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Millimeter Wave Wireless Technology and Testbed Development for Wideband Infrastructure Access[1]

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Abstract

A wideband wireless testbed is described for receiver and channel characterization at the newly defined broad spectral bands at 2.5, 5.2/5.8, 28, 38/41, and 60 GHz. RF transmission measurement results from a 28 GHz channel with a one GHz bandwidth containing 80 QPSK modulated digital channels and four CW tones are presented. Also a spread spectrum sliding correlator channel characterization system is described for measurements at 38 and 60 GHz.

The growth in demand for multimedia communications in the last few years has been phenomenal. Examples are everywhere, for instance, our impatience at delays in accessing a rapidly saturating Internet, or the expectation that we should be able to choose from well over 100 television programs to watch at any given time. This demand for wideband communications coupled with the desire to have the freedom to define our work and living spaces, that is not to be physically tethered to the communications infrastructure, leads to the engineering challenges of how to best provide broadband wireless access to the communications infrastructure.

In order to address these broadband requirements, the FCC has been involved in defining new spectral bands, particularly at 2.5, 5.2/5.8, 28, 38/41, and 60 GHz for high data rate applications such as wireless local area networks (WLAN), wideband wireless local loop (W-WLL), and local multipoint distribution systems (LMDS). Some examples of architectures that could be used for wideband access to existing cable infrastructure are shown in Figure 1. The bandwidths set aside at these frequencies are historically reserved for high quality, low bit error rate fiber optic or cable networks. This quality of service must be maintained in the wireless access channels.

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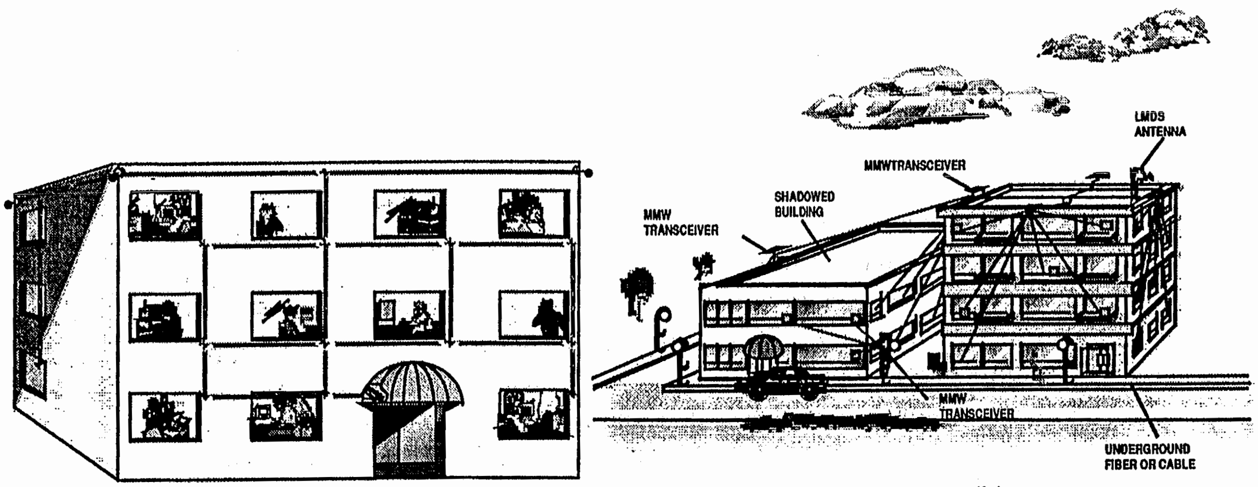
Wideband Wireless Testbed Development

Evaluation of the wideband wireless architectures described by Figure 1 requires experimentation with the system components in various channel environments. Testbed capability is being assembled to include modular multi-band RF transmitters and receivers at the frequencies of interest using commercial off-the-shelf (COTS) components. The entire RF band is block up- or down-converted to a common IF band between 950 and 2050 MHz for access to and from high-speed digital baseband modems[1] as shown in Figure 2. The high-speed (>5 Mbps and up to 30 Mbps) commercially available burst modem subsystem uses a QPSK or M-QAM modulation which can be programmed to conform to the LMDS or W-WLL modulation scheme being tested. The testbed components are readily transportable to perform measurements in any required RF environment to provide measured results to assess the technical and economic viability of a system.

An example of an IF waveform consisting of approximately 80 digital (16-QPSK) DBS video channels between 950 and 1450 MHz and with four carrier tones positioned at 1800, 1825, 1850, and 1900 MHz (combined occupied bandwidth of 950 MHz) which was used to drive a COTS 28 GHz upconverter is shown in Figure 3(a). An 300 μW RF signal was broadcast from a 10 dB gain horn antenna a distance of 32 meters from an outdoor location to a receiver and downconverter located on a second story walkway. The received waveform is shown in Figure 3(b), and expanded waveforms are shown in Fig. 3 (c) and (d), respectively. We have also recorded the effects on the spectrum due to multi-path for the 28 GHz system when transmitted in an office hallway a distance of 26 meters.



