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# Small Device For Short Range Antenna Measurements Using Optics

Boyan Yanakiev, Jesper Ødum Nielsen, Morten Christensen, and Gert Frølund Pedersen

**Abstract**—This paper gives a practical solution for implementing an antenna radiation pattern measurement device using optical fibers. It is suitable for anechoic chambers as well as short range channel sounding. The device is optimized for small size and provides a cheap and easy way to make optical antenna measurements using off-the-shelf components. Verification measurements are made to confirm the benefits.

**Index Terms**—Antenna measurements, Antenna radiation patterns, Optical fiber measurement applications, Propagation measurements, Electrically small antennas

## I. INTRODUCTION

UNTIL recently, the practical importance of the radiation pattern of an electrically small antenna was typically considered low. Usually there is little that can be done for the shape of the pattern and design was focused on optimizing efficiency. While a good case can be made for the performance insights the pattern can give [1], [2], it is not common practice to utilize this for practical designs of mobile phone antennas, for example. One of the very important advantages of the pattern data is the ability to accurately model the interaction with the propagation channel. Presently this becomes an important part of multi-antenna system evaluation, where parameters such as correlation and branch power ratio depend exclusively on the radiation pattern and propagation environment.

One of the biggest problems in measuring small antenna patterns accurately is the current flowing on the entire structure [3] and interacting with the measurement cables. Various methods can be deployed to reduce this measurement error using balun

chokes [4], [5], feed cable position optimization [6], or ferrite beads [7]. A very popular approach is to entirely remove the coaxial cable and use optical fibers to replace it. The idea was introduced in [8], where the tested antenna is equipped with a photo detector and the RF signal is delivered over optical fiber. The RF power delivered is usually low leading to short range. Various practical implementations have since been investigated based on different RF over fiber technologies [9]–[13].

This work attempts to fill a gap in the above publications by providing schematics based on off-the-shelf and up-to-date components and implementation guidelines. While the principles are the same as in [8], the focus has been on the practical implementation.

## II. DEVICE DESCRIPTION

Our design goals were primarily small size, low power consumption, and use of off-the-shelf components. The photo detector chosen is the Emcore 2651E for its good performance and availability. According to Emcore specifications [14], the bias voltage should be in the range of 10 – 15 V. Small batteries with such nominal voltage are hard to find, so a single 3 V *Li/MnO<sub>2</sub>* cell was used, followed by a boost converter [15], to deliver the necessary 12V. Such single cell batteries have limitations on the maximum continuous current, as detailed in [16]. The current drawn from the photo detector is in the range of 1 – 4 mA for typical laser optical power range of 2 – 6 dBm. Converting from the operating 12V to the source 3V battery cell, gives a range of 8–20 mA. A convenient form factor which is small, fairly widespread, and supports continuous 20 mA current drain is, for example, the CR 1/3N [16], which is the one used here.

The proposed device schematic is shown in Fig. 1. Since D1 is a photo detector connected in reverse, it works as a current source, and the current

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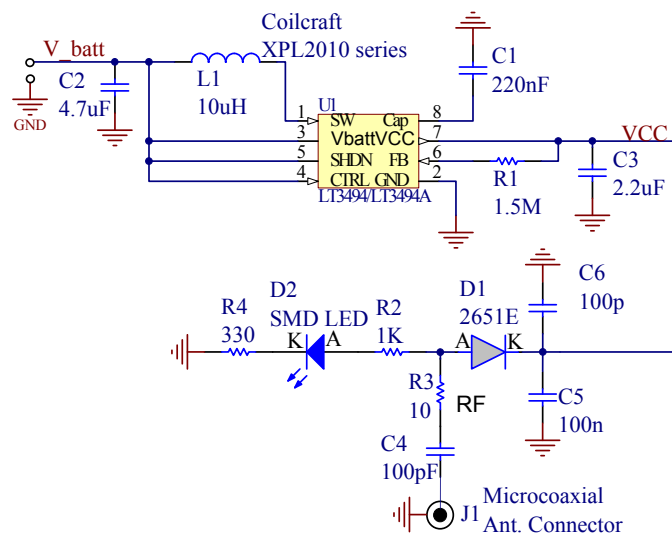


Fig. 1. Optical unit schematic

generated is determined by the optical power input. D2 is a simple SMD LED used as an indicator and does not add to the total power consumption due to the operation mode of D1. An important consideration is to drive D2 into the linear part of its V-A curve at the operating optical power input. The visual indicator D2 can be an important practical feature and reduces the chances for operator error. The boost converter circuit is directly taken from the application notes for the chip [15]. With such a schematic D2 is only lit, if the following two conditions are met: a) the battery is not exhausted and b) sufficient optical power is delivered to D1. R3 is used for matching to the 50 ohm interface and C4 is DC block on the RF signal path. C3, C5 and C6 are filtering capacitors.

The final device is shown in Fig. 2. The housing is made in a 3D rapid prototyping printer from PC-ABS material. The dimensions are 20x17x10 mm with the battery curvature adding another 2.5 mm. In the photo, the SC-APC optical connector at the end of the photo detector and a standard SMA through are shown for size comparison. With battery capacity of about 160 mAh the total operation time is around 6 hours at 6 dBm optical power input.

Since the optical link replaces a single coaxial cable, the calibration procedure is straight forward using the micro-coaxial connector.

