RECOMMENDATION ITU-R F.1332*

RADIO-FREQUENCY SIGNALS TRANSPORTED THROUGH OPTICAL FIBRES

(Question ITU-R 204/9)

(1997)

The ITU Radiocommunication Assembly,

considering

a) that optical fibres are widely used in subscriber networks or in-building wiring;

b) that radio-frequency signals transported through optical fibres may be applied to access links to radio base stations in many wireless applications;

c) that the reduction of equipment at the radio base station is realized by the above technique;

d) that the above technique has advantages in maintenance and operation aspects,

recommends

1 that the basic configuration of a fibre-radio system in which radio-frequency signals are transported directly through optical fibres is given in Fig. 1;

2 that by using a fibre-radio system the following advantages are expected:

– intensive deployment of modulators and demodulators in a central station (CS) contributes to simplification of equipment at out stations (OS) as well as maintenance and operation cost reduction;

– a spectrum delivery switch presented in Fig. 2 may reduce the total number of radio channels required for all the OSs in the multiple access scheme;

3 that possible applications to the fixed service using a fibre-radio system are given in Table 1;

4 that when using high-frequency bands above about 10 GHz, the centre frequency of a modulator may be selected to be in intermediate frequency (IF) bands;

5 that for the design of fibre-radio systems the technical information contained in the Annex 1 can be referred to.

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* This Recommendation should be brought to the attention of Radiocommunication Study Group 8 (Working Party 8A) and Telecommunication Standardization Study Group 15 (Working Party 4).

TABLE 1

Possible applications for the fixed service using fibre-radio systems

Service area	Indoor	Outdoor	
Application	Radio local area network (RLAN)	Wireless Local Loop (WLL)	Transportable service
User's terminal	Local area network (LAN) module	Cellular system terminal for fixed use point-to-point/ point-to-multipoint fixed terminal	Transportable video/ data terminal
Possible RF(1)	UHF/SHF/EHF	UHF/SHF	SHF/EHF
Access scheme in the radio link	TDMA/CDMA	TDMA/CDMA/FDMA	TDMA/CDMA/FDMA

TDMA: time division multiple access

CDMA: code division multiple access

FDMA: frequency division multiple access

(1) UHF (decimetric waves): 300-3 000 MHz
SHF (centimetric waves): 3-30 GHz
EHF (millimetric waves): 30-300 GHz.

ANNEX 1

1 Introduction

In future broadband integrated services digital networks (B-ISDNs) optical fibres will be extensively introduced in subscriber networks realizing the concept of what is called fibre-to-the-office (FTTO) or fibre-to-the-home (FTTH). On the other hand, customers may wish to use various services provided by a B-ISDN in wireless applications. These applications include WLL, transportable data/video terminals or transportable personal computers used for RLAN modules. In order to satisfy these demands, it will be effective to introduce fibre-radio systems in which radio-frequency signals are transmitted directly through optical fibres.

This Annex discusses the basic concept and technical basis of fibre-radio systems.

