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ETHERNET ON ONE PHONE LINE

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Memorandum No. UCB/ERL M89/26

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ETHERNET ON ONE PHONE LINE

Martin Graham

March 4, 1989

Abstract

A technique for implementing 10 Megabit/second Ethernet operation on a single telephone line (Unshielded Twisted Pair) for distances up to 500 feet is described. The two circuit techniques used, pseudo reclocking and hybrid directional couplers, enhance the performance of the system and simultaneously lower the cost.

I. Introduction

The ANSI/IEEE 802.3 Local Area Network (LAN) Standard is a Carrier Sense Multiple Access with Collision Detection (CSMA/CD) system. Each piece of Data Terminal Equipment (DTE) is connected to a common 50 ohm coaxial bus (Multiple Access) by a transceiver. All transceivers sense the presence of a signal (10Mbits/second Manchester encoded data) on the bus (Carrier Sense) and will initiate a transmission only when the bus is quiescent. In addition, each transceiver detects the presence of more than one signal due to its own transmission (Collision Detection). When two or more signals are present on the bus all transceivers cease transmission. Figure 1 outlines and compares the current 50 ohm coaxial cable systems that conform to the Standard and a new system based on 100 ohm unshielded twisted pair telephone wire that would conform to a slightly modified standard.

II. Three Differences

When the 50 ohm coaxial cable is replaced with unshielded telephone twisted pair wire three changes occur:

1. The characteristic impedance of the wiring system is doubled from 50 ohms to 100 ohms.
2. Operation of the wiring system is switched from unbalanced to balanced.
3. Connections are made only to the ends of the twisted pair wire link; the basic physical wiring system is not multiple access, but a two transceiver system.

III. Required Modifications to 802.3

The overall system must emulated the multiple access topology of the ANSI/IEEE 802.3 standard. That topology is depicted in Figure 2. In the figure it can be seen that there are three sub-LANs hooked together by repeaters. Figure 2b shows the same three sub-LANs hooked together using a combination of transceivers and unshielded twisted pair (UTP). The transceiver making the connection between the coaxial cable and the UTP is a new version of a repeater MAU. It translates signals between the 100 ohm UTP and the 50 ohm coax. Up to 500 feet of UTP can connect this MAU to the Hub via a Hub Transceiver. The common Hub logic connects all the Hub Transceivers together. This combination of transceivers and UTP functionally emulates the repeaters of Figure 2a. There are three basic modifications to the repeater portion of the ANSI/IEEE 802.3 standard necessary to standardize this implementation of a UTP system:

1. The MAU portion of the new repeater needs to be modified to convert the signals between the unbalanced 50 ohm level to the balanced 100 ohm level.

2. The AUI cable in the repeater should be changed to a single 100 ohm UTP. The current (II) levels should be the same as those on the coax but the voltage and impedance levels are doubled. Also, since there are connections to the UTP only at the ends, it is feasible to make the active circuitry in the transceivers unbalanced and use a balum to match this circuitry to the balanced line.

3. The UTP system is now a multiport repeater, with no limit on the number of ports. In addition, there may be up to 500 feet between an MAU and the main body of the repeater, the Hub.

IV. Implementation Notes

Figure 3 shows some of the details of the components of the multiport repeater. Figure 3a shows a repeater MAU connecting a DTE to a Hub. Figure 3b shows a four channel Hub. It consists of four Hub Transceivers and the common Hub Logic. Finally, Figure 3c shows the signals exchanged between a Hub Transceiver and the Hub Logic. The requirements for the signals are outlined below:

1. Carrier Sense (A signal is being received from the repeater MAU):

- Any signal that accomplishes this within the time constraints of ANSI/IEEE 802.3 is acceptable. If this signal appears from more than one Hub Transceiver, Transmit Collision is activated.

2. RECEIVE DATA:

- The signal is in the 802.3 MAU format. This signal should be hooked to every other Hub Transceiver's Transmit DATA.

3. Transmit DATA:

- The signal is in the 802.3 MAU Format.

4. Transmit Collision:

- This can be any signal that would result from two simultaneous arbitrary transmissions (e.g., a continuous -80mA).

