High Power-over-Fiber Feed for Radio-over-Fiber Systems with Remote Antenna Units

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Abstract. We experimentally demonstrated a radio-over-fiber transmission integrated with a power-over-fiber system for next generation access networks, which can drive remote antenna units and improve bandwidth utilization effectively. We have achieved high transmission performance and expanded the signal transmission capacity.

1. Introduction
With the exponential growth of information traffic in the 5G era, the available spectrum resources are even scarcer, and the pressure on various communication systems is increasing. Therefore, the Radio-over-Fiber (RoF) is an indispensable technology, which transmits radio-frequency (RF) signals between a central station (CS) and many remote antenna units (RAUs) over optical fibers [1]. The bandwidth of the RoF is very high, so it can improve the rate of communication significantly.

In the future mobile communications, in order to improve bandwidth utilization effectively, a reduction in the cell size of RAUs is required to support higher data rates of RF signals, and a huge number of the RAUs need to be installed, especially in densely populated areas [2]. Therefore, it is important to provide cost-effective installation, operation, and maintenance for the RAUs. Power-over-fiber (PWoF) is one of the attractive solutions of these problems, because the use of it enables us to centralize the overall power supply system in the CO [3].

We applied the fusion of radio and power systems based on fiber-optic communications, which uses the optical domain to create millimeter wave and transfers it to the base station. The base station performs basic processing on the received optical signals and transmits them to the remote users for reception.

Simulation results indicate that the transmission effect meets the requirements of communication, and the transmission length of single-mode fiber reaches 25 kilometers. The optical carrier suppression technology is utilized to realize the simultaneous downlink transmission of two signals and high-power signals.

2. Experimental Setup
The block diagram of the experimental setup is shown in figure 1. In the transmitting end, the continuous wave generator generates a laser signal, which is generated by two sidebands of the DPMZM. In the downstream direction, the two sidebands are separated, the upper sideband is added with a Mach-Zehnder modulator for downlink signal transmission, and the lower sideband is used for transmitting signals to the base station as an uplink signal. In addition, a high-power transmitter is added, which supplies power to the remote antenna unit. The three signals pass through the AWG coupler into the 25Km single-mode fiber to the base station [4]. After transmission, the signals...
carrying different signals are separated by filtering, and then the Q factor and the bit error rate are detected.

![System schematic](image)

**Figure 1.** System schematic

### 3. Results and Discussion

In this experiment, the wavelength of the laser is 193.6 nm, which is impressed by two 18G carriers. Then, the modulated light is separated by filtering to obtain two sidebands. One sideband is used to carry the downlink signal, and another sideband is used to transmit to the base station as the uplink signal. The sideband of the downstream and upstream signal is illustrated in figure 2.

The signal waveforms after transmission through single mode fiber are illustrated in figure 3. They include signals for downstream data, uplink signals, and high-power signals. The upper and lower sidebands of the downlink signal remain intact after transmission over a single-mode fiber. Moreover, high power signal only lost about 2.5 mw. We have accomplished high transmission performances under the high-power optical feeding.

![Upper and lower sideband waveform of downlink](image)

**Figure 2.** Upper and lower sideband waveform of downlink
BER is the ultimate measure of transmission quality. The optical signal coupled to the optical fiber is distorted by noise, nonlinearity, dispersion (PMD/CD) and other factors. When it reaches the end of the optical fiber link, the receiver converts the optical signal back into electrical signal, which will cause error code. Within the time interval t, the number of pulses that distinguish errors \(N_e\) and the total number of pulses (1 or 0) \(N_i\) in this time interval are divided to get the bit error rate. The BER is given by the formulation (1)

\[
BER = \frac{N_e}{N_i} = \frac{N_e}{Bt}
\]  

(1)

The Q value is defined as

\[
Q = \frac{I_1 - I_0}{\sigma_1 + \sigma_0}
\]

(2)

Where \(I_1\) and \(\sigma_1\) are the mean and variance of 1 Gaussian pulse output, \(I_0\) and \(\sigma_0\) are the mean and variance of 0 Gaussian pulse output respectively.

The relationship between Q value and BER is as following

![Figure 3-(a). Sideband waveforms after fiber transmission](image)

![Figure 3-(b). High power waveform after fiber transmission](image)
\[ BER = \frac{1}{2} \text{erfc} \left( \frac{Q}{\sqrt{2}} \right) \approx \frac{1}{\sqrt{2\pi Q}} \exp\left( -\frac{Q^2}{2} \right) \]  

(3)

Q value corresponds to BER one by one. Q value can simply express the system tolerance in decibels.

![Figure 4. Downlink signal Q factor waveform](image)

![Figure 5. Bit error rate waveform of high-power signal](image)

just as dBm is usually used instead of mW to represent optical power. If the BER before error correction is small, the Q value is large and the link performance is better.

Figure 4 is the downlink signals Q factor waveform, we can conclude that the Q factor is basically above the value 1, which is relatively high. The Q factor is related to the signal-to-noise ratio in the simulation result parameters. The higher the Q factor, the smaller the bit error rate.

As shown in figure 5, when the required downlink signal is transmitted in the single-mode fiber simultaneously with the high-power signal, the lowest bit error rate of the high-power signal is observed to reach $10^{-4}$, and the signal quality is not disturbed. So while transmitting the downlink signal to the base station, it is successful to allow the high-power signal reach the remote antenna unit.

4. Conclusion

We have successfully proposed and demonstrated hybrid optical wireless communication system, which combines fiber-optic communication and a big power signal characteristic to complement each
other. The obtained results show that the optically powered RoF system not only makes the frequency band utilization higher, but also realizes simultaneous downlink transmission of two signals and high-power signals. In the future, hybrid access network integrated with radio-over-fiber and power-over-fiber is an indispensable technology for transmitting signals to fiber links between central stations and remote antenna units.

We have simulated the designed optical wireless communication system. From the results, we can see that the transmission effect meets the requirements of communication, and the transmission length of single-mode optical fiber reaches 25 kilometers. At the same time, the optical carrier suppression technology is used to realize the simultaneous downlink transmission of two signals and high-power signals. High-power signals supply power to the remote antenna unit. When natural disasters occur, the remote power can be self-sufficient, which solves the defect of power transmission by cable.

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6. References
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