PHOTONIC REMOTING OF THE RECEIVER OF AN ULTRA-HIGH DYNAMIC RANGE RADAR

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ABSTRACT

Fiber optic links have been designed and built to remote the antenna of a radar with ultra-high dynamic range, the AN/SPQ-9B ADM. The links tested successfully in receive configuration without significantly degrading the radar's 83-dB SNR. These results demonstrate that photonic technology can meet the phase noise requirements for remoting modern radars.

INTRODUCTION

Two fundamental advantages of optical fiber over RF cable are low signal loss per unit length and true time-delay array beamforming[1]. These properties make fiber optics ideal for controlling and remoting microwave systems such as the transmitter/receiver (T/R) module of a dish or phased array radar. From the microwave systems perspective, however, these are non-trivial tasks because modern radars have stringent phase noise requirements, and any additional phase or amplitude noise introduced by the fiber-optic link (FOL) may degrade the radar's sensitivity.

Recently, we reported initial demonstrations of photonic links meeting the phase noise and signal-to-noise ratio (SNR) specifications of modern radars[2]. In that work, we designed and built FOLs to remote the transmitter and antenna of the AN/SPQ-9B ADM radar in transmit configuration. The 90-dB SNR of this radar provided a stringent test for a photonic link in this type of application. In this paper, we demonstrate the receive configuration.

SYSTEM DESCRIPTION

Figure 1 shows a simplified schematic diagram of the AN/SPQ-9B ADM radar. The system consists of a rotating antenna, an exciter, a transmitter, a receiver, and a low-noise amplifier (LNA). The antenna is a parabolic torus dish rotating at 30 rpm with a gain of 44 dBI and a one-way 3-dB beamwidth of 1.25° in azimuth. Figure 1 also shows the placement of the remoting FOL. The fiber optic link was required to allow positioning of the antenna up to 40 meters away from the receiver. Table 1 summarizes the FOL specifications. The noise figure (NF) and 1-dB compression specifications for the FOL were chosen to preserve the signal-to-noise ratio and dynamic range of the AN/SPQ-9B ADM receiver, respectively.

Figure 2 shows the FOLs designed and built to remote the AN/SPQ-9B ADM. The remoting units consisted of a basic FOL (enclosed within the boxes in fig. 2) followed and preceded by microwave amplifiers and attenuators. The basic

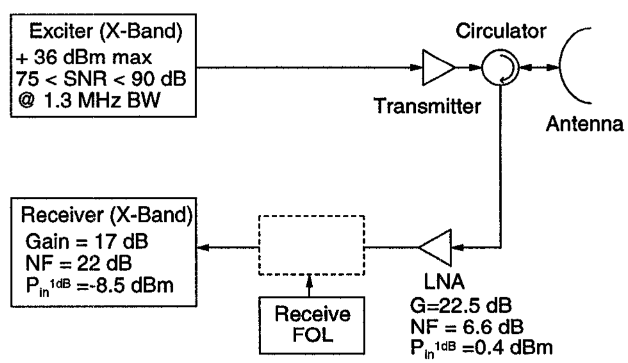

Fig. 1 AN/SPQ-9B diagram with receive FOL.

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Characteristics	Spec.	Measured	
(X-Band)		XMOD	DMOD
Gain, dB	0	0.06	-0.09
Noise Figure, dB	< 22	16	18
Compression, dBm	> -8.5	-10	-4

Table 1. FOL characteristics.

FOLs performed both the remoting and the RF-optical-RF conversion functions. The microwave amplifiers compensated for the 30-40 dB RF losses of the basic FOLs, and the microwave attenuators were used to achieve an overall system gain of 0 dB and prevent saturation of both the FOLs and the microwave amplifiers. A comparison was made between two basic FOLs. One link was based on external modulation (XMOD) of a diode-pumped solid-state laser (fig. 2a), while the other one was based on direct modulation (DMOD) of a DFB laser diode (fig. 2b).

