SMILE Antenna Arrays for Wireless Communication

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This presentation will discuss about the recently proposed smart antenna architecture based on Spatially MultIplexing of Local Elements (SMILE) technique. The proposed SMILE system offers a drastic reduction in hardware requirements for the smart antenna system. In this scheme a single element of the array is sequentially connected to signal processing circuitry in order to sample the incoming modulated carrier. The sampling rate is higher than the signal bandwidth so the information of the original signal can be fully restored in the post stages using low pass filters. This system offers an N times reduction in hardware for an N element array. The basic architecture is shown in Fig.1. The objective of SMILE approach is to reduce the required number of RF channels to one, without loss of the signal fidelity. This is achieved by turning on and off individual antenna elements sequentially at a speed above the signal bandwidth, which is equivalent to sampling the modulated carriers using sequences of pulses. The spatially sampled signals from different elements are then multiplexed to form a single feed line output, in a way similar to the Time Division Multiple Addressing (TDMA) scheme in communication. Through the amplification and down conversion, the signal is demultiplexed at either IF frequency or baseband to recover the original signal from each antenna path. Based on the Nyquist sampling law, the signals can be fully restored without loss of information by applying lowpass filters after demux. Hence the restored signals from multiple antenna paths can be sampled and processed in digital domain for beamforming or space-time decoding.

Compared to conventional approaches, the SMILE arrays have advantages in two aspects. First, it significantly reduces the system overall cost and power dissipation by N fold, where N is the number of antenna elements. Second, it provides great conveniences in design of RF front-ends. For example, the feed line network design can be much simplified. Because more space is available, some of the active RF devices such as low noise amplifiers can be integrated with planar antennas to reduce the feed line loss. Mutual coupling of antenna elements can also be minimized as only one element is turned on in any time. Another important feature is that with a fraction of hardware requirement, the SMILE array offers almost the same performance as the conventional array in terms of diversity gain and signal/noise performance. Since the original amplitude and phase information for each antenna element is intact at the outputs as long as the spatial sampling speed is fast enough, the array is eligible for any standard array signal processing.

To validate the proposed concept experimentally, a 4-element SMILE array operating at 5.8 GHz has been fabricated. A distributed spatial sampler made of PIN diodes is integrated with the antenna elements. It should be noticed that full-wavelength long feed line segments have to be used to maintain the impedance match during the switching. The S parameter measurement has shown 0.7 dB insertion loss from the sampler and feed line network. Data transmission at 1Mbits/S data rate has been tested. Simple beamforming and scanning capability has also been demonstrated as in Fig.2, which presents antenna patterns at three different angles synthesized by digital beamforming algorithms.

Further research has been carried out to study how the mutual coupling of the SMILE array is affected by the feed line network. The essential idea is to minimize the parasitic current on antenna elements by changing the load impedance, which is determined by the length of the feed line when the element is turned off. Thus the parasitic radiation field caused by the adjacent

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elements can be reduced so that the active element pattern approaches the single element pattern. Full wave electromagnetic simulators such as FDTD and MoM codes are implemented to obtain an understanding of how the location of the switching device in the feed network may be used to reduce surface currents on adjacent elements. By choosing an optimum location, ultimately the active element pattern can be improved to nearly the single element pattern.

Since it is evident that the reduction of induced surface currents on the adjacent antenna elements may result in reduced mutual antenna coupling. Specifically for a patch antenna array under consideration, the following techniques can be implemented for reduction of surface currents. When an element in the array is connected to the array feed network through a forward biased PIN diode, the element sees a matched load. However, when the element is off, the loading impedance is very high and may be modeled as an open circuit. In order to minimize currents on the surface of the off patch, the location of the open circuit should be placed correctly to minimize current on the surface of the element. Each patch antenna is matched with an inset feed point. Through numerical study, it is found that locating the switch approximately $\lambda/4$ from the inset feed point minimizes surface currents. This is because the $\lambda/4$ transmission line transforms the open circuit to a short circuit load in the patch's antenna phase center. Once the phase center is grounded by this load, only minimal currents flow on the surface. Furthermore, if the system is designed without regard to this phenomena, mutual coupling may be worsened by the array feed network.

In conclusion, a new method of reducing mutual coupling in the recently introduced SMILE type smart antenna receiver has been proposed. The new method utilizes the dynamic switching nature of the SMILE array feed network to reduce mutual coupling. It is shown that proper placement of the switching device in the feed network reduces the magnitude of the surface current on the patch elements not activated by the SMILE system. Through simulations this reduction in current is shown to improve the active element pattern to nearly the ideal single element pattern. Furthermore, it is shown that the radiation patterns formed by the SMILE smart antenna array using this technique match extremely closely with ideal patterns predicted by theory.

References

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[2] J.D. Fredrick, Y. Wang and T. Itoh, "Smart Antennas based on Spatial MultIplexing of Local Elements (SMILE) for Mutual Coupling Reduction," IEEE Trans. Antenna and Propagation, to be printed 2003.

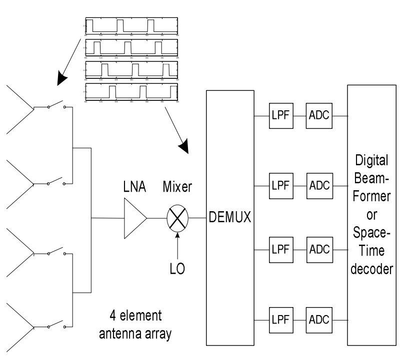

Fig.1 Block diagram of the proposed SMILE receiving array system.

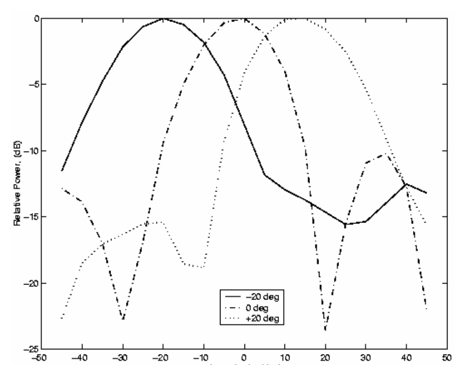

Fig.2 Baseband digital beamforming antenna pattern.