

# Real Time Bidirectional Wireless Digital Multiplexer (WiDMX512)

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**Abstract**—Digital multiplexer512 (DMX 512) is a standard for digital data transmission mainly to control stage lighting. Conventional DMX512 employs bus topology in a daisy chain network. The network consists of one master and one or more slave devices connected through wires. Although wired connection validates reliable data transfer, yet it increases network complexity, specifically, where wires can be prohibitively lengthy. Additionally, wired connected DMX512 devices limits mobility and scalability while on other hand it increases labor and cost. Hence, there exists a need to replace the wired DMX512 with the wireless one. In this paper, we propose a wireless DMX512 system. Keeping in consideration the characteristics given by the DMX512 standard, we propose a novel design where master and slave can transfer DMX512 packets wirelessly. Simulation results and successful implementation validated the performance of the system.

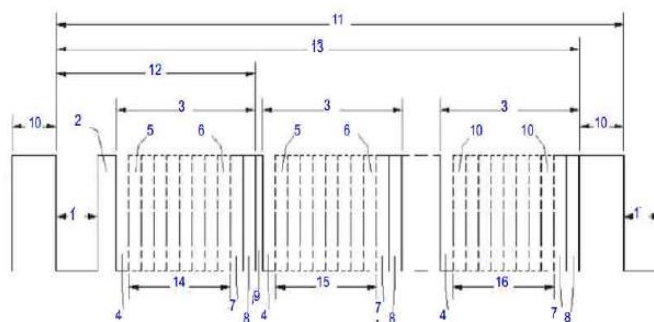


Fig. 1. DMX512 frame structure [4]

**Keywords**— DMX512, wireless system design, WiDMX512, system configuration, wired-wireless star topology.

## I. INTRODUCTION

The entertainment theatres is one of the most important spheres of the economic activity. Lighting effects in these theatres play a pivotal role to enhance the prominence of situation. The performance of an actor/s on the stage can be made more prominent with the help of effective lighting control. In recent times, with the surge of technology and networking, the lighting in the theatres is controlled through the standardized protocol named as digital multiplexer512 (DMX512) [1]~[3].

DMX512 is an international standard for digital communication networks that is mainly used for stage lighting control inside the theatres [4]. This standard provides interoperability with controllers manufactured by different brands. DMX512 is unidirectional and employs TIA-485-A (or RS-485) differential signalling at its physical layer. It is asynchronous serial digital data transmission lighting controller consists of a single master and one or more slaves. The master and slaves are connected in a simplified daisy chain manner using the bus topology. Although DMX512 is an effective lighting controller used in industry, yet there exist some shortcomings that need to be improved. For example, the wired connectivity of master slaves in bus topology increases system complexity, especially, in architectural lighting installations where wire lengths can be excessively long. Moreover, wired connected DMX512 devices are mostly

Table 1. Figure 1 key

|   |                            |    |                          |
|---|----------------------------|----|--------------------------|
| 1 | Space for break            | 9  | Mark time between slots  |
| 2 | Mark after break           | 10 | Mark before break        |
| 3 | Slot time                  | 11 | Break to break time      |
| 4 | Start bit                  | 12 | Reset sequence           |
| 5 | Least significant data bit | 13 | DMX512 packet            |
| 6 | Most significant data bit  | 14 | Start code (slot 0 data) |
| 7 | Stop bit                   | 15 | Slot 1 data              |
| 8 | Stop bit                   | 16 | Slot nnn data (max 512)  |

fixed and cannot be moved easily, hence, resulting in limiting mobility [5][6]. Also, wired DMX512 devices requires much cost and labor efforts to expand the network that result in restrictive scalability. Due to the mentioned inadequacies, this article proposes a wireless DMX512 protocol that will be named WiDMX512 henceforth in this article.

Rest of the paper is organized as follow. Next section describes the proposed WiDMX512 system in detail. In section 3 system performance is given. Finally, section 4 concludes the paper.

## II. PROPOSED SYSTEM

In this section, first we give the basic protocol of the DMX512. Next, based on values given in the standard protocol, we describe the design of the proposed WiDMX512 system.

