Planning and Simulation of DRM Digital Radio Technology Using Single Frequency Network Method for Indonesia

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ABSTRACT

This study aims to design a digital radio network using a single-frequency network (SFN) and Digital Radio Mondiale (DRM) technology in Indonesia. The single frequency used is 87.1 MHz. Based on the ITU Radio Regulation, this frequency channel is still part of the broadcasting allocation for Region 3 and has not been used for analog radio in Indonesia. SFN design and simulation were carried out using existing analog transmitters owned by RRI to cover the entire territory of Indonesia. The simulation uses CHIRplus_BC software, which is based on recommendations, reports, and ITU-R publications on parameters and technical provisions of SFN. The technical provisions that are a limitation in SFN design are the maximum distance between transmitters of 75 km. However, the existing transmitter location of RRI transmitters is not evenly distributed throughout Indonesia, so not all transmitters can be used. Therefore, this design requires 3 scenarios in order to cover 95% of the population of Indonesia. The first condition in this plan is to use the existing transmitter sites owned by LPP RRI with a maximum distance of 75 km between the transmitter locations. The second condition is to use the transmitter sites owned by TVRI to cover the remaining blank spots in regions not covered by RRI's locations. If both of them still could not cover all regions in Indonesia, then it will need to add some new transmitters in blank spot locations. The simulation result showed that service in all regions in Indonesia requires at least 330 transmitters consisting of 153 existing RRI transmitters, 45 TVRI transmitters and 132 new transmitters with a settled technical parameter. To be able to cover all regions of Indonesia through SFN design, RRI still needs to build new transmitters as much as 40% of the total transmitters needed

1. Introduction

Indonesia is an archipelagic state located between the Pacific and Indian Oceans, with a total land area of 1.904.569 km2. As an archipelagic state, Indonesia has 17.504 islands, including the mainland of Sumatera, Jawa, Kalimantan, Sulawesi, and Papua, as well as its small islands surrounding it. In the middle of 2023, the total population will be 278,696,200 (Badan Pusat Statistika, 2023), spread from Sabang to Merauke.

The large population and diverse geographical distribution require effective and efficient information dissemination. Information broadcasting using terrestrial radio is still the main means of reaching even remote locations in Indonesia.

At the moment, radio broadcast in Indonesia still uses analog technology on the MF frequency band (popularly known as AM radio) and the VHF Band II frequency band (popularly known as FM radio). In general, the broadcasting activities of AM radio are performed by public broadcasters and commercial

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broadcasters. In contrast, FM radio is performed by public broadcasters (LPP-RRI), local public broadcasters (LPPL), commercial broadcasters (LPS), and community broadcasters (LPK). As shown in Figure 1, the number of radio FM broadcasters for LPP-RRI and LPS is currently spread throughout Indonesia.

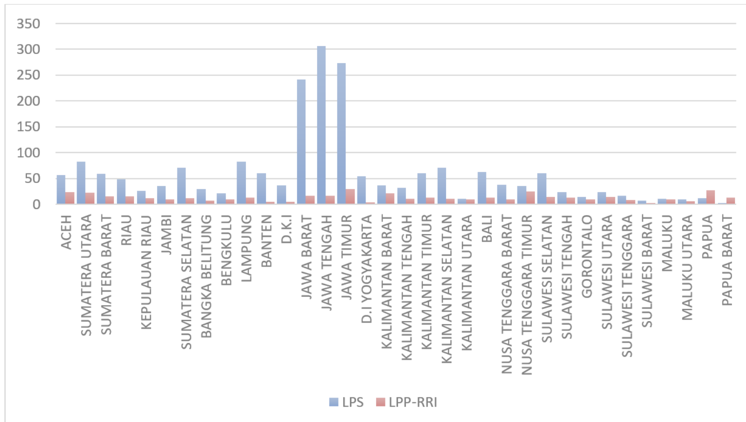


Figure 1. FM Broadcast Radio in Indonesia

Source : (Direktorat Jenderal Sumber Daya Perangkat Pos dan Informatika, 2024)

A large number of radio operators caused the use of radio frequency channels, mainly FM radio, to be congested, especially in big cities (e.g. Jakarta, Bandung, Semarang, and Surabaya). FM radio channels in adjacent service areas must use 400 kHz spacing to prevent interference. For instance, the frequency 87.6 MHz used in Jakarta could be used again at a 100–160 km distance. This means that 87.6 MHz could be reused in Indramayu. Therefore, it is necessary to create channel allotment for each region. The channel numbering and allotment in every service area is done based on Regulation No. 5 of the Minister of Communication and Informatics for 2023.

