Design of Optical Fiber Route for Digital Television in Single Multiplexing System in Jakarta

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***Abstract*—In this paper, we propose optical fiber routes for a digital television single multiplexing system in Jakarta. Twenty routes were designed, each of which connects a broadcaster with the central broadcaster (TVRI). The route performances were evaluated based on the link power budget and rise time budget. The results of our link power budget analysis reveal that every route would function within the 27-dB maximum acceptable loss, with the highest and lowest losses being 21.11 dB and 10.99 dB, respectively. The rise time budgets were analyzed using the non-return to zero (NRZ) modulation scheme. The results show that all the rise time budget values would be within the allowable rise time limits of the broadcaster specifications. Therefore, the proposed design is suitable for implementation.**

Keywords—Optical fiber; Digital TV; Single Mux; Link Power; Rise Time

I. INTRODUCTION

The need for information is rapidly increasing as is the development of telecommunications technology, including television technology. At present, Indonesia is transitioning from an analog to digital television system (DVB-T2). To support this system, a number of trials have been conducted in a few regions, which have demonstrated better video and audio performances for end users. Moreover, the signal quality is more stable than in the analog system. DVB-T2 also tends to provide opportunities for emerging new broadcasters, because this system uses less bandwidth, thus allowing more channels at the same frequency. When this conversion is fully complete, there will be a residual frequency, also known as a dividend frequency, which can be used for other applications [1].

The digital television transition process in Indonesia is constrained by many rules, especially those regarding system implementation [2]. There are three types of proposed implementation systems, single multiplexing (single mux), multi-multiplexing (multi-mux), and a hybrid. Single mux is a multiplexing broadcast system operated by one broadcaster. In this case, that broadcaster is owned by the Indonesian government (TVRI). Multi-mux consists of private television broadcasters who are authorized to manage their frequencies and number of channels. In hybrid systems, multiplexing broadcasters comprise a combination of government and private broadcasters. Each of these systems has shortcomings and strengths. To date, there has been no decision regarding the system that will be adopted [3].

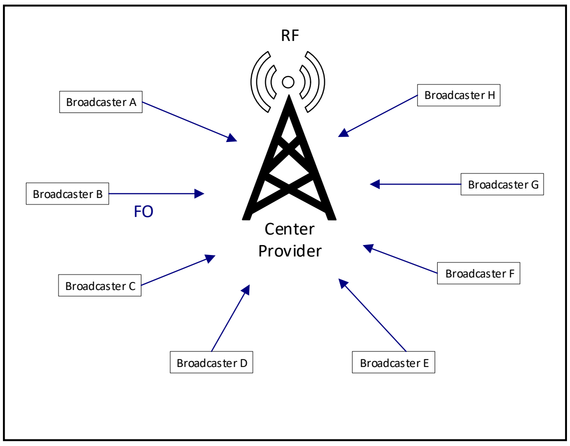

Fig. 1. Digital Television Single Mux Topology

Technically speaking, the difference between a single mux and other systems lies in the distribution of video and audio signals transmitted by the television broadcasters. The single mux system in Indonesia would be managed by the national television network (TVRI) [4], whereby TVRI would be the center for collecting the broadcasts of all channels from each television broadcaster, and would then be distribute them to various regions throughout Indonesia. Figure 1 shows a schematic of the broadcast channel collection process by TVRI.

When a single mux system is implemented, each broadcaster must transmit its signals to the central broadcaster. There are several ways to transmit channels, including microwave transmission, data streaming, and optical fiber. The large number of high-rise buildings in Jakarta makes line of sight (LOS) transmission difficult and data streaming is somewhat unstable and characterized by long delays. Therefore, optical fiber is a more effective transmission method. Moreover, optical fiber can ensure a high enough bandwidth and bit rate. [5]

Point-to-point fiber-to-tower (FTTT) optical fibers have been designed and created [6] to link Paris Van Java TV to the central tower. In this research, we focused on the design of the point-to-point or FTTT optical networks with respect to the parameters used in our power-link budget and rise time analysis, specifically in the Jakarta area. The proposed design and calculation model is expected to serve as a reference if the Indonesian government implements a single mux broadcaster system.

II. Design of System

A. Proposed Topology

Figure 2 shows the proposed point-to-point topology in which a television broadcaster transmits its broadcast to the central broadcaster (TVRI) via optical fiber. In this study, we considered the G.652-type optical fiber cable, which is the single-mode standard fiber utilized for long distances in accordance with ITU standards. This type of fiber can cover a distance of 25 km without the need for a splice with a data rate up to 2 Gbps [7].

