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A PC based digital transmitter/digital receiver/digital signal processing system

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1 Introduction

Although basic weather radar transmitter, receiver and antenna design have remained stable for many years now, there has been much positive research to advance signal processing algorithms. The understanding of such algorithms, and the availability of signal processing hardware to execute the algorithms has caused a major change in the way weather radars are used. The other major change that is coming for weather radar is the need to operate such radars in increasingly difficult RF environments. Weather radars will find more and more frequency and power restrictions to contend with. To meet new RF requirements, radars will be expected to both cause less interference and accept more interference from other sources such as mobile handsets and military equipment.

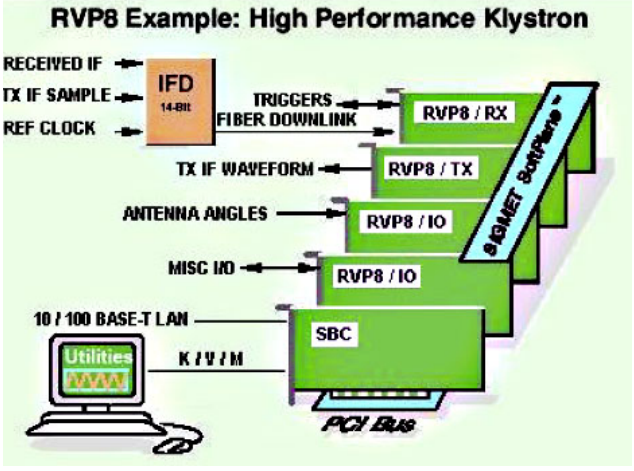

Fig. 1. here

2 Next generation processing

In order to address the needs of real-time execution of the latest signal processing algorithms, and the need to have an RF agile system for interference mitigation, SIGMET has designed and produced the RVP8. The RVP8 represents the latest in a line of signal processors from SIGMET extending back more than 20 years. The core concepts of the RVP8 are built around the most successful features of the previous signal processor from SIGMET, the RVP7, of which approximately 200 units have been provided worldwide.

3 Processor for NexRad

For the USA National Weather Service NexRad network of radars, the modernization of the Radar Product Generator (RPG) has recently been successfully fielded. The focus of the NexRad community is now on modernizing the Radar Data Acquisition (RDA) equipment, which is centered around replacing the signal processor with a modern and flexible COTS unit.

The SIGMET RVP8 signal processor was chosen to be the new NexRad processor by the scientific committee in charge of the RDA modernization project. In July, a prototype signal processor was installed at the NexRad test bed site in Norman, Oklahoma. In August, a design review was held in Oklahoma to discuss final RVP8 design issues prior to production of the "first article" systems to be installed at approximately 10 sites throughout the USA in 2003. Full deployment at the approximately 150 NexRad sites is schedule for 2004 and 2005. SIGMET's RCP8 radar control processor and IRIS/Radar software are also part of the RDA equipment to be installed at each modernized NexRad site.

For NexRad, it is planned to utilize the RVP8 configuration as shown in the below graphic of a high performance klystron system. This includes the RVP/TX card which will output the modulated waveform. In this way, NexRad will be able to use phase modulated pulses to resolve multiple trip echoes.

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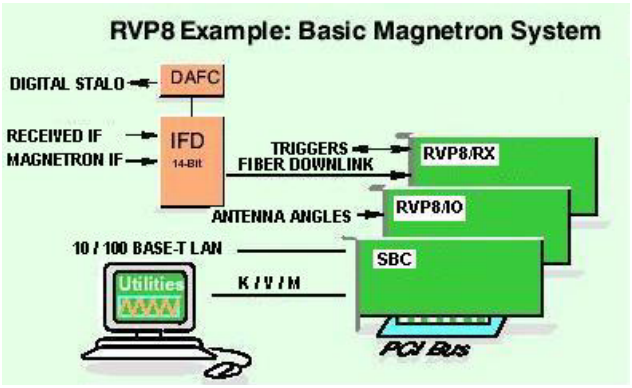

Fig. 2. here

4 Hardware components

Unlike the RVP7, which was built using a proprietary chassis, the RVP8 is based on PCI technology, thus utilizes standard PC enclosures. This allows the RVP8 to take advantage of existing PC features such as scalable and ever growing processing power, network connectivity, local storage, GUI, etc.

