OPTOELECTRONIC SYSTEM FOR NEAR FIELD ANTENNAS MEASUREMENTS

Yevhen Yashchyshyn*, Józef Modelski†, Pawel Wegrzyniak

Institute of Radioelectronics, Warsaw University of Technology
15/19 Nowowiejska Str., 00-665 Warsaw, Poland
* e.jaszczyszyn@ire.pw.edu.pl, † j.modelski@ire.pw.edu.pl

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Abstract

The paper presents a near-field antenna measurements solution using a fiber-optic techniques to improve phase measurements accuracy. The main problem in the near-field antenna measurements is phase distortions which result from the changes of cable geometry during the measurements. Measurement solution has been proposed, allowing to illuminate phase errors, and consequently, to enhance measurement accuracy in comparison to conventional technique.

1 Introduction

Near-field antenna measurements occupy an important place among other measurement techniques such as, for example, far-field range or compact range techniques. Different near-field antenna measurement techniques have been developed in the world leading research centers. These methods are based on the measurements of electromagnetic field in discrete points over a preselected surface in the neighborhood of an antenna. It is assumed that antenna is the only source of electromagnetic field on that surface. Measurements surface is situated in the radiating near-field of the test antenna.

With the use of a suitable transformation, the far-field radiation pattern can be reconstructed from the near-field data. In practice, the scanning probe is used to measure the electric field. The information about the amplitude and the phase of the electric field components is desirable. Depending on both, the shape of the measurement surface and the arrangement of the measurement points, different types of near-field antenna measurement techniques are distinguished. Widely used techniques, are based on planar, cylindrical and spherical near-field scanning surfaces. Planar near-field data can be acquired over a rectangular, polar or bipolar grid [2].

Near-field antenna measurements have some advantages in a significant reduction of dimensions of the test range and the ability to perform indoor measurements, with isolation from external disturbance factors. Many factors which have great influence on the accuracy of the results of the near-field antenna measurements, are connected with the measuring probe itself. Among them, the most important are: the errors of probe positioning, probe relative radiation pattern and polarization properties. The influence of scanning probe pattern should be taken into consideration, and it can be compensated. However, in case of near-field scanning, there also appear phase errors, caused by the flexing of cables during probe moving [1].

In this paper, the scanning probe connected by coax cable, is replaced by photonic antenna, which consists of high-speed InGaAs/InP p-i-n photodiode matched with probe antenna, and connected by means of fiber-optical cable and high-speed laser diode module to microwave oscillator or vice versa. The proposed measurement solution allows to illuminate phase errors, and consequently enhance measurement accuracy in comparison to conventional technique. Measurement signal is led to or from the photonic antenna by means of fiber-optic cable. For conversion of the measurement microwave signal into the intensity-modulated optical signal, the high-speed laser diode module is used. For conversion of the intensity-modulated optical signal into microwave signal, the high-speed InGaAs/InP p-i-n photodiode is used.

It seems that using photonic antenna, significantly decreases phase differences between the opposite measurement values of field, with relation to the tested antenna center. Due to the optical signal transmission system, the field distortion can be ignored because of the size of the probe, and phase errors caused by the flexing of the cables during the probe moving can be also significantly decreased.

2 Conventional measurement setup

The Antenna Laboratory of the Institute of Radioelectronics, Warsaw University of Technology is equipped with modern measurement system consisting of three main parts: a block of measuring instruments from Agilent Technologies, scanning mechanism and a computer with GPIB card with specialized software. The whole system is managed by the computer, which communicates with measuring instruments over GPIB interface and with scanning mechanism over RS232 interface. Measurement system can be configured in different ways as required, hence, it is very universal and it allows to realize different measurement tasks which were mentioned in the introduction. This configuration is suitable for near-field or far-field antenna pattern measurements (it depends on the distance *L* between the measuring and test antenna).

