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Photonic-applied Electromagnetic Measurement Technologies for Antenna Measurement

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Abstract We have developed some antenna measurement systems using photonic-applied electromagnetic measurement technologies. Our measurement system can replace the metal coaxial cables and suppress the reflection waves from the coaxial cable. In this paper, we show some antenna measurement systems and measurement results.

Keywords antenna measurement, optical device, optical fiber link technology, Electromagnetic interference measurement

1. Introduction

The conventional antenna measurement system usually uses metal coaxial cables. The system has some problems, such as the attenuation of signals in the cables, reflection waves on the outside surface and the difficulty of its handling. In order to replace the coaxial cable, we have proposed some optical fiber link antenna measurement systems.

In this paper, we explain some antenna measurement system using photonic-applied electromagnetic measurement technologies. At first, we explain a transmitting system using an optical signal to electrical signal conversion device [1]. And a receiving system using an electrical signal to optical signal conversion device[2]. Then we explain a near field antenna measurement system using a very small optical reflection type LN-MZ electromagnetic field sensor[3][4][5]. Then, we explain the millimeter wave antenna pattern measurement system using a nested LiNbO3 Mach-Zehnder (LN-MZ) modulator and a uni-traveling carrier photo diode (UTC-PD)[6][7]. Finally, we explain a simple optical fiber link antenna measurement system using a radio over fiber modules[8].

2. Optical to electrical conversion device and electrical to optical conversion device

2.1 Optical to electrical conversion device

We have developed an optical fiber link transmitting module using photodiode as an optical signal to electrical signal conversion device. Our transmitting system consists of a photo biased type photo diode module, a microwave amplifier, a photovoltaic photodiode to make DC bias for microwave amplifier. Our proposed transmitting system can be transmitted microwave signal using three optical fibers without metal DC bias cables and coaxial cables. Figure 1 shows outline of our optical fiber link transmitting system. Figure 2 shows that $S_{21}(\omega)$ measurement results of photo biased photodiode alone [PD], microwave amplifier alone [Amplifier] and photo biased photodiode with microwave amplifier [PD+Amplifier]. In the case of output power of 10 dBm of VNA, measurement result shows the fact that our transmitting system [PD+Amplifier] can be generate more than 0 dBm in the frequency range from 10MHz to 6 GHz, and more than -10 dBm up to 10 GHz .

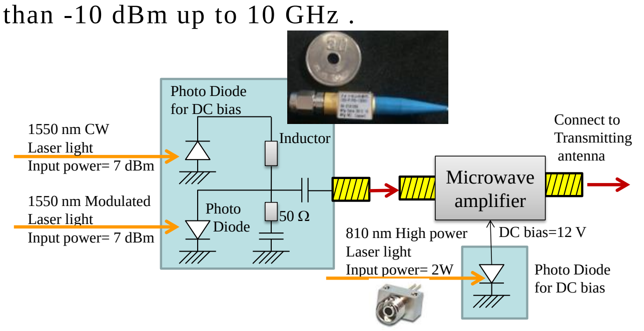

Fig. 1 Outline of our optical fiber link transmitting system

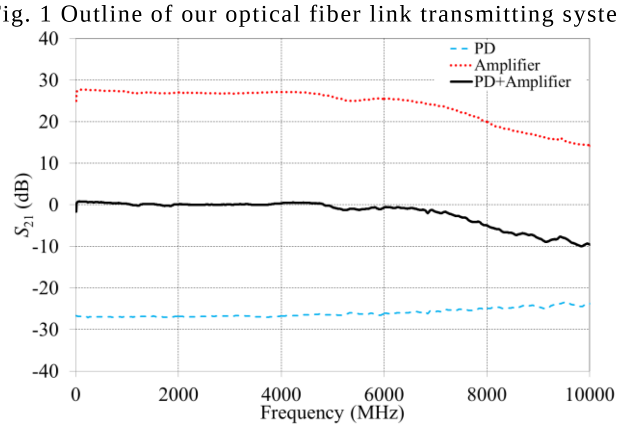

Fig. 2 $S_{21}(\omega)$ measurement results of photo biased photodiode alone, microwave amplifier alone and photo biased photodiode with microwave amplifier.