Table 2. DMX512 Timing Diagram

| Designation | Description                    | Min. | Typical | Max.  | Unit    |
|-------------|--------------------------------|------|---------|-------|---------|
| --          | Bit Rate                       | 245  | 250     | 255   | kbps    |
| --          | Bit time                       | 3.92 | 4       | 4.08  | $\mu$ s |
| --          | Min. Update Time for 513 slots | --   | 22.7    | --    | ms      |
| --          | Min. Update Rate for 513 slots | --   | 44      | --    | Hz      |
| 1           | "SPACE" for BREAK              | 88   | --      | --    | $\mu$ s |
| 2           | "MARK" after BREAK             | 8    | --      | <1.00 | $\mu$ s |
| 9           | "MARK" Time between slots      | 0    | --      | <1.00 | s       |
| 10          | "MARK" Before BREAK (MBB)      | 0    | --      | <1.00 | s       |
| 11          | BREAK to BREAK Time            | 1196 | --      | --    | $\mu$ s |
| 13          | DMX512 Packet                  | 1196 | --      | --    | $\mu$ s |

### A. DMX512 protocol

Figure 1 shows the basic frame structure of the standard DMX512 protocol. DMX512 is a simple two-wired serial data communication protocol that uses TIA-485A and having

transmission rate of 250kbps [7]. DMX512 signal comprises of 513 slots per packet. Break indicates start of a new packet. Mark after break separates the break and start code. Then maximum of 512 data slots. In each data slot there is a start bit and two stop bits as shown in timing diagram. Finally, here is a mark time between slots.

Moreover, from transmission viewpoint, each entity should be transmitted with certain rate for normal operation as given in table 2. For example, the minimum time required for break is 92 $\mu$ s while mark after break is at-least 12 $\mu$ s. The typical update time for the DMX512 frame is 22.7ms (44Hz).

### B. Wireless DMX512 System Design

This section describes the proposed system in detail. To make conventional DMX512 wireless, we have used Texas Instrument (TI) CC1110 RF module that used 915 MHz ISM unlicensed band with the master and slave devices. Whenever, the master receives signal from signal generator it gives it to the RF module. The master's RF module transmits the DMX512 signal wirelessly to the slave devices. The slave lighting devices receives the DMX512 signal from the master through respective RF modules and send it to the lighting devices for proper action as shown in figure 2. The in-depth configuration of system and used topology is explained in coming sub-section.