In the XMOD FOL (fig. 2a), the RF signal was fed to a $LiNbO_3$ Mach Zehnder optical modulator (MZM). The MZM intensity-modulated the input from a 1319 nm solid-state laser. This laser had a linewidth of 5 kHz and a relative intensity noise (RIN) of -165 dB/Hz. The modulated optical signal was then routed through 40 meters of SMF-28 fiber to simulate the desired remoting distance. The RF signal was recovered using a 10 mW, 15 GHz photodetector (PD). In the DMOD FOL (fig. 2b), the RF signal directly modulated a 10 mW, low-noise, 25 GHz, 1550-nm DFB laser diode having a RIN of -155 dB/Hz. An optical isolator

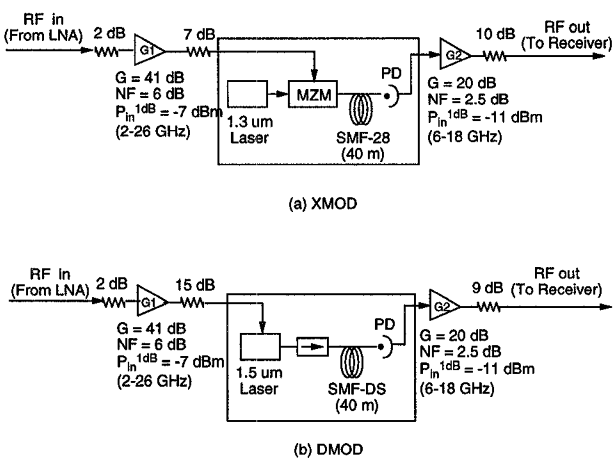


Fig. 2. Receive FOLs

was spliced to the output of the DFB laser. The RF-modulated optical signal was then routed through 40 meters of dispersion-shifted (DS) fiber and detected with another 10 mW, 15 GHz photodetector. Table 1 summarizes the measured gain, noise figure, and compression points for the FOLs. The lower compression point in the XMOD FOL was caused by saturation of the MZM, which was designed for 1550nm rather than 1300nm operation. This compression point could be improved by increasing the front-end attenuation in the FOL at the expense of a higher noise figure. The particular configuration chosen provided a compromise between low noise figure and high compression point.

Figure 3 shows the measured frequency response for the FOLs. The observed roll-off below 6 GHz was due to the 20-dB amplifier. The roll-off from 9 to 18 GHz in the XMOD FOL was due to the microwave amplifiers and the MZM. We note that the fiber optic links were not optimized for wideband operation because the AN/SPQ-9B ADM operates over a narrow frequency range. However, many of the associated RF components used in the FOLs were already capable of bandwidths in excess of 10 GHz, and a better selection of optical components would permit wideband operation.

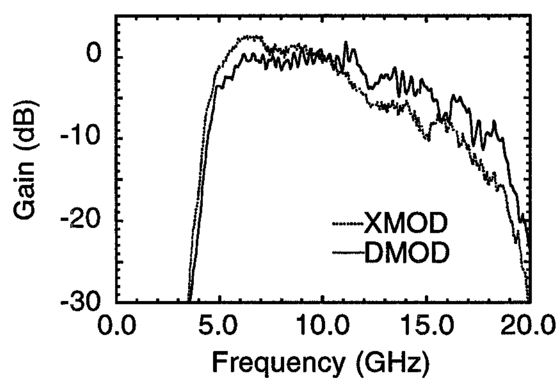


Fig. 3. Measured frequency response for the FOLs.

REMOTING TEST RESULTS

The remoting test consisted of scanning the AN/SPQ-9B ADM antenna beam past a stationary target and measuring the ambiguous range/Doppler data with and without the FOLs. The target chosen was a corner reflector situated approximately 16 km from the radar. Three range/Doppler data sets were recorded. One measurement was made without the FOLs and provided the baseline. The other two measurements were made with the XMOD and DMOD FOLs separately.