2.1 Electrical to Optical conversion device

Conventional EAM is usually driven by a DFB laser. To stabilize the time stability of frequency response of the EAM, the conventional EAM usually uses a thermo-electric cooler (TEC) and DC bias. In the case of EAM without TEC control, the frequency response and DC bias point of EAM fluctuate by the ambient temperature variation. In order to decrease the variation of the frequency response of EAM, we have proposed an EAM driving system using super luminescent diode(SLD). Figure 3 shows the outline of our proposed EAM driving system. Our proposed system consists of a SLD, an optical circulator, an optical variable attenuator and a photo diode. Figure 4 shows $S_{21}(\omega)$ measurement results of EAM with step attenuator. Our proposed EAM system can be received the signal more than -86 dBm up to 6 GHz. Figure 5 shows the standard deviation of measured $S_{21}(\omega)$ magnitude and phase of our proposed EAM system without temperature control and DC bias. In the case of the input microwave level = -86 dBm, the standard deviation of measured $S_{21}(\omega)$ magnitude of the EAM system is less than 0.2 dB up to 6 GHz. And, In the case of the input microwave level = -86 dBm, the standard deviation of measured $S_{21}(\omega)$ phase of the EAM system is less than 3 degree up to 6 GHz.

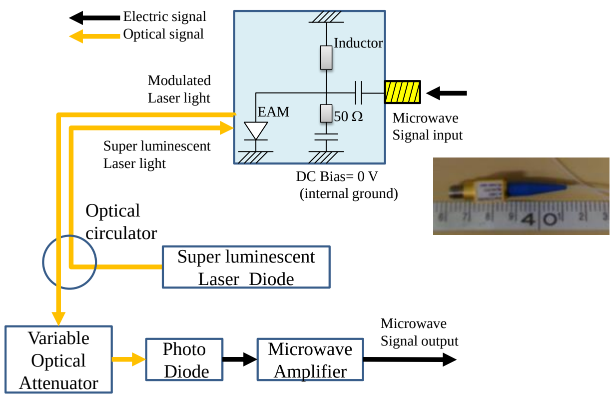