2 Basic configuration of fibre-radio systems

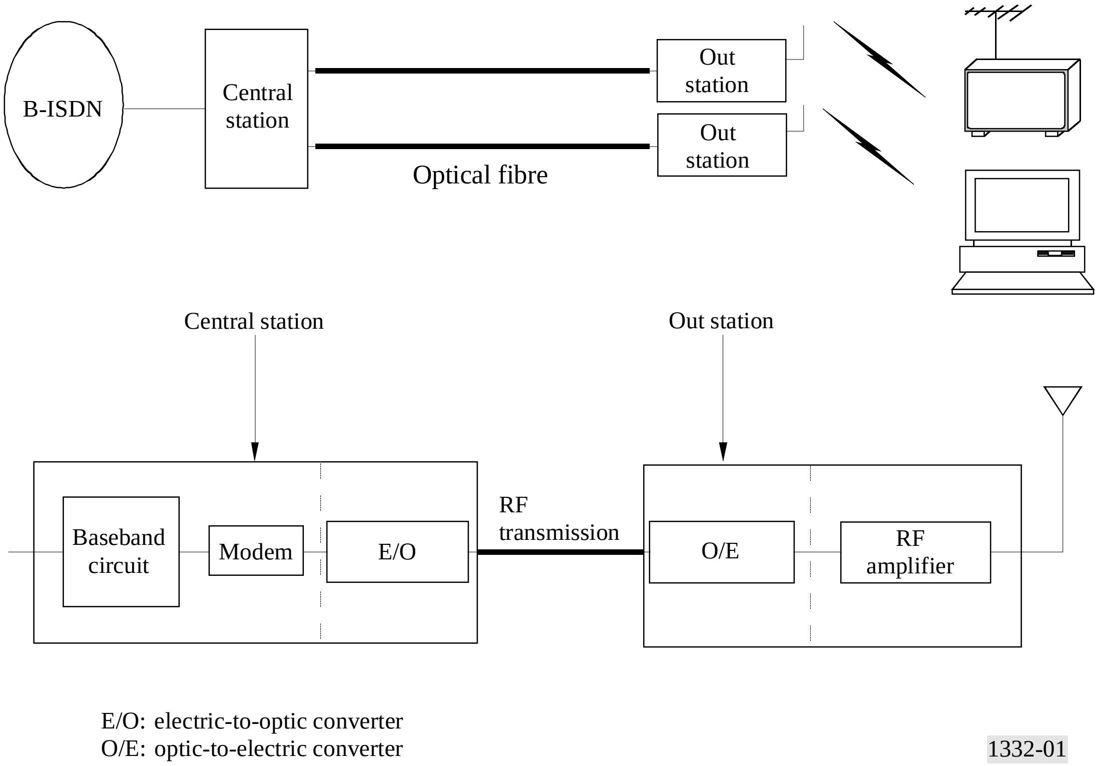
As shown in Fig. 1, a fibre-radio system is composed of a CS, OS and optical-fibre links connecting these stations. It can form an infrastructure for access networks providing wireless services to users' terminals.

In conventional digital radio equipment, a modulator/demodulator and a power amplifier are generally installed at the same station. However, in fibre-radio systems a CS is equipped with several modems which are commonly used for more than one OS (see Fig. 2). The system presented in Fig. 2 often requires a multiple access technique to cope with traffic demands from many wireless terminals. CS also has a function to control the access technique efficiently utilizing the frequency spectrum. In such cases, the relation between CS and OS corresponds to that of point-to-multipoint radio systems for subscriber networks.

In Fig. 2 a spectrum delivery switch (SDS) installed at the CS is one of centralized control methods. It can assign any radio carrier to any OS according to the traffic demand. This dynamic channel assignment with the SDS effectively improves blocking probability. In other words, SDS reduces the total numbers of radio channels required for all the OSs for a fixed blocking probability.

FIGURE 1

Basic configuration of fibre-radio system



However, there is a technical upper limit for the radio frequency to be transmitted through optical fibres due to the operating speed of the E/O (and O/E). When a cost-effective E/O (and O/E) is required to implement fibre-radio systems, an IF transmission could be suitable since the cost effective E/O (and O/E) operates within the IF bands. After being transmitted over the optical fibre link, the IF carriers are converted into radio frequencies at the out station (see Fig. 3).

3 Application of fibre-radio systems

Figure 4 illustrates two categories of the application of fibre-radio systems. In Fig. 4a) an OS works as a central module for a RLAN operating at each office room, while the CS controls the assignment of radio channels used by all the OSs. As illustrated in this Figure, fibre-radio systems have the following merits:

– Since a modulator/demodulator is separated from a power amplifier in this system, equipment in an OS becomes smaller. Thus, efforts for site selection of OSs can be reduced.

– CS equipments including network interfaces and service units which provide voice service, digital packet service and so on are concentrated in one room. For that reason, maintenance work and replacement of any equipment is efficiently done in a short time.

Figure 4b) gives an example of outdoor applications. An OS provides wireless access link to individual homes within a service coverage. The function of the CS is almost the same as for indoor systems and the above merits can also be expected in this application. In conventional systems, since radio equipment is usually installed on a high pole, some danger is unavoidable in maintenance works. However, in fibre-radio systems, such works can be much reduced.

