NEW DOCSIS COMPLIANT WIRELESS TRANSIEVER: A LOW-COST, FAST DEPLOYMENT FOR IMMEDIATE REVENUE GENERATION

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Abstract

This paper describes a low-cost wireless transceiver system that can be introduced as an alternative solution for difficult return-path environments. The design challenges of such a transceiver system are discussed for both CATV and SMATV bands. The lack of a guardband in the CableLabs DOCSIS protocol has been resolved by a novel frequency plan. Also, innovative techniques have been introduced for system automatic gain control and phase locking. Two-way digital testing of the new low-cost transceiver system has shown complete support of the DOCSIS protocol. Finally, testing has demonstrated full Federal Communications Commission (FCC) compliance for the wireless transceiver system.

INTRODUCTION

Emerging from distributing analog video to the perfect pipeline for advanced services like high-speed data and digital video, the cable television industry is faced with ever-increasing demands from its business and residential clients to expand advanced service offerings [1].

Thanks to cable's broadband infrastructure and pervasive networks, the growth of residential high-speed Internet services has been remarkable during the past year [2]. In reaction to such growing demand, CableLabs has introduced two-way system standards by establishing the DOCSIS protocol. However, in some cases the process of adding return-path to an existing network is hampered by lack of access to support structures, long physical distances or budgetary issues, allowing another ISP to attract the customer by using technologies like DSL or DBS.

This paper describes a cost-effective wireless solution developed to tackle the return-path issue. In addition, the system can be used for extending services to areas where no cable network currently exists. The solution developed by *AML Wireless Systems Inc*. is a full-duplex product incorporating the *ACCESS Transceiver* located in a hub site and an *ACCESS Receiver* placed at the headend facility. The purpose of this paper is to discuss the design challenges of such a transceiver system for both CATV and SMATV bands.

The major design barrier is the lack of a guardband for the DOCSIS protocol between the uplink and downlink frequencies. This issue becomes particularly important for a cost-effective system incorporating a single-polarized antenna at both ends. Two DOCSIS compatible plans for solving these guardband issues have been proposed, meeting the FCC constraints at 13 and 18 GHz frequencies. Another design issue considers upstream phase locking. Because the return-path signal is located in the upper portion of the band, sending the standard pilot-tone would be technically impractical. A lack of phase-lock will result in unwanted phase deviation at the local oscillator, degrading the phase noise and resulting in potential jitters at the receiver. This will be particularly problematic for some cable modems that incorporate CDMA techniques [3]. This solution introduces a pilot-tone used for phase-locking purposes as well as AGC operation. New block up/down converters have been designed to interface with the cable modem and CMTS equipment at the hub and headend respectively. In order to maximize the available bandwidth, a special filter design has been incorporated to shrink the guardband to less than 13 MHz.

The new cost-effective transceiver system has been tested digitally in full two-way implementations. Downstream results for 256QAM modulation resulted in 35 dB of MER and the upstream link has shown full-band transparency for QPSK, 16QAM and even 64QAM. Additionally, the results of FCC tests (for spurious levels, signal leakage, spectral regrowth and frequency stability) have demonstrated full compliance for the return-path transceiver.

DESIGN CONSTRAINTS

Developing a wireless transceiver, specifically for cable television services, requires careful attention to the legal rules and conditions that apply to licensed band implementations. In particular, a return-path radio connecting to fiber nodes must satisfy the following conditions:

- Transmitting standard VHF channels as specified by ANSI.
- Complying with FCC regulations for fixed wireless services.
- Adapting the constraints imposed by the DOCSIS protocol for two-way data over cable services.

In order to deploy a wireless link, the cable service provider has to obtain a license for operating at CARS-band (13 GHz) or SMATV-band (18 GHz). The following design criteria are applied to the radio:

1. It should transmit the standard channel array without any change or spectrum reversal.
2. The system should comply with FCC regulations.
3. The radio should operate in accordance with DOCSIS requirements. i.e. multichannel video plus up to 256QAM data downstream, as well as QPSK/16QAM data transmission in the upstream path.