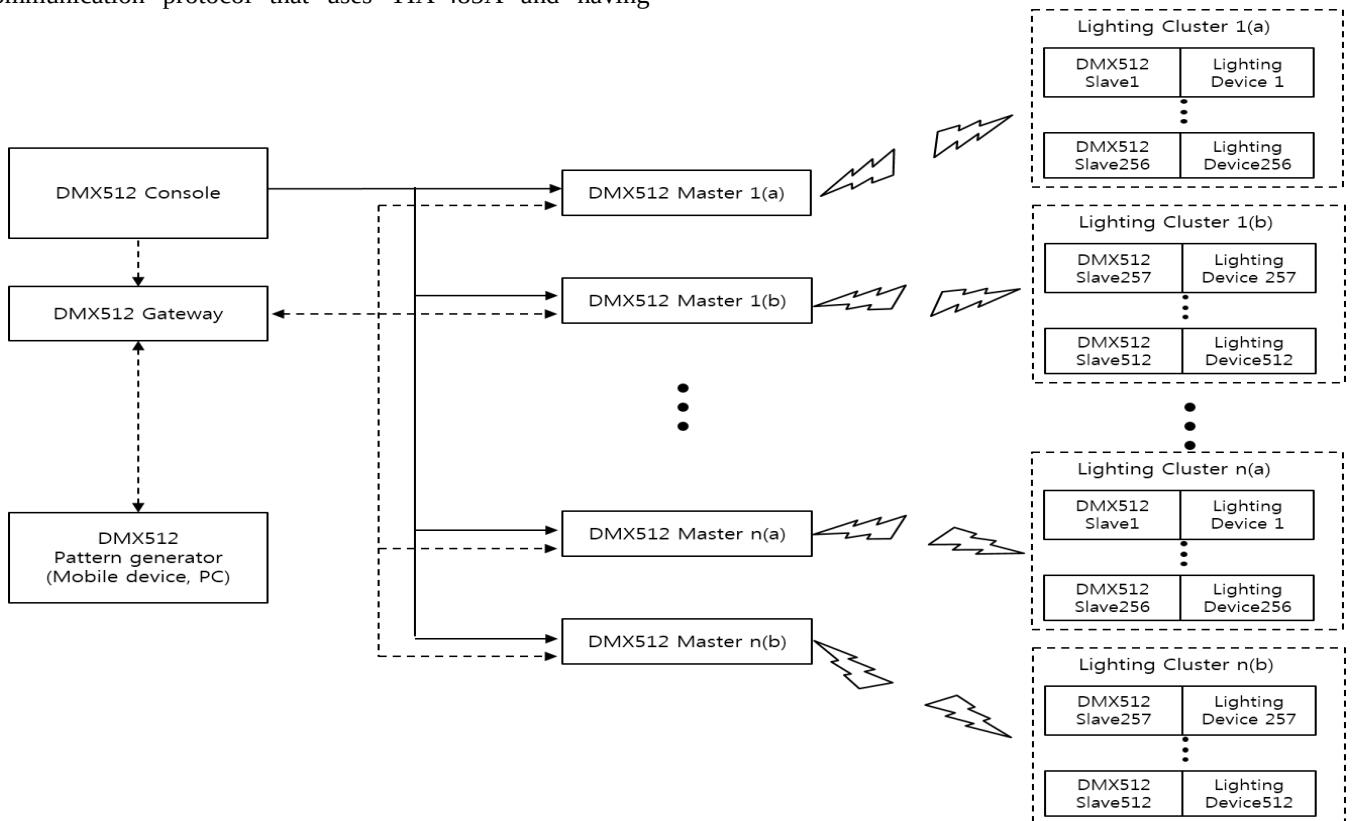


Fig.2. WiDMX512 structure

## 1. System Configuration

### i. Master module design

Figure 3 shows the block diagram of WiDMX512 master module. The master module consists of controller unit, RAM and RF transceiver. The controller unit of master module receives DMX data signal from the signal generator through any appropriate user interface. Further, the controller unit splits the DMX signal into two portions (i.e. 256 bytes each) and write them into the RAM. Data splitting is required because if 512 bytes signal is transmitted through the given RF transceiver at a rate of

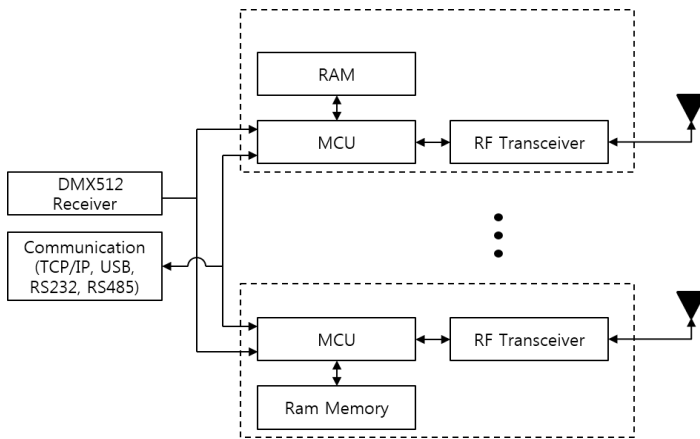


Fig. 3. Master module block diagram

250kbps at once it takes 31.2ms which exceeds the maximum value given in the standard (i.e. 22.7ms) as given in table 2. Therefore, RAM contains two buffer zones as shown in figure 4. At same clock, when one buffer reads the data, the other buffer writes the data. Hence, each master's RF transceiver transmits the data on two channels in order to hold the standard values. Finally, the RF transceiver transmits the 256 bytes DMX signal at a rate of 250kbps to the slave's transceiver.

