofing filter)**
FFT Window	**Blackman-Harris**
Resolution Bandwidths (including windowing)	**3.2 kHz to 25 Hz (3.2-kHz roofing filter) 22 kHz to 172 Hz (22-kHz roofing filter) 200 kHz to 1.56 kHz (200-kHz roofing filter)**
Accuracy[2]	**2° rms typical**
Sensitivity[3]	**<10 µV/m for 2° rms jitter, typical**
Noise Figure[4]	**<12 dB, typical (20 to 2000 MHz)**

1. **Response times include remote commands to change frequency and take LOB. Assumes 25-kHz resolution bandwidth and single LOB calculation.**
2. **System accuracy highly dependent on environment and ability to calibrate out these effects. Typically systems perform with 2° rms error in controlled conditions.**
3. **Sensitivity dependent on frequency, antenna configuration, integration time, resolution bandwidth, external noise contributions, and other factors.**
4. **System noise figure set by preamplifiers in antenna. For a WJ-9886-1A DF antenna with WJ-8986A DF processor and 100 ft of RG-214 coaxial cable, noise figure typically less than 12 dB.**

DF Processor Options

Model #	Features	Physical Characteristics
WJ-8986/OC Operator Channel	• RF channel with AM, FM, CW & SSB demodulation • Monitoring frequency spectrum for signals of interest	• Standard IFBWs: 10, 20, 50, 100 & 300 kHz • 3-kHz IFBW for SSB demodulation (See WJ-8607 data sheet) • With WJ-8986/FE, specify OCE
WJ-8986A/CH4 or WJ-8986A/CH5 Add'l RF Channels	• Up to 5 processing channels	• Specialized antenna arrays • Installs on vehicle or airborne platform
WJ-8986/BFP Blank Front Panel	• Exclusively remote control	• External CRT & keyboard
WJ-8986/DIG[1] Digital Compass	• Interface with a KVH Autocomp 1000 (or similar compass)	• Additional hardware & software
WJ-8986/NAV[2] Navigation Synchro Interface	• Interface with standard navigation synchros (with 115-Vac reference input & 90-Vac line-to-line 3-wire output)	• Additional hardware & software
WJ-8986/ACS Antenna Calibration	• Database generation for arbitrary antenna configurations or correction of site-related errors	• Contact factory for details
WJ-8986/IRO Independent Receiver Option	• External serial control of operator channel • Amplified IF output for digitization by an A/D Converter	• Rear-panel amplified 21.4-MHz IF

[1] Not available with 3.2-kHz roofing filter or /NAV option
[2] Not available with 3.2-kHz roofing filter or /DIG option

Special Assistance

- Configurations that allow unique applications or use of existing arrays
- Particular cabling for requirements that vary significantly from system to system
- Integration assistance in site evaluation, equipment integration &/or platform calibration

DF Processor Specifications

Frequency Range	**20 to 512 MHz, tunable to 2 MHz (512 to 2000 MHz optional)**
Noise Figure[1]	**12 dB, max (20 to 512 MHz) 15 dB, max (512 to 2000 MHz with FE)**
Input Impedance	**50 ohms, nominal**
Input VSWR	**2.0:1, typical 3.0:1, max at the tuned frequency**
Tuning Resolution	**100 Hz, synthesized**
Internal Reference Accuracy	**$\pm$1 part in $10E^{-6}$ (0 to 50°C)**
External Reference Frequency	**10 MHz, 0-dBm nominal input level**
Preselection	**Tracking preselector (20 to 512 MHz, 10% nominal bandwidth) Suboctave filters (512 to 2000 MHz)**
3rd-order Intercept Point	**+5 dBm (2 to 20 MHz) +8 dBm (20 to 512 MHz) 0 dBm (512 to 2000 MHz)**
2nd-order Intercept Point	**+45 dBm (20 to 512 MHz) +35 dBm (512 to 2000 MHz)**
Dynamic Range	**100 dB**
Instantaneous Dynamic Range	**65 dB, typical**
Control Processor	**80486/66 MHz**
FFT Processors	**DSP56001/27 MHz**
Correlation Processor	**TMS320C30/33 MHz**
Graphics Processor	**Vector scan RISC**
LO to Antenna Radiation	**<-90 dBm**
Processor Roofing Bandwidths	**22 & 200 kHz (3.2 & 2.2 kHz, or 3.2 & 200 kHz optional)**
Display Type	**EL panel (color CRT optional)**
Display Resolution	**640 x 480 pixels (VGA, 27-kHz horizontal sync)**
LOB Resolution	**0.1°**
Instrument Accuracy[2]	**<1° rms**
Remote Control	**IEEE-488.2**
Operating Temperature	**0 to 50°C**
Power Requirements	**90 to 132 Vac/180 to 264 Vac, 47 to 63 Hz (User selectable)**
Power Dissipation	**250 W, typical**