The implementation of analog technology in radio broadcast in the VHF Band II frequency band linked to the vast regions of Indonesia caused the issue of the large number of FM radio service areas, which are currently recorded as 2,054 FM service areas, and all of them have not covered 50% of the whole administrative area in Indonesia. This large number of service areas caused a complication in pattern arrangements for radio frequency reuse between service areas.

Analog broadcasting could not cover all regions in Indonesia in terms of channel availability and transmitter ability. However, digital technology has brought a new paradigm to the radio frequency reuse pattern. While an analog radio needs one frequency channel to transmit one broadcast service, digital broadcasting offers more than one broadcast service in a single frequency channel based on the illustration of these analog and digital radio transmission comparisons shown in Figure 2

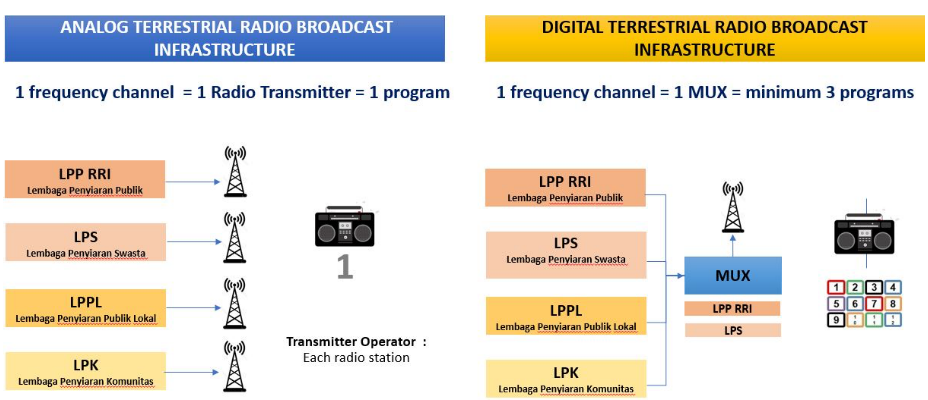


Figure 2. Analog and digital broadcast radio transmission.

However, for radio broadcasts to reach national coverage in Indonesia, the use of digital radio technology needs to be carefully balanced with efficient network planning in terms of frequency usage, better broadcast quality, and avoiding interference. Thus, a single frequency network (SFN) design could be the solution given the channel availability and channel numbering simplification. SFN is only possible by using digital technology. The enactment of Regulation of the Minister of Communication and Informatics No. 5 Year 2023 about the Spectrum Masterplan and Technical Operation Provisions of the Use of Radio Frequency Spectrum for Sound Broadcasting Service Through Terrestrial Media has allowed an opportunity for radio operators to broadcast using DRM or DAB+ digital technology. Table 1 describes digital radio technology for each frequency band.

Table 1. Digital Radio Technology

Band Frequency	Range Frequency	Standard Technology	
		Analog	Digital
MF	526.5-1606.5 kHz	AM	DRM
VHF Band II	87-108 MHZ	FM	DRM
VHF Band III	174-230 MHz	-	DRM and DAB

Regarding infrastructure, for information dissemination to reach all administrative areas, the Indonesian government has its way through public broadcasters, namely RRI and TVRI. As a state-owned radio broadcaster, RRI has periodically deployed transmitters for analog broadcasting throughout all regions in Indonesia based on their needs. Meanwhile, TVRI transmitters, particularly digital ones, are spread more evenly in Indonesia, but half of their planning is based on Multi-Frequency Networks. In the same area, two or more frequency channels are still used; hence, the transmitter location setting is not a consideration as long as both of its frequency channel spaces are according to the criteria.

This paper proposes radio broadcast network planning using the SFN method in all regions of Indonesia by utilizing transmitters from public broadcasters as the network basis. The frequency band used is the VHF Band II, particularly 87.1 MHz. This frequency channel is still near the FM analog radio tuning range, making it more familiar to radio listeners in Indonesia. However, in terms of usage, there has yet to be any existing radio broadcast on this frequency channel, considering FM itself starts from 87.5 MHz. Thus, there is no potential interference with the existing analog radio.

The technology used is DRM technology, which works in the VHF Band II frequency band range. The use of this frequency is considered more effective and efficient in terms of transmitter design because it can utilize existing FM analog transmitters. The DRM MUX can also accommodate 3-4 broadcast contents, making it more efficient and suitable for rural areas, while the DAB MUX can accommodate up to 16 broadcast contents. For big cities, it is feasible because the need for broadcast radio is large. But in small cities like Papua, it is not efficient to provide that much MUX. Therefore, DAB is not suitable for SFN implementation throughout Indonesia.

