Radio Access Network Power Management Considering Radio over Fiber Technique for 4G Mobile System

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ABSTRACT – Radio over fiber technique was suggested as excelent candidates for 4G radio access network considering large number mobile users. With higher number of base stations, a microwave link presents more disadvantages across base stations in relation to power management, interference effect, atmosphere effects, and maintenance. In this paper, the radio over fiber power management technique is introduced. It transmits and receives signals with lower losses and dispersion effect through the fiber link. The signal quality is improved with the parameters optimization for practical applications. It proposed better power level for 4G mobile base stations with the expected coverage area, as well as power control and signal improvement for the system.

Key-Words – Radio over fiber, 4G mobile system, radio access network, power manaegment, fiber dispersion.

1 Introduction

Microwave link used in mobile communications systems, such as global system mobile (GSM) systems and universal mobile telecommunications systems (UMTS), present many disadvantages in relation to interference, atmosphere effects, maintenance, and high costs. Thus, there is a need to identify alternate links that can overcome these shortcomings. Radio over fiber (RoF) is the best solution for this problem. By using RoF as a link between base stations to and from central base stations to base stations, the number of carrier frequencies is minimized in 4G mobile communications. Such approach is suitable for the abovementioned disadvantages. However, because of the coverage of the cells, power control and the transmitted power management also present itself as a problem, as the power launched into the fiber is limited by both minimum (Brillouin power) and maximum power (Raman power). In order to minimize power dispersion and scattering, power management is essential. In this paper, we proposed a new technique for power management (i.e., power limit, losses minimization, and dispersion reduction), Some results show that using the proposed technique lead to improved signals. The handover problem is controlled, coverage is enhanced, and finally, the aforementioned microwave problems could be prevented.

2 Radio over fiber technique

RoF has found a suitable technique for future mobile communications systems (e.g., 4G and above operating system). It is generally utilized as a link between the base station and remote antenna, as well as between base stations. RoF offers many advantages compared to the microwave link, such as those related with atmosphere affects on signals, maintenance, and interference. Higher data rate and signal quality can be accommodated as well. However, RoF involves high-cost installation, although it has lower running costs in the long run.

Three main RoF system architectures have been proposed for commercial in-building wireless deployments: (i) radio frequency (RF) transmission over fiber, (ii) infrared (IF) transmission over fiber, and (iii) digitized IF transmission over fiber [1,2]. RoF technology allows for the implementation of a microcellular network system by using a fiber-fed distributed antenna network [1]. The signal is converted optically by an electrical-to-optical (E/O) converter. Then, it is modulated and launched into the optical fiber cable. In the receiver, the light signal is detected by the photo detector. Finally, it is re-converted to electrical signal by optical-to-electrical (O/E) converter. The scheme is shown in Fig.1.

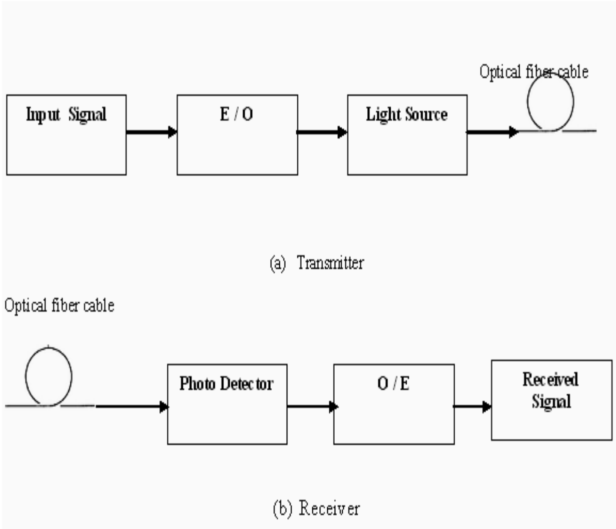

Fig. 1 Simplified RoF block diagram:(a)transmitter;(b)receiver

Factors that restrict the transmission of the RoF system include chromatic dispersion, non-linearity of fibers, and crosstalk. First, in RoF systems, the decline caused by chromatic dispersion is reflected as the periodical changes of signal power in the transmission along fibers. Fiber non-linearity is the second effect. When the power over the fiber is very high, non-linearity significantly affects the system, especially the high-rate system. Two types of non-linearity exist: stimulated Brillouin scattering (SBS) and stimulated Raman scattering (SRS). SBS is an effect of scattering generated in the fiber media due to the interaction of light-wave and phonon in the silicon dioxide media; SRS results from the dependency of refractivity and optical power. Crosstalk is the third effect, which refers to the effect of other signals to the required signals. In a bidirectional RoF system, additional crosstalk to the system occurs when data are transmitted in two directions over a single fiber. In addition, the crosstalk inside channels caused by component leakage also suppresses system transmission [2].