FIGURE 2

Radio spectrum distributing equipment at the central station

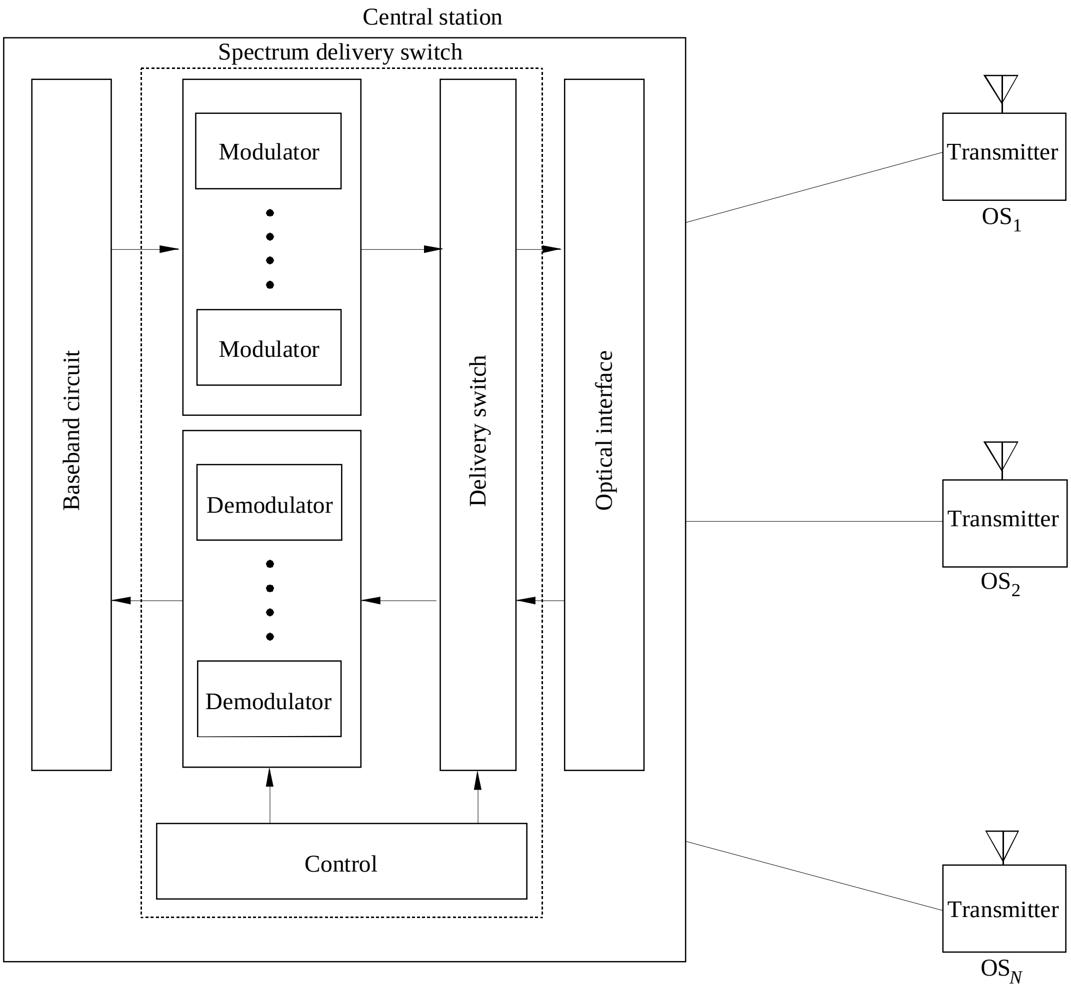


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FIGURE 3

IF transmission in fibre-radio systems