### III. VERIFICATION MEASUREMENTS

To confirm the accuracy of this design, multiple verification measurements were performed. 800 and

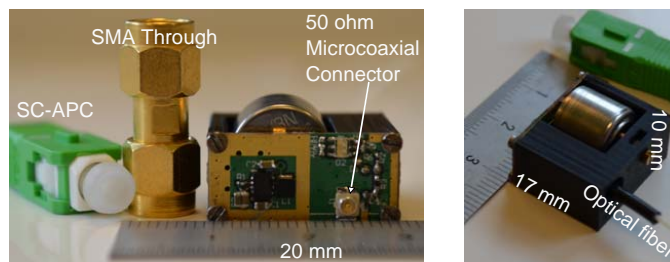


Fig. 2. The complete device: front view compared to SMA through (left) and side view with additional dimensions (right)

2500 MHz were used as test frequencies, with the usable range up to 3 GHz. The range can easily be extended to about 6 GHz.

A potential concern is our use of a switched mode power supply, which can lead to higher order harmonics. In addition, if the device is placed in a high electromagnetic field region of the radiating structure, DC-DC coupling can also occur. To prevent such problems, a small shielding box can be used to cover the power supply along with the filtering capacitors. The harmonics were measured to be around -70 dBc for the device in Fig. 2 at both test frequencies.

The linearity and dynamic range are a function of both the laser and detector and cannot be separated easily. Using a simple direct modulation laser with no pre-amplification Fig. 3 was produced. The device has excellent linearity and around 90 to 100 dB of dynamic range.

The long term stability of the link also depends on both the laser and detector circuits. Using an off-the-shelf, cooled laser transmitter, the effect of battery drain was less than 0.1 dB from full charge to converter shutdown. Typically, the link would have at least two optical connections, each of which adds another 0.3 dB [17] of uncertainty. The total uncertainty in the link assuming a well defined transmitter is 0.5 dB. Repeated measurements over multiple days and battery states were within these 0.5 dB.

Finally, a simple PIFA antenna mock-up was measured, first with cables and then with the optical device proposed here, to demonstrate the benefits of using this non-galvanic method. The mock-up has a size of 40x16x6 mm. The measurements were done at the critical 2200MHz, where the entire structure is at resonance. Fig. 4 shows the measurement set up for a) the cabled measurement and b) a close up on the optical unit integration. Fig. 5 shows

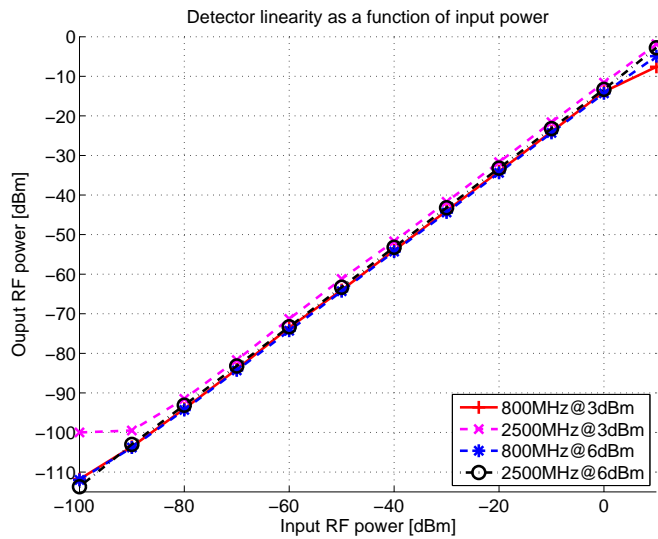


Fig. 3. Linearity and dynamic range

the measured radiation patterns compared to the simulated one.

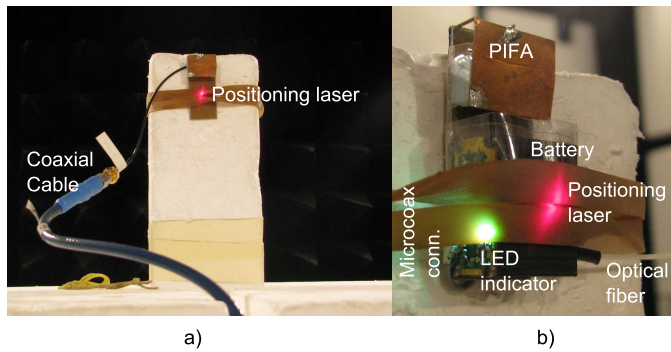


Fig. 4. a) Cabled set-up and b) optical unit integration close up

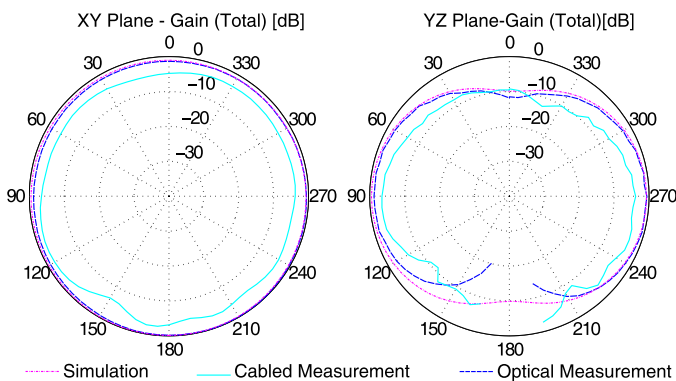


Fig. 5. Normalized pattern comparison between cabled and optical measurement

## IV. CONCLUSION

This paper presents a simple photo detector circuit for antenna measurements using optical links. The primary benefit of the method is the non-galvanic connection to the device, which improves the measurement accuracy in the case of electrically small antennas. The optical unit is smaller than previously proposed devices, simple to build, and utilizes only standard, off-the-shelf components. The optical link with this circuit is shown to be linear and stable with 90-100 dB of dynamic range. A simple electrically small antenna is measured with coaxial cables and the optical link and the validity of the method is confirmed.

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