Ultra-Wide Band, High-Repetition Rate Single Channel Mobile Diagnostic System

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Abstract

The problem of diagnosing transient electromagnetic signals with ultra-wideband, multi-octave spectra extending into the microwave region occurs in a number of areas, including lightning phenomena, electrostatic discharge testing, laser and pulsed-power research, and electronic effects testing. While sometimes these phenomena can be diagnosed by standard single-shot means, they often occur at repetition rates in the kHz range and higher, and determining waveform time and frequency domain shot-to-shot reproducibility is often of major importance to the researcher. This paper describes a novel single-channel diagnostic system, the System Verification Apparatus (SVA), which is capable of measuring 100-ps risetime signals on a single-shot basis, while simultaneously measuring pulse-to-pulse variation. The SVA is a fully integrated system which includes a broadband sensor, signal and trigger conditioning electronics, multiple parallel digitizers with deep local storage, a fiber-optic data link to the controlling computer, and automated software for accurately reconstructing, archiving, and analyzing waveforms.

Introduction

A broad range of research devices generate ultra-wideband (UWB) electromagnetic signals, loosely defined here as those with a frequency spectrum extending into the microwave region and spanning 1 octave or more. While these signals can be single shot, they also often occur at repetition rates of a kHz or higher. The high frequency content of UWB signals usually results from an electromagnetic signature with fractional-ns risetime. Their broad bandwidth results from the lower frequency features which follow the initial fast-rise portion, and can extend to 10s-100s of nanosecond pulse lengths. Characterizing UWB signals encountered in typical research applications poses new challenges for diagnostic systems due to simultaneous requirements for: (1) multi-GHz bandpass recording of the UWB signal's leading edge; (2) high bandwidth, though typically sub-GHz bandwidth, recording of the long record length (> 100s of ns) portion of the signal associated with other than the leading edge; and (3) determining shot-to-shot reproducibility for repetitive signals.

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Digitizer Hardware

While no single instrument can simultaneously meet the requirements for tens to hundreds of nanosecond record length and multi-GHz bandwidth for the leading waveform edge, a combination of commercial digitizer technologies can. An example of how the technique can be applied to a typical UWB waveform is shown schematically in Figure 1. Because the typical UWB waveform has a fast leading edge, often with sub-nanosecond risetime, a multi-GHz analog bandwidth, single-shot capable digitizer is necessary to record it. The only commercially available digitizers with bandwidths exceeding 2 GHz use scan-converter technology combined with a traveling-wave electron beam deflection system (Ref. 1). In the SVA apparatus described here, we utilize the 6-GHz bandpass Tektronix 7250 for recording the leading edge of the waveform. This scan converter digitizer has an intrinsic risetime for a delta function source of 60 psec, and can store 30 waveforms locally at multi-Hz repetition rates. Its main limitation, like all electron beam based digitizers, is a very short record length. For example, to capture a signal with a 200 psec risetime, the maximum record length would be no longer than 10 nsec, and possibly only 5 nsec. Fortunately, for the vast majority of UWB-type electrical signals, essentially all of the frequency content above 1 GHz is due to waveform variation in the first few nsec of the pulse. Thus, a Tek 7250 can be used to effectively capture that portion of the spectrum above 1 GHz.

As shown in Figure 1, the 7250 captures only a small portion of the overall waveform. However, that portion which it does capture is recorded with full fidelity due to its intrinsic 6-GHz single-shot bandwidth. Operating in parallel with the Tek 7250, the entire waveform can also be recorded by a 1-GHz analog bandwidth solid-state digitizer, the Tektronix DSA602. All but the first few ns of the signal will be recorded with excellent fidelity in this way, because the slow time variations of the latter portions of the signal yield sub-GHz (i.e. in-band) frequency content. Thus, by splitting the signal to be diagnosed prior to the 7250, and routing it to a separate solid-state digitizer with extremely long record length (i.e. up to 32,000 points for the DSA602) and partially overlapping time domains (note the cross-hatched region of Fig. 1 which is recorded by both digitizers), it is straightforward to time-tie the resulting stored waveforms after the fact with automated software.