3 4G Mobile system

The 4G mobile system, referred to as the wireless system of the future, integrates other wireless systems like WiMAX, 2G, and 3G. Its Radio Access Network (RAN) includes many cells with base stations connected with radio network controllers, then through access gateways to core networks via the Internet. A simplified RAN architecture for 4G mobile is shown in Fig. 2. A 4G mobile system may have the following specifications: high-speed transmission (peak of 50–100 Mb/s; average of 200 Mb/s), larger capacity (~10 times greater than 3G systems), next-generation Internet support (IPv6 and QoS), seamless services, flexible network architecture, use of microwave band (2–8 GHz), and low system costs (1/10~1/100 of 3G systems)[3].

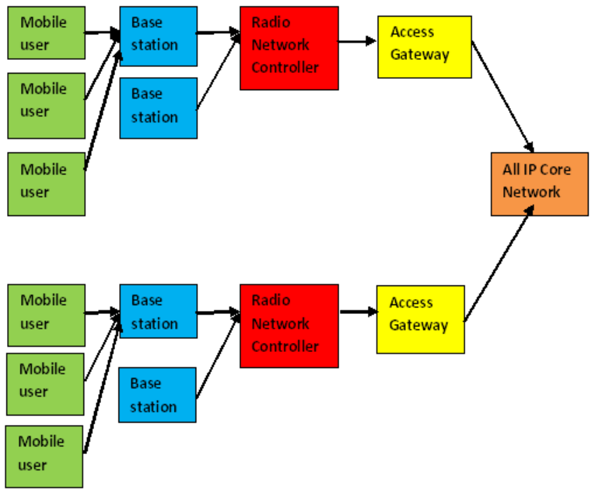

Fig. 2 Simplified 4G Radio Access Network (RAN) architecture

In this paper, the 4G mobile system radio network architecture was suggested using RoF network, and the proposed power management technique as depicted in the following section, it provides optimum power input launched to the fiber and lower effects of dispersion. Factors on non-linearity and crosstalk are discussed in the Results.

4 Related work

Power management in the RoF link for the base station power control is very important, as it controls the coverage and capacity of the system. Many have proposed and studied this topic. In [1,2] generation of millimeter-wave generation and RoF are given, a 4G mobile architecture given in [3,6-10], theoritical and practical main fiber parameters are studied in [4-5, 11-13], the summery of the litersture work survey given in Table (1), the cross sign means not studied and the right sign means studied. In work, the power management has been proposed for 4G mobile RAN considering RoF as shown with right sign in the last row in Table (1) by optimization of the fiber parameters to the optimum value.

TABLE 1 Comparisin of related work

Ref. No.	4G mobile	RoF	RAN	Power management
[1]	X	✓	✓	X
[2]	X	✓	X	X
[3,6-10]	✓	X	✓	X
[11]	✓	✓	X	X
[12]	X	✓	✓	X
[13]	X	✓	X	X
This work	✓	✓	✓	✓

5 Results

Power launched into the fiber in the RoF link for 4G mobile systems is rather limited due to many factors, such as chromatic dispersion and non-linearity scattering based on the two-power levels of Brillouin and Raman powers. In this work, practical optimization for these parameters was employed. Overall dispersion in the multimode fibers comprised of both intramodal and intermodal terms. The total rms of pulse broadening σ_T is given by [4]:

$$\sigma_T=(\sigma_c^2+\sigma_n^2)^{1/2} \quad (1)$$

where σ_c is the intramodal or chromatic broadening, and σ_n is the intermodal broadening caused by delay differences between the modes (σ_s for multimode step index fiber and σ_g for multimode graded index fiber).
The intermodal dispersion for the multimode step index and graded index fiber are given by Equations (2) and (3), respectively.

$$\sigma_s=(L X n_1 X \Delta) / (3.4 X c) = (L X (NA)^2) / (6.8 X c) \quad (2)$$

$$\sigma_g=(L\ X\ n_1 X\ (\Delta)^2)/\ 34\ X\ c \quad (3)$$

where L is the fiber length, NA is the numerical aperture, Δ is the relative index difference, and c is the free space light speed [4].
Brillouin threshold power P_B is given by [5]:

$$P_B = 4.4\ X\ 10^{-3} X\ d^2\ X\ \lambda^2 X \propto_{dB}\ X\ v \text{(watts)} \quad (4)$$