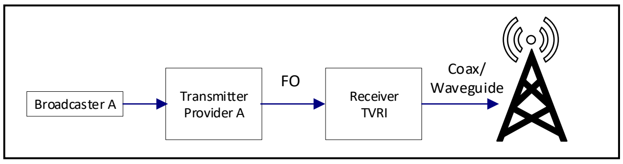

Fig. 2. Proposed topology of a point-to-point route by using optical fiber

The other broadcasters in the system will use the same topology, distinguished only by the length of their optical fiber paths and the volume of data transmitted. In this research, we considered the use of 20 lines to determine the power-link and rise time budgets. Some routes consist of multiple channels, hence their data rates will be higher than that for a single channel.

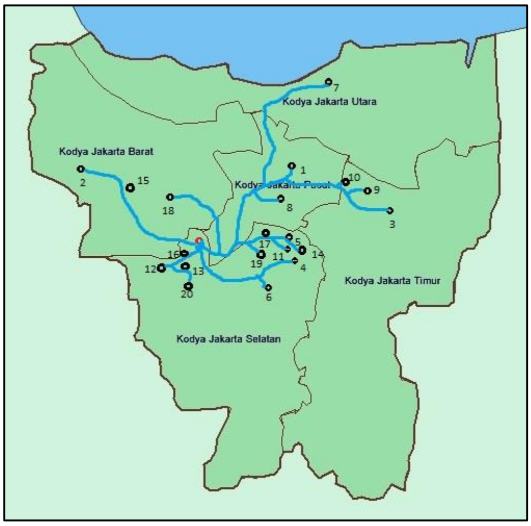

Fig. 3. Route map of TV broadcasters to TVRI

Figure 3 shows a map of the Jakarta area with the optical cable paths from the television broadcasters to the central organizer. Table I lists the distances of the broadcasters from the central broadcaster and the estimated lengths of the optical fiber cables that will be used.

B. Design Specifications

The design specifications include the fiber length, wavelength, and data rates and losses. To determine the length of the optical fiber, we used a 10% tolerance for the distance between the broadcasters and the center broadcaster, as shown in Table I [8]. The data rate value depends on the number of delivered channels and the type of broadcast video. Based on the ITU-T H.264 standard, a standard definition (SD) video has a 720 x 576 resolution and a minimum data rate of 3.6 Mbps, whereas that for a high definition (HD) video is 8.160 Mbps.

The G.652-type optical fiber cable allows wavelengths of 1310 nm with a single-mode fiber for long-distance transmission. The modulation scheme is non-return to zero (NRZ) and the bit error rate (BER) is 10^{-8}. Losses are generated between two connectors at the transmitter and receiver ends with 2 dB/connector. We used 6 dB for the link margin system.

TABLE I. DISTANCE AND OPTICAL FIBER LENGTH TO TVRI

Route	Broadcaster	Distance (km)	Fiber Length (km)
1	Magna TV	9,3	10,2
2	Metro TV (Metro TV SD and HD)	9,4	10,3
3	TV One (TV One and Sport One)	17	18,7
4	ANTV	8,4	9,2
5	Berita Satu (BS and BS World)	5,1	5,6
6	Trans Media (Trans7, TransTV, CNN Indonesia)	6,5	7,2
7	DAAI TV	20,2	22,2
8	TV Mu	8,9	9,8
9	Nusantara TV	15	16,5
10	Tempo TV	11,1	12,2
11	NET TV	6,3	6,9
12	Kompas TV	4,4	4,8
13	Gramedia TV	2,2	2,4
14	RTV	5,7	6,3
15	MNC Group (RCTI, GTV, MNCTV, INEWSTV)	8,2	9,0
16	O Channel	1,8	2,0
17	Elshinta TV	4,5	5,0
18	Emtek (SCTV and Indosiar)	2	2,2
19	Jak TV	4,9	5,4
20	Jawa Pos TV	4,1	4,5

III. CALCULATION DESIGN AND ANALYSIS

A. Link Power Budget

In the power-link budget, we considered the amount of light received at the photodetectors as the optical power. This value also depends on the losses occurring along the fiber length and from the connectors. As shown in Table II, the amount of output power P_S from the transmitter and the optical sensitivity P_R of the receiver are based on SFP 7707VT-8 and SFP 7807LR-2 specifications for transmitting and receiving, respectively [9][10]. These parameters determine the maximum acceptable loss P_T by the transmission system, which can be calculated using Eq. (1). Equation (2) is used to determine the total optical power loss α_T for every route, based on the cable attenuation α_f, connector loss α_c, and link or system margin [11].