The plan for infrastructure planning will be divided into three scenarios. The first scenario is to use the RRI analog radio transmitter with a maximum distance of 75 km between transmitters. This distance limit is the maximum limit to prevent interference with its network. The second scenario is to use the TVRI digital television transmitter location in the service areas that should have been covered in the first scenario. The distance criteria of the TVRI transmitter follow the same pattern, which is 75 km from the other transmitter. The third scenario is the addition of new transmitters to cover the rest of the uncovered areas from the first and second scenarios.

2. Literature review

2.1. Digital Radio Broadcasting System

Digital radio technology services continue to grow with the development of technology in various aspects. According to the International Telecommunication Union in the ITU-R Rec BS.1114 document, six digital technologies have been developed and used around the world, as in table 2 below.

Table 2. Digital Radio Broadcasting System

Digital System	A	C	F	G	H	I
Common Name	Digital Audio Broadcasting (DAB)	In-Band On-Channel (IBOC)	Integrated Services Digital Broadcasting Terrestrial for Sound Broadcasting (ISDB-TSB)	Digital Radio Mondiale (DRM)	Convergen Digital Radio (CDR)	Real-time Audio Visual Information System (RAVIS)
Type	Open System (no annual license fees)	Prorietary US (+annual license fees)	Proprietary Japan	Open System (no annual license fees)	Proprietary China	Proprietary Rusia
Operating Band	VHF Band 3	1. MF (AM) 2. VHF Band 2 (FM)	1. VHF Band 3 2. UHF	1. LF (AM) 2. MF (AM) 3. HF (AM) 4. VHF Band 1 5. VHF Band 2 (FM) 6. VHF Band 3	VHF Band 2 (FM)	1. VHF Band 1 2. VHF band 2 (FM)
Bandwidth	1536 kHz	Analog + 2x100 kHz (VHF Band 2)	1/14 x ISDB-T channel raster (6/7/8 MHz)	1. LF/MF/HF a. 4.5 kHz b. 5 kHz c. 9 kHz d. 10 kHz e. 18 kHz f. 20 kHz 2. VHF Band 1,2,3 : 96 kHz	1. 100 kHz 2. 200 kHz	1. 100 kHz 2. 200 kHz 3. 250 kHz
Regular services	EU, SK, China, AUS	US	Japan	India, Pakistan, China, rusia, South Africa	China	Rusia

The allocation of radio frequency spectrum used for broadcast radio is regulated by the ITU, as shown in Table 3 below. Referring to the ITU is also regulated nationally by the technical rules of frequency used for broadcasting through the Ministry of Communication and Informatics. Five frequency band allocations could be utilized for broadcasting services, both analogously and digitally, as shown in Figure 3.

Table 3. Broadcast Radio Frequency Band Allocation

Band Frequency	Range Frequency	ITU's Regulation	Indonesia's Regulation
MF	526.5-1606.5 kHz	GE75 : LF/MF ITU region 1 &3	PM Kominfo 5 Year 2023
HF	3-30 MHz	ITU-R RR 12 for HF: worldwide	Not yet regulated
VHF Band I	47-68 MHz	RRC-06-Rev ST61: parts of Regions 1&3	Not yet regulated
VHF Band II	87-108 MHZ	GE84 Regions 1	PM Kominfo 5 Year 2023
VHF Band III	174-230 MHz	GE06: Parts of Region 1&3	PM Kominfo 5 Year 2023

2.2. Broadcast Radio Frequency Characteristics for Digital Radio

In the Ministry of Communication and Informatics (MCI) Regulation number 5 Year 2023 (*Peraturan Menteri Kominfo Nomor 5 Tahun 2023 tentang Rencana Induk dan Ketentuan Teknis Operasional Penggunaan Spektrum Frekuensi Radio untuk Keperluan Jasa Penyiaran Radio Melalui Media Terestrial, 2023*), some frequency bands could be used for broadcast radio, as shown in Table 2. Each frequency band has different characteristics that allow it to be used for several radio services. Generally, the low frequency would reach a wider area (country, even continent) with one transmitter. As for higher frequency, it could only reach certain areas, hence its suitability for regional services.

1. Medium Frequency Band
   This frequency band has been used for analog AM broadcast radio. Using this frequency band, either analog or digital, shall follow the provisions defined in the GE75. The rules regulate every country's use of frequencies in terms of frequency assignment, transmitter location, bandwidth, transmission power, and antenna height. Modifying or adding parameters to the GE75 requires a coordination process and ITU approval (ITU-R, 1975). SFN design in this frequency band requires long procedures and extra consideration to prevent interference with other countries.
2. High Frequency Band
   HF Frequency Band is used for international broadcasting in international or even continental ranges because of the propagation factor. However, the nature of this propagation always changes throughout the day of the ionization in the atmosphere. In analog broadcasting, this condition might be tolerable. However, it could not be done in digital technology to cover nationwide using SFN. HF frequency use must follow through HFCC coordinations held twice yearly for Season A and Season B (Radio Regulation-Article 12, 2019). Indonesia uses 3 HF frequencies, which are 3325 kHz, 4750 kHz, and 7290 kHz.
3. VHF Frequency Band

   VHF Frequency Band I (47–68 Hz) currently is not used in Indonesia. This is because the band is highly affected by the sporadic E layer. VHF Band II (87-108 MHz) has been the sweet spot for analog FM radio broadcasts that are well-known globally. With 2.319 broadcasters, including LPP-RRI, commercial broadcasters, and community broadcasters, this band is also the best fit for a digital broadcast radio system. VHF Band III (174-230 MHz) is a commonly known band for digital radio broadcasts using DAB technology.