Block of measuring instruments from Agilent Technologies consists of 8530A microwave receiver, 83650B microwave synthesized source and 8511B frequency converter. 8530A microwave receiver is the basic measuring instrument. It manages 83650B synthesized source and 8511B frequency converter over an internal GPIB bus forming connected subsystem. 8530A is a controller of this subsystem. Microwave receiver communicates with computer over another, external GPIB interface (Fig. 1). By making the measurements of tangential electric field vector components over plane *XY*, it is possible to calculate plane-wave spectrum of electromagnetic field radiated by the measured (test) antenna. Measurements of tangential electric field components over measurement surface are performed in the $z = z_t$ plane (Fig. 2).

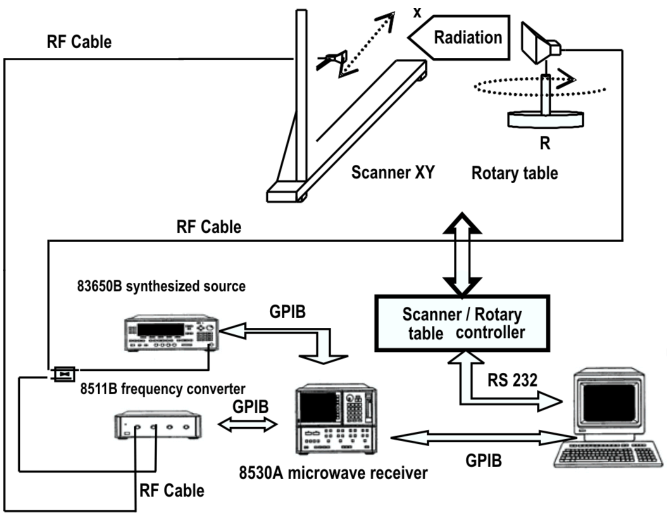


Fig. 1. Experimental set-up for conventional near-field measurement

Planar near-field measurements allow to determine antenna pattern only in limited angular sector [3]. Size of that angular region is defined by the geometry of the test antenna, geometry of the scan area and the distance between test antenna and the measurement plane as shown in Fig. 3.

If the measurement plane is situated outside the reactive near-field region (it is assumed $z_t > l$), then we can make an assumption that the components of plane-wave spectrum for which $k_x^2 + k_y^2 \geq k^2$ are negligible, because they are highly attenuated. In that case, maximum permissible sample spacing is given by the formulas: $\Delta x_{\max} = \Delta y_{\max} = l/2$.

As it was mentioned, the significant source of errors in planar near-filed measurements can be caused by the flexing of measuring cables during the probe moving. These are phase errors. Minimization of this effect can be achieved by the use of an optoelectronic system with new photonic antenna [4].

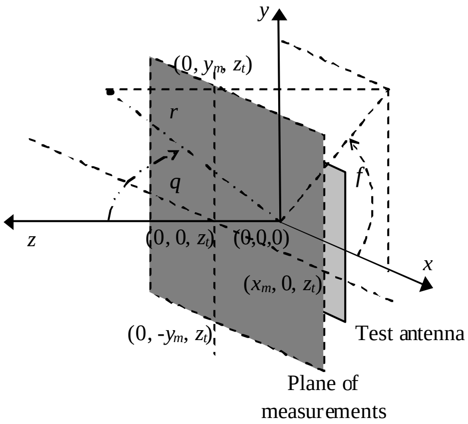


Fig. 2. Location of the test antenna in the reference coordinate system used in an analysis.

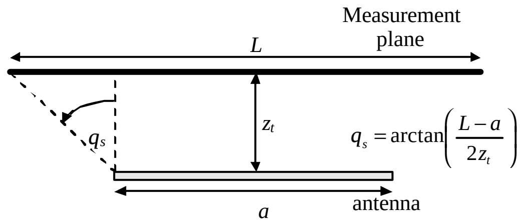


Fig. 3. Measurement plane and an angular sector with reference to aperture dimension.

3 Optoelectronic system

The optoelectronic system consists of high-speed InGaAs/InP p-i-n photodiode module and high-speed laser diode module. Measurement signal can be led to or from the photonic antenna by means of fiber-optic cable.

