4:15pm - 4:30pm
EOS4.3

A Novel Optically Controlled Phased Array Antenna System Using a Programmable-Dispersion Fiber and a Mode-locked Laser

Dennis T. K. Tong and Ming C. Wu
UCLA, Electrical Engineering Department, Los Angeles, CA 90095-1594

The overall system cost, complexity, and robustness are key to the practical implementation of optically controlled phased array antenna (OCPAA) systems [1-5]. Recently, it has been shown that using the chromatic dispersion in optical fiber to implement the true-time delay can significantly reduce system complexity. In this paper, we propose an extremely compact OCPAA in which a novel "programmable-dispersion" fiber delay line is employed in conjunction with a monolithic mode-locked semiconductor to synthesize all the time delays for the entire array. The basic idea is to use each mode from the mode-locked spectra as a carrier of the RF signal. The dispersion of the optical fiber causes temporal "walk-off" among different optical frequencies. The proposed approach is shown schematically in Fig. 1.

The programmable-dispersion for n-bit resolution fiber consists of n stages of dual fiber delay lines with +D and -D (ps/nm-km) dispersion and lengths of L, $2\times L,\ldots, 2^{n-1}\times L$, respectively. The overall dispersion of the fiber can vary from $-(2^n-1)\times D\times L$ to $+(2^n-1)\times D\times L$ (ps/nm) by programming the n 2×2 optical switches. The monolithic mode-locked laser generates m equally-spaced wavelengths, $\lambda_1, \lambda_2,\ldots,\lambda_m$. Microwave signals modulate all wavelengths simultaneously through an external electro-optic modulator. After passing through the programmable-dispersion fiber, relative time delays from $\Delta T = -(2^n-1)\times D\times L\times\delta\lambda$ to $\Delta T = (2^n-1)\times D\times L\times\delta\lambda$ in increments of $2\cdot D\cdot L\cdot\delta\lambda$ are introduced between adjacent WDM channels, where $\delta\lambda = \lambda_i - \lambda_{i+1}$. The WDM demultiplexer direct λ_i to the i-th element of the array. A linear time shift of $\{0, \Delta T, 2\times\Delta T,\ldots,(n-1)\times\Delta T\}$ are generated across array elements.

To experimentally demonstrate the feasibility of this concept, an 80 GHz monolithic colliding pulse mode-locked (CPM) InGasAs/InGaAsP quantum well laser is used as the WDM laser source. The RF signal is applied to all channels through an external EO modulator with a bandwidth of 5 GHz. With a tunable filter, different channels and hence different delays can be selected. The relative phase shifts among different channels introduced by a 2.3-km and 20-km long standard single mode fiber are measured using an RF network analyzer; the result are shown in Fig. 2 and Fig. 3 respectively. Very linear phase shift with frequency is observed. A maximum phase shift of 518° (408 ps) is achieved for the 20-km fiber at 3.7 GHz. Longer delay can be achieved by using wider channel spacing, and high-dispersion fibers.

In conclusion, we have proposed and demonstrate a novel scheme for OCPAA using a single monolithic CPM laser and a programmable-dispersion fiber delay line. This system is extremely compact and no critical matching of fiber lengths are needed since all RF signals travel through the same fiber. Moreover, the proposed system is robust and highly scaleable in either number of antenna elements or resolution.

The authors would like to thank Dr. Norman Kwong of Ortel and Dr. Jay Simpson of AT&T Bell Labs. for their loan of the fiber, and Masa Ichimura of Sumitomo company for their loan of the modulators. This project is supported by ARPA NCIPT and Parkard Foundation.

