FIXED LOW FREQUENCY BROADBAND WIRELESS ACCESS RADIO SYSTEMS

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Abstract

This paper provides an overview of fixed low frequency (less than 11 GHz) wireless access radio systems for point-to-multipoint voice and data applications. From the product system requirements, design of the radio subsystem is defined and current radio technologies are presented, as well as analysis of microwave transmission.

I – Introduction

Fixed broadband wireless access (BWA) is a communication system that provides digital two-way voice, data, internet, and video services. BWA low frequency radio systems, 2.5 GHz (MMDS), 3.5 GHz, and 10.5 GHz, are presented. The BWA market targets wireless multimedia services to home offices, small- and medium-sized businesses and residences. The BWA system has a point-to-multipoint architecture comprising of customer premise equipments (CPE), and base stations (BS), as in Fig. 1. The BS and CPE may include an

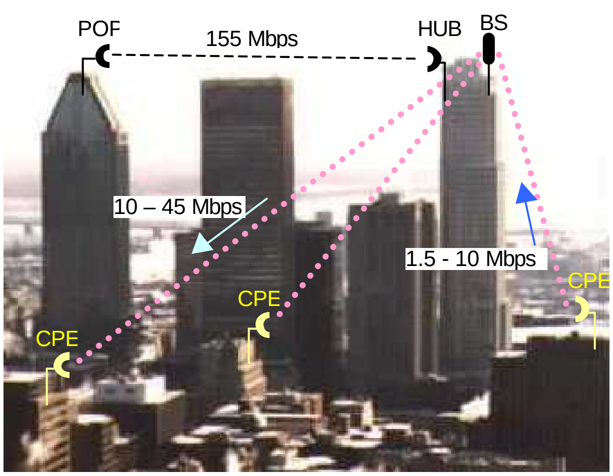

Fig. 1. BWA point-to-multipoint network.

Outdoor Unit (ODU) which includes the radio transceiver and antenna, and an Indoor Unit (IDU) for modem, communication and network management (see Fig. 2). The two units interface at an intermediate frequency (IF).

First, the product system requirements are reviewed. Then, the radio unit is considered, comparing modulation schemes, radio architectures, the influence in transceiver performance, as well as transmission analyses.

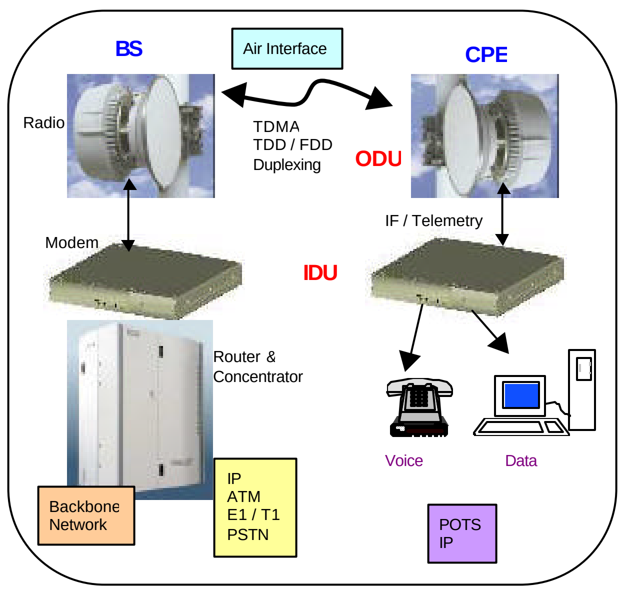

Fig. 2. BWA system elements.

II – Product System Requirements Overview

A BWA system is comprised of at least one base station and one or more subscriber CPE stations. The BS assigns the radio channel to each CPE independently and according to the policies of the Medium Access Control (MAC) air interface (see Fig. 2). Time in the upstream channel is usually slotted, providing for Time Division Multiple Access

(TDMA). Each CPE station can deliver the voice and data using common interfaces, such as POTS, Ethernet, and E1/T1. The BS grooms the voice and data channels of several carriers and provides connection to a backbone network (i.e., IP or ATM) or transport equipment. Each BS has a certain available bandwidth per carrier that can be fully or partially allocated to a single CPE either for a certain period of time (i.e., variable bit rate (VBR), Best-Effort), or permanently (i.e., constant bit rate (CBR)). BWA systems are envisioned to work with a TDMA rather than a CDMA scheme. This TDMA access scheme can be applied to either frequency division duplexing (FDD) or time division duplexing (TDD) [1]. Both duplexing schemes have intrinsic advantages and disadvantages, so the optimum duplexing scheme to be applied depends on deployment-specific characteristics, i.e., bandwidth availability, Tx-to-Rx spacing, and traffic usage.

