## 2. MEASUREMENT SYSTEM

The impulse response measurements presented in this report were taken using the Digital Impulse Response Measurement System (patent pending) developed jointly by the Institute for Telecommunication Sciences and Telesis Technologies Laboratory, Inc. This system is comprised of a separate transmitter and a dual-channel receiver employing spatial diversity. The transmitter was installed in a mini-van and utilized a well-regulated diesel generator mounted on a trailer to provide AC power. Figure 2.1 shows a photograph of the transmitter van. For the measurements in both of the rural cells, the receiver was mounted in a large van and kept at a fixed location. The antennas were mounted on a telescoping mast 8.7 m aboveground. A photograph of the receiver van is shown in Figure 2.2. In the urban high-rise cell, the receiver was located on the rooftop of a building approximately 103 m aboveground in the center of the high-rise district in downtown Denver. The building height was typical for the buildings in this area. The height of the ground above average terrain at the receiver site out 5 km in radius was -4 m, +12 m, and -8 m in the flat rural, hilly rural, and urban high-rise cells, respectively. These heights do not include the antenna mast heights in the rural cells or the building height in the urban high-rise cell.

### 2.1 Transmitter

A block diagram of the transmitter is shown in Figure 2.3. The pseudo-random noise (PN) code generator produces a 511-bit maximal-length code and is clocked at a 10 Mbit/s rate by a rubidium frequency standard. The PN code is then level-shifted to eliminate the DC component and amplitude clamped. A low-pass filter with a cutoff frequency of 10 MHz is used to attenuate spectral components above the first null. This PN code is used to modulate an RF carrier in the 1850-1990 MHz band producing a binary phase-shift keyed (BPSK) signal. This signal is bandpass filtered, amplified to the appropriate level, and transmitted through a vertically polarized, omnidirectional, biconical antenna with a gain of 0 dBi. The power level is set to provide 50 W effective isotropically radiated power (EIRP).

### 2.2 Receiver

Figure 2.4 shows the receiver block diagram. A personal computer is used to control the measurement system receiver via a GPIB bus. The spectrum analyzers and digital oscilloscope are all under GPIB control. A vertically polarized, omnidirectional, biconical antenna with a gain of 0 dBi is used for each channel to receive the transmitted signal. The spatial separation between the antenna for Channel 1 and the antenna for Channel 2 is 15 wavelengths at the center of the 1850-1990 MHz band. The received signal is first bandpass filtered to eliminate undesired signals and then amplified using low-noise amplifiers to minimize the system noise figure. After filtering and amplification, the BPSK signal is downconverted to IF using portable spectrum analyzers and an additional double-balanced mixer stage. The IF signal is then low- pass filtered to eliminate the local oscillator frequency from the additional mixer stage. After this, video amplifiers are used to boost the signal level before it is digitized by the digital oscilloscope. A rubidium frequency standard is used to phase lock the spectrum analyzers and the signal generators. The

Figure 2.1. Photograph of the measurement system transmitter van.

Figure 2.2. Photograph of the measurement system receiver van.