### ii. Slave module design

Figure 5 shows the block diagram of WiDMX512 slave module. The slave module also consists of controller unit, RAM and RF transceiver. The 256 bytes signal transmitted by master when receives at the slave transceiver, the controller unit stores it in the RAM buffer. In the next clock when the slave transceiver receives the other half signal, the controller send it to the RAM second buffer. When the slave receives complete DMX signal, then it is send to the lighting device.

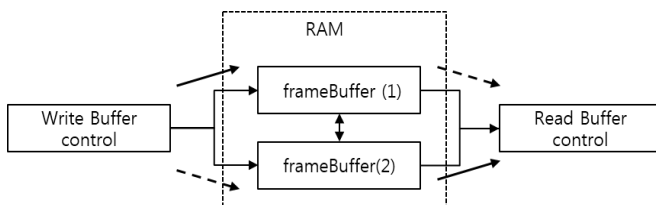


Fig. 4. Memory management

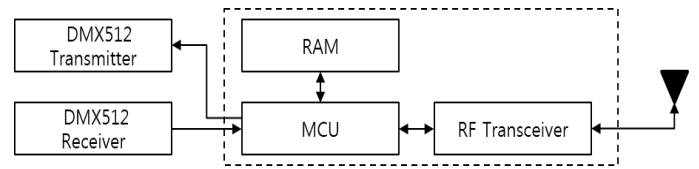


Fig.5. Slave module block diagram

## 2. Channel and Addressing Configuration

In WiDMX512 we also propose the channel and addressing configuration using bidirectional data transmission. Bidirectional communication has the advantage over unidirectional DMX512 in the sense that in unidirectional data transmission the master is not aware whether the slave is configured properly. The flow chart in figure 5a and 5b shows the bidirectional communication between master and slave modules for proper channel and addressing configuration.

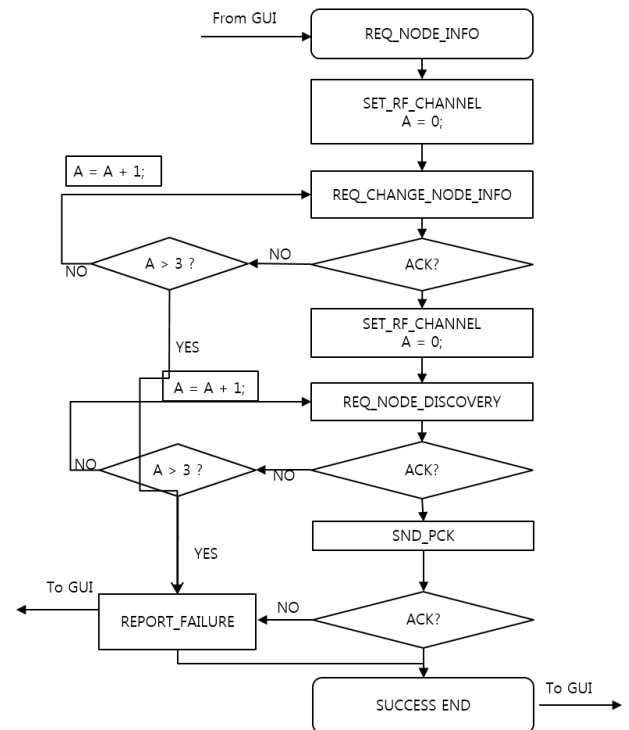


Fig. 6a. Master module Flow chart

As shown in figure 6a, if master module receives signal from the signal generator through user interface it will transmit request on specific RF channel. Master module may get response from multiple slaves over the same channel. Or in the second case, it may not get response from any module. In the latter case, it will send the same request again. Once master get response from the slaves on the specific channel, it will send request for the specific slave connected to the concerned lighting device. When master module gets acknowledgment

from the slave connected to specific device, it will develop connection with the slave and will send the DMX512 packet. Once master get an acknowledgment from the slave it will report success to the user interface. Otherwise it will report failure.