There are two circuits particularly useful in achieving this implementation. They are shown in Figure 4. They hybrid circuit is used for all low frequency control signaling. It allows full duplex transmission of the control signals, very fast detection of carrier and collision, and greater operating tolerances.

The non-linear differentiator provides equalization for the UTP and permits some simplification of the retiming requirements of repeaters. The circuit provides pseudo-reclocking of Manchester encoded signals. Figure 5 shows some photographs demonstrating its performance. The second photograph shows the signal after 500 feet of UTP and a differentiator. The third shows the signal after 500 feet of UTP, a differentiator, a transmitter, another 500 feet of UTP and then one more differentiator.

V. Conclusions

Unshielded twisted pair telephone wire is an excellent media for high speed data transmission. It is installed in almost all new buildings as well as existing ones and is much less expensive than coaxial or fiber optic cable.

Currently there are a number of proposed techniques for a new ANSI/IEEE standard for 10Mbit Manchester data on unshielded twisted pair telephone wire. Many of these suggested techniques require the use of two twisted pairs, one for receive data and one for transmit data. The system presented here requires only one twisted pair while maintaining the quality of performance achieved with the two pair systems.

In addition, the one pair system requires modification of only one portion of the ANSI/IEEE 802.3 standard. Because of the pseudo-reclocking nature of the diode differentiator, it is possible to simplify the repeater circuitry and consequently reduce the cost. The clocking for the system is supplied only by the DTE's. In addition, since the transmitting DTE controls the entire LAN and has its own Jabber circuitry, the repeater no longer needs this function.

This new proposal has the advantages mentioned above, but it also simplifies and generalizes the current 802.3 standard. The change from the 2-port to an n-port repeater simplifies installation of new networks and the extension of existing networks. It also allows the architecture of those networks to become more generalized.

Figure 1.

System Comparisons

ANSI/IEEE 802.3 10 Base 5 & 10 Base 2

- 50 Ω coaxial cable
- Unbalanced
- Multiple connections on a cable
- - 80 mA / - 2 volts

Unshielded Twisted Pair

- 100 Ω unshielded twisted pair telephone wire
- Balanced
- 2 connections per cable (at ends)
- - 80 mA / - 4 volts

UTP System Features

Data

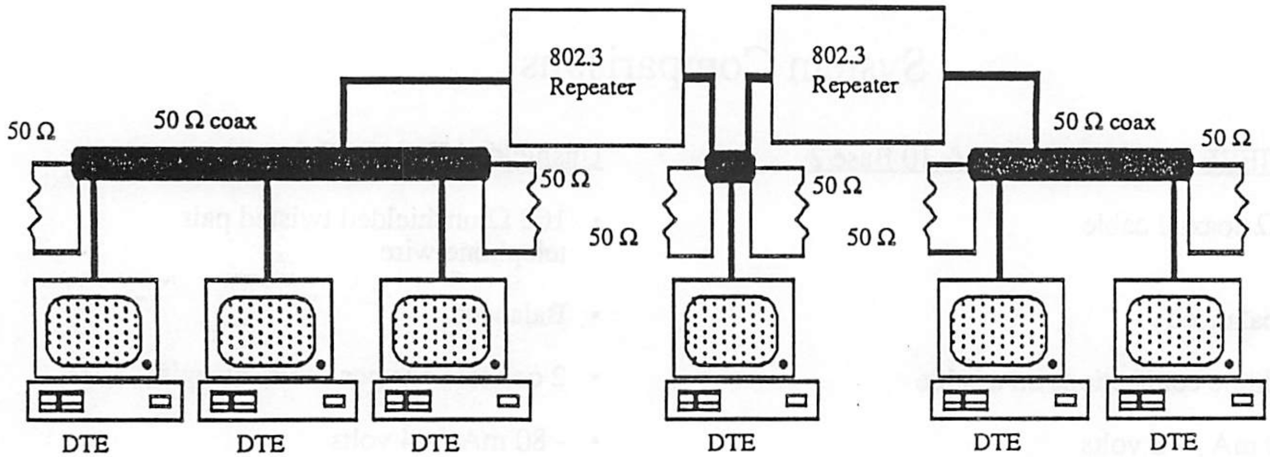
- 10 Mbits/sec
- Half duplex
- Non-linear differentiator circuit for improved performance and elimination of reclocking requirements