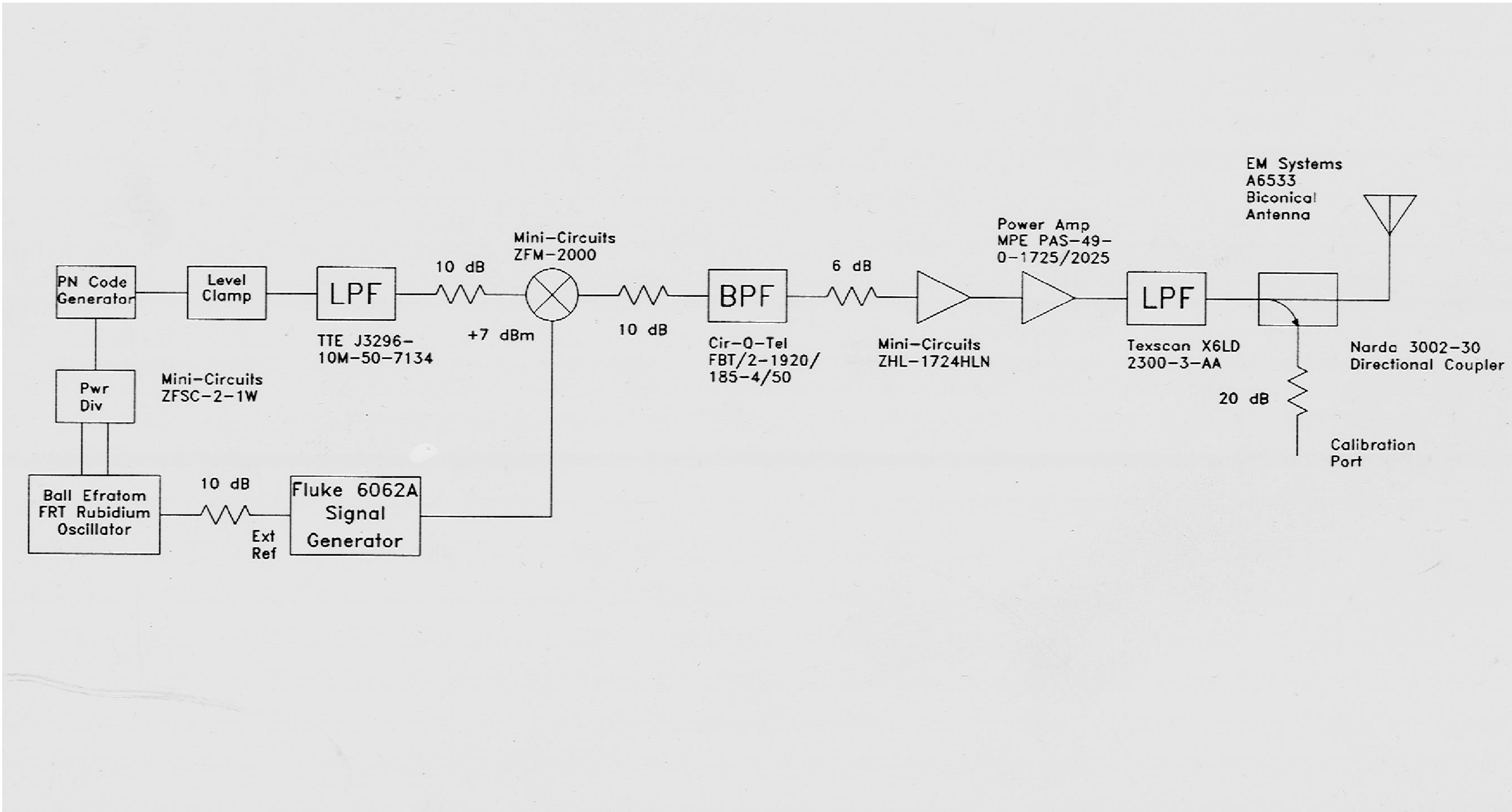


Figure 2.3. Block diagram of the measurement system transmitter.

