Technical Data

WATKINS-JOHNSON

May 1996

HF DF System
WJ-9012

Watkins Johnson built the WJ-9012 HF Direction Finding (DF) System around the IEEE-1155 VMEbus Extensions for Instrumentation (VXI) standard. The system uses commercial off-the-shelf (COTS) equipment and is a fully functioning Tactical/Strategic High Frequency (HF) DF System using minimum rack space. The WJ-9012's man-machine-interface (MMI) is built around field-proven software. Open-system architecture, COTS hardware and software, and the IEEE-1155 standard ensure users of general industry support for future products and upgrades.

The WJ-9012 turnkey system provides modern, modular, building blocks that expand the MMI to accommodate growth to VHF/UHF DF as required. The life-cycle cost benefits of this design approach permits a logical expansion of capability as a function of time at minimum cost.

Features

- ❑ *1.5 to 30 MHz frequency coverage*
- ❑ *N-channel design (8 channels typical)*
- ❑ *Resolution of co-channel interference*
- ❑ *Superresolution algorithms*
- ❑ *Open-system Architecture*
- ❑ *WJ-8721 VXI HF Receivers*
- ❑ *Windows NT GUI*
- ❑ *Built-in test circuitry*
- ❑ *Variety of networking options*
- ❑ *Support of Variable Antenna Configurations*

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System Controller

The WJ-9012 System Controller is a Pentium-based IBM-compatible computer running the Microsoft Windows™ NT operating system. WJ houses the unit in a standard desktop chassis. It contains:

- Pentium Processor
- 32-Mbyte DRAM
- 1-GB Hard Disk Drive
- 17-in Color Monitor
- 1024 x 768 Graphics Adapter
- Internal 1.44-MB Floppy
- SCSI DAT Drive
- IEEE 802.3/Ethernet
- EIA RS232C Serial Ports
- Keyboard and Mouse
- Windows™ NT

The System Controller provides the control interface for the DF Acquisition Unit (DAU). The operator interface is a Windows™ NT-based MMI that provides a user-friendly control paradigm for DF and receiver-control operations. Standard displays provide an easy-to-use operator interface for DF operations, system configuration, and world-map displays with Line of Bearing (LOB) and fix overlays. Depending on user requirements, WJ can configure the system software with displays for acquisition receiver control, intercept collection, demodulation control, database management, and report generation.

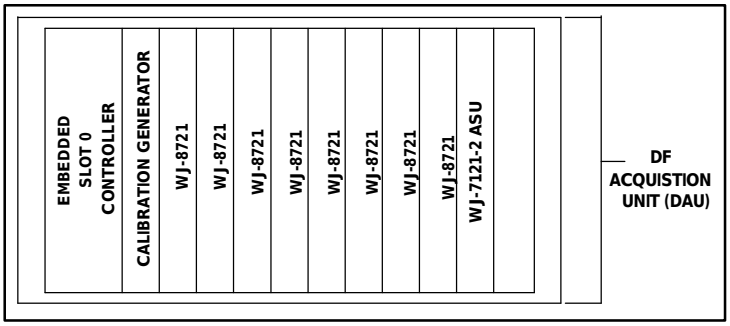
DF Acquisition Unit (DAU)

The DAU contains all the necessary hardware and software to provide LOB to the System Controller. The DAU consists of three types of VXI equipment:

- Embedded 486 Controller
- Calibration Generator
- WJ-8721 HF Receivers

The embedded 486 Controller is a VXI Slot-0 controller that provides overall control and coordination of the signal acquisition and DF process. This unit has a 66-MHz 80486 processor that receives DF requests from the System Controller. The embedded controller then processes the calibration functions, receiver control, data acquisition, and digital signal processing (DSP) DF algorithms to provide a final LOB to the System Controller. A dual TMS320C40 Processing Card performs the DSP. This card resides in one of two available Industry Standard Architecture (ISA) expansion slots located in the Embedded Controller.

The Calibration Generator is a VXI function generator that provides a calibration source for the correction of phase and amplitude errors in the receiver channels. The generator automatically calibrates on each new frequency or on significantly altered signal levels. The output of the calibration unit is connected to the WJ-7121-2 Antenna Switch Unit (ASU), which injects the calibration signal into all the receiver channels.