Control

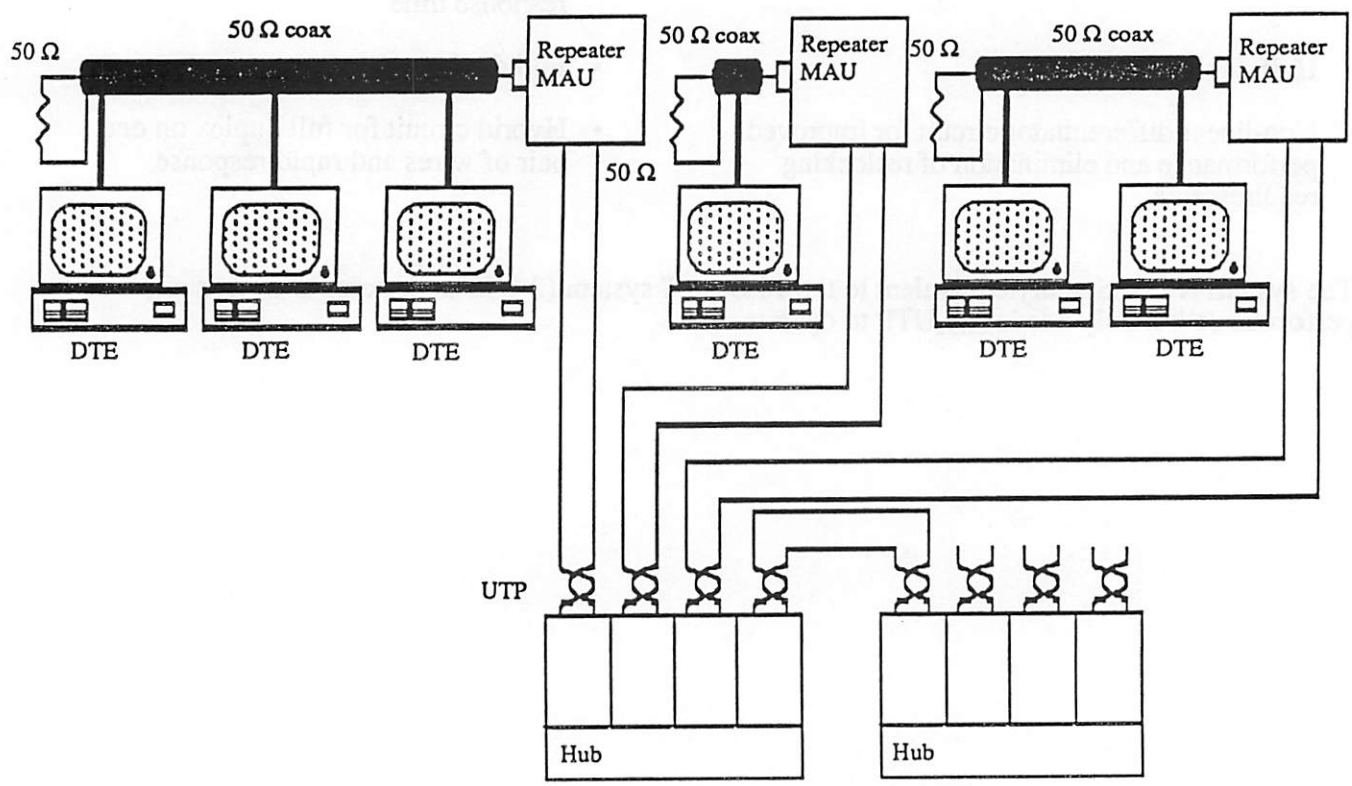
- Approximately 1 microsecond response time
- Full duplex
- Hybrid circuit for full duplex on one pair of wires and rapid response

The system is functionally equivalent to the 10 Base T system (2 UTP's) in noise and error rate performance but only needs one UTP to operate.

Figure 2. Topology.