2.3. Digital Radio Mondiale

Digital Radio Mondiale (DRM) is one of the digital radio technologies specifically designed to operate in the same frequency bands as AM and VHF analog radio, which are currently used (N. Laflin, 2020). Figure 3 provides an overview of the frequency bands where DRM functions.

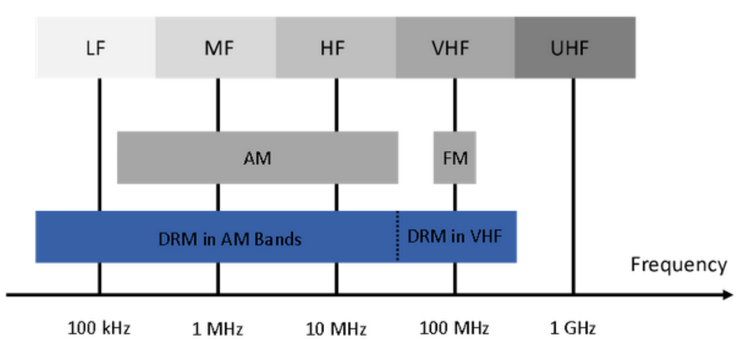


Figure 3. DRM Digital Radio Standard for All Bands (N. Laflin, 2020)

The DRM standard outlines various operating modes (modulation parameter sets) for physical transmission, which can be categorized into two main groups as follows:

a. DRM transmissions below 30 MHz
   DRM utilizes the current AM broadcast frequency bands for transmissions under 30 MHz, aligning with existing AM broadcast band plans that use 9 kHz or 10 kHz bandwidth signals. Additionally, it accommodates half-channels with 4.5 kHz or 5 kHz bandwidth and double-channels with wider bandwidths of 18 kHz or 20 kHz. Robustness modes (Modes A to D) can adjust the signal for different propagation conditions.
b. DRM transmissions above 30 MHz
   For transmission above 30 MHz, DRM uses robustness Mode E, which has a fixed bandwidth of 96 kHz (half the bandwidth of an analog FM service) and is tailored to fit the FM broadcast band plan with a frequency grid of 100 kHz. Its narrow spectrum requirements make it suitable for use in congested bands, even in cases where there is limited space for additional analog FM services. DRM offers bit rates ranging from 37 kbps to 186 kbps and, similar to the AM bands, supports up to three audio plus data services.

This flexibility allows for broadcasting single or a few audio services together, promoting efficient spectrum utilization. Each mode is defined in Table 4 as follows:

Table 4. DRM Transmission Mode

Mode	Bandwidth options (kHz)	Typical Uses	Transmission Frequency
A	4.5, 5, 9, 10, 18, 20	LF & MF ground-wave, 26MHz band line-of-sight	Below 30 MHz
B	4.5, 5, 9, 10, 18, 20	HF & MF transmission on sky-wave	Below 30 MHz
C	10, 20	Difficult sky-wave channels on HF	Below 30 MHz
D	10, 20	NVIS sky-wave (highest Doppler & delay spread)	Below 30 MHz
E	100	local/regional transmissions in the VHF bands, including the FM band	Above 30 MHz

Source : (N. Laflin, 2020)

DRM can offer two types of services: DRM data services and DRM audio services. A DRM transmission can offer one to four services, three of which are audio. Thus, DRM technology is capable of enhancing frequency usage efficiency.

2.4. Single Frequency Networks

Single Frequency Networks are geographically dispersed Radio Frequency transmitters operating on the same carrier frequency, modulating the same program material. Multiple transmitters or transmitter stations separated by a certain distance broadcast the same signal at the same frequency and are synchronized to coordinate their transmissions perfectly. An SFN's main objective is to improve FM or HD and extend coverage areas. Another goal of an SFN is to fill coverage gaps because of terrain shielding and geographical contours that need to be served by the main signal.