The InGaAsP/InP p-i-n photodiode has front-illuminated p^+-region placed in a pigtailed fiber-optic module. To enhance the responsivity and to reduce the reflection from the fiber-air and air-chip interfaces, the special matching medium with refractive index close to that of quartz fiber has been placed between the chip and the fiber.

High-speed laser diode module represents the injection multiquantum-well strip InGaAsP/InP laser with Fabry-Perot resonator placed in pigtailed fiber-optic module. Fig. 4 shows the connection circuit of high-speed laser diode and photodiode modules, which consist of DC resistance *Rdc*, blocking capacitance *Cb* and inductance *Lb*, package capacitance *Cp* and inductance *Lp*, and coplanar transmission line with impedance $Z_L = 50\ \Omega$.

Figure 5 shows the microwave gain of optoelectronic pair laser diode module – photodiode module versus frequency under different bias voltage of the photodiode.

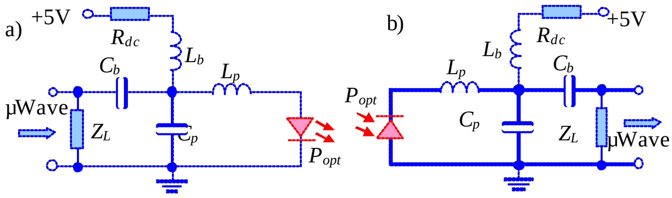


Fig. 4. Connection circuit of high-speed laser (a) and photodiode (b) modules.

One can see that the bandwidth of optoelectronic pair at the level -3 dB is 8 GHz under bias voltage -5 V. It is worth noting that the photonic antenna can operate without bias voltage, although in this case, it is necessary to use photodiode with higher bandwidth.

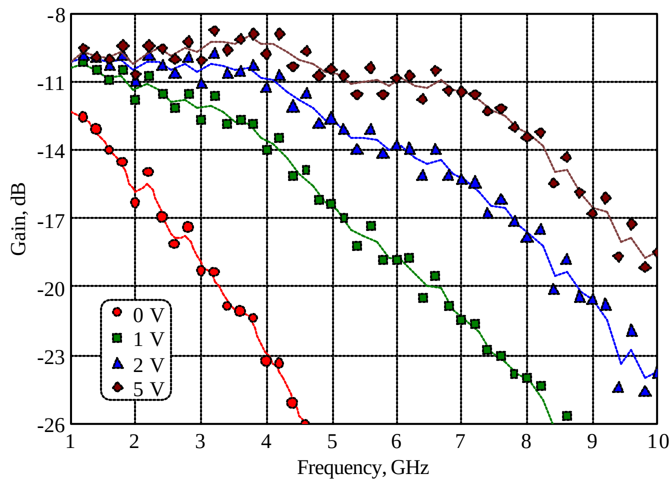
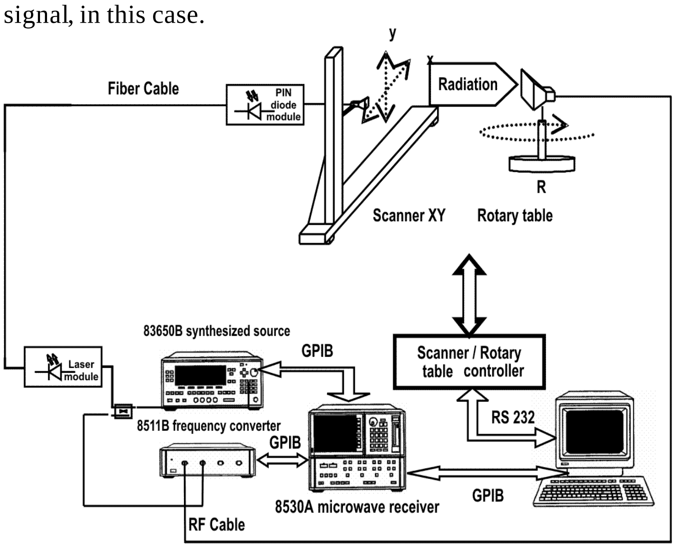


Fig. 5. Microwave gain of optoelectronic pair laser diode module – photodiode module versus frequency under different bias voltage of the photodiode.