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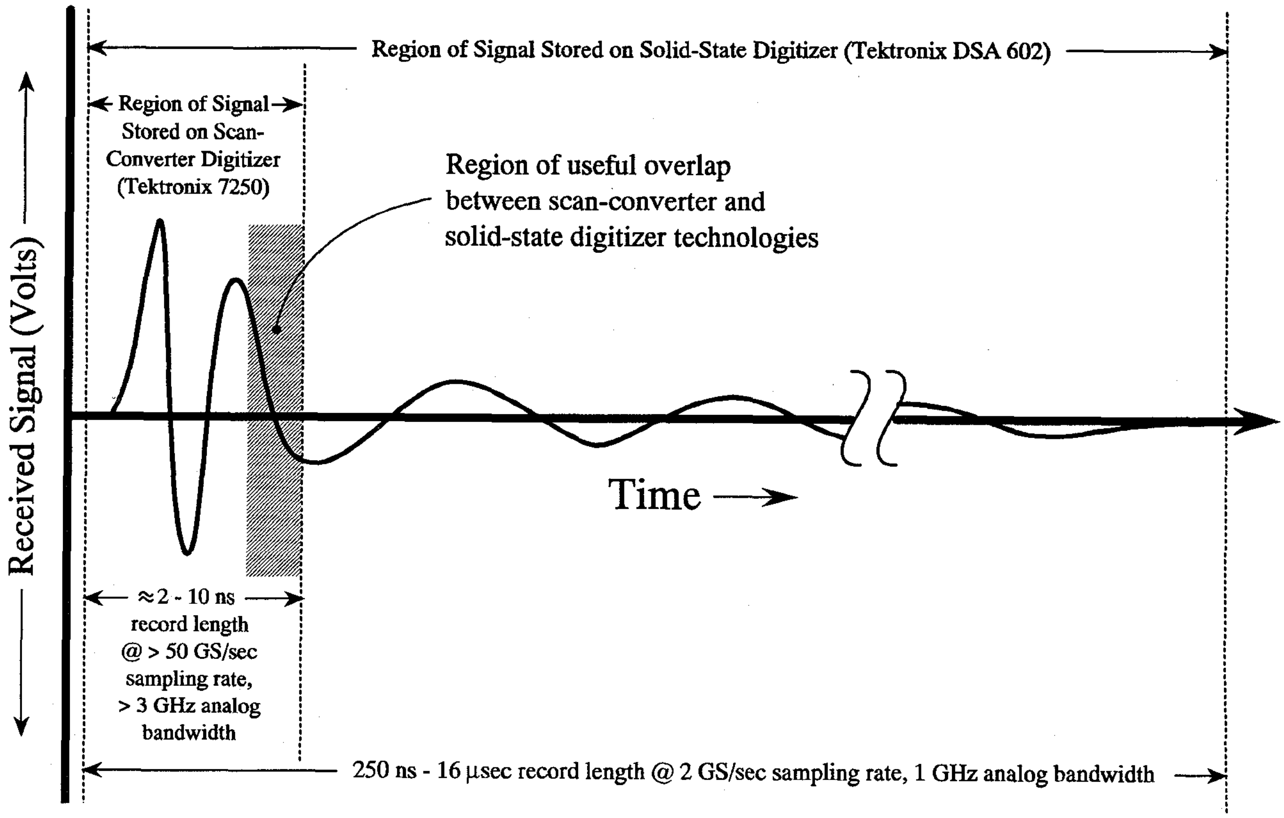

Figure 1. Accurate recording of a typical UWB signal using multiple digitizers.

Because advances in solid-state digitizers allow hundreds of shots to be temporarily stored locally at the digitizer, the SVA can preserve its multi-GHz single-shot bandpass even for bursts of many separate shots. The Tek DSA602 can rearm at rates exceeding 100 Hz, and the Tektronix RTD720 digitizer, which has a somewhat lower analog bandwidth of 500 MHz, can rearm at rates exceeding 100 kHz. Similarly, the 7250 scan-converter digitizer can store 30 shots locally, albeit at a slower, although still multi-Hz, repetition rate. These 3 instruments, all operated in parallel on the same signal, are used in the SVA to provide maximum possible bandwidth under a wide variety of rep-rate conditions, within the limitations imposed by the hardware's local storage/rep-rate capabilities.

Associated Hardware

The SVA is a fully integrated system for measuring radiated UWB electromagnetic signals. A 6-GHz bandpass free-field ACD D-dot sensor (Ref. 2) with an associated 10-GHz bandwidth balun (Ref. 3) provides a time-differentiated replica of the incident electric field. Output from this solitary EM sensor drives a low loss cable which is routed to the recording instrumentation which is housed in a portable 100-dB shielded aluminum enclosure suitable for field use. The 3 digitizers previously described, the trigger and signal conditioning electronics, and a fiber-optically isolated IEEE-488 (GPIB) data link to the controlling computer are mounted in this shock-isolated enclosure.

Data Acquisition, Archival, Analysis, and Control

Data is archived and displayed on an 80486 computer which is located up to 2000 m from the shielded diagnostic enclosure. A fiber-optic-based data link provides electromagnetic isolation of the data recording computer from any spurious currents that would otherwise be generated on conducting lines. Automated software for accurately reconstructing, archiving, and analyzing received waveforms, based on a user-friendly Windows environment, has been implemented. System turn around is very rapid. For example, all data channels from a 10 shot burst can be automatically retrieved, reduced to meaningful electric field vs. time data, archived on hard disk, displayed to a color VGA monitor, and printed to a laserprinter within 2 minutes. The rapid turn around is particularly helpful in field test situations where workers are required to quantitatively monitor electromagnetic field levels on a near-real-time basis.

References

[1] Model 7250 (6-GHz bandwidth) or Model SCD5000 (4.5-GHz bandwidth) from Tektronix Inc., Beaverton, Oregon 97077

[2] Model ACD-11A(R), EG&G Washington Analytical Services, Albuquerque, New Mexico 87119

[3] Model BIB-100G, Prodyn Inc., Albuquerque, New Mexico 87107