Table 1 gives the system characteristics for each BWA low frequency product. Cost is an important issue that has to be addressed from the first stage of the product design. BWA systems must offer a low cost solution, as well as a compact footprint and must be virtually maintenance free.

Table 1. System characteristics.

Product	MDS / MMDS	3. 5 GHz	10.5 GHz
Frequency (GHz)	2.1-2.3 / 2.5 – 2.686	3.4 – 3.6	10.15 – 10.65
Tx/Rx Spacing (MHz)	300 / 48	100	350
Channelization (MHz)	6	5	7
CPE upstream capacity (Mbit/s)	9.6	8	10
CPE downstream capacity (Mbit/s)	20	17	23

III – Radio System

1) Radio Frequency Subsystem

There are many ways to implement the RF subsystem. In addition to meet all the functional, performance, regulatory, mechanical, and environmental requirements, the radio system is to achieve the most of the following criteria: a) Cost effectiveness; b) Easy to maintain; c) Easy to upgrade; d) Easy to install; d) Attractive appearance; e) Flexible; and f) Scalable.

a) Radio Hardware Description

Figure 3 shows the block diagram of the outdoor radio unit which consists of the transmit and receive paths, frequency sources, a diplexer connected to the antenna, and a cable interface to connect to the indoor modem unit.

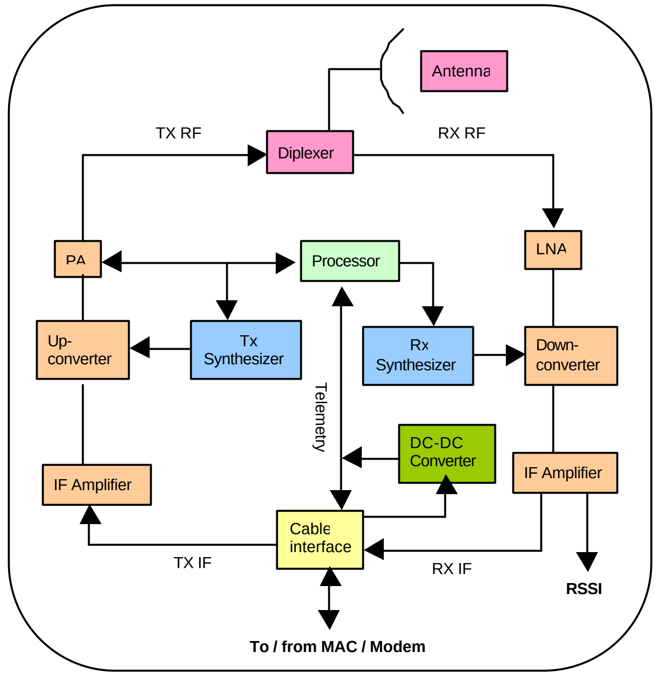

Fig. 3. Outdoor radio block diagram.

b) Modulation Schemes

The modulation scheme chosen for the radio system depends on several product definition factors, such as required channel size, upstream and downstream data rates, transmit output power, minimum carrier to noise ratio (C/N), system availability, and coverage. Table 2 gives the characteristics for QPSK and QAM signals typically used for BWA systems.

Table 2. QPSK and QAM modulation typical characteristics for a 6 MHz channel bandwdith.

Modulation	Bits/s/Hz	Data rate (Mbps)	C/N for 10^{-6} BER
QPSK	1.6	9.6	13.5
16-QAM	3.4	20.16	17.6
64-QAM	5	30.24	23.8

A system can require symmetric or asymmetric capacity depending on its specific application. For a symmetric capacity system, upstream and downstream traffic is equivalent, whereas for an asymmetric system usually the downstream requires more capacity. Hence, higher level modulations with higher capacity are better suited for downstream transmissions. Using n-QAM modulations for downstream transmissions become advantageous, whereas QPSK can be used for the upstream direction.