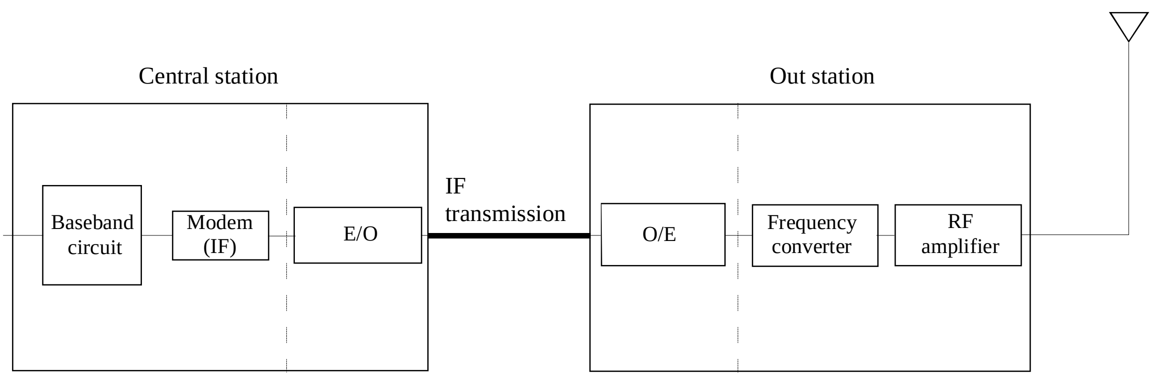

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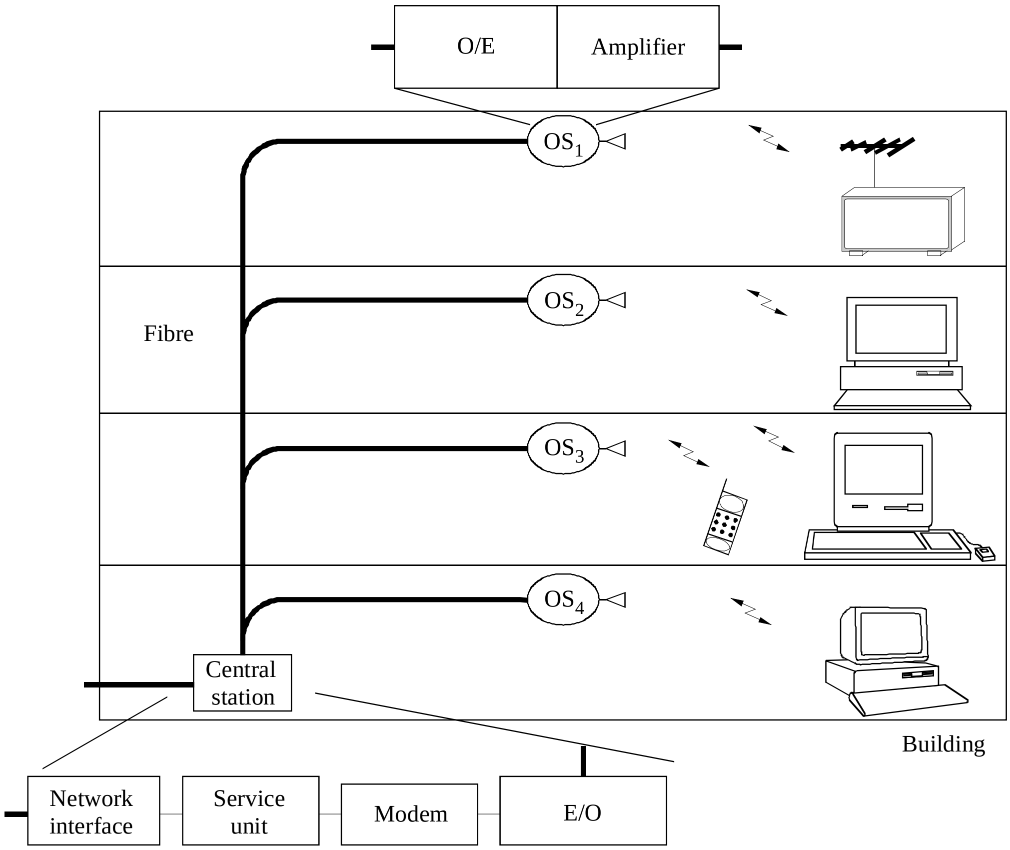
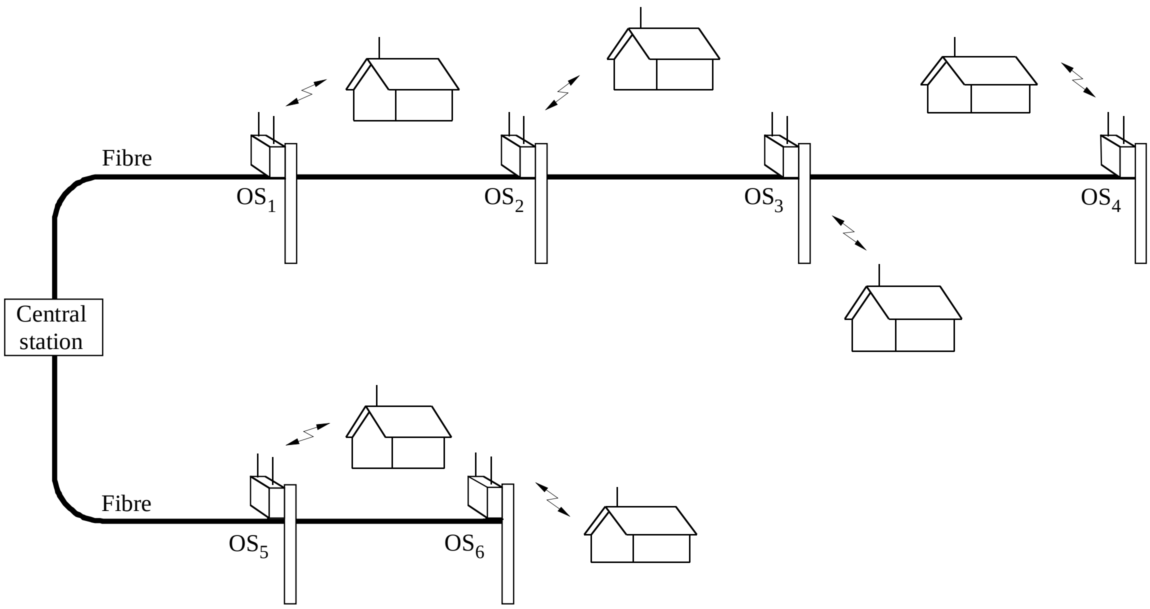
FIGURE 4