The threshold Raman power in a single mode fiber is given by [5]:

$$P_R = 5.9\ x\ 10^{-2} x\ d^2\ x\ \lambda\ \text{x}\ \propto_{dB} \text{(watts)} \quad (5)$$

where d and λ are the fiber core diameter and operating wavelength in micrometers, respectively, $\propto_{dB}$ is the fiber attenuation in dB/km, and v is the source bandwidth (injection laser) in GHz.
For the experimental results, the summary of the input power P_i to the attenuator and output power P_o are shown below. These were obtained by using a spectrum analyzer and optical spectrum analyzer.

P_i = -1.88 dBm = 0.64863 mW sin wave ,
P_i = -2.333 dBm = 0.58438 mW pulse.

For L = 2 km lenghth multimode fiber (MMF), attenuation of 1 dB/km, core diameter = 50 µm, cladding diameter = 125 µm, P_i from attenuator = 0 dB, P_o = -15.6 dBm = 0.02754 mW, and P_i = 0.04364 mW, the total input power P_i (total) to transmitter was :
P_i (total) = 2000.04364 mW, therefore, Raman power (P_R) = 2000.04364 mW., P_i (total) = 0.6561 mW therefore, Brillouin power (P_B) = 0.6561 mW.

For L = 3 m length singlemode fiber (SMF), attenuation of 0.06 dB, core diameter = 10 µm, cladding diameter = 125 µm, P_i from attenuator = 0 dB, P_o = -3.7 dBm = 0.42657 mW, and P_i = 4.3251 mW,
P_i (total) = 1000.43251/3 = 0.33347mW, therefore, Raman power (P_R)= 0.33347mW, P_i (total) = 4.3251 mW, therefore, Brillouin power (P_B)= 4.3251 mW.

For L = 10 m length SMF, attenuation of 0.2 dB, core diameter = 10 µm, cladding diameter = 125 µm, P_i from attenuator = 0 dB, P_o = -4.05 dBm = 0.39355 mW, and P_i = 41.2 mW.
P_i (total) = 1000.412 mW, therefore, Raman power (P_R)= 1000.412 mW., P_i (total) = 41.2 mW, therefore, Brillouin power (P_B)= 41.2 mW

Equations (2) and (3) were employed for SMF with lengths of 10 m and 3 m. Theoretical values were compared with practical values (Table 2). The two powers P_R and P_B theoritical values compared to the practical obtained in this work given in Table (2). For MMF, Equations (2) and (3) cannot be used, as they are only applicable for single mode fibers.

TABLE 2 Summary of results

Fiber length	P_B **Practical**	P_B **Theoretical**	P_R **Practical**	P_R **Theo.**
10 m	41.2mW	29.7mW	1.000412W	1.534W
3 m	4.3251mW	8.923mW	0.33347W	0.4602W

The difference between theoritical and practical powers given in Table (2) because practically the optical fiber impairements like dispersion, attenuation , bending and scattering affects theses powers, in this work the management of the powers for minimum affects of theses impairements has been reduced as shown in Figures 3-6. Figs. 3–5 illustrate the relation between Brillouin and Raman power versus fiber length, attenuation, and cell radius, it is shown that for 4G mobile system which coverage between 2-3 km, the powers P_B and P_R will be (0.008-0.014) and (0.48-0.54) watts respectively,

Fig. 6 shows the relation between input and output powers for different fiber lengths, it is shown that increasing the fiber length needs more input power and leads grater output power, Fig. 7 demonstrates the relation between frequency and output power, it is shown that different frequencies leads in different input and output power depends on the fiber type singlemode or multimode, Figs. 8–11 denote the output signal spectrum, as shown in the details in the figures. Finally, Fig. 12 presents the experiment setup of RoF used in the present study. The equipment utilized a spectrum analyzer optical spectrum analyzer, RoF transmitter, RoF receiver, RF generator, optical fiber cables (3 m and 10 m SMF), and 2 km MMF.

The novelty and originalty of this work delas with the 4G mobile system network architecture management and are :

- In the proposed base stations connections using RoF technique.
- How to manage the powers launched into fiber.
- Minimization of he impairements during system installation and system service.
- Practically how can be the 4G mobile system base stations links be more relaiable through the use of RoF.