Since lower level modulations perform better in more constrained environments, they can be not only used in burst, low-power, low-capacity or upstream transmissions, but also adjusted dynamically in link fading conditions.

c) Radio Intelligence

A minimal of "intelligence" is required in the radio to control the power level throughout the transceiver. Development of software controlled radios are presently under way, but the issue of cost-effectiveness remains. Typically for residential markets, cost is the main factor that comes into play, hence, simpler design by limiting the radio "intelligence" may translate into a lower performance product. Software controlled radios present many advantages, such as reducing hardware complexity, but it is up to the design engineers to compromise for high performance, low cost, and flexibility of the product.

A "dumb" transceiver diagram is shown in Fig. 4. It includes an open loop gain control on the receive (RX) path. A microcontroller controls the phase lock loop (PLL) for the transceiver synthesizer and can put the power amplifier (PA) into mute mode. Single up/down conversion stages further reduces the overall cost, but at the expense of lower radio performance. Two separate IF cables simplify the interfacing.

An "intelligent" transceiver involves more digital and software controlled circuitry. Figure 5 shows a diagram which includes closed loop gain control and cable compensation on the transmit and receive paths; i.e., power detection circuits on Rx IF, Tx chain, and PA. The transmitter mutes on lock detect and on no Rx signal. The microcontroller provides for the receive signal strength indicator (RSSI) level for antenna

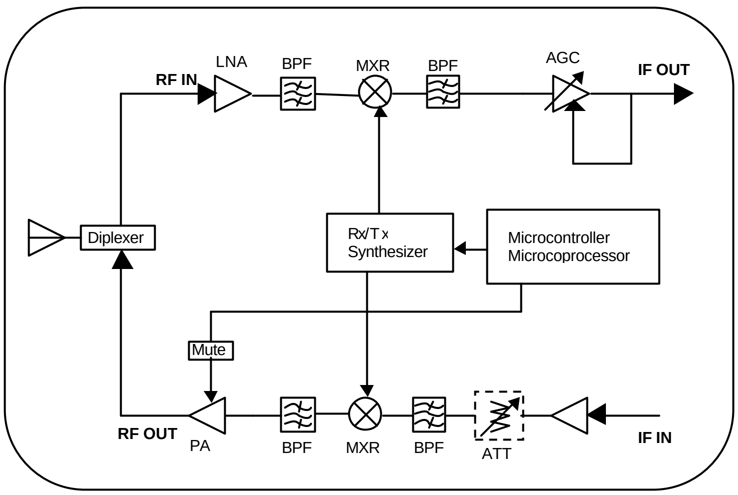

Fig. 4. "Dumb" transceiver block diagram.