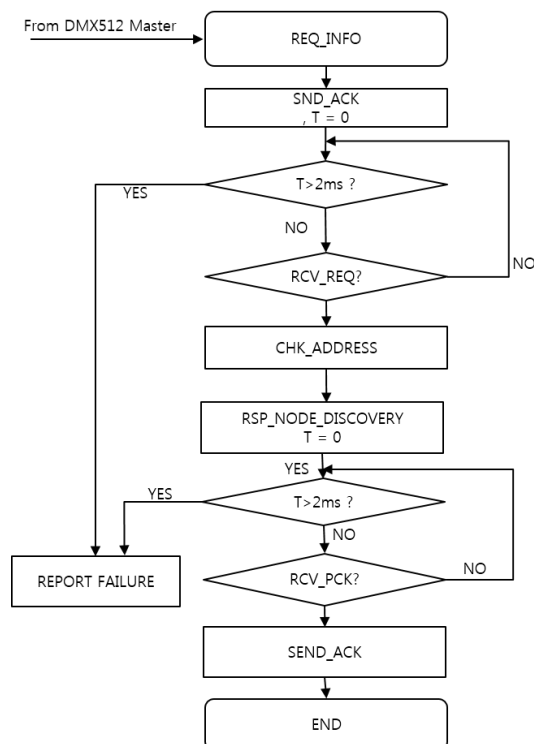


Fig. 6b. Slave module Flow chart

On the slave side, as shown in figure 6b, when slave get any message from the master it sends acknowledgment to the master and waits for further instructions. When it receives another message from the master regarding lighting device, it checks the address of the connected lighting device and if the address matches it respond back to the master with acknowledgment. And then the slave waits to develop connection with the master and receive DMX signal. Note that, the slave cannot develop a connection by itself and only will wait for the master to develop the connection. When it receives the DMX signal, it will send acknowledgment message to the master and forward the DMX signal to the lighting device for proper configuration.

### 3. Topology

The proposed WiDMX512 system, consists of one multichannel master and one or more single channel slave modules that are connected in star topology as shown in the figure 6. The multichannel master can communicate with all slaves on the associated channel while slave modules can either only send messages to the master or can relay the messages.

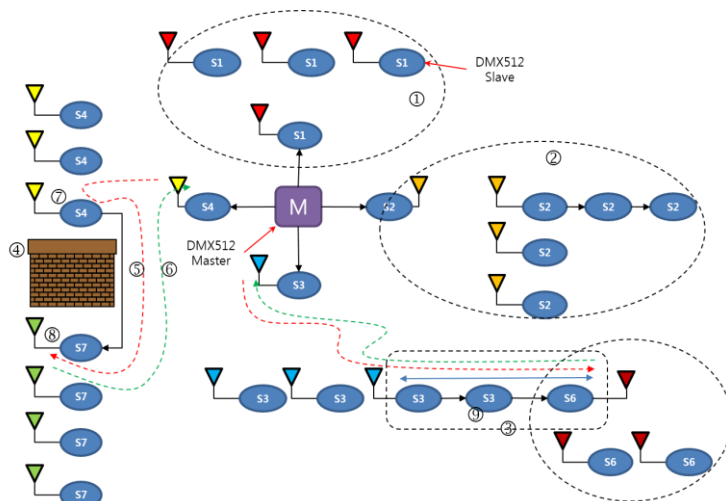


Fig. 7. Topology

In addition to the straight forward communication between master and slaves over the same RF channel there exist a couple of interesting scenarios. 1. In first scenario there exists RF blockage between the master and slave (see S7). 2. In second scenario the slave is not in the RF range of the master (i.e. S2 on the right most side). 3. While in the third scenario, the slave is using the RF channel over which master is not transmitting (for example S6). In all these special scenarios master is unable to communicate directly with these slaves as shown by red line in the figure. Taking into account these scenarios, we have proposed a novel special case wired-wireless connecting topology. For the first case the slave module that is across the RF blockage is connected through wire to slave module that is in the range of master. In figure 6 S4 is connected through wire with S7. In this case master can send messages to S7 using S4 as relay slave module. In the second special case, the slave that is beyond the RF range of master is connected through wire to the slave which is in the RF range of master. And hence it is also connected in the network. Similarly, for the third special case, the slave which is not receiving on the master transmitting channel is connected through wire with the slave that uses the master transmitting channel. In authors' knowledge, it is first time to propose wired wireless star topology for WiDMX512 system.