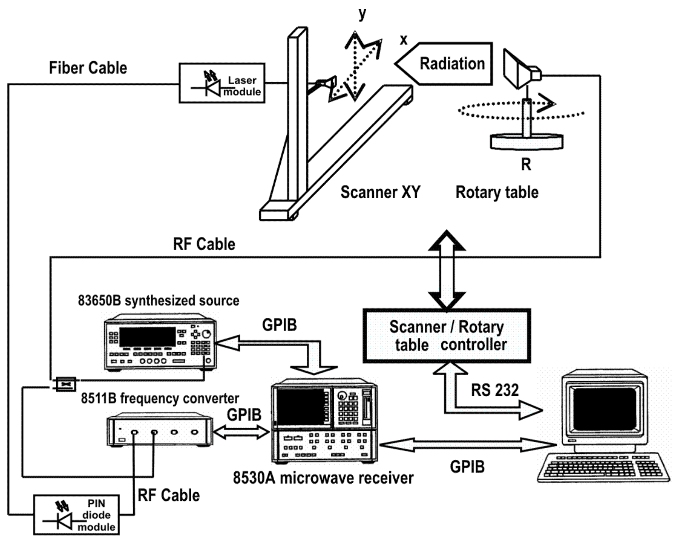
4 Measurement setups for application of optoelectronic system

Figure 1 depicts the conventional near-field measurement system which uses an RF cable for transmitting the measured signal from probe to microwave receiver. We call the results obtained by this system a "Cable". Figure 6a) shows the near-field measurement system which uses an optoelectronic system for transmitting the RF signal from the synthesizer to the scanning probe. We call the results obtained by this set-up - "FiberINV". Figure 6b) shows the near-field measurement system which uses an optoelectronic system for transmitting the measured signal, but it transmits signal from the scanning probe to the receiver. For conversion of the measurement microwave signal to the intensity-modulated optical signal, the high-speed laser diode module is used in this case. We call the results obtained by this set-up - "Fiber".

The main difference between these two optoelectronic systems is that in the first case, the laser diode is modulated by high level of RF signal. Photonic antenna is connected with photodiode and is used as a transmitter. In the second case, photonic antenna is connected with laser and is used as a receiver. The laser diode is modulated by low level of RF signal, in this case.



a) "FiberINV"



b) "Fiber"

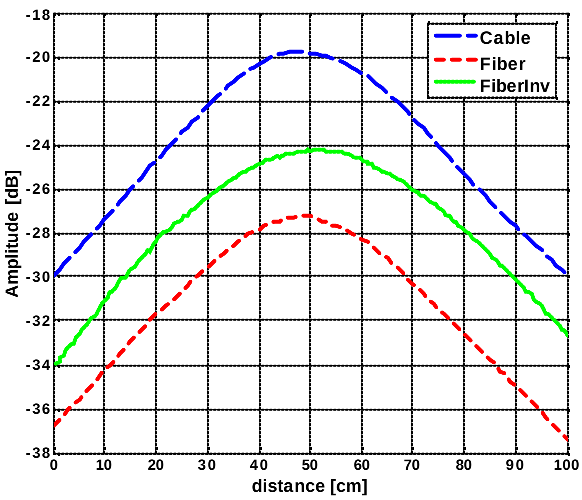
Fig. 6. Experimental set-up for different assembly optoelectronic transmission system