The DRM system can function with Single Frequency Network (SFN) operation. This occurs when multiple transmitters broadcast identical DRM signals on the same frequency. Typically, these transmitters are strategically positioned to have overlapping coverage areas, allowing a radio to receive signals from multiple transmitters within these areas. As long as these signals reach the receiver with a time difference less than the guard interval, they will strengthen the signal. As a result, the service coverage at that location will be enhanced compared to having just one transmitter providing service there. By careful design and using several transmitters in an SFN, a region or country may be covered entirely using a single frequency rather than several different frequencies, thus dramatically improving spectrum efficiency.

To design an SFN DRM using mode E, it is necessary to meet the predetermined parameters, as shown in Table 5. A DRM transmitter operating in an SFN needs to be designed to avoid self-interference. The maximum transmitter distance should not exceed the length of the OFDM guard interval.

Table 5. DRM Technical Parameters

Technical Parameters	Value
The elementary time period T	83 1/3 µs
Duration of helpful (orthogonal) part Tu = 27 x T	2.25 ms
Duration of guard interval Tg = 3 x T	0.25 ms
Duration of symbol Ts= Tu +Tg	2.5 ms
Tg/Tu	1/3
Duration of transmission frame Tf	100ms
Number of simbols per frame Ns	40
Channel bandwidth B	96 kHz
Carrier spacing 1/Tu	444 4/9 Hz
Carrier number space	Kmin = -106; Kmax = 106
Unused carriers	none

Source : (N. Laflin, 2020)

The minimum distance between transmitters can be calculated using the data in the table above and the speed, distance, and time formula.

$D = V \times t$ ….. …………………………………………………………………………..1)

Where:

D: distance

V : speed 3×10^{-8}

t: guard interval

In Table 5, it can be seen that the value of the guard interval is 0.25 ms. If the speed is defined as the speed of light, using equation 1 will result in a minimum distance between transmitters of 75 km.

2.5. Benchmark Countries

2.5.1. *Research the SFN DRM in Venezuela*

Research about the SFN DRM digital radio network has been conducted in Venezuela (O. V. Varlamov, 2021). Using a low-frequency band in the MF range, where the service area radius is considered the maximum natural condition, The analysis of the radio broadcasting network in the Republic of Venezuela shows that even though the number of radio transmitters used within the MF range is extensive, coverage of the whole country is not guaranteed. The quality of the analog signal received is low

The technical basics for digital network broadcasting design in certain areas have been developed by considering climatic features, soil conductivity in several areas, and the maximum level of radio noise distribution in the atmosphere.

An example of the Venezuelan MW large-cluster single-frequency synchronous DRM network topology developed, considering the above provisions, consists of three clusters, two of which have a transmitter service area radius of 140 km, each consisting of 7 and 8 transmitters. The third has a transmitter service area radius of 90 km and consists of 7 transmitters. The topology proposed only uses three radio frequencies, so all of them could be chosen in the low part of the frequency range from the MF range, where the service area radius in natural conditions is considered maximum.

The availability of broadcast transmitters and solutions to ensure the matching of antenna-feeder systems with the required characteristics makes it possible to proceed with implementing the system design for a synchronous digital broadcasting network following the DRM standard for Venezuela. That paper considers linking broadcasting facilities with the existing infrastructure, including energy and telecommunication.

Regarding the paper mentioned, this study also conducted national-scale planning for all regions in Indonesia using SFN DRM, but with a frequency band on VHF Band II that is more stable to climate features, soil conductivity in some areas, and the maximum level of radio noise distribution in the atmosphere. The MF frequency band potentially reaches neighbouring countries and requires international coordination to consider its use and prevent interference. Meanwhile, the VHF Band II broadcast coverage is less than the MF frequency, making it more suited for national-scale network planning.

2.5.2. *Trial DRM on VHF Band II in Brazil*

Besides Venezuela, Brazil has also completed a DRM+ trial on VHF Band II, generally known as the FM band. This is important because this band is the most often utilized VHF frequency globally. The study uses the 104.7 MHz frequency in three separate sites with varying transmit powers: high power (500 watts), medium power (70 watts), and extremely low power (1.36 and 5.36 watts). Those three locations are distinct from one another, with no network connecting them.

The trial yielded static reception data from three separate field tests. The coverage of each trial varies depending on the number of EIRPs given. A trial with high power provides more coverage than one with lower power. Unlike the study in Brazil (J. M. Matías, 2013), this only uses three location points and a nearby two-frequency analog radio.

The DRM trial in Brazil is still limited to three locations with three different powers. Even though it uses the same frequency, 104.7 MHz, it is not designed as an SFN. The SFN approach is used in this strategy to cover all of Indonesia's regions at 87.1 MHz. The frequency is chosen by considering the neighbouring three from analog FM radio, and this space channel is the safe distance from interference between FM and DRM.