SIGMET manufactures three separate PCI based cards and one IF Digitizer module for the RVP8:

RVP8/RX: RVP8 digital receiver interface card. Contains FIR array to buffer (and process) up to 80 μs of 36 MHz IF samples. This is particularly useful for deconvolving long modulated transmit pulses (pulse compression). The output of the RVP8/RX card is digital I and Q data that is written across the PCI bus to target processors on the SBC, or to other destinations wanting the I/Q data.

RVP8/TX: RVP8 digital transmitter interface card. Contains multiple field programmable analog IF outputs. One output is normally externally upconverted to RF using a single side band modulator mixer to be the transmit pulse (such as for a klystron or TWT transmitter). The IF signal from the RVP8/TX card can be programmed with frequency modulation (for pulse compression), phase modulation (for range unfolding), etc.

RVP8/IO: This is a general purpose I/O card. It can be used to provide radar triggers, to input antenna position information to the RVP8, to perform serial I/O with other radar components under control of the signal processor, etc. This is the same I/O card used in the SIGMET RCP8 Radar Control Processor.

RVP8/IFD: This module is located external to the RVP8 enclosure and is connected to the RVP8/RX card via a fiber optic connection. The IFD performs the digitization of the raw received IF and also digitizes the transmit pulse (to obtain frequency, phase and amplitude information). The A/D converters in the IFD operate at 36 MHz, soon to be expanded to 72 MHz.

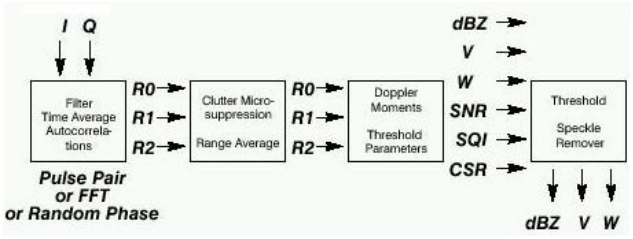

Fig. 3. here

5 Software architecture

The RVP8 differs greatly from its predecessor the RVP7 in software architecture. Like the open PCI bus architecture adopted by the RVP8, the RVP8 also offers an open software API allowing for user written algorithms to be inserted into the processing chain of the RVP8. Such algorithms can be inserted into the processing anyplace from the initial operations on the raw I and Q data, to the final output of weather moments such as Z, V, W, ZDR, etc. This is an important improvement over the RVP7 where no such customization of the processing chain was possible. However, the RVP8 certainly can also be used directly without customization, as the RVP8 offers a full suite of algorithms suitable to most every operational scenario for the weather radar.

The operating system used by the RVP8 is standard PC Linux. The Linux operating system allows for use of COTS PCI based hardware to be used as part of the processor (networking, storage, communications, etc). Also, the Linux provides a comfortable, convenient and supportable software environment.

6 Operational algorithms

The RVP8 will directly implement all of the algorithms offered by its predecessor, the RVP7. This includes the full suite of dual polarization algorithms which are used operationally by many fielded RVP7 systems. Examples of other such algorithms include:

- PPP and FFT processing (TZVW - see below)
- Dual Polarization (ZDR, PhiDP, KDP, LDR)
- 2nd Trip Phase Coding (Random and SZ8/64)
- Dual PRT for pulse staggering
- Dual PRF for velocity unfolding

In addition to the above mentioned RVP7 algorithms, the RVP8 will also offer some additional algorithms. One example of this is pulse compression. The RVP8 accomplishes pulse compression by first producing the IF version of the pulse radiated by the transmitter. The RVP8 does this by utilizing waveform coefficients and then performing a D/A conversion. A compressed pulse incorporates frequency modu-