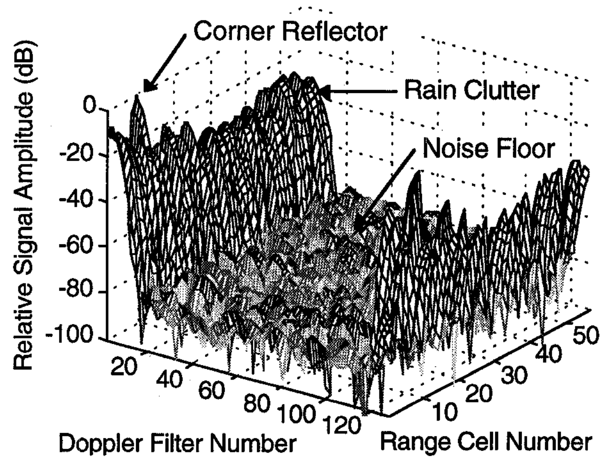
Figure 4a shows the measured range Doppler plot for the baseline. The main peak corresponds to the corner reflector. The mean thermal noise floor was -82.6 dB, 7 dB higher than the lowest achievable noise floor (-90 dB) for this radar. This reduction in SNR was caused by the limited signal power received from the corner reflector due to the heavy rain experienced during the test; this is evidenced by the strong echoes over all range cells at low Doppler values in fig. 4a. Figures 4b and 4c show the measured ambiguous data with the remoting FOLs inserted. Both measurements were normalized with respect to the baseline peak for comparison. Table 2 summarizes the measured peak and SNR values for the range/Doppler plots. The SNRs measured with the FOLs were slightly lower than that measured for the baseline. For the DMOD FOL, the degradation was 0.3 dB, whereas for the XMOD FOL, the degradation was 1.1 dB. Again, the higher SNR degradation measured with the XMOD FOL was caused by saturation of the MZM. This problem could be solved by increasing the RF attenuation at the front-end of the FOL and/or by using an MZM optimized for 1300 nm operation.

	Baseline	XMOD	DMOD
Signal Peak (dB)	0	0.3	1.3
SNR (dB)	82.6	81.5	82.3

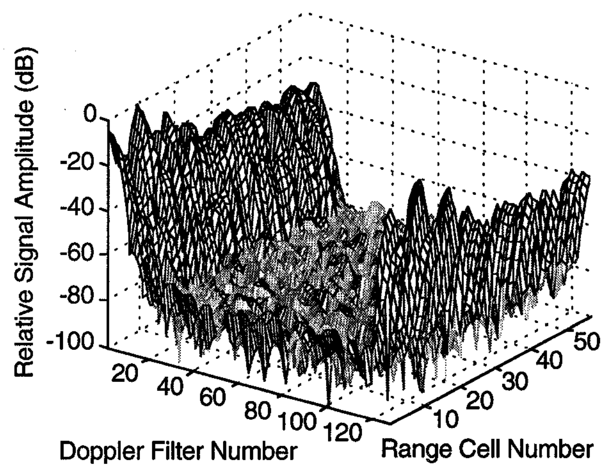
Table 2. Signal peak and SNR for range/Doppler plots.

CONCLUSION

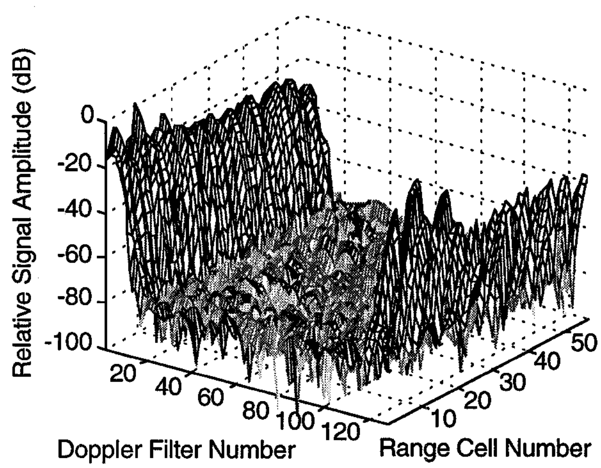
We have successfully designed, built, and tested fiber optic links for remoting an ultra-high dynamic range radar. These results are further proof that photonic links and subsystems (e.g. beamforming) can meet the stringent phase noise requirements for remoting modern radars.



(a) Baseline (No FOLs)



(b) XMOD FOL



(c) DMOD FOL

Fig. 4. Measured range/Doppler data for receive test.

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ACKNOWLEDGMENT

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1. H. Zmuda and E. N. Toughlian, Photonic Aspects of Modern Radar, Artech House, Boston, 1994.

2. J. E. Román, L. T. Nichols, K. J. Williams, R. D. Esman, G. C. Tavik, M. Livingston, and M. G. Parent, 'Photonic Remoting of AN SPQ-9B ADM Ultra-High Dynamic Range Radar,' 1998 IEEE Radar Conference, Dallas, TX.