Examples of wireless applications using fibre-radio systems



a) Indoor application



b) Outdoor application

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4 Technical subjects

Fibre-radio systems generally use a subcarrier multiplexed (SCM) technique. At the E/O side, several outputs from the modulators with different frequencies are multiplexed in the combiner. Then the combined signal composed of the several subcarriers directly modulates the laser diode (LD). Thus, the subcarriers can simultaneously transmit through the optical fibre. The LD produce a modulated optical signal whose intensity is proportional to the input electrical current.

In the opposite direction, a photodiode in the O/E converts the received optical power into electrical power with a linear response. Each desired radio channel is separated by an electrical filter after the photodetection.

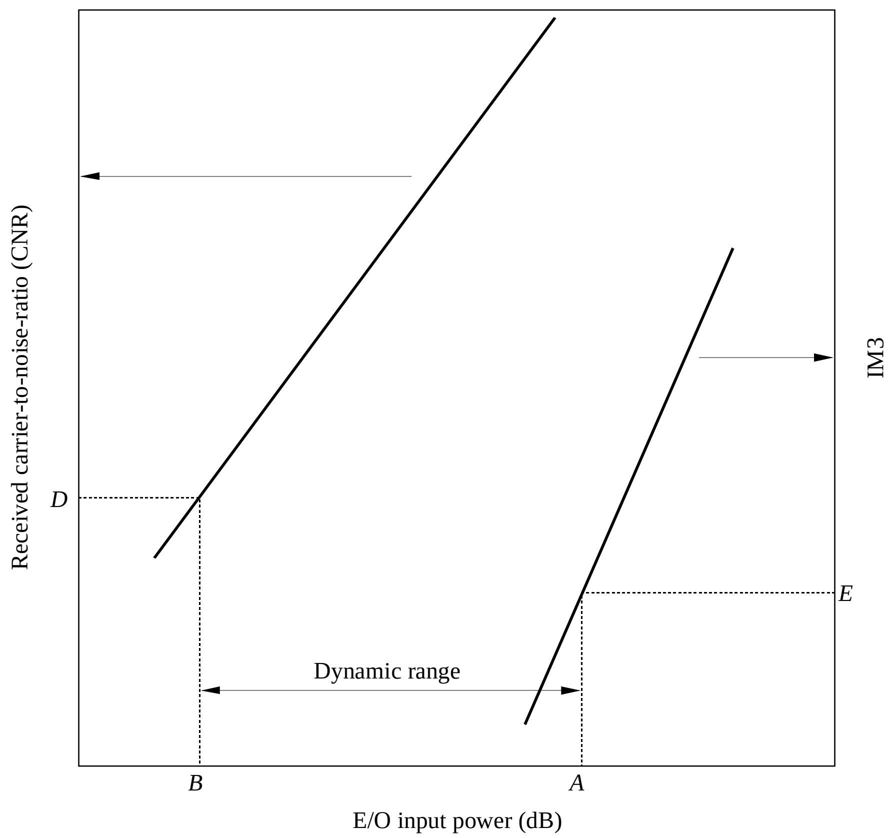
For outdoor microcell applications, the received signal power is subject to a slow or shadow fading and decreases according to the well-known inverse fourth-power law between an OS and a wireless terminal. When an OS loses line-of-sight condition, the received signal drops sharply due to the diffraction loss.