4 Results of near-field measurements

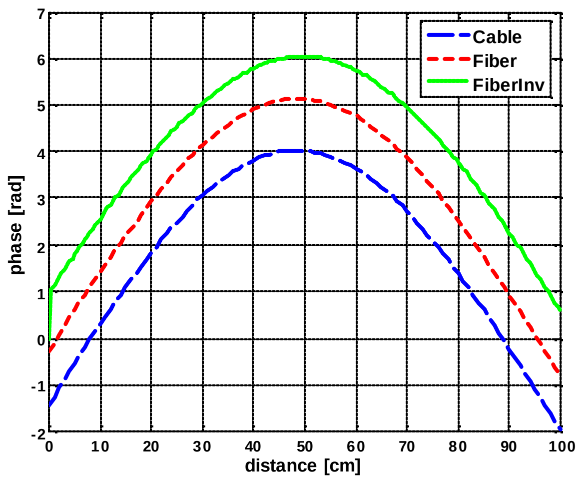
A planar electrical field scanner has been set-up using the probe mounted at a XY-positioner. The scanning area is 1000 mm by 1000 mm. To test the experimental set-ups, the near field distribution of the three antennas have been used: an open end of waveguide R-48 with collar, a wideband horn (bandwidth equals fom 1 up to 26 GHz) of dimensions 120mm by 100 mm, and a reflector parabolic antenna of diameter equal to 400 mm with operational frequency equals 10 GHz. Each antenna has been scanned with a minimal necessary step for certain frequency: 1.25 GHz, 5.68 GHz and 10 GHz.

As a probe, we have used three different antennas. The dipole antenna for frequency equals 1.25 GHz, small patch antennas (11x8 mm) on high permittivity substrate for frequency equal to 5.68 GHz and an open end of waveguide for 10GHz.

Figure 7 shows the obtained amplitude (a), and the phase (b) distributions (in the H-plane) of a horn operated on 1.25 GHz for different transmission systems. Figure 8 depicts the obtained results, where phase differences between the opposite measurements values of electrical field along *X* direction (H-plane) with relation to the tested antenna center are presented.



a)



b)

Fig. 7. The obtained amplitude (a), and the phase (b) distributions of horn (1.25 GHz) for different transmission systems.

Figure 9 shows the obtained amplitude (a), and the phase (b) distributions (in the H-plane) of a waveguide operated on 5.68 GHz for different transmission systems.

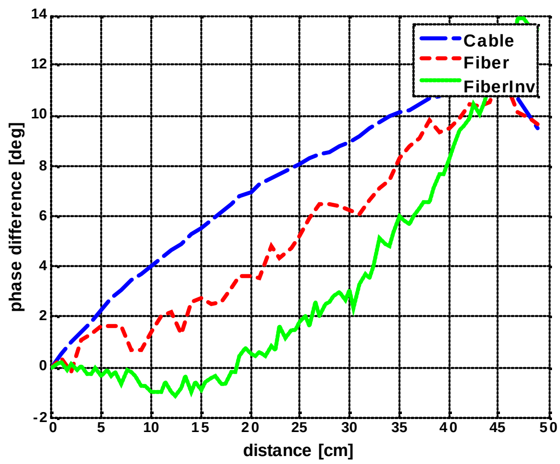
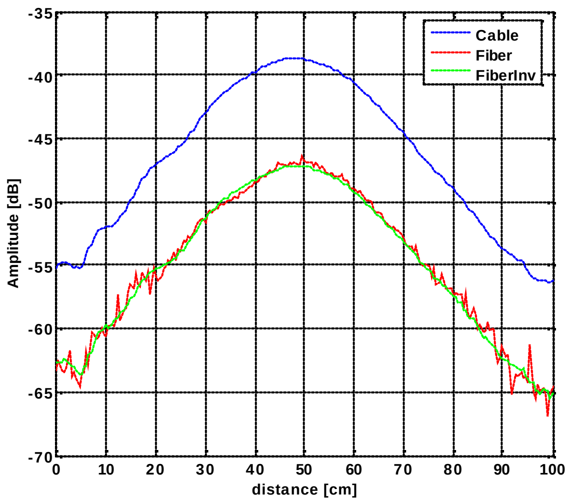
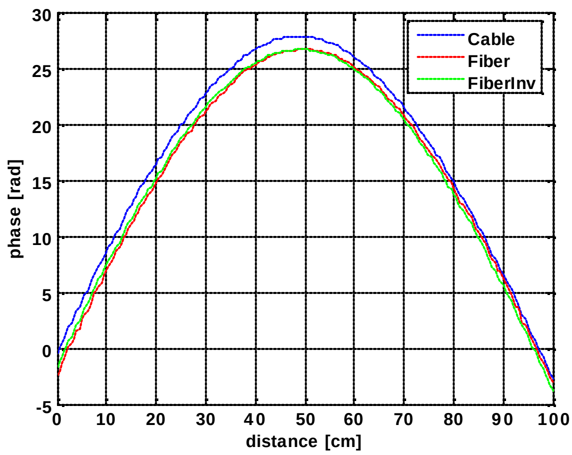