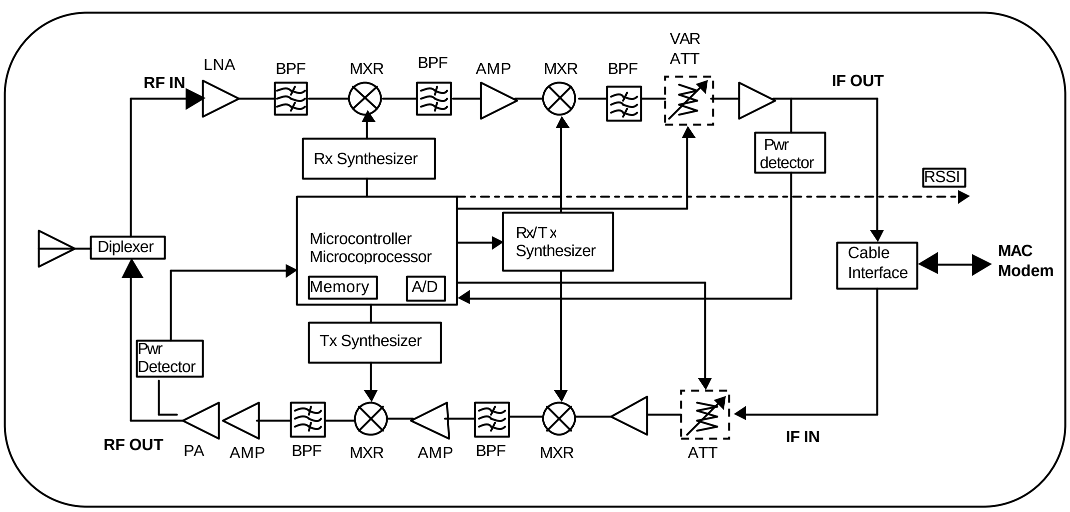

Fig. 5. "Intelligent" transceiver block diagram.

alignment, and for control and monitor channels. A single cable interfaces both input and output IFs from the modem.

2) Radio Transmission System

The maximum cell size for the service area is related to the desired availability level. Principal factors affecting cell radius and availability include the rain region, the antenna and its height, foliage loss, modulation, Tx power, Rx sensitivity, and sectorization. These effects are generally related to the service area such as dense urban, suburban and low density. As an aid to determine these parameters, a powerfull point-to-multipoint RF engineering tool is used to estimate the maximum distance between the BS and the CPE while maintaining the desired link performance and availability in a single or multihub environment. Table 3 gives some typical radius coverage range for each product. Taken into account are the margins required to combat the multipath fading, rainfall attenuation, and interferences. The effect of the rainfall attenuation on 2.5 GHz is negligeable but noticable at 10.5 GHz.

Table 3. Typical coverage range for each product.

Radius Distance	Frequency
24 km (15 mile)	2.5 GHz
19 km (12 mile)	3.5 GHz
8 km (5 mile)	10.5 GHz

3) Base Station Requirements

The BS is divided into a number of sectors to accommodate all receiving signals and cumulative traffic from the CPEs. The number of cell sectors affects the cost per cell and complicates the cell planning, but also increases the capacity of the system. Figure 6 shows an example of a 4 sector radio / antenna deployment on a tower. To avoid interruption where a failure occurs, the BS must be a redundant unit, hence, one scheme is to have two radios included in the same enclosure with an RF switch.

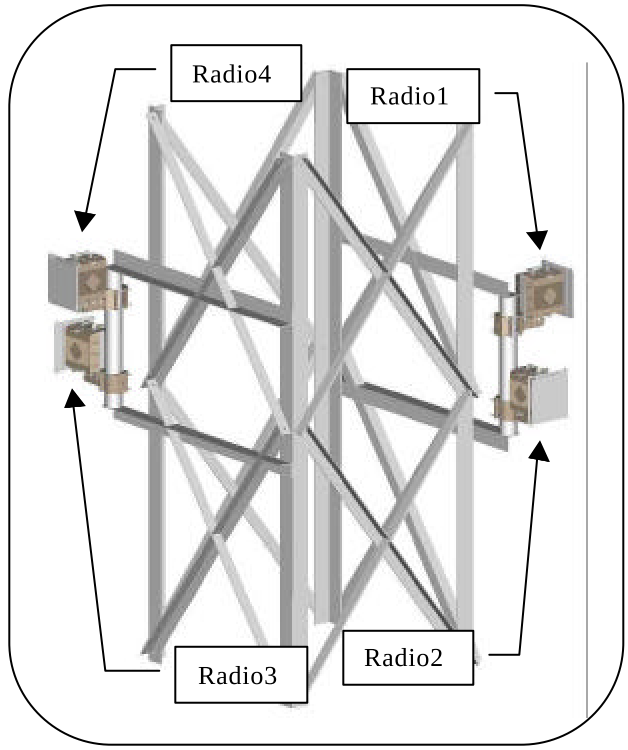

Fig. 6. Base station example of radios deployed in 4 sectors mounted on a tower.

IV – Conclusions

System requirements and radio architecture design for fixed wireless broadband products, such as MMDS, 3.5 GHz, and 10.5 GHz systems, were presented. System design teams must propose a cost-effective, as well as a high performance product to accommodate the BWA market.

V – References

[1] J. Klein, “TDD vs. FDD: The Drive for Effective Bandwidth Management”, *RF Design*, August 1999, pp. 36-55.