References:
1. W. Ng, *et al., J. Lightwave Technol.*, vol. 9, p. 1124, 1991.
2. R. Soref, *Appl. Optics*, vol. 31, p.7395, 1992.
3. R. D. Esman, *et al., IEEE Photonics Technol. Lett.*, vol. 5, p.1347, 1993.
4. P. M. Freitag and S. R. Forrest, *IEEE Microwave and Guided Wave Lett.*, vol. 3, p. 293, 1993.
5. D. T. K. Tong and M. C. Wu, to be presented in *IEEE/LEOS 1995 Summer Topical Meetings*

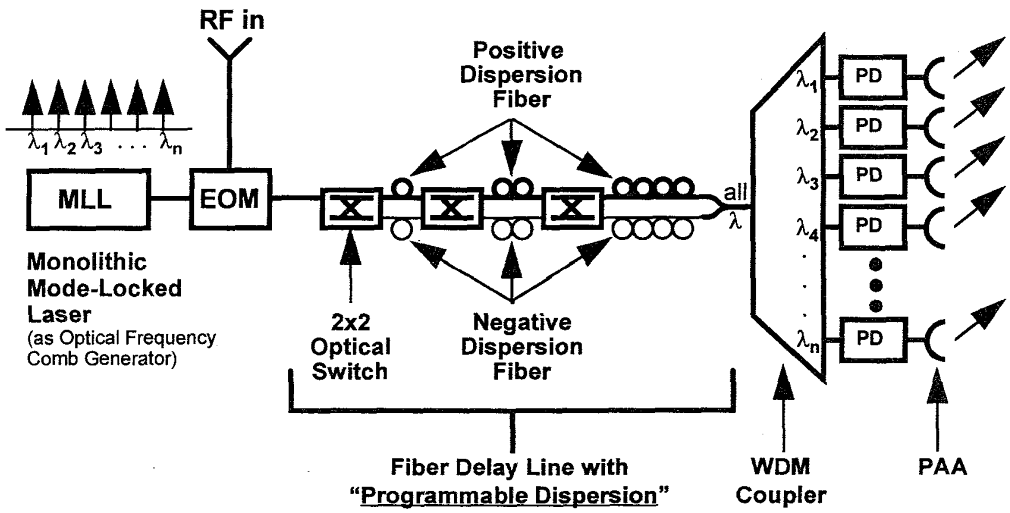

Fig. 1. Schematic diagram of the proposed OCPAA system using a monolithic mode-locked laser and a programmable dispersion fiber delay line.

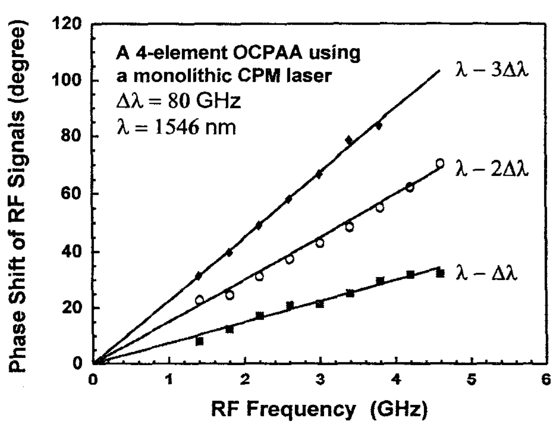

Fig. 2. RF phase shift versus frequency for 4 optical wavelengths using a 2.3-km fiber

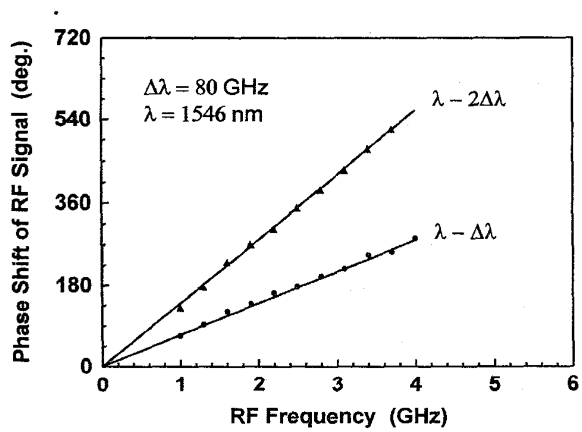

Fig. 3. RF phase shift versus frequency for 3 optical wavelength using a 20-km fiber.