Fig. 3 Outline of our proposed receiving system

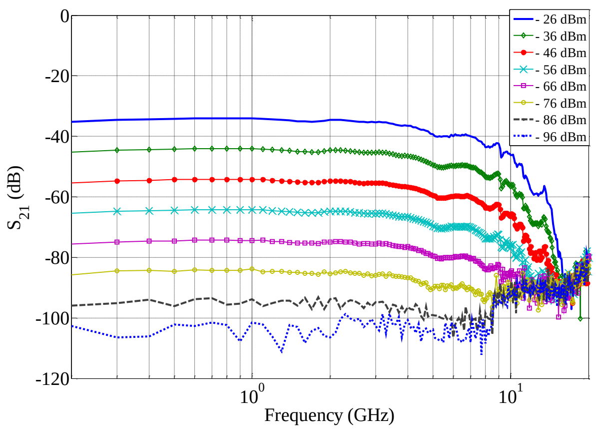

Fig. 4 Frequency characteristics of our receiving system

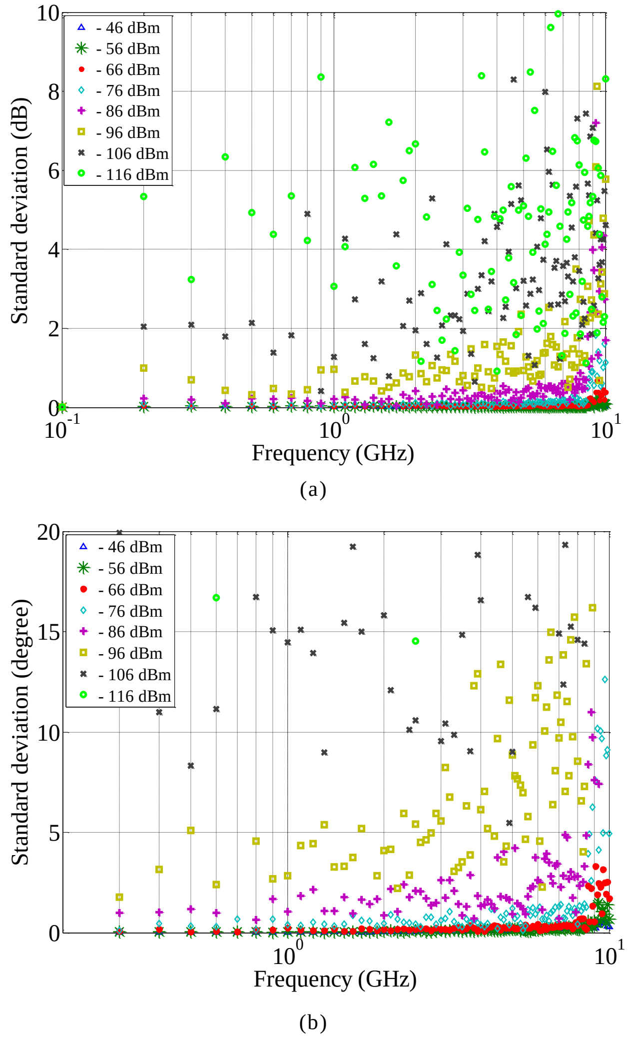

Fig. 5 Standard deviation of (a) $S_{21}(\omega)$ amplitude and (b) $S_{21}(\omega)$ phase

3. Antenna pattern measurement using a MZ-LN photonic sensor for near field measurement

We have developed a near field antenna pattern measurement system using an optical reflection type Mach-Zender LiNbO3 photonic sensor as a receiving probe. Conventionally, an open-ended waveguide (OEWG) probe is used for the near field antenna measurement more than 1 GHz. OEWG is made of metal and aperture size is as large as a half wavelength. Our photonic probe is very small compare to the wavelength. Figure 6 shows the photo of our photonic sensor and OEWG. Figure 7 shows one of the near field measurement setup using the photonic probe and the measurement facility of NSI Inc.. Our photonic probe and the near-field method can be used to measure the antenna radiation patterns even if the probe is very close to the antenna apertures.

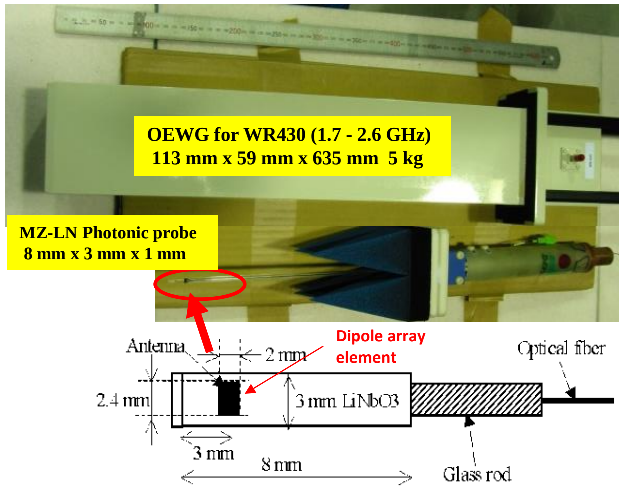

Fig.6 Geometrical structure of photonic sensor and photo of OEWG.

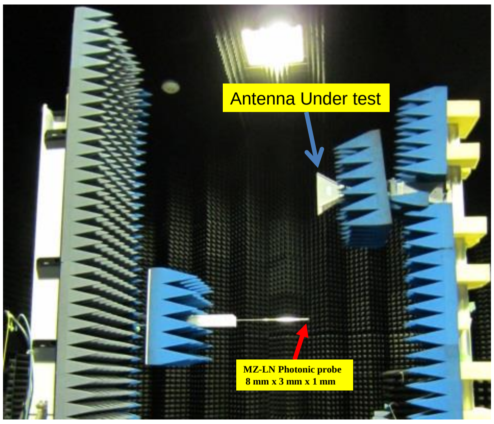

Fig. 7 Planer and cylindrical near field antenna measurement setup using photonic probe.