(a) (b)

Figure 1. Examples of wideband systems that could use millimeter waves for access to cable/fiber/wireless infrastructures: (a) wideband WLL network implemented outside a building and (b) point-to-multipoint access for a group of buildings.

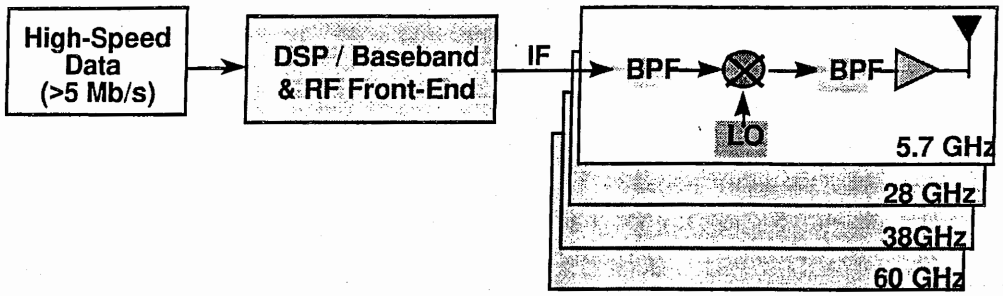


Figure 2. Block level representation of a modular testbed transmitter. The testbed capability includes the evaluation RF and baseband transmitter and receiver components in a variety of RF environments.

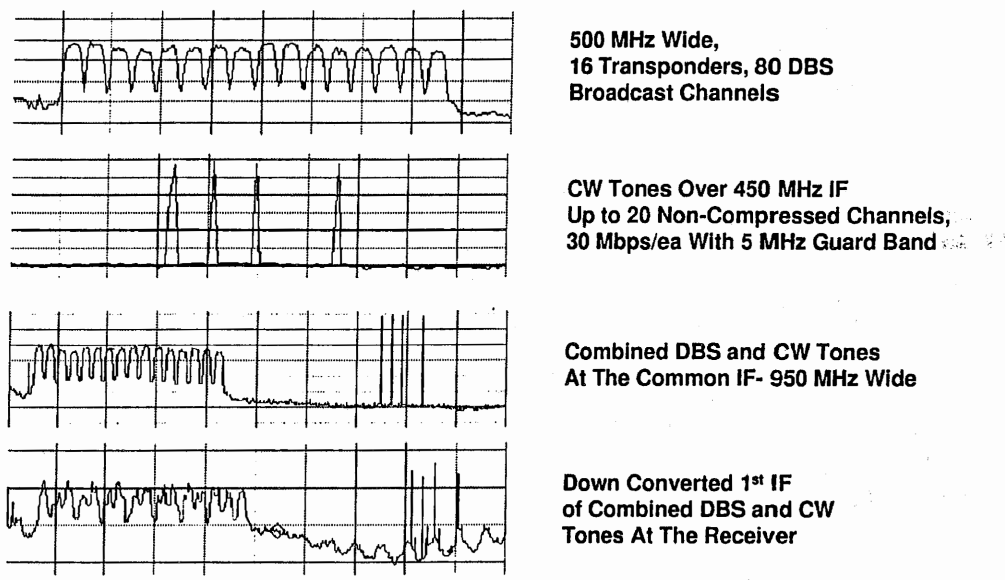


Figure 3. DBS broadcast channels and four tones transmitted 32 meters at 28 GHz through an outdoor channel using a commercially available LMDS transmitter and receiver. The first three figures show the spectrum to be upconverted and transmitted, the last figure shows the received signal after downconversion to the common IF band (950-2050 MHz).

RF Channel Characterization

The ultimate bandwidth of these high data rate millimeter wave systems is constrained by deleterious effects of the RF channel itself. Of primary concern is signal degradation due to multi-path delay spread, attenuation from shadowing and wall penetration, Doppler frequency spread, and co-channel interference. Multi-path delay spread results in signal dispersion which manifests itself as frequency selective fading in wideband channels. Therefore, full understanding of the radio environment in which the testbed wideband transmitters and receivers will operate must include RF channel characterization (also know as RF channel sounding).

To date, wideband channel characterization has been conducted at 5.85 GHz[2,3] and 38 GHz using a pseudonoise (PN) direct sequence spread spectrum sliding correlator channel sounding system developed by Virginia Tech and HRL Laboratories. Also, channel sounding capability has recently been extended to 60 GHz. Since the transmitter and receiver are physically separated it is essential that high quality microwave local oscillators that can be locked to a frequency standard are used in the up and downconversion process. The 38 GHz upconverter is capable of radiating 0.5 W, while the 60 GHz upconverter can radiate 20 mW. A system drawing of the channel sounder is shown in Figure 4. Currently, the system is capable of chip sequences up to 100 Mcps which allows multi-path resolution to about 3 meters, but 500 Mcps PN circuits are being constructed. Results of measurements of a 38 GHz RF channel between two buildings at Virginia Tech are shown in Figure 5. In that figure it can the seen that multi-path components can rise prominently in severe weather.