Since two or more signals with quite different levels are commonly received at the OS receiver, it is difficult to select a suitable gain for all the signals. Therefore, for the uplink (from OS to CS) a fibre-radio system needs a wide dynamic range. This is called a near/far problem. The dynamic range is limited by the noise and non-linear performance of the whole link. It is important to improve the non-linearity of the optic devices as well as radio equipment.

The non-linearity of the E/O mainly determines the upper limit of E/O input level. In Fig. 5 the input level of *A* produces the maximum permissible IM3 level of *E*. On the other hand, the lowest limit of E/O input level is decided by the required carrier-to-noise-ratio (CNR) *D* corresponding to the level of *B*. In this case, the dynamic range of the E/O converter is defined by (*A* – *B*) dB.

FIGURE 5

Dynamic range of fibre link



D: required CNR (threshold level)
E: maximum permissible IM3 level

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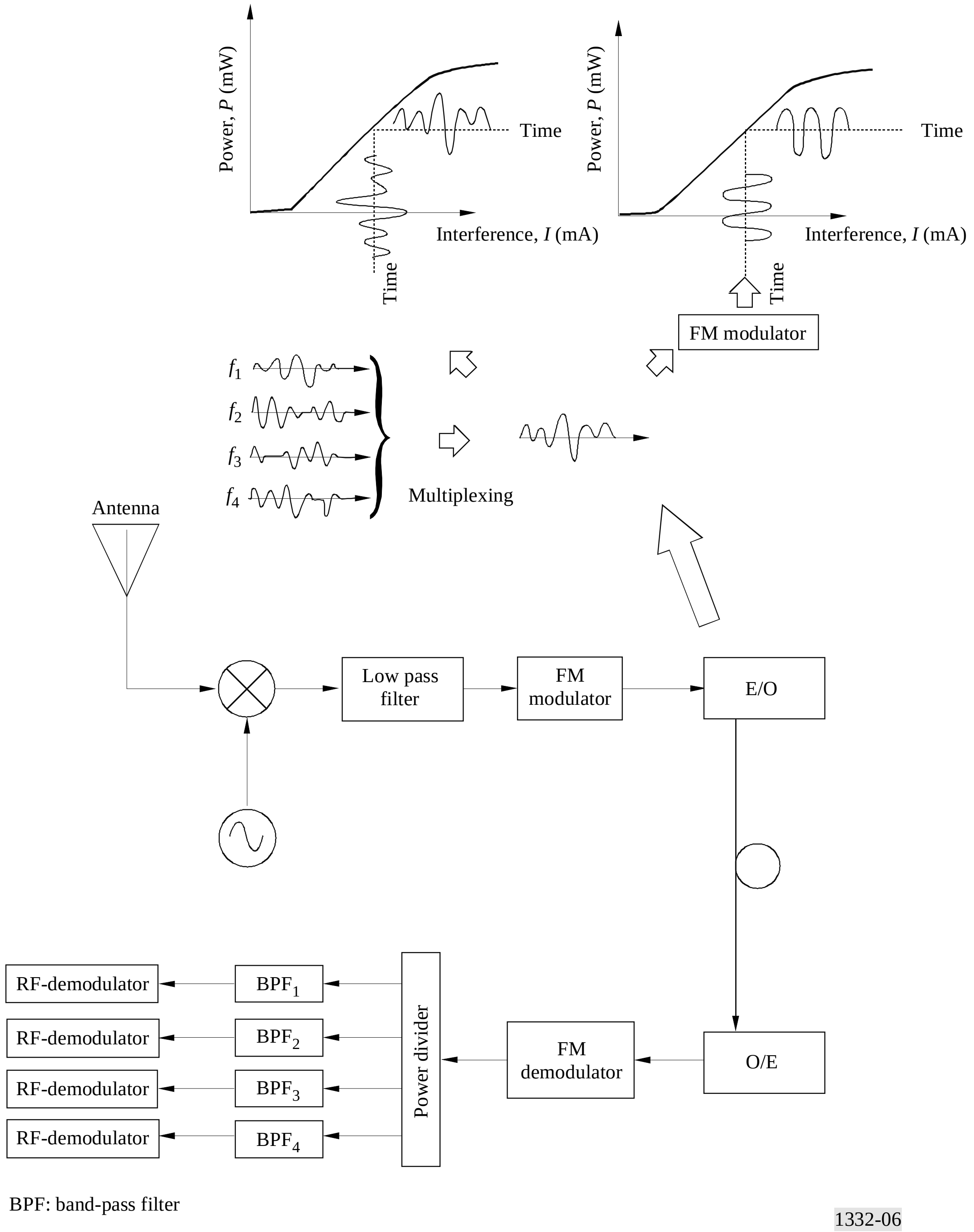
An improvement technique using an FM modulator has been proposed for increasing a dynamic range. Figure 6 illustrates overview of this method. When using the conventional method, the low-level carrier is likely to be affected by IM3 interference due to the non-linearity. On the other hand, the input signal level to the E/O converter is kept constant by using an FM modulator. Although the bandwidth of the FM signal varies depending on the highest frequency and peak voltage of the modulation signal, the peak injection current of the LD is almost fixed.