4. Millimeter-wave antenna pattern measurement system using nested LN-MZ modulator and UTC-PD

We have proposed an antenna pattern measurement system using a nested LiNbO3 Mach-Zehnder (LN-MZ) modulator and a uni-traveling-carrier photodiode (UTC-PD). Due to this technique, we can use an optical fiber as the transmission line and miniaturize the connection between antenna and the mm-wave source. Accordingly, we can suppress the disturbance from the waveguide components, and achieve precise pattern measurements in mm-wave region. Figure 8 shows a photo of our proposed system and outline of our system. The RF signal with the frequency up to 50 GHz modulates the optical signal at the LNMZ modulator. By controlling the DC bias voltage of the modulator, 1st order harmonics is depressed and the 0 and 2nd order harmonics is enhanced. After the 0-order spectrum is attenuated by FBG, two-tone spectra whose frequency difference is quadruple of RF frequency can be generated. The modulated two-tone optical signal is amplified by optical amplifier and travels to the UTC-PD through an optical fiber. When the modulated optical signal is arrived to the UTC-PD, the mm-wave signal of the quadruple of the RF frequency is generated by optical heterodyne of two-tone optical spectra and transmitted from the antenna. Figure 9 and 10 show the dynamic range of the system and measured E-plane antenna radiation pattern of W-band standard gain horn antenna at 120 GHz. These results show that our millimeter wave photonic-applied electromagnetic measurement system can be measure the antenna radiation pattern without some conventional mixer modules.

5. Antenna measurement using radio over fiber (RoF) module

Our proposed optical fiber link module consists of a photodiode, a direct modulation type laser diode and optical fiber coupler. This module can measure the transmitting and receiving microwave signal.

We carry out the $S_{21}(\omega)$ measurement between two log-periodic antennas of UHALP9108A1 (LPDA) as AUTs by the proposed system without coaxial cables after a response calibration to normalize frequency response. These LPDAs is usually uses a radiated electromagnetic interference measurement. These two LPDAs set 2m high from the absorbing material on the floor with 4 m antenna distance. The $S_{21}(\omega)$ measurement setup and a photo of the setups are shown in Fig. 11. Figure 12 and 13 show measured $S_{21}(\omega)$s and calculated $S_{21}(t)$ envelopes, respectively. [Horizontal Pol.] and [Vertical Pol.] show the measurement results of the horizontal and vertical polarization setting of two LPDAs. The calculated $S_{21}(t)$ envelopes using our proposed system has some difference after 30 ns because the reflection wave arrived from the absorbing materials on the floor.

