Advanced Antenna Testbed

Outputs

- Wideband radio channel sounding measurements.
- Antenna array diversity gain data.
- Angle of arrival input data for adaptive antenna schemes.
- 16-element MIMO response over a conductive ground plane.

The use of wireless mobile personal communications services (PCS) and wireless local area networks (WLANs) is expanding rapidly. Multiple-access schemes based on frequency division, time division, and orthogonal coding are presently used to increase channel capacity and optimize channel efficiency. Adaptive or "smart" antenna arrays can further increase channel capacity through spatial division. Antenna arrays can produce multiple beams as opposed to a simple omnidirectional antenna. Numerous narrow beams can be used to divide space, allowing the re-use of multiple-access schemes, and thereby increasing channel capacity. Adaptive antennas can also track mobile users, improving both signal range and quality. For these reasons, smart antenna systems have attracted widespread interest in the telecommunications industry for applications to third generation wireless systems.

ITS has developed an advanced antenna testbed (ATB) to serve as a common reference for testing adaptive antenna arrays and signal combining algorithms, as well as complete systems. The ATB builds on wideband channel measurement systems previously developed by ITS. These systems use a maximal length pseudo-noise (PN) code generator to apply binary phase-shift keying (BPSK) modulation to a radio channel carrier frequency at the transmitter. The received signal is correlated at the receiver with the known PN code producing an impulse-like response. The impulse response characterizes the channel over a wide bandwidth (up to 50 MHz) about the carrier frequency. Digitization of the received data allows for post-processing to examine various combining algorithms and digital beam forming schemes. Channel sounding can be done continuously or in selected bursts.

Figure 1. 16-element transmit and receive antenna arrays used for MIMO testing at the NIST open area test site. The closer array is the receiving antenna (photograph by P. Papazian).

A recent ATB application is a 16-element multiple input, multiple output (MIMO) experiment. Two 16-element MIMO arrays were fabricated and tested and then deployed at the NIST open area test site, as shown in Figure 1 on the previous page. The objective of the test was to measure the **H** matrix in a known RF environment. This allowed a comparison between the Bell Labs layered space-time (BLAST) theory and the measurement capability of a wideband system using orthogonal coding (see **Recent Publications** below).

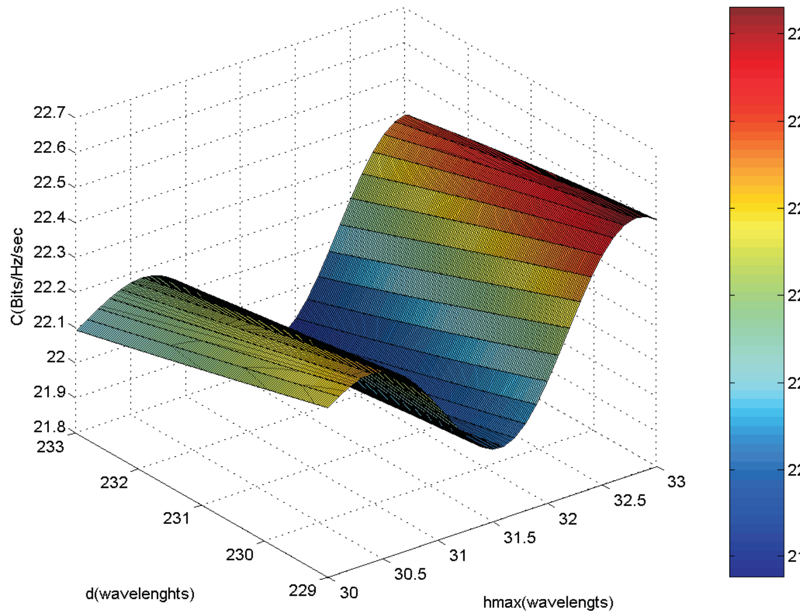

Figure 2. The capacity (C) of a 16x16 element array situated over a ground plane versus the antenna array separation (d), and the height above the ground plane of the top element of the receiving array (hmax).

A transmitter capable of generating 16 orthogonal pseudo-noise codes, one for each transmit element, was designed and fabricated using field programmable gate array (FPGA) technology. The signal received on each antenna element will then consist of the signal from all 16 transmitters after combination by the radio channel. After recording the sixteen receive channels, the 256-element channel matrix **H** can be assembled from the data. The MIMO capacity C for a communications link with n_T transmitters and n_R receivers can then be calculated using the following formula:

$$C = \log_2\left[\det\left(I + \frac{\rho}{n_T} HH^+\right)\right] bits / hz$$

$$where\ I = identity\ matrix$$

$$\rho = signal\ to\ noise\ ratio$$

$$H = complex\ transmission\ matrix$$

$$H^+ = hermetian\ transpose\ of\ H$$

Since it was known that small changes in transmitter separation and array height could change the **H** matrix, a parameter study was done to evaluate the effects of array positioning errors. Some results of this study are shown in Figure 2 above.

The ATB system is portable: both transmit and receive systems may be van-mounted. ATB measured data can be applied to the design of smart antenna PCS systems, evaluating system performance, channel model development and verification, and large communications system simulations. (See the Tools & Facilities section, p. 69, for more information about the ATB.)

Recent Publications

P. Papazian and M. Cotton, “Relative propagation impairments between 430 MHz and 5750 MHz for mobile communication systems in urban environments,” NTIA Report TR-04-407, Dec. 2003.

P.B. Papazian, Y. Lo, J.J. Lemmon, and M.J. Gans, “Measurements of channel transfer functions and capacity calculations for a 16x16 BLAST array over a ground plane,” NTIA Report TR-03-403, Jun. 2003.

For more information, contact:
Peter B. Papazian
(303) 497-5369
e-mail ppapazian@its.bldrdoc.gov