[1] System noise figure set by preamplifiers in antenna. For a WJ-9886-1A DF antenna, WJ-8986A DF processor and 100 ft of RG-214 coaxial cable, noise figure typically less than 12 dB.

[2] Instrument accuracy measured using input signal level of -95 dBm, resolution bandwidth of 25 kHz, and 100 integrations.

Antenna Specifications

WJ-9883 Ground-mounted Monopole Array	**HF**	
	Frequency Range	2 to 30 MHz
	Signal Type	Vertically polarized ground waves & sky waves
	Monopole Length	15 ft (4.6 m)
	Baseline	14 ft (4.3 m), 3-element configuration
	Weight	120 lbs (54.5 kg) 4 pieces, 3-element configuration
	Operating Temperature	-20 to +60°C
WJ-9886-1	**VHF/UHF**	
	Frequency Range[1]	20 to 1200 MHz
	Signal Type	Vertically polarized
	Operating Temperature	-20 to +60°C
WJ-9886-2 (Low Profile)	Frequency Range[1]	20 to 1700 MHz
	Signal Type	Vertically polarized
	Operating Temperature	-20 to +60°C
WJ-9886-1A	Frequency Range	20 to 2000 MHz
	Signal Type	Vertically polarized
	Operating Temperature	-20 to +60°C

[1] Indicates maximum frequency for 5-element arrays. Refer to antenna data sheet for other configuration.

Fixed-site or Vehicular Antennas

Range	Physical Characteristics
2 to 30 MHz HF sky- & ground-waves	• Fixed-site monopole array (WJ-9883)
20 to 512 MHz VHF frequency band	• Dipole antenna arrays (WJ-9886-X)
20 to 1200 MHz UHF frequency band	• Extended VHF antenna arrays (WJ-9886-X)
20 to 2000 MHz UHF frequency band	• Extended VHF antenna arrays (WJ-9886-1A, -2)

Rear-panel Connectors

	Connector	Designator	Type
Standard Unit (WJ-8986A/CH3)	External Printer	J1	25-pin D-type Centronix
	External VGA Video (RGB)	J2	15-pin D-type
	External control	J4	25-pin D-type
	Antenna control	J5	25-pin D-type
	ANT #1	J10	N-type
	ANT #2	J11	N-type
	ANT #3	J12	N-type
	CAL SIG	J15	N-type calibration signal
	10-MHz OUT	J16	BNC
	EXT 10-MHz REF	J17	BNC
	AC Power Input	FL1J1	110/230 Vac
	IEEE-488	J8	IEEE-488.2-1987 interface
WJ-8986A/CH4 or CH5			
	ANT #4	J13	N-type
	ANT #5	J14	N-type
WJ-8986/OC			
	Video	J18	BNC
	Switched audio	J19	BNC
	Omni antenna	J20	BNC
WJ-8986/DIG[2]			
	Digicompass/RS-232	J6	Serial port
	RS-232	J7	Serial port (not used)
WJ-8986/NAV[3]			
	Syncro	J21	Interface to syncro device

[2] The DIG option is not compatible with 3.2-kHz roofing BW or the NAV option.

[3] The NAV option, is not compatible with 3.2-kHz roofing BW or the DIG option.

Accessories

Model #	Features
WJ-8986/FE Frequency Extender	• Frequency range from 512 MHz to 2 GHz • 4- & 5-channel rack-mountable FEs
WJ-9321 Antenna Adapter/HF Preselector	• Interface circuitry for WJ-9883 DF antenna w/rack-mountable hardware • Switching capability between 2 antenna arrays • Up to 5 channels
WJ-8986/CRT External CRT Display	• Viewing of color graphic display
WJ-8986/KBD External Keyboard	• Easy operator interface

Technical Update

WATKINS-JOHNSON

August 1996

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LO to Antenna Radiation ..... < -90 dBm

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