Frequency Plan

Based on DOCSIS, the return-path has been specified as 5 to 41 MHz. However 13 and 18 GHz radio links will employ different frequency plans to satisfy the FCC constraints as discussed below:

(A).13 GHz Return

The FCC limits the bandwidth of the 13 GHz CARS-band to 500 MHz, ranging from 12.7 to 13.2 GHz. A cost-effective solution is made possible by accommodating the upstream channels within the CARS-band. A suggested plan is shown in Figure 1.

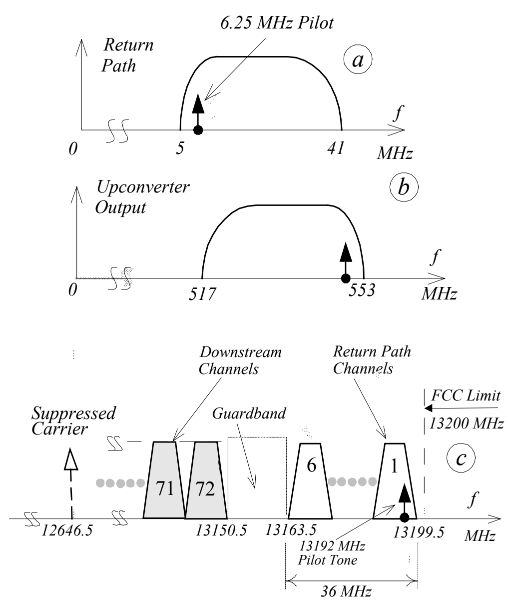

Figure 1. Frequency plan of 13 GHz return-path. (a) baseband signal with pilot-tone, (b) upconverter output, (c) microwave spectrum.

Figure 1(a) shows the return-path signal. The design feature introduces a 6.25 MHz pilot-tone for AGC and phase-locking purposes. The pilot-tone has been located close to the band edge to avoid interference with the inband carriers. The output of a VHF upconverter module is reversed as shown in Figure 1(b), shifting the pilot-tone to the upper edge of the spectrum. Finally, the upstream microwave spectrum is shown in Figure 1(c), where the return-path signal and its guardband occupy the last eight channels of the CARS-band (Ch.73 to Ch.80).

(B).18 GHz Return

Similarly, a new frequency plan has been developed for the 18 GHz band, allowing cable operators to deploy a wireless return-path. The design is shown in Figure 2.

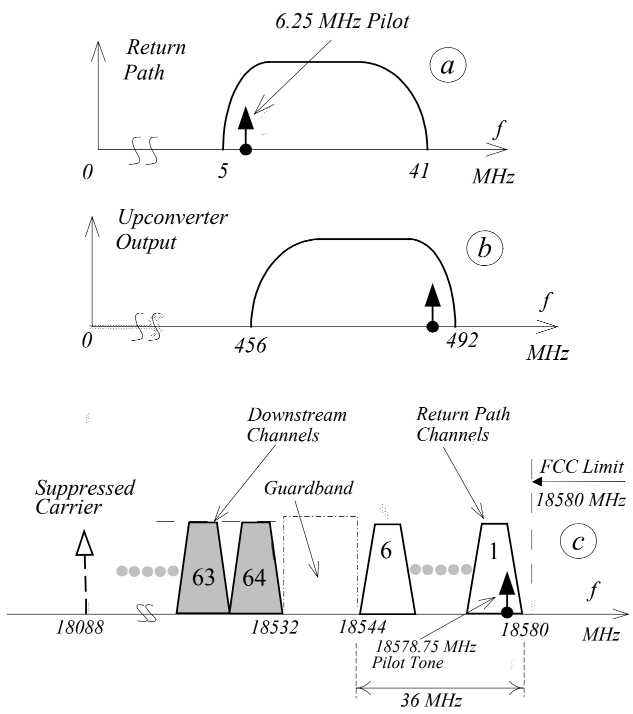

Figure 2. Frequency plan for 18 GHz return-path. (a) baseband signal with pilot tone, (b) upconverter output, (c) microwave spectrum.