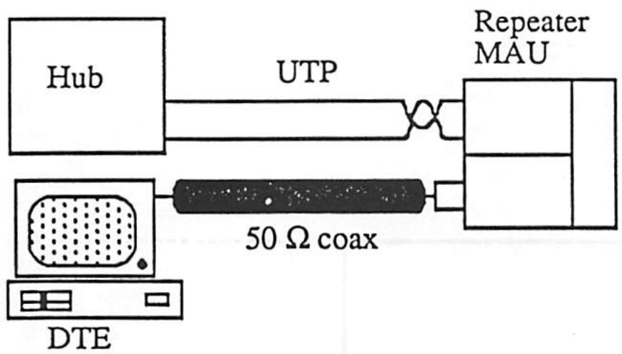


(a) The figure is representative of the current ANSI/IEEE 802.3 topology.

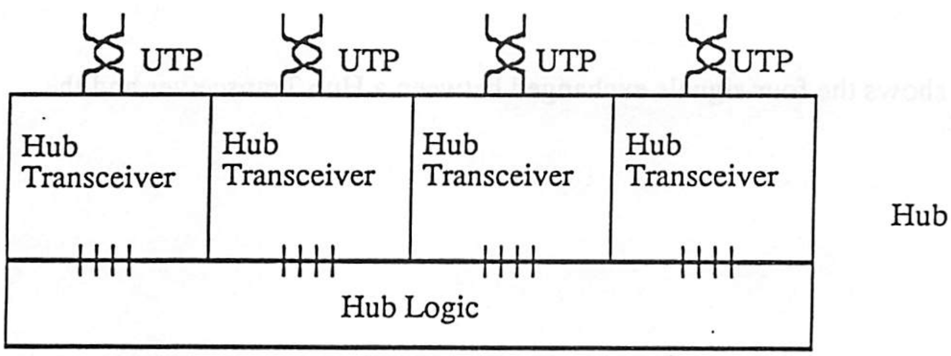


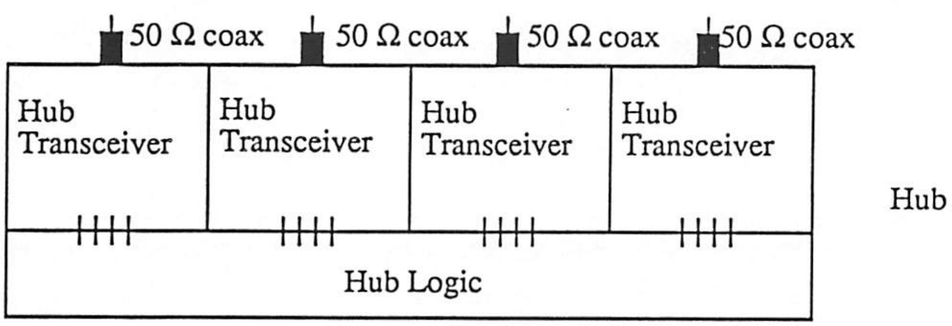
(b) The figure shows the proposed UTP topology. Each of the UTP connections may be up to 500 feet.

Figure 3. Hub Details



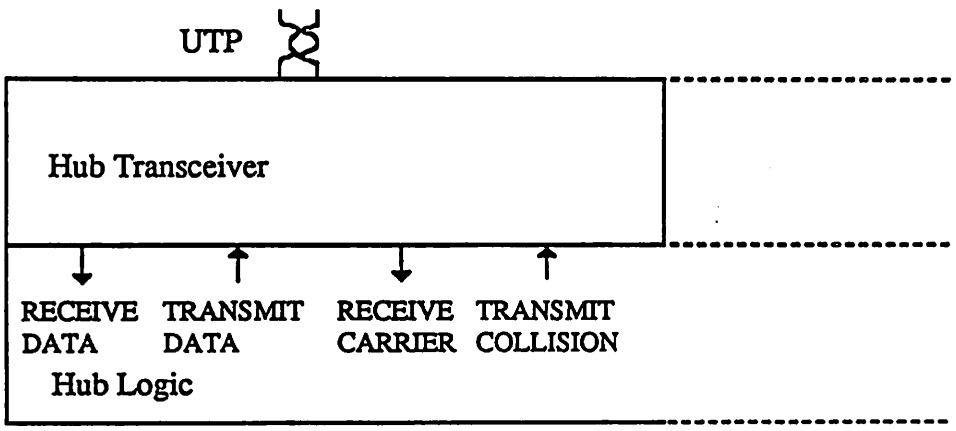
(a) This figure shows a repeater MAU. It matches 100 Ω UTP to 50 Ω coaxial cable.