Acknowledgments

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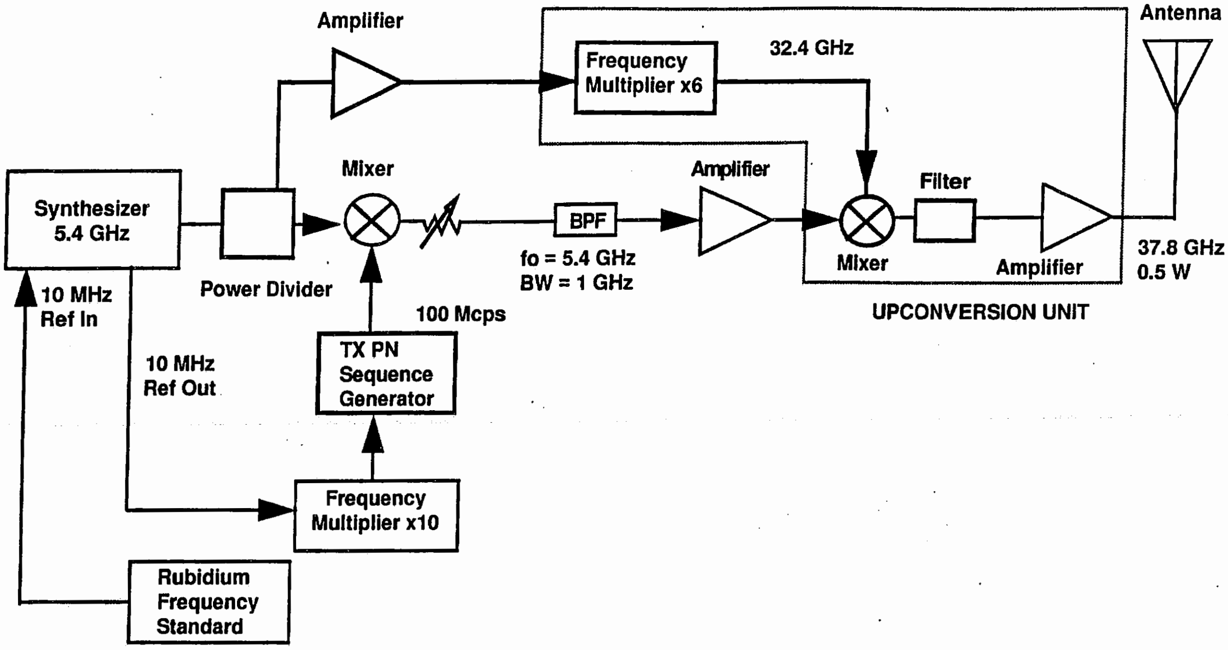

Figure 4. The transmitter of the direct sequence spread spectrum channel sounder configured for 38 GHz.

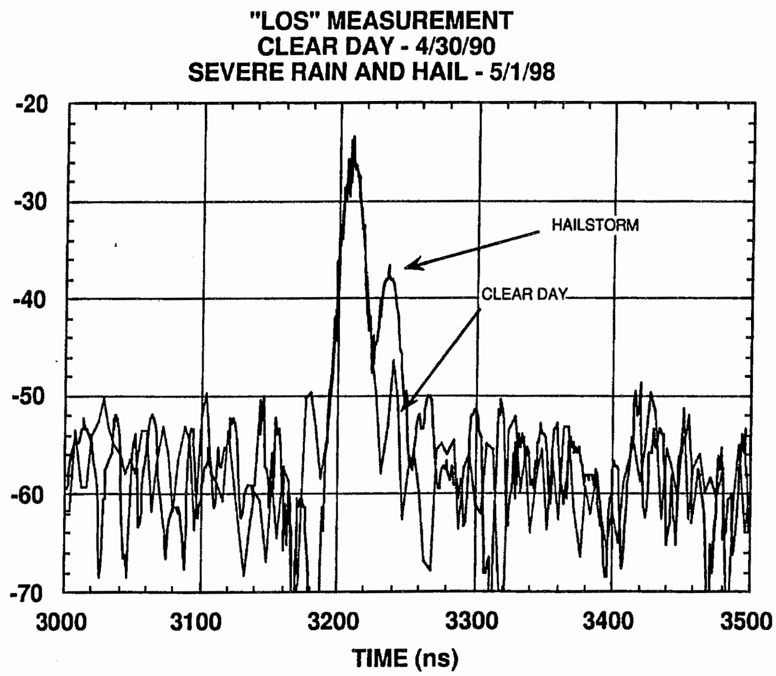

Figure 5. Measured 38 GHz power delay profile showing effect of weather on a multi-path component in a presupposed line-of-site link.