The upstream method for 18 GHz is the same as that explained for the 13 GHz design.

Phase Locking

The performance of existing digital modulation schemes is based on phase variation. This makes the modulation sensitive to the phase shift between the local oscillators of the upconverter and downconverter. Generally, the higher the modulation scheme, the more susceptible it is to phase deviation, and consequently the higher bit error rate. The 6.25 MHz pilot is picked up by the downconverter module in order to phase lock its local oscillator with the upconverter, thereby eliminating any phase error. This capability has given the *AML Wireless Systems Inc.* transceiver superior performance in conjunction with highly sensitive CDMA modems.

AGC Operation

The novel frequency plans shown in Figures 1 and 2 cannot include a standard pilot-tone (≈74 MHz for CARS and ≈73 MHz for SMATV). The pilot-tone is used for AGC operation inside the downconverter module to compensate for received signal variation due to atmospheric changes in the transmission path.

In summary, the pilot tone will add quality to the *ACCESS* system by improving the receiver sensitivity as well as its frequency stability.

LOW-COST RETURN PATH

The maturity of computer technology and the consistent growth of software have made computers affordable to the majority of households. Meanwhile, the advent of Internet protocol has triggered enthusiasm for the computer users to communicate from long distances by exchanging files, data, voice and even video.

In several cases, the narrow-band, low-speed nature of telephone networks has caused many users to select an alternative Internet service connection. This allows cable service providers an excellent opportunity to emerge into the massive telecommunications market by just adding a return-path to their existing infrastructure, increasing revenue and profits.

The broadband nature of the cable networks, promoting high-speed connections without reliance on the telephone line, has positioned the cable companies as a preferred choice as Internet service providers for both their existing customers and new clients.

ACCESS Transceiver

A low-cost, quickly deployable solution is recommended using new and/or existing equipment. A typical wireless link in a cable network is shown in Figure 3.

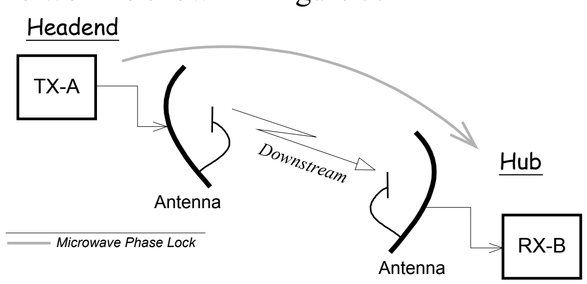

Figure 3. Multichannel radio link in the licensed band

This radio link can be in one of the licensed bands such as 13 or 18 GHz. An upgrade to the return-path is possible by replacing the receiver RX-B with the *ACCESS Transceiver* at the hub site and re-using RX-B as the upstream receiver (URX) at the headend, as shown in Figure 4.

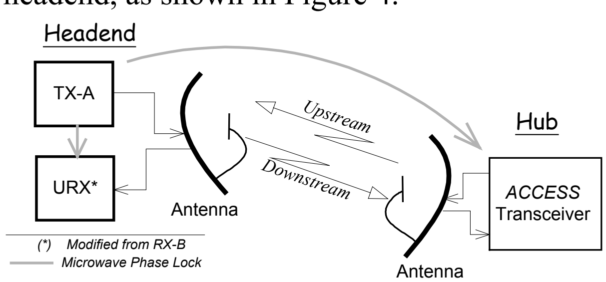

Figure 4. Return-path using ACCESS transceiver

The receiver RX-B will be upgraded in the field by adding the downconverter and performing a few necessary adjustments. A duplex filter assembly to separate the upstream and downstream traffic will be added behind each antenna. Either single or dual-polarized antennae can be used in this upgrade. [4]

Microwave Phase Lock

It should be noted that the 6.25 MHz upstream pilot-tone is used for phase-locking the downconverter unit (at URX) to the upconverter (at the transceiver). The gray lines in Figure 4 show the direction of the microwave phase-lock.