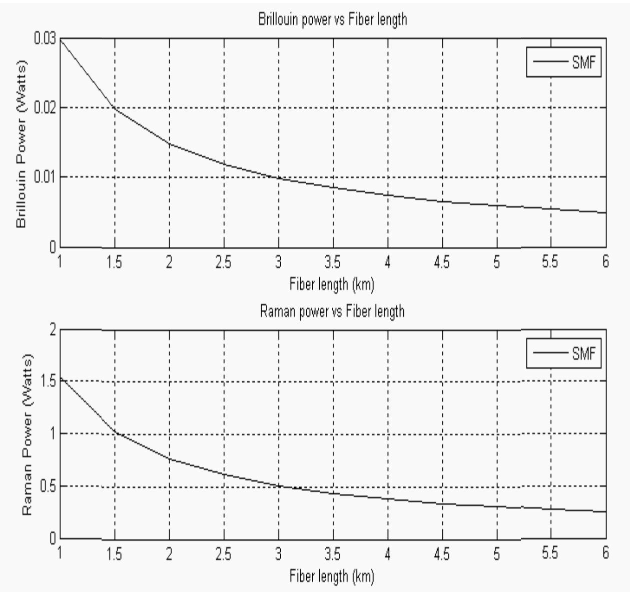

Fig. 3 Brillouin and Raman powers vs Fiber length

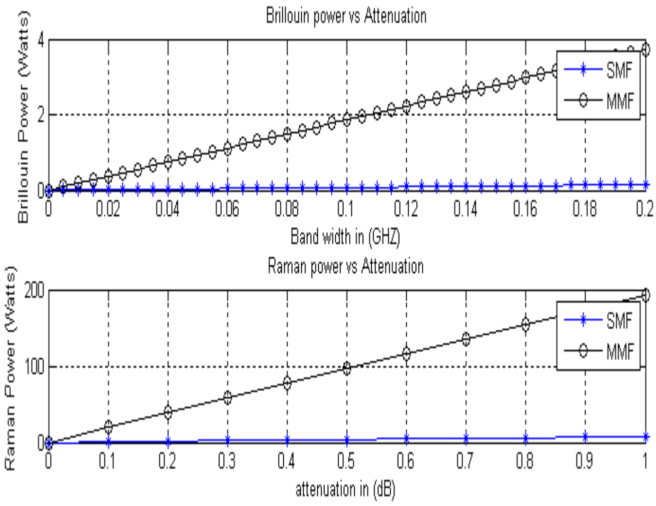

Fig. 4 Brillouin and Raman powers vs Attenuation

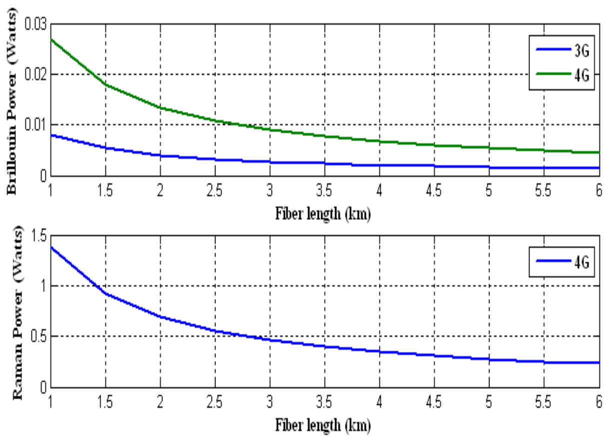

Fig. 5 Minimum and Maximum power vs. Cell radius

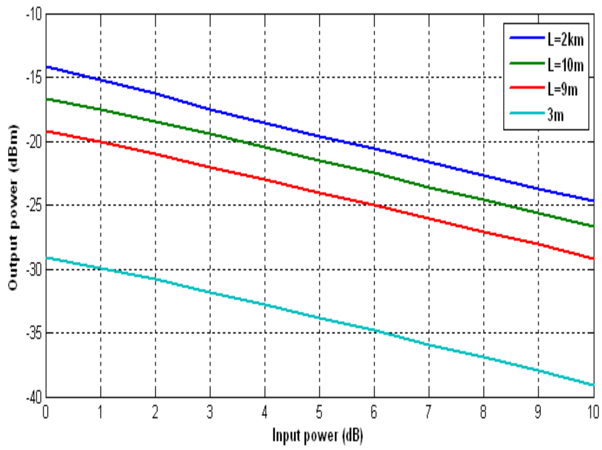

Fig. 6 Input power vs Output power

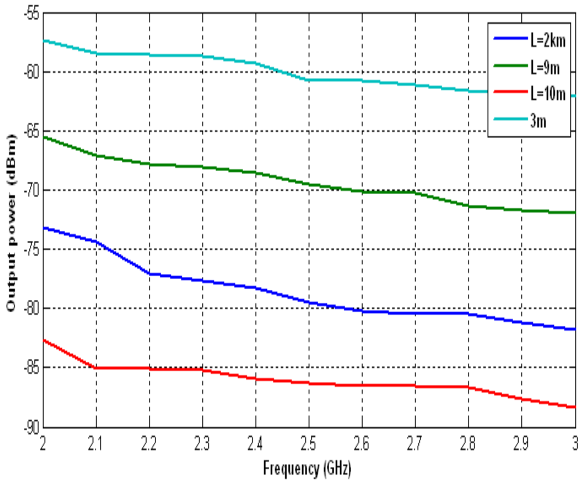

Fig.7 Frequency vs Output power

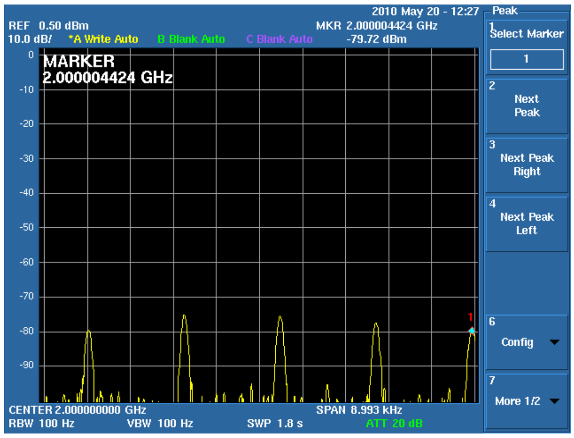

Fig. 10 Output power spectrum for 2 GHz with pulse input

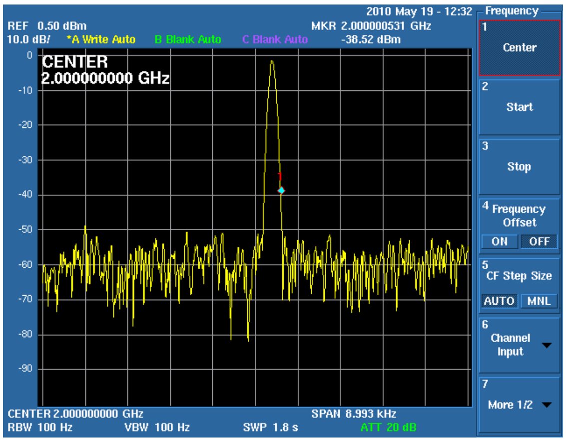

Fig. 8 Input power spectrum for 2 GHz carrier frequency

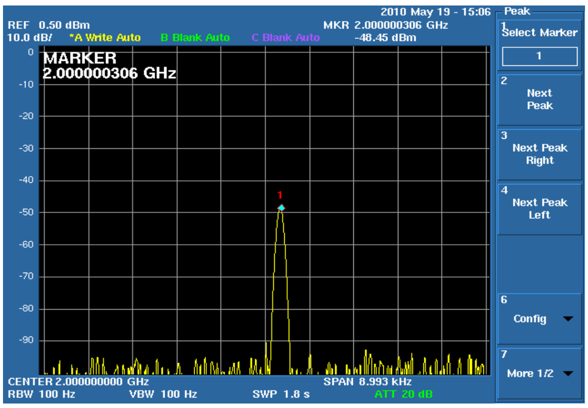

Fig. 9 Output power spectrum for 2 GHz carrier frequency with sin wave input

Fig. 11 Experimental setup components and connections

6 Conclusions

This paper describes 4G mobile base station distribution, connections, and power management. The RoF link (i.e., fiber optic) determines and optimizes the threshold minimum (Brillouin power) and maximum (Raman power) powers launched into the fiber. These can ensure better signal transmission and reception for the base station in the network. In addition, the frequency effect and attenuation level are explored. For long distances, results demonstrate that the SMF fiber has more advantages for multiple signals multiplexed using one of the multiplexing techniques for example Wave Division Multiplexing (WDM), however, for short distances, MMF is a better option. Meanwhile, as the 4G base station covers about 2-3 km radius, the SMF is preferred.

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