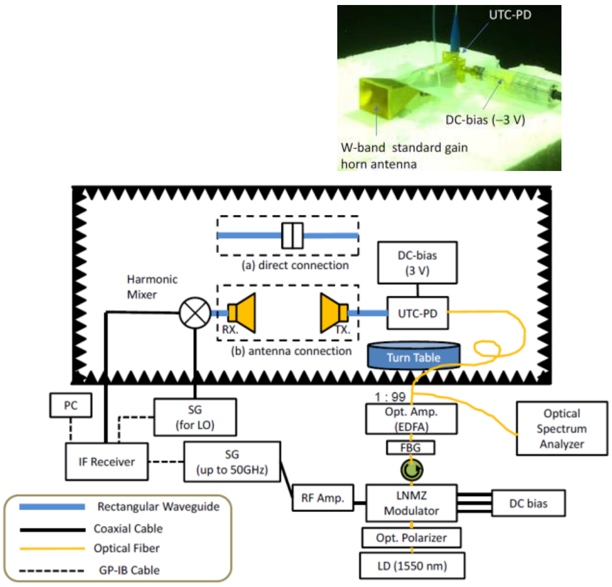

Fig. 8 Antenna pattern measurement system using nested MZ-LN and PD

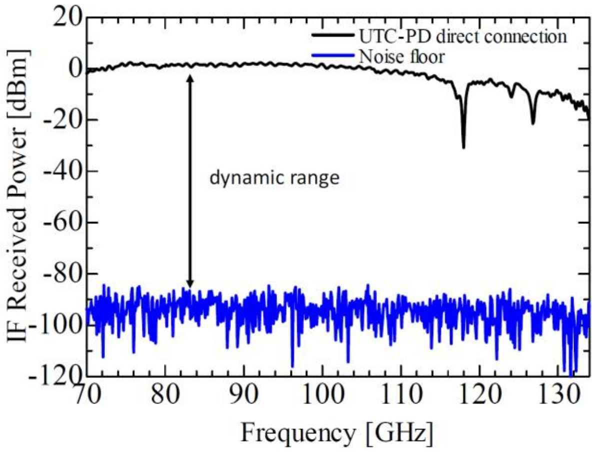

Fig. 9 Frequency characteristics and dynamic range of our system

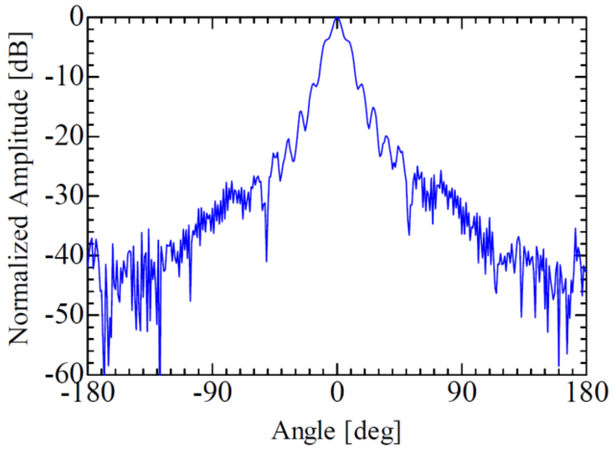

Fig. 10 Measured antenna radiation pattern in the E-plane at 120 GHz

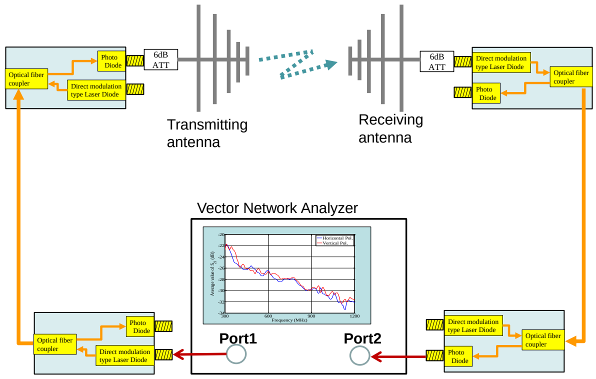

Fig. 11 Outline of antenna measurement setup using four simple optical fiber link modules.

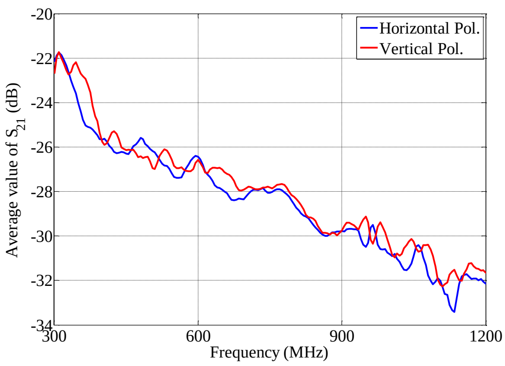

Fig. 12 $S_{21}(\omega)$ of LPDAs using simple optical fiber modules

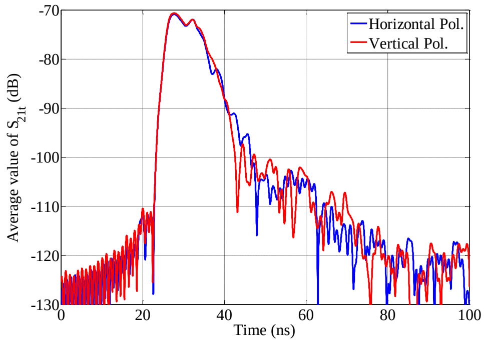

Fig. 13 $S_{21}(t)$ of LPDAs using the simple optical fiber modules.

5. Conclusion

In this paper, we have shown the antenna measurement system using photonic-applied electromagnetic measurement technologies. We show that the photonic system can replace the coaxial cable to the optical fiber cable. Then we have shown the antenna pattern measurement system using optical reflection type MZ-LN photonic sensor and using nested LN-MZ modulator and UTC-PD. Finally, we have shown the antenna measurement system using a radio over fiber modules.

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