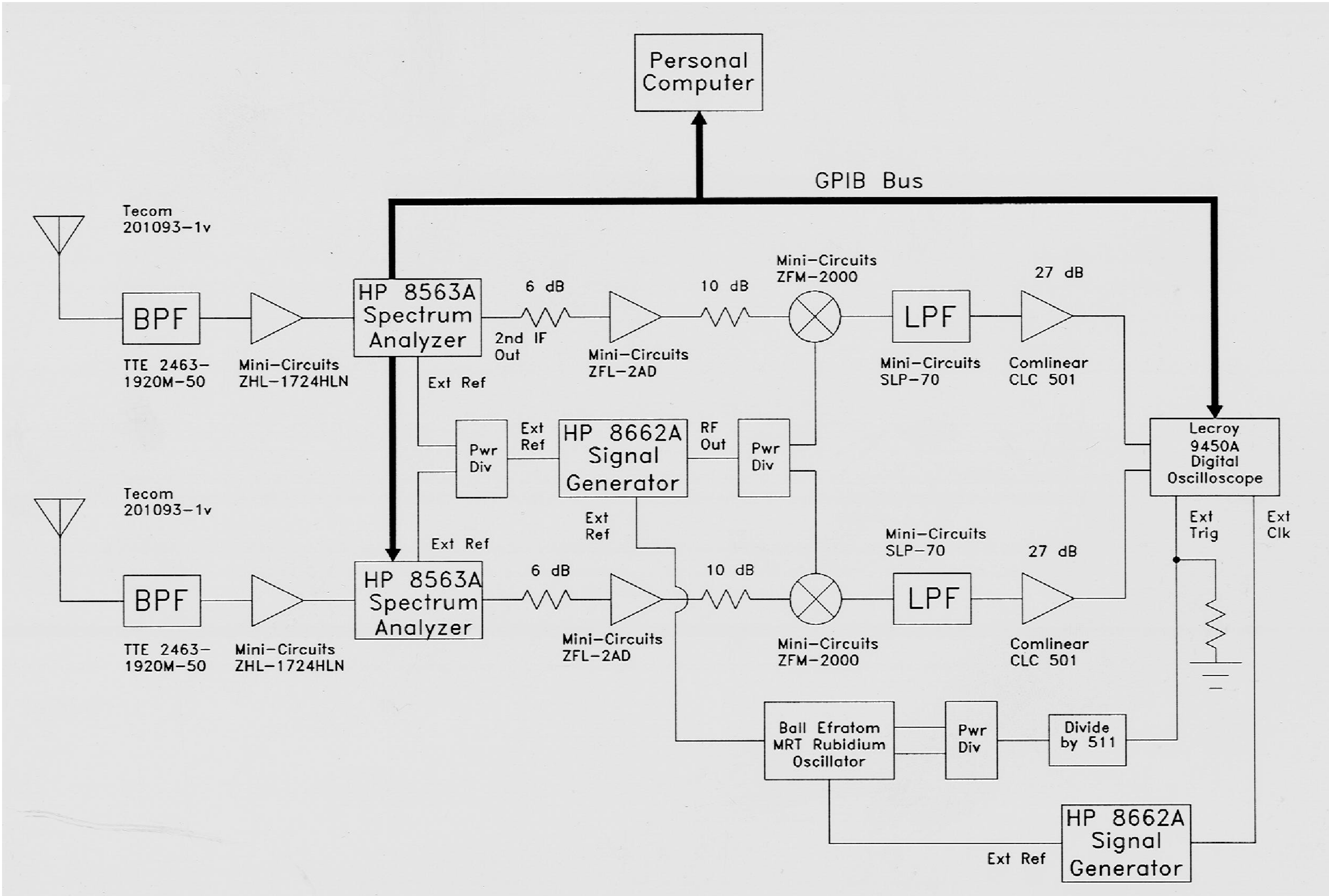


Figure 2.4. Block diagram of the measurement system receiver.

divide-by-511 counter is clocked by the 10-MHz output from the rubidium frequency standard. The output of this counter produces a pulse train used for externally triggering the digital oscilloscope. The pulses (100-ns pulse width) occur at the start of every PN code word transmitted. Synchronization between the PN code word and this pulse train is accomplished by circuitry that resets both the PN code generator in the transmitter and the divide-by-511 counter in the receiver simultaneously. This synchronization provides absolute time measurement capability to the Digital Impulse Response Measurement System. The absolute time capability has a resolution determined by the relative frequency drift between the transmitter and receiver frequency standards.

After the signal is digitized by the oscilloscope, the digitized IF signal is then transferred over the GPIB bus to the computer and stored on the hard disk. The in-phase and quadrature phase components, as well as the impulse responses, are derived in software; this processing can be performed either immediately after the raw data has been taken or at a later date.