Fig. 8. Phase differences between the opposite measurements values with relation to the horn center



a)



b)

Fig. 9 The obtained amplitude (a), and the phase (b) distributions of open end of waveguide (5.68 GHz) for different transmission systems

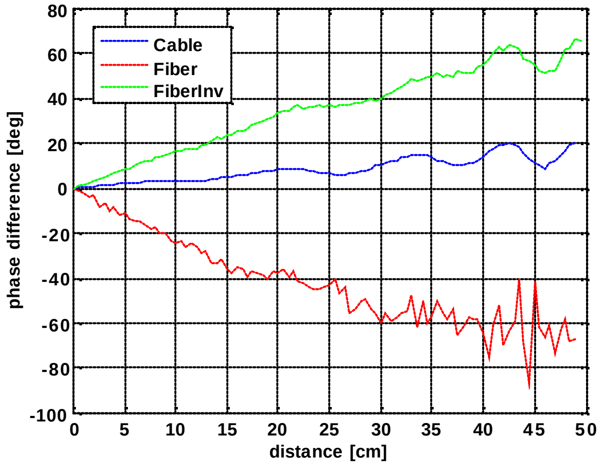
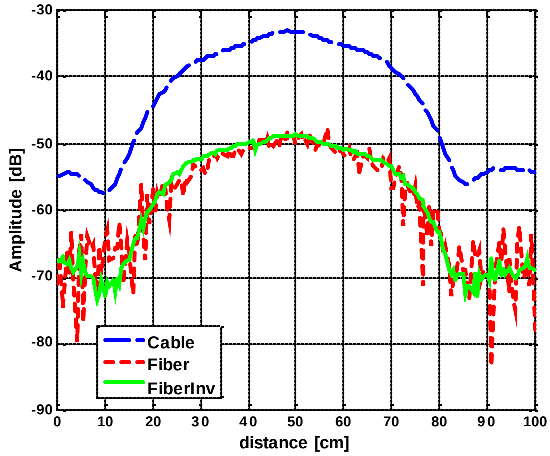
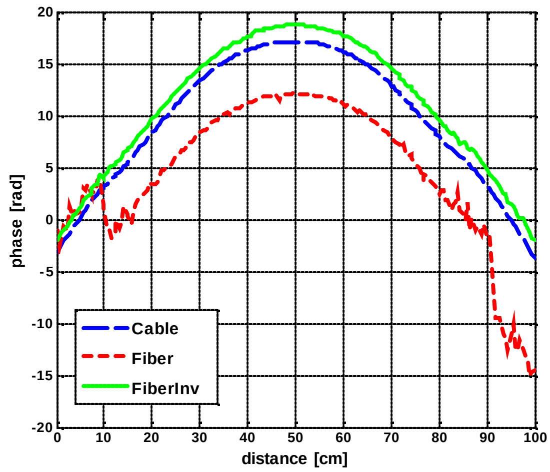


Fig. 10. Phase differences between the opposite measurements values with relation to the open end of waveguide center



a)