The microwave local oscillator in the transceiver is locked to the headend transmitter (TX-A) using the standard downstream pilot-tone. Similarly, the upstream receiver (URX) must be phase locked to TX-A using a jumper connection, as no standard pilot is sent in the upstream.

A simplified block diagram of the *ACCESS Transceiver* is given in Figure 5, showing the major components.

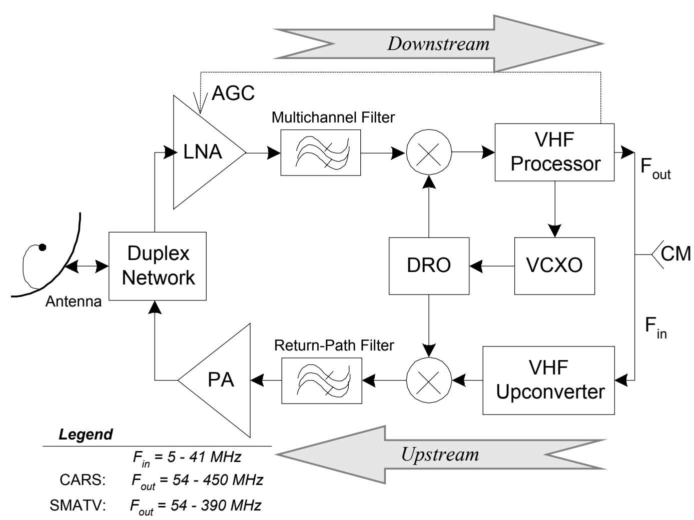

Figure 5. Simplified block diagram of ACCESS transceiver

The input to the transmitter is one or more QPSK/16QAM modulated signals in the range of 5 – 41 MHz. This range will be upconverted to the appropriate VHF frequency as explained. The 6.25 MHz pilot-tone is added to the signal in the upconverter module.

The output of the receiver is a multichannel VHF signal including analog and digital video, as well as data channels with up to 256QAM modulation.

The frequency range will be different for 13 GHz (CARS) and 18 GHz (SMATV) transceivers as explained in Figure 5. All components except the duplex filter network are enclosed in the transceiver housing. The duplex filter network includes bandpass filters and a circulator, inside a weather proof housing with O-ring grooved flanges for pressurization. The duplex filter network is usually mounted behind the antennae.

EXPERIMENTAL RESULTS

The 13 GHz *ACCESS Transceiver* has been tested in order to evaluate the critical parameters required by FCC regulations. The test criteria included spurious level, signal leakage, spectral regrowth, and frequency stability [5].

Bandwidth Overload

A 64QAM test signal occupying 6 MHz bandwidth was applied to the transceiver input. The test signal had a 26 Mb/s bit rate with spectrum as shown in Figure 6.

To verify the effect of the transceiver on signal bandwidth, microwave output has been measured with a spectrum analyzer as illustrated in Figure 7. The transmitter output has been raised to the nominal level (i.e. 6.5 dBm per 6 MHz channel).

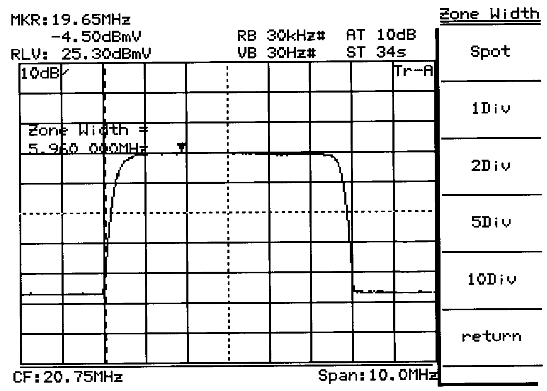

Figure 6. Spectrum of 64QAM test signal as the input to the transceiver.