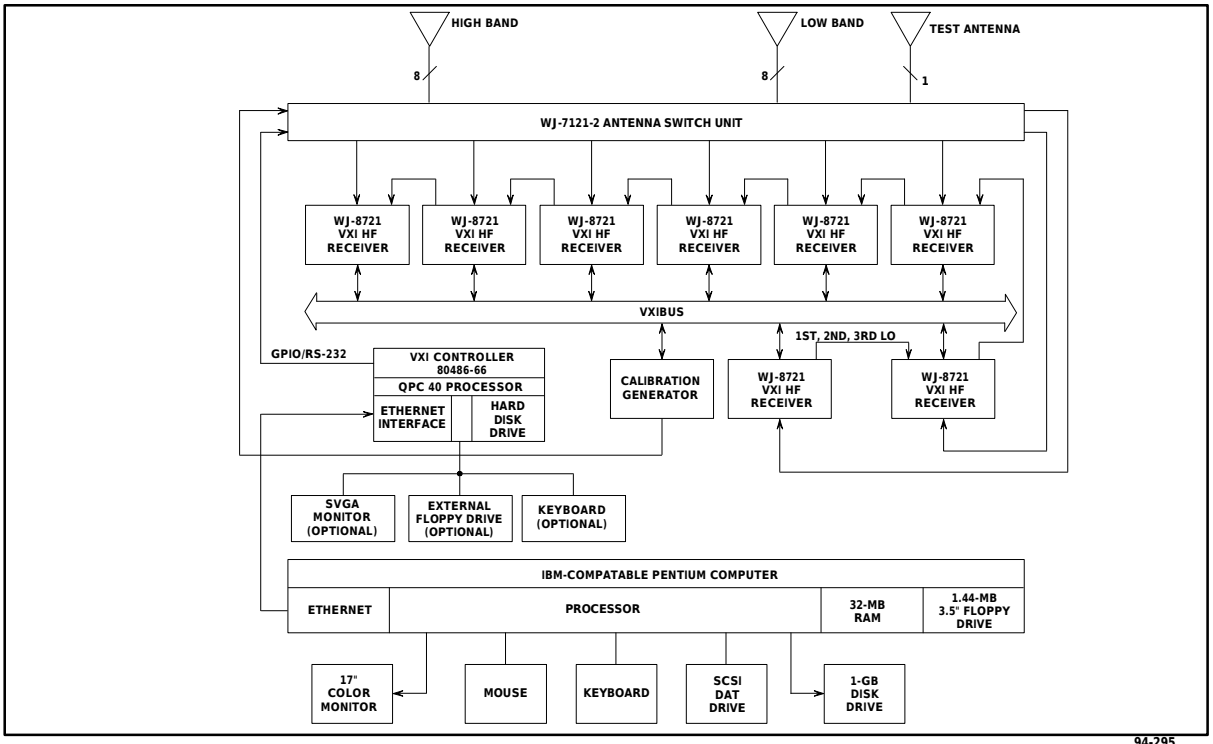
WJ-9012 System Rack Elevation

The WJ-8721 is a fully synthesized, general-purpose HF receiver for signal monitoring, and DF of RF communications from 5 kHz to 30 MHz with 1-Hz tuning resolution. WJ packages this unit in a single-slot C-size VXI module. WJ uses DSP techniques for a variety of module functions such as IF filtering, Automatic Gain Control (AGC), demodulation, and Beat Frequency Oscillator (BFO) tuning. Digital stability and repeatability provide filters with superior amplitude and group delay characteristics. The receiver provides up to 66 standard selectable IF bandwidths (IFBWs). Available detection modes are AM, FM, CW, USB, LSB, and ISB. A tunable BFO is adjustable in 10-Hz steps over a ±8000-Hz range. Passband tuning further enhances the reception of signals in dense spectral environments. Fast, Slow, and Manual AGC modes are available with the standard receiver. However, the AGC loop is controlled at the system level, when used in the WJ-9012.

Although used as a stand-alone receiver, the WJ-8721 is also ideal for systems like the WJ-9012 that require multichannel, phase-locked, synchronous acquisition. This system routes all three Local Oscillators (LO) on the master receiver to the front panel for daisy chain routing to subsequent slave receivers. Similarly, the unit synchronizes the Analog-to-Digital (A/D) converters on slave receivers to the master receiver. This ensures synchronous sampling for all the A/D converters. Once data is acquired, the Embedded Controller retrieves it from each receiver for signal processing.

Antenna Switch Unit (ASU)

A WJ-7121-2 ASU interfaces with existing HF antenna arrays or with an optional HF Monopole Antenna Kit. Since many HF DF system requirements are upgrades to



WJ-9012 System Functional Block Diagram

the receiving/processing subsystems only, the standard system design allows interfacing with existing HF antenna arrays, such as the *Pusher* array. However, the WJ-9012 System also interfaces to Non-circularly Disposed Antenna Array (CDAA) geometries through antenna-location inputs. Check with the WJ factory for the best possible array geometry.