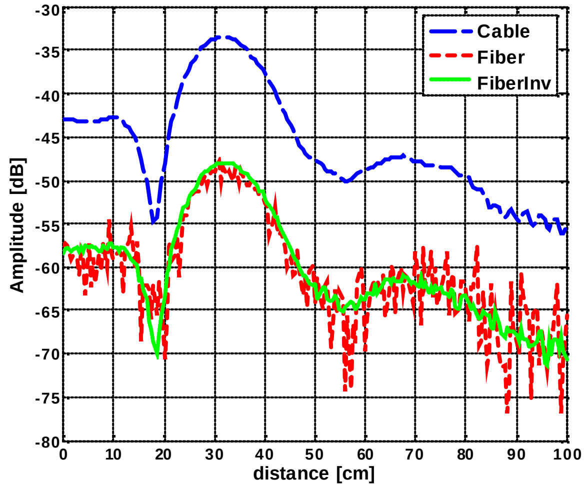


b)

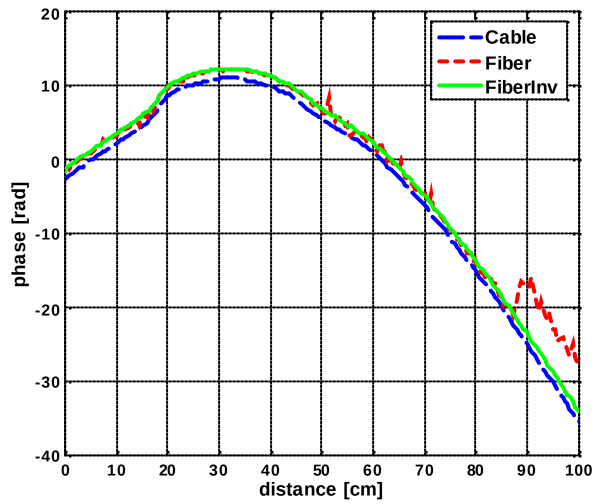
Fig. 11 The measured amplitude (a), and the phase (b) distributions of horn (H-plane, 5.68 GHz) for different transmission systems

Figure 10 depicts the obtained results, where phase differences between the opposite measurements values of electrical field along *X* direction (H-plane) with relation to the open end of waveguide center are presented.

Figures 11-12 show the measured amplitude (a), and the phase (b) distributions (in the H-plane and E-plane, respectively) of a horn (operated on 5.68 GHz) for different transmission systems.



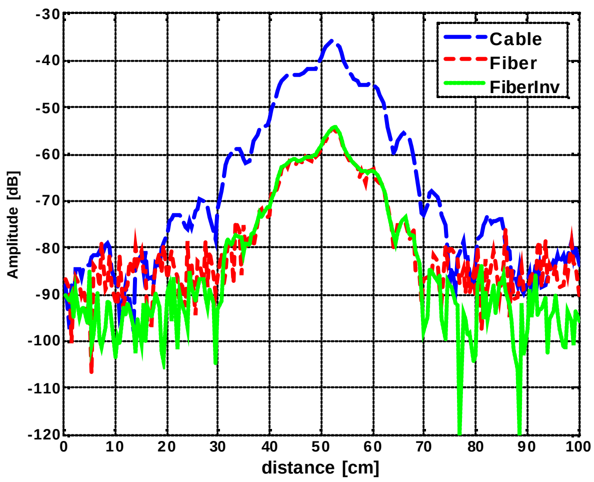
a)



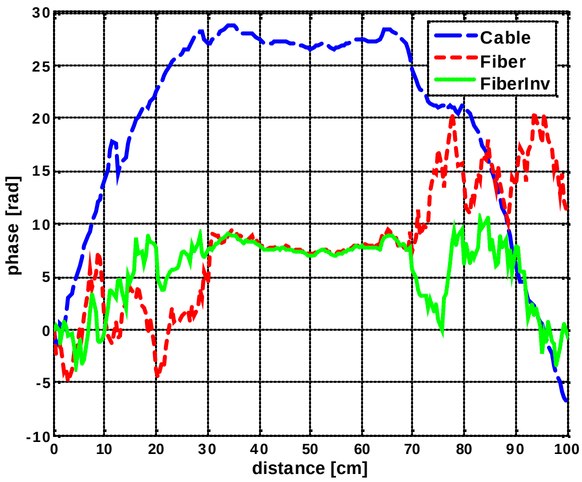
b)