FIGURE 6

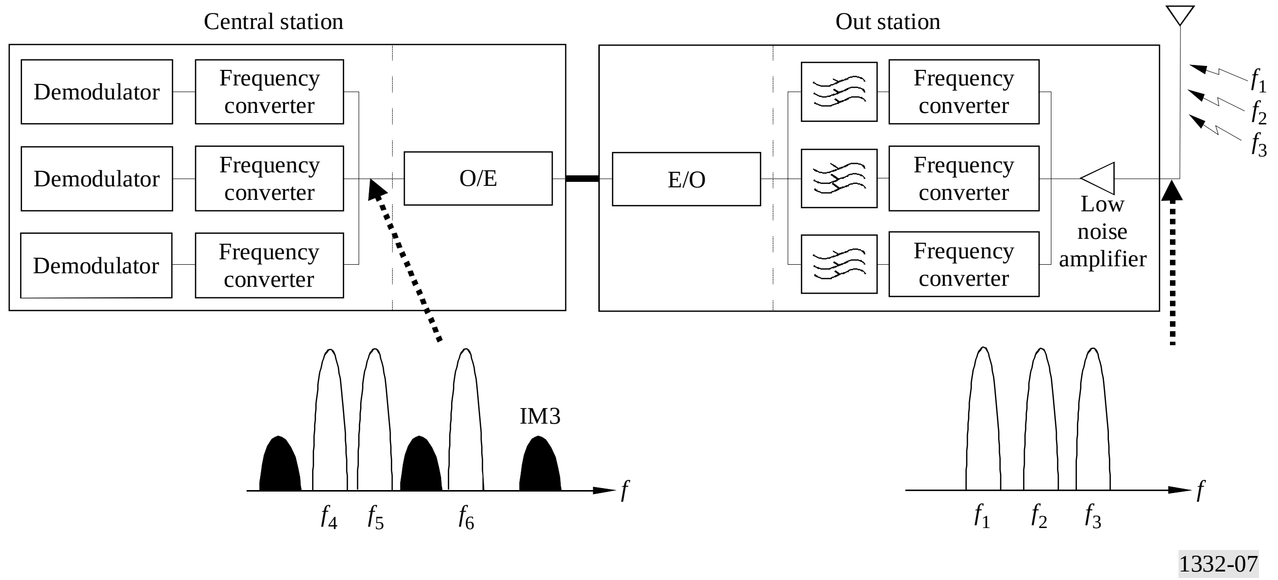
Overview of FM technique for the uplink



Signal extraction and frequency arrangement (SEFA) on fibre has also been proposed as a way of increasing the dynamic range as shown in Fig. 7. In this technique, undesired signals from other cells are removed before optical modulation. By extracting the desired signals whose frequencies are f_1, f_2 and f_3 in OS, and then converting their frequencies to f_4, f_5 and f_6, respectively, the two-tone type signal of IM3, $2f_2 – f_1$, may not interfere with the signal of f_3. The frequency converted signals modulate the LD. Of course, each extracted signal power can be adjusted by an automatic gain control (AGC) or a limiter. Since LD non-linearity can be ignored, SEFA can increase the optical modulation index leading to the CNR improvement.

FIGURE 7

Principle of signal extraction and frequency arrangement (SEFA) technique



Permissible optical loss should be determined including the loss of the optical connectors so that the total carrier-to-noise performance could meet according to various radio modulation schemes. Fibre delay between a CS and OSs is one of the key parameters, in particular for TDMA-TDD (time division duplex) systems. A radio signal is delayed by fibre transmission approximately by 5 µs/km for a single-mode fibre compatible with ITU-T Recommendations G.652, G.653 or G.655. This delay over the two-way link may exceed the guard time between the transmitting and receiving timing.