3. Method

This study proposes and implements a digital broadcast radio network using DRM technology and an SFN technique. This research employs an 87.1 MHz frequency. The design incorporates primary data from RRI and TVRI radio transmitters in Indonesia and secondary data from several new stations. Three scenarios were carried out in this network planning design. In this research process, a research framework is made in the form of steps taken and depicted in a research flowchart, as shown in Figure 4.

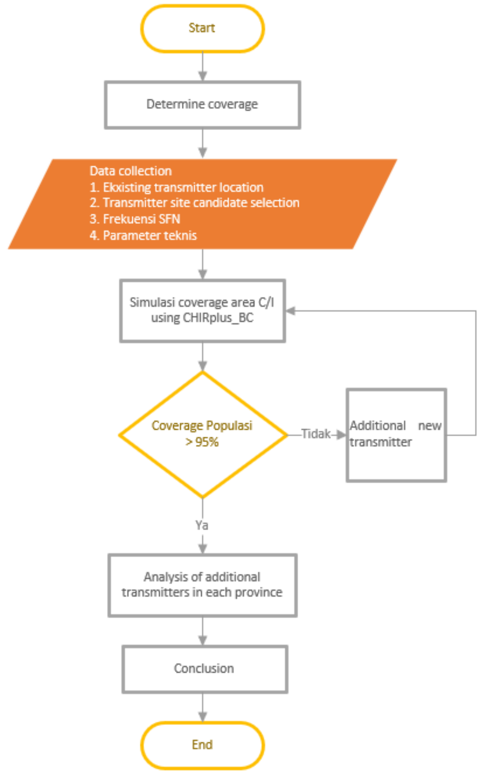


Figure 4. Research flowchart

3.1 The First Scenario

The initial part of this research is to discover the locations of RRI transmitters employed in the SFN network. Based on spectrum licensing data (Direktorat Jenderal Sumber Daya Perangkat Pos dan Informatika, 2024), 439 existing analog radios belong to RRI. However, based on the maximum distance between transmitters in SFN, only transmitters with a maximum distance of 75 km will be used. For example, RRI in the DKI Jakarta area was identified as using four frequencies at two transmitter locations 3 km apart, which is shown in Table 6

Table 6: Frequency utilization of LPP RRI in the Jakarta service area

Broadcast Radio	Frequency	Transmitter Location	
		Latitude	Longitude
LPP-RRI Pro 1	88.8	06S13 28.81	106S48 14.08
LPP-RRI Pro 2	91.2	06S15 07	106S48 30
LPP-RRI Pro 3	92.8	06S15 07	106S48 30
LPP-RRI Pro 4	105	06S15 07	106S48 30

Source : (Direktorat Jenderal Sumber Daya Perangkat Pos dan Informatika, 2024)

The four frequencies are within a location distance of <75 km, so they are combined in one transmitter, as shown in Table 7.

Table 7. Frequency use in Single Frequency Network

Frequency Transmitter	Frequency	Transmitter Location	
		Latitude	Longitude
RRI DRM-Jakarta	87.1	06S13 28.81	106S48 14.08

The same is true for all existing RRI transmitters throughout Indonesia. After identifying RRI transmitter usage is completed, the next step is to conduct simulations to determine the coverage area of the design using only RRI transmitters.

3.2 The Second Scenario

To install TVRI transmitters in areas previously not covered by RRI transmitters. The transmitter used meets the maximum requirements of 75 km from the RRI and TVRI transmitters. Next, another simulation was carried out to see the coverage area of the RRI and TVRI transmitters.

3.3 The Third Scenario

Suppose the simulation results suggest that there are still locations in Indonesia that need to be covered by digital radio transmissions. In that case, some new transmitters will be put in those blank spots. The new transmitter is placed with a maximum distance of 75 km between the RRI transmitter, TVRI transmitter and the new transmitter. The addition of new transmitters was carried out until the simulation result covered all of Indonesia.

BC Chirplus software is used with the predetermined technical parameters in the simulation stage. Customized technical parameters include as shown in Figure 5:

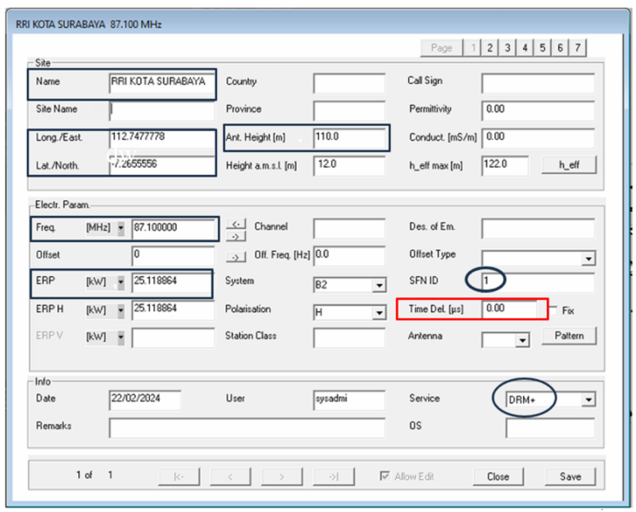


Figure 5. Technical Parameter filling

a. Frequency, all transmitters in the network are designed to use the same frequency, namely 87.1 MHz
b. Transmitter location, RRI transmitter and TVRI transmitter use locations according to existing real locations. For new transmitters, they are placed in blank spot positions with a maximum distance of 75 km between transmitters.
c. Antenna height, RRI and TVRI use an antenna height that matches the existing one. The antenna height for the new transmitter is between 40 - 80 meters.
d. The ERP used is between 800 watts – 3000 watts. Besaran ERP yang digunakan, bergantung pada lokasi dari pemancar.
e. SFN-Id provides the same SFN-Id value for all transmitters used. The function of SFN-Id is to indicate transmitters in the same SFN Network.

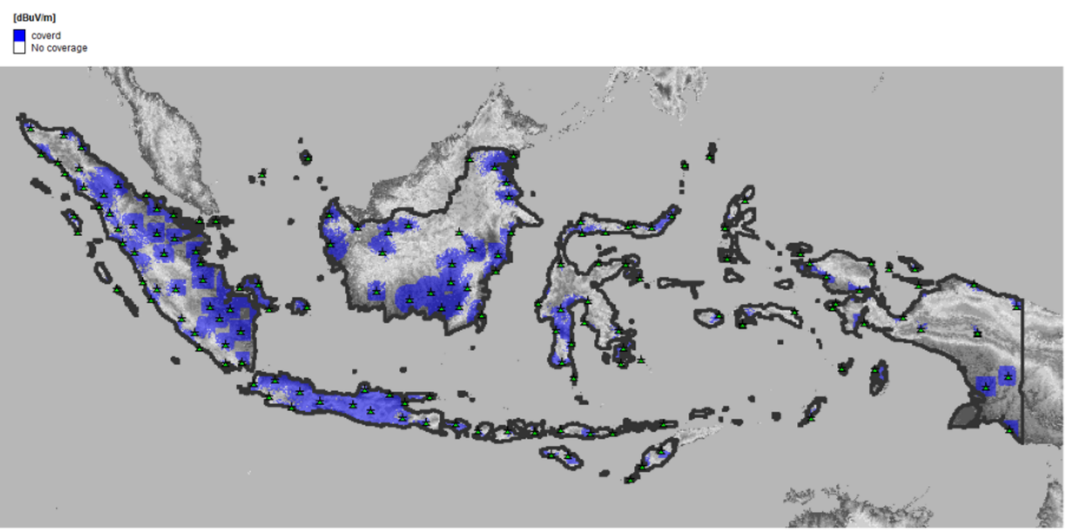
After defining the frequency utilized for SFN network design and the distance between transmitters in the network to prevent self-interference, the next step is to create a network that connects all regions of Indonesia. This study uses the network of public broadcasting institutions, both RRI and TVRI, to achieve maximum coverage outcomes.

4. Result and Discussion

4.1. The primary design based on RRI transmitters

RRI continues to operate throughout Indonesia using 439 analog radio frequencies as of right now. Under the regulations, RRI was permitted to use up to four frequencies in each service region. Using a single transmitter for many frequencies is a common practice to reduce operating costs and the cost of purchasing transmitters. By using the first scenario, we obtain 153 optimal RRI transmitters for the SFN planning using DRM regarding the transmitter distance maximum restriction.

The ERP regulation adapts to service area boundaries and field conditions. The ERP value impacts coverage since a higher ERP value results in a better and farther-reaching signal. In this design, the ERP value ranges from 800 to 3.000 Watts. As shown in Figure 6, the area coverage results in 91.8% with 153 transmitters. The areas shown in blue represent those covered by the SFN network, according to the simulation's results. This demonstrates that DRM digital broadcasting services are available practically everywhere on the island of Java. However, there are still some rather substantial gaps in Kalimantan, Sulawesi, and Papua.

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=====================================================================================================
Result          : >=    0.00 dB    < 999.00 dB

                                      Popul./Inhab.    %%     |  Cov. Area/sqKm    %%
=====================================================================================================
IN                                    249685467      91.28     2945405.8145    26.44
OUT                                   23838154        8.72     8193077.6676    73.56
=====================================================================================================
Total Population in Area :            273523621
Total Area calculated    :                                     11138483.4821
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Figure 6. Coverage of the area with 153 transmitters

4.2. The addition of TVRI transmitter locations into the design

DRM could make use of digital transmitters called TVRI that are dispersed throughout Indonesia. By using the second scenario in the method, 45 TVRI transmitters were obtained, which could cover the blank spots from the first scenario. The simulation's result demonstrates that not all of Indonesia has been reached by 153 RRI transmitters and 45 TVRI transmitters, only 198 current transmitters, as shown in Figure 7.