Fig. 12 The measured amplitude (a), and the phase (b) distributions of horn (E-plane, 5.68 GHz) for different transmission systems

Figures 13-14 show the measured amplitude (a), and the phase (b) distributions (in the H-plane and E-plane, respectively) of a parabolic antenna (operated on 10 GHz) for different transmission systems. Presented results show that optoelectronic system can be applied in near-field measurements, especially for decreasing phase error. It seems that the main set-up is the one we named “FiberINV”. The main disadvantage of the investigated optoelectronic system is a lower level of the measured signal. It seems that this problem can be solved [4] by matching a photodiode to the impute impedance of probe. It needs to be also noticed that optoelectronic system does not use any amplifier.



a)



b)

Fig. 13 The measured amplitude (a), and the phase (b) distributions of parabolic antenna (H-plane, 10 GHz) for different transmission systems

Conclusion

The results of applying the optoelectronic system for the near-field measurements have been presented. Due to the optical signal transmission system, the field distortion can be ignored and the phase errors caused by the flexing of the cables during probe moving can be significantly decreased. It seems that the main set-up is the one, which uses an optoelectronic system for transmitting the RF signal to the scanning probe from the synthesizer. The main disadvantage of the investigated optoelectronic system is lower level of the measured signal, especially for higher frequencies.

Acknowledgments

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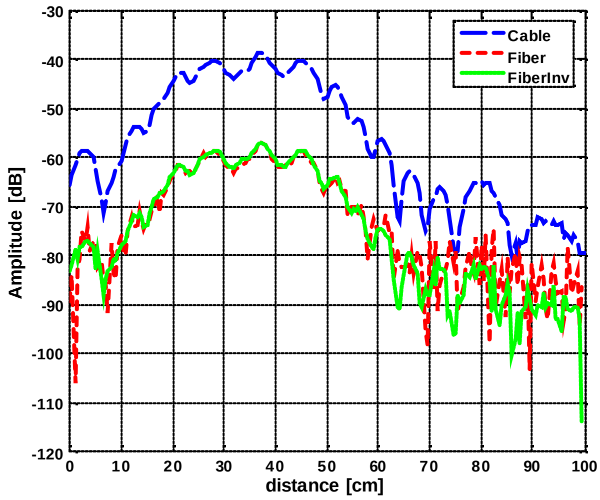
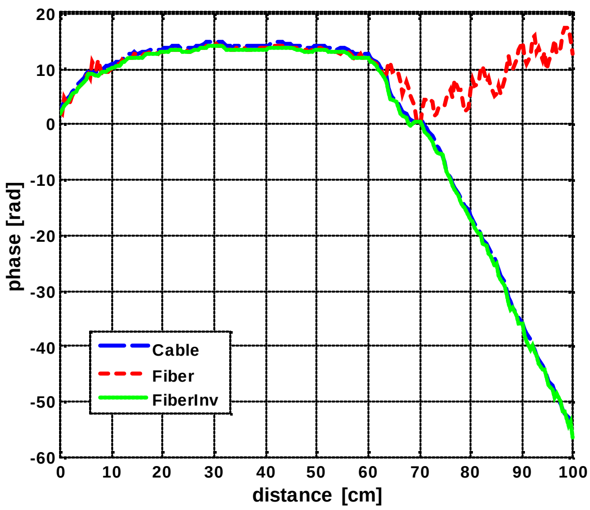


a)



b)

Fig. 14 The measured amplitude (a), and the phase (b) distributions of parabolic antenna (E-plane, 10 GHz) for different transmission systems

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