The ASU provides an interface between antenna arrays, calibration signal, and receivers. For systems that employ two independent antenna arrays (e.g., two concentric arrays), the ASU accommodates both arrays and automatically switches between them, depending on the selected frequency. WJ labels the antenna array inputs as lowband and highband for identification when used with systems such as the *Pusher* array. However, each is available for signals in the 1.5 to 30 MHz band. During calibration of the DF System, the ASU injects the calibration signal into all the receivers.

System Architecture

Using standard system architecture allows the configuration of a WJ-9012 System for stand-alone operations. Another configuration allows netted operations with other WJ-9012 Systems for emitter location processing. In a netted configuration, the WJ-9012 may use a variety of communications links to internetwork the Net Control Station (NCS) with the DF outstations. Each outstation consists of a DF antenna array, a WJ-9012, and a communications link. WJ configures the DF net for one NCS and two to five remote DF outstations. In stand-alone or netted systems, the DAU is usually co-located with the antenna array. The System Controller is located either at the antenna array with the DAU, or remotely over a Thicknet Ethernet interface.

Ethernet as well as modem communications send DF requests to outstations and provide LOB reports from the outstations to the NCS. The WJ-9012 protocol software supports standard DF Flash Net operations. An operator uses the communications window on the display to control message generation and release. The system can also interface with existing communications networks such as *Bull's-eye*.

Equipment control screens control monitoring receivers and other devices. An operator selects and controls all parameters by point-and-click method using a mouse. Slider bars permit control of analog features such as frequency tuning , while pull-down menus allow discrete selections such as bandwidth and demodulation.

World-map databases provide Mercator, Polar, and Gnomonic projections with easy-to-use features such as zoom and notes. Maps can depict rivers, roads,

internal boundaries, water bodies, and railroads. An operator can overlay DF site locations, LOB, and emitter positions to provide real-time geolocation and data fusion. High-resolution digitized maps are optional. The standard WJ-9012 uses a Microsoft® Access database system that generates simple contact reports on data such as frequency, time of intercept, bandwidth, and detection mode.

WJ conferred with long-time operational users to design the equipment displays. The basic DF display provides receiver control, Power Spectral Display (PSD), Azimuth and Elevation Histograms, and Equipment Status. Additional displays for multistation operations are available. These include Chatter Display for incoming and outgoing messages, and a Report Generator.

The receiver-control displays access all standard receiver functions such as frequency, bandwidth, detection mode, and gain mode (i.e.: normal, preamp, or attenuation). The system also provides retune functions linked with the PSD to allow fine tuning that eliminates co-channel interference.

The PSD provides a high-resolution pan display that allows an operator to select a given signal within the audio channel for DF processing. Frequently, multiple signals are present in the same channel. By using the cursor to select the signal of interest, an operator may retune the DF set to take a DF reading on the selected signal while rejecting interfering signals.

Histogram displays of multiple readings taken on a given signal provide an operator with a visual means of estimating the LOB and elevation Angle of Arrival (AOA). When multiple emitters operate on the same frequency in a netted configuration, an operator can use the AZ and EL cursors to select each azimuth and to measure the elevation AOA for the signal arriving on that bearing. A Tip Queue provides a list of incoming DF requests with an associated priority. As a tip is serviced, the DF set tunes to the appropriate frequency and initiates DF readings.

When an operator at a different DF station wants to provide information related to a signal of interest, or to simply relay a message, the system displays incoming messages in a chatter box (networked option only) near the bottom of the screen. When the operator replies, the display shows the outgoing chatter message on the bottom of the screen.

Superresolution Algorithm

The term superresolution (SR) defines a technique that resolves two simultaneous co-channel signals whose angular separation is less than the natural beamwidth of an antenna array. SR-DF has a number of other benefits that depend upon the application:

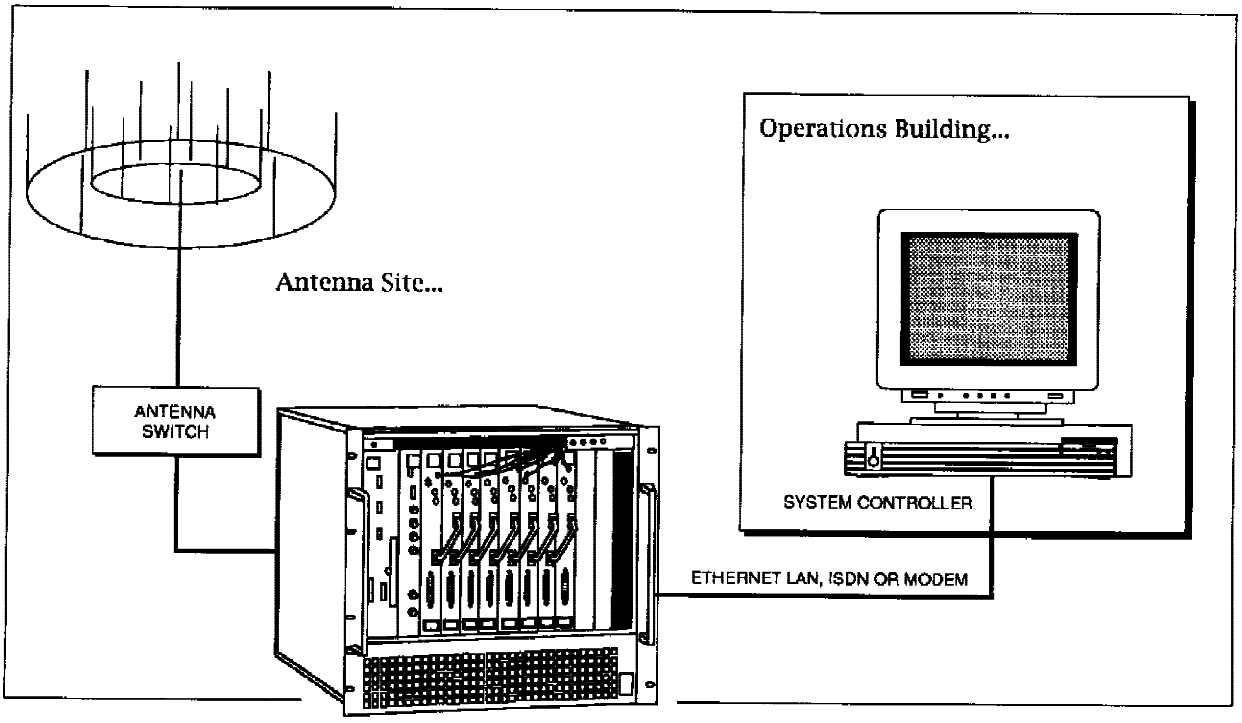
- SR-DF does not rely on any particular antenna geometry: it is only necessary to know the relative positions of the array elements and their patterns. With this flexibility, an operator can apply the technique to existing arrays, or to locations where a conventional array is impractical or may not offer maximum aperture.
- SR-DF has demonstrated superior accuracy in operational environments even with small apertures and low signal-to-noise ratios.
- SR-DF provides multiple co-channel signal operation, plus an indication of the number of signals present.
- SR-DF is very robust and provides operation in poor multipath environments and cluttered sites.
- SR-DF techniques require only a few samples of the signal environment to provide an accurate bearing. Therefore, an operator can use it with short duration signals.
- Recently developed SR-DF capabilities resolve multiple fully coherent co-channel signals.

These SR-DF capabilities offer solutions to many long-standing problems not solved by conventional DF systems. In addition to SR-DF algorithms such as MUSIC, an operator can program the WJ-9012 hardware for interferometry, correlative DF, or maximum-likelihood algorithms. The system can also provide real-time digital beamforming and therefore signal separation.