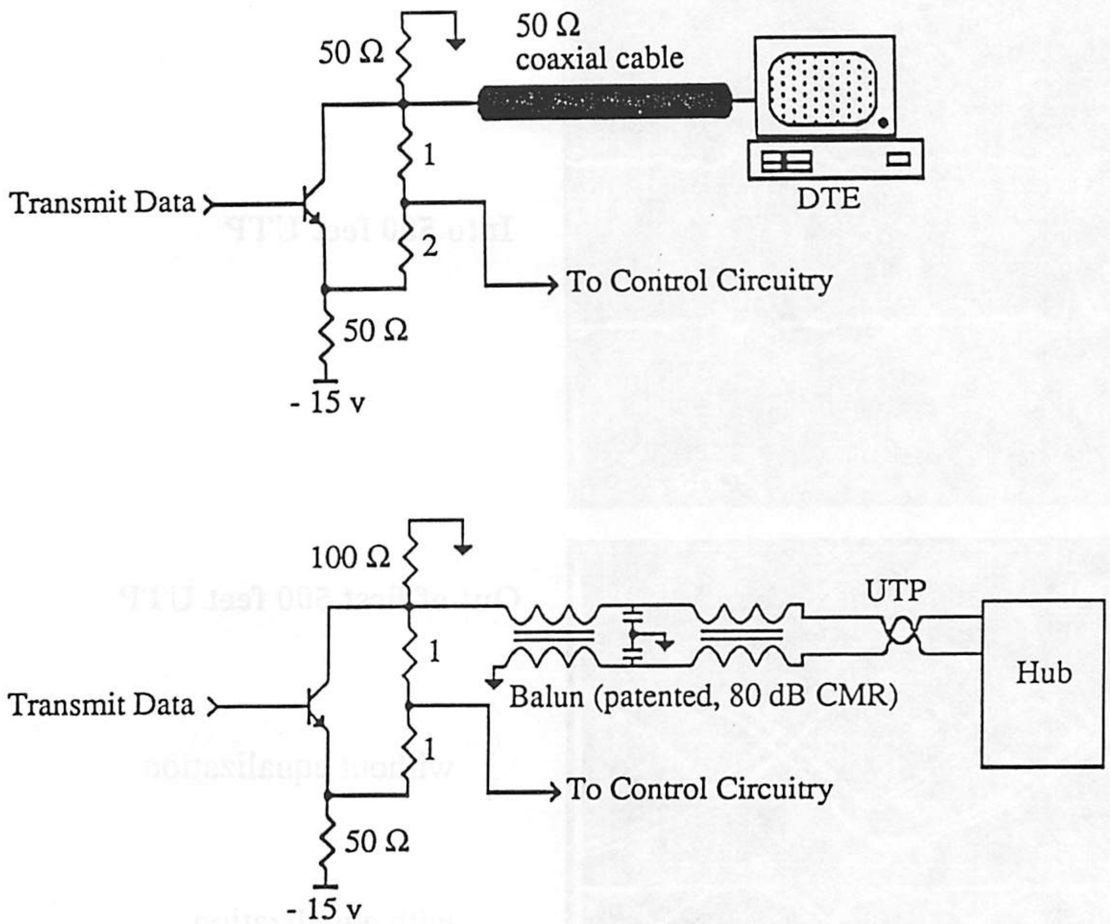
(b) Two four channel Hubs are shown. They both consist of four Hub Transceivers which exchange information with each other through the shared Hub Logic. The top Hub is used with the UTP system. The bottom one is a multiport repeater for coaxial based systems. The internal circuitry is essentially the same for both and simplifies the current ANSI/IEEE 802.3 repeater requirements.