### III. PERFORMANCE

We have done a series of experiments in real time to check the performance of the WiDMX512 system. First, we design the system for full DMX512 protocol packet (i.e. 512 bytes) and transmit from the master at the rate of 250kbps and measure the time taken to update all 513 slots. It comes out to be 31.2ms that exceed the standardized 22.7ms update time. Hence we change our design and transmit 256 bytes at 250kbps using two RF transceivers. Figure 7 shows the timings results for 256 bytes. It took total 15.2ms to transmit

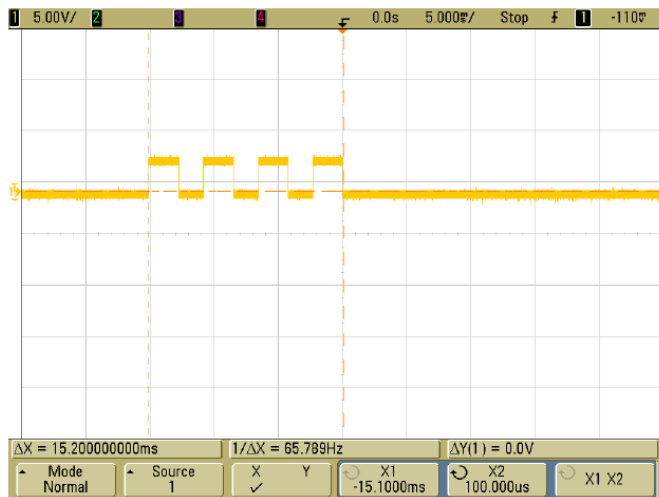


Fig. 8. Master module data processing time

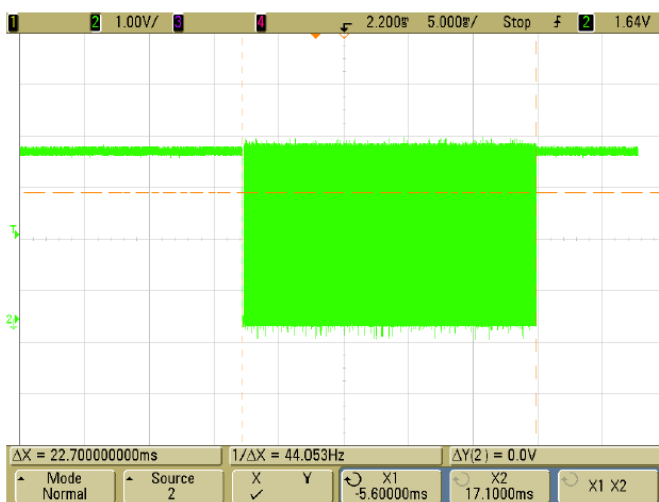


Fig. 9. Slave module data processing time

complete DMX512 packet with the described WiDMX512 design and configuration. The packets were successfully transmitted to the lighting devices. The dimming and light control validates the performance of the proposed system. Moreover, to validate the system performance at the lighting device, we have measured the time to receive complete packet at the lighting device from the slave module. From the figure 8, it can be seen that it took exactly 22.7ms which confirm that the proposed WiDMX512 system operates according to the standard DMX512 protocol.

#### IV. CONCLUSIONS

In this article, we have proposed a WiDMX512 system for the stage light controlling that can be used as an alternate to the wired DMX512 system. The proposed design introduces the RF transceiver at the master and slave side to make the existing standardized system wireless. Keeping the DMX512 standard in consideration, the master and slave modules were designed. The modules were configured to transmit and receive DMX512 packet according to the standard. Finally, a

unique wired-wireless star topology was proposed for reliable communication. The proposed system have multiple advantages over conventional system. As compared to conventional DMX512 system, besides eliminating web of wires, the WiDMX512 is flexible in terms of scalability and mobility along with the reduction in cost and labor.

#### ACKNOWLEDGMENT

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