TABLE II. DESIGN PARAMETERS

Parameter	Value
SD data rate	3.6 Mbps
HD data rate	8.16 Mbps
Wavelength	1310 nm
BER	10^{-8}
Modulation scheme	NRZ
Link margin	6 dB
Maximum acceptable loss	27 dB
Single-Mode Cable ITU-T G.652	
Attenuation	0.5 dB/km
Dispersion	18 ps/(nm.km)
Loss connector	2 dB/connector
Transmitter 7707VT-8	
Output power Tx	7 dBm
Rise and fall time	900 ps
Spectral width	0.2 nm
Receiver 7807LR-2	
Optical sensitivity	-20 dBm
Bandwidth	36 MHz

$$P_T = P_S - P_R \quad (1)$$

$$\alpha_T = 2\,\alpha_c + \alpha_f L + system\ margin \quad (2)$$

Table III shows the total optical power loss along each route. The maximum loss of 21.11 dB occurs on the seventh route and the minimum loss of 11.1 dB on the eighteenth route. All power losses are under 27 dB, which is the maximum allowable.

TABLE III. LINK LOSS BUDGET

Route	*afLsys* (dB)	α_T (dB)
1	5,11	15,11
2	5,17	15,17
3	9,35	19,35
4	4,62	14,62
5	2,80	12,80
6	3,57	13,57
7	11,11	21,11
8	4,89	14,89
9	8,25	18,25
10	6,10	16,10
11	3,46	13,46
12	2,42	12,42
13	1,21	11,21
14	3,13	13,13
15	4,51	14,51
16	0,99	10,99
17	2,47	12,47
18	1,1	11,1
19	2,69	12,69
20	2,25	12,25

B. Rise Time Budget

Next, we performed a rise time budget analysis to determine the quality of performance with respect to the information conveyed by the optical network system. The number of channels and type of broadcast system influence the bit rate, so each path may have a different bit rate. The maximum allowed dispersion t_{maxsys} can be approximated using Eq. (3), where the modulation scheme is 70 % of the NRZ. The receiver rise time t_{rx} is obtained using Eq. (4) and the rise time of the group velocity dispersion is obtained using Eq. (5). D is dispersion from a fiber and L and σ_λ are the respective fiber length and spectral width. The total rise time can be obtained using Eq. (6), which uses the sum total of t_{tx}, t_{GVD}, and t_{rx}.

$$t_{maxsys} = 0.7 * \left(\frac{1}{BitRate}\right) \quad (3)$$

$$t_{rx} = \left(\frac{350}{Brx}\right) \quad (4)$$

$$t_{GVD} \approx |D|L\sigma_\lambda \quad (5)$$

$$t_{sys} = \sqrt{t_{tx}{}^2 + t_{GVD}{}^2 + t_{rx}{}^2} \quad (6)$$

TABLE IV. RISE TIME BUDGET

Route	Bit rate (Mbps)	T_{maxsys} (ns)	T_{GVD} (ns)	$Tsys$ (ns)
1	3,6	194,44	36,83	38,10
2	11,76	59,52	37,22	38,48
3	3,6	194,44	67,32	68,02
4	3,6	194,44	33,26	34,67
5	7,2	97,22	20,20	22,43
6	10,8	64,81	25,74	27,53
7	3,6	194,44	79,99	80,59
8	3,6	194,44	35,24	36,57
9	3,6	194,44	59,40	60,20
10	3,6	194,44	43,96	45,03
11	3,6	194,44	24,95	26,79
12	3,6	194,44	17,42	19,97
13	3,6	194,44	8,71	13,08
14	3,6	194,44	22,57	24,59
15	14,4	48,61	32,47	33,91
16	3,6	194,44	7,13	12,09
17	3,6	194,44	17,82	20,32
18	7,2	97,22	7,92	12,57
19	3,6	194,44	19,40	21,72
20	3,6	194,44	16,24	18,94

Table IV shows allowable rise time for every route, which depends on their bit rates, whereby a higher bit rate has a lower maximum allowable rise time. The highest t_{sys} is 80.59 ns of the seventh route, because it has a longer optical fiber length, and the smallest is the sixteenth route with 12.09 ns. Overall, all routes fall below the maximum rise time. Therefore, this design is suitable for application.

IV. CONCLUSION

In this study, we designed optical fiber routes for a single mux digital television system. The proposed routes connect 20 television broadcasters to the TVRI governmental broadcast tower. The link power budget and rise time budget of every broadcast point exhibited values below the maximum allowed loss and rise time. Therefore, this proposed optical fiber design is suitable for implementation in a digital television single mux system in Jakarta.

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