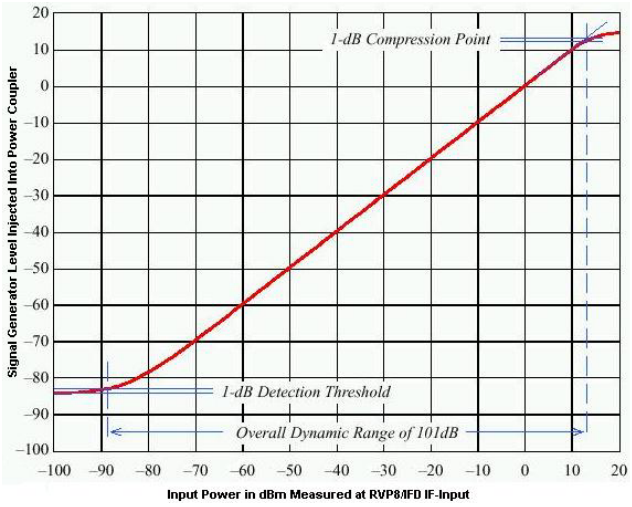

Fig. 4. here

lation. Upon receiving returns, the RVP8/RX card first recognizes the signature of the pulse. This is useful in that external interference is rejected as such interference would have only a low correlation to the signature of the transmitted pulse. The frequency modulation of the pulse also provides for range resolution that is essentially the same as the resolution of a short pulse.

The other advantage to the RVP8 pulse compression algorithm is that a pulse compression transmitter not only rejects interference from other sources from entering the receiver, but it causes this radar to cause less interference to other systems. The reason for this is two fold. First, a pulse compression radar uses a much lower peak power. A peak power of 10 KW is typical as opposed to 250 KW for a traditional weather radar. With a lower peak power, but no more bandwidth requirements, a pulse compression radar will be much more RF friendly to other radar and communications systems. This in turn should make it easier to obtain frequency allocations in tight RF environments.

It should also be noted that the RVP8/TX board works in combination with the RVP8/RX board. The RVP8/RX board samples each pulse of the transmitter. If the transmitter pulse is distorted verses the desired IF pulse produced by the RVP8/TX board, the TX board will have the ability to pre-distort the transmit pulse so the actual RF radiated pulse is more accurate. This results in a cleaner transmit spectrum (RF friendly) and in a more coherent radar.

7 Key specifications

The RVP8 is a signal processor that accepts as signal input the IF of the radar receiver after down conversion from RF. As the input is IF, the traditional dynamic range limiting components of the radar receiver are bypassed, thus the RVP8 has a linear dynamic range of approximately 98 dB for a 1 μs pulse and 101 dB for a 2 μs pulse. The below graph shows the linearity of the RVP8. As 1 dB of more signal power is presented at the receiver front end, this results in a 1 dB increase of signal power measured at the IFD. The maximum linear input signal to the IFD is approximately +6.5 dBm. Because of the over sampling at IF, the RVP8 is able to linearly extrapolate the high end of the input signal to approximately +12 dBm as shown below.

Some other key specifications include:

- IF Ranges 22–32 MHz, 40–50 MHz, 58–68 MHz
- True 14 bit A/D with 36 MHz sampling rate
- Analog AFC output 10 to +10 VDC
- Digital AFC with max 24 bits control
- PRF of 150 Hz to 20 KHz continuous
- Min Range Res 50 M selectable in 8.3 M steps
- Up to 2048 range bins
- Phase Stability $< 0.1^\circ$

8 Summary

The RVP8 weather radar signal processor is based on more than 20 years of signal processor technology from SIGMET. The first fielded system was provided to MIT Lincoln Labs in August 2002. Processors are currently on order for delivery and installation in other systems in the USA, Japan and Europe. The entire national network of NexRad radars in the USA will receive the RVP8 incrementally during the next three years. The RVP8 is well suited for operational users such as Meteorological Agencies. It is much better suited for research institutes than the RVP7 was, as the RVP8 offers a rich API for incorporation of user algorithms anywhere in the processing chain from introduction of I and Q data, to the final outputs of the weather moments.