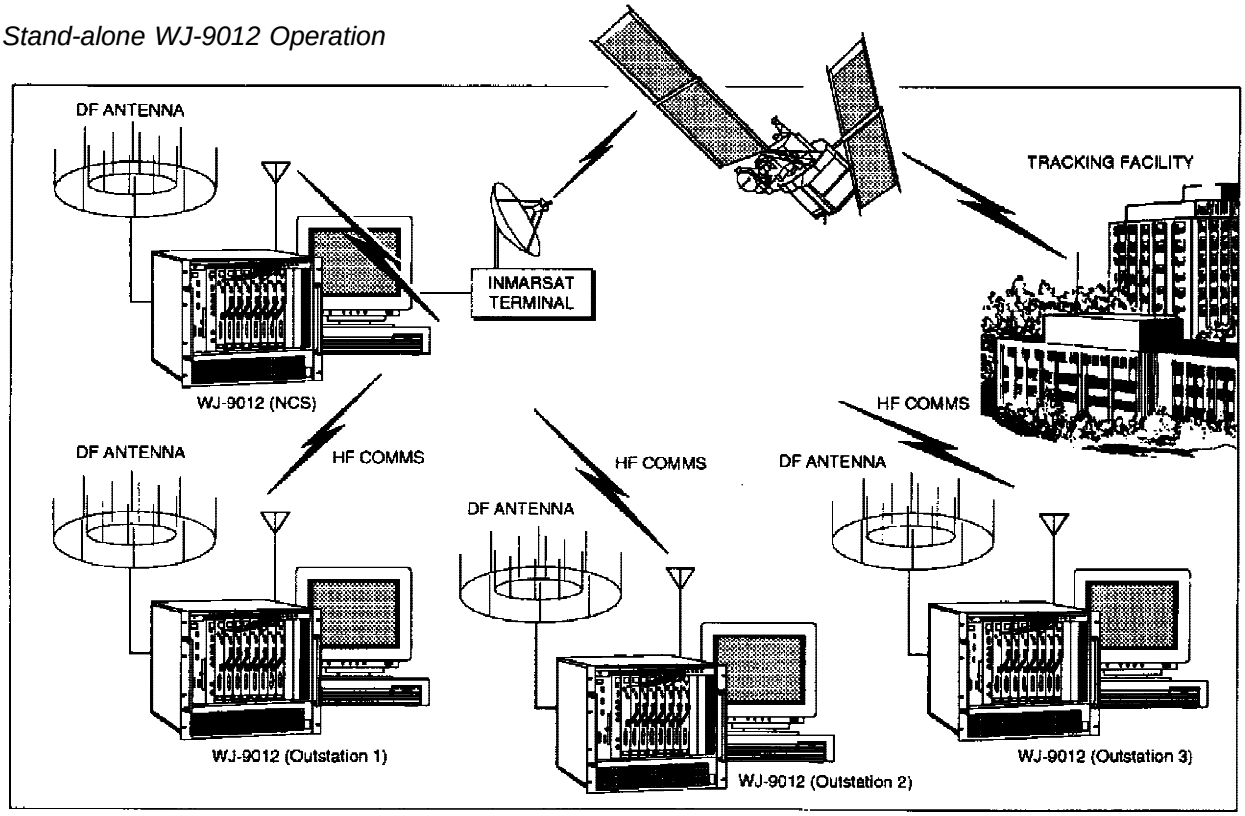
Options

WJ-9012/ANT
16 elevated monopole elements with erection kit

Various options in development
Contact factory for details



Stand-alone WJ-9012 Operation



Netted WJ-9012 Operation

Specifications

System Accuracy	**<2° typical**
System Resolution	**0.1°**
Frequency Range	**1.5 to 30 MHz**
Receiver Noise Figure	**14 dB**
Tuning Resolution	**1 Hz**
Preselection	**11-band suboctave**
Available RF Attenuation	**59 dB**
Available Digital Gain	**-20 to +112 dB**
Preamplifier Gain	**10 dB**
Attenuator (Front End)	**15 dB**
System AGC	**True manual gain Each receiver normalized to reference channel**
Available DF Bandwidths	**66 IFBWs from .056 to 16 kHz**
Detection Modes	**AM, FM, CW, USB, LSB, ISB**
Internal Reference Stability	**>0.7 ppm (0 to 50°C)**
External Reference Frequency	**Accepts 1, 2, 5 or 10 MHz (>+1 ppm)**
Antenna Inputs	
Array 1 (8 Inputs)	**8 Inputs**
Array 2 (8 Inputs)	**8 Inputs**
DF Algorithm	**MUSIC**
LOB per Second	**~20**
Power Spectral Display	
Bandwidth	**16 kHz**
Refresh	**10 per sec, typical**
Maps	**World DB II, Polar, Gnomonic, Mercator, LOB Overlay, Site Positions, Emitter Positions**
DF Display	**AZ & EL Histograms, PS, Maps, Equipment Control**
System Controller	
Platform	**IBM Compatible**
Processor	**Pentium**
Memory	**32-Mbyte DRAM**
Disk Drive	**1-GB Hard Disk Drive**
Monitor	**17-inch color**
Graphics	**1024 x 768**
Floppy	**Internal 1.44-MB Floppy**
Networking	**IEEE 802.3/Ethernet**
Peripheral Ports	**EIA RS232C Serial Port**
Keyboard & Mouse	**IBM PS/2-compatible**
System Software	**Windows™ NT**
Database	**Microsoft® Access**

See separate WJ-8721 VXI HF Receiver Data Sheet

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