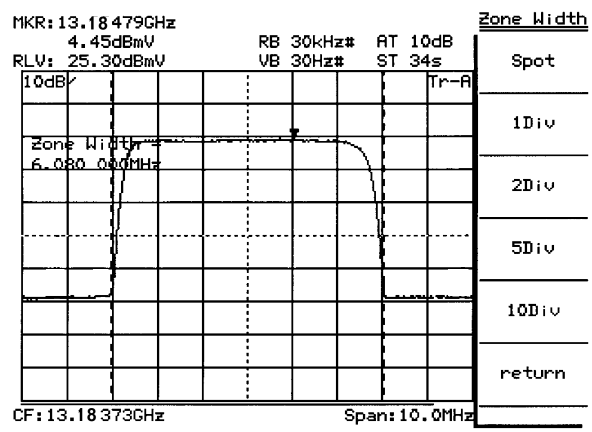

Figure 7. Measurement of transceiver output at 6.5 dBm/ channel.

Consistent with FCC regulations, the comparison of Figures 6 and 7 shows that the transceiver does not overload the signal bandwidth.

Spurious Level

To verify the spurious compliance, the VHF LO frequency (558 MHz) has been ed at the transceiver output. This major spurious is only 5 MHz away from the band edge and is difficult to remove.

Figure 8 shows the LO spectrum at 13204.5 MHz which is 70 dBc down from the reference level, well exceeding the 50 dBc requirement by the FCC.

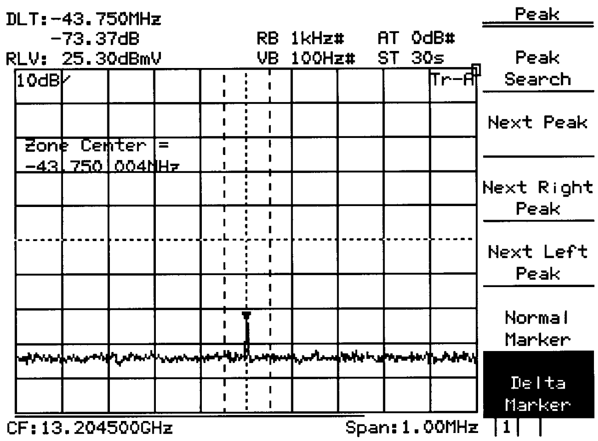

Figure 8. VHF LO frequency appearing in the transceiver output.

Frequency Stability

The performance of this 13 GHz *ACCESS Transceiver* has been monitored throughout a –40 to +50 °C temperature range. Figure 9 shows the frequency drift of the microwave carrier, which is well below the FCC limit (5 ppm).

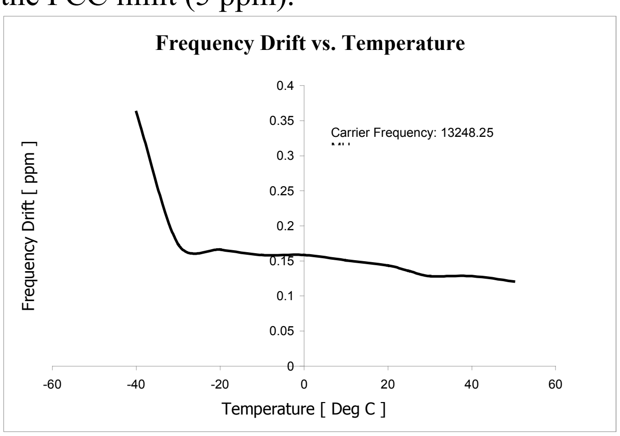

Figure 9. Frequency drift of the carrier frequency vs. temperature.

CONCLUSION

A low-cost solution has been designed for cable television providers that allows them to quickly deploy a wireless return-path in response to the growing demands for Internet access and immediately increase revenues. Novel frequency plans have been introduced for return-path transport within the 13 and 18 GHz licensed frequency bands. A cost-effective transceiver has been developed to provide full upstream transmission using new equipment or integrating with an existing system. Finally, the test measurements prove the transceiver's performance is in full compliance with FCC regulations.

REFERENCES

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[4] AML Wireless Systems, Inc., *13 GHz ACCESS Transceiver: Theory of Operation*, February 2000.

[5] AML Wireless Systems, Inc., *FCC Test Documentation for 13 GHz ACCESS Transceiver,* May 2000.