Figure 3. Hub Details Continued

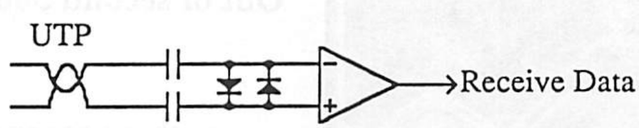


(c) The figure shows the four signals exchanged between a Hub Transceiver and the Hub Logic.

Figure 4. Circuit Implementations

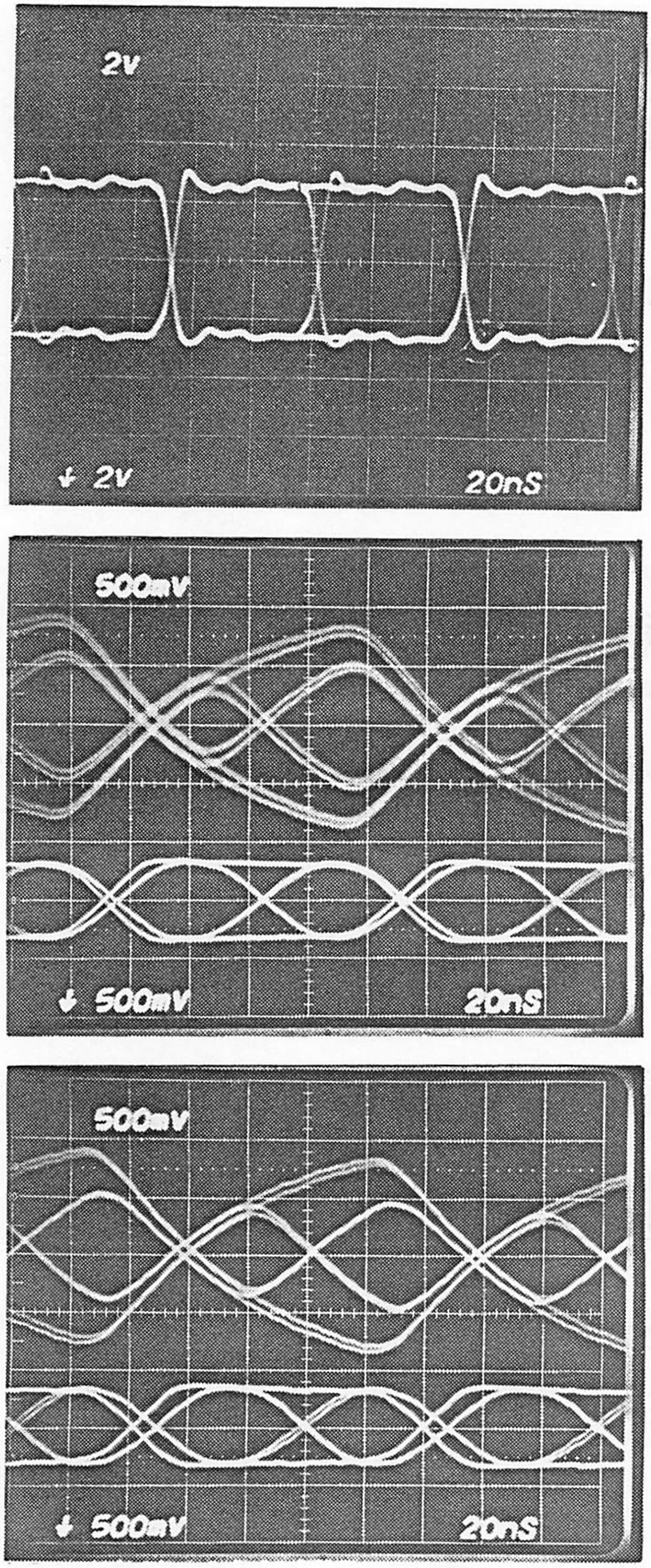


(a) Hybrid circuits for control signals.



(b) Equalizer (Non-linear differentiator; shown balanced).

Figure 5. Voltage Wave Forms



Into 500 feet UTP

Out of first 500 feet UTP

without equalization

with equalization

Out of second 500 feet UTP

without second equalization

with second equalization