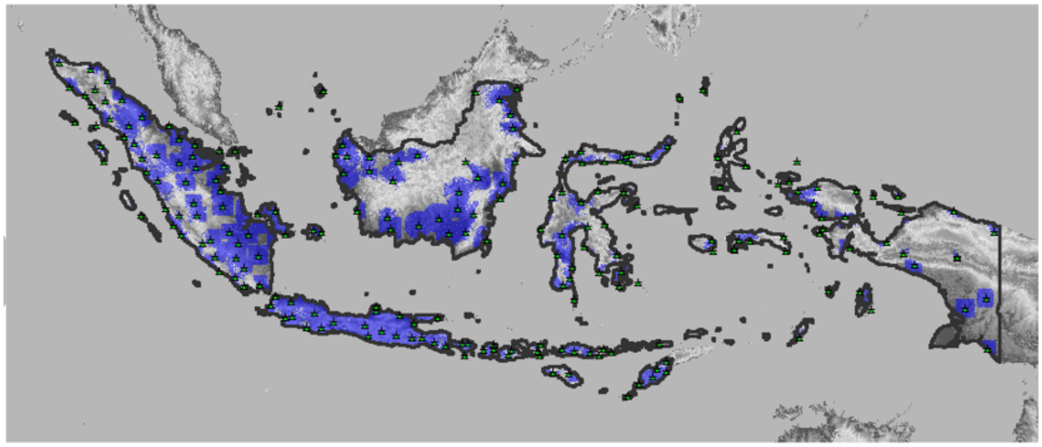


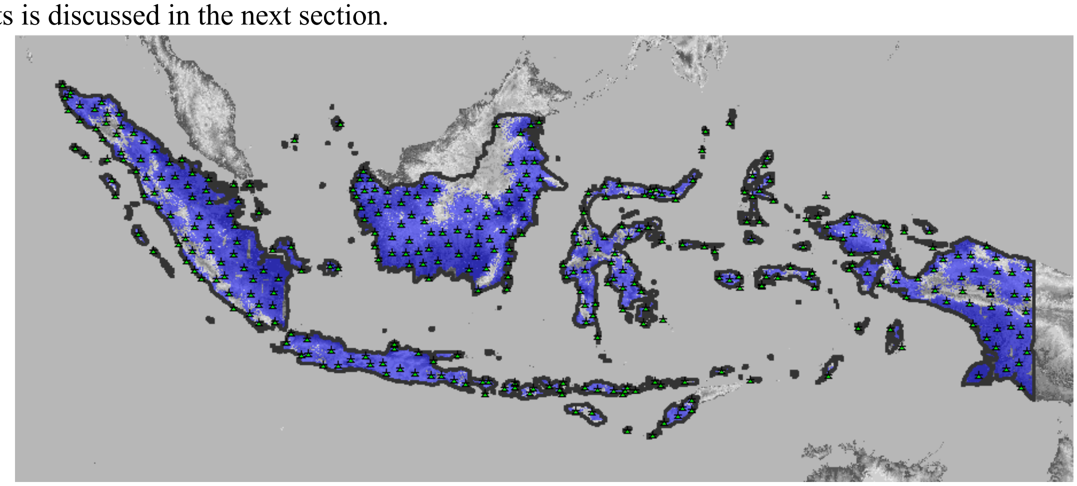
Figure 7. Coverage of the area with 198 transmitters

In this scenario, Java Island is almost covered by DRM services. Sumatra Island is partially covered. Meanwhile, Kalimantan, Sulawesi, and Papua Islands still have many blank spots. Therefore, this design continues with the third scenario.

4.3. Additional New Transmitters

Given that the handicaps, particularly mountains and dense forests, obstruct Indonesia's contour condition, the design simulation result involving 198 transmitters still leaves some blank spot locations. Some repeaters are added in blank spot locations to suit the area coverage requirements throughout Indonesia, and transmitter development is still conceivable. The presence of a population in an area designated as a blank spot is considered when selecting new areas for transmitter placement. According to the third scenario, 132 transmitters will need to be added in order to complete the area coverage simulation. The result is shown in Figure 8.

Figure 8 shows that the target population coverage 95.03% has been achieved. The analysis of transmitter requirements is discussed in the next section.



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==================================================================================================
Result          : >=    0.00 dB   < 999.00 dB

                                    Popul./Inhab.   %%    |  Cov. Area/sqKm   %%
==================================================================================================
IN                                  259928521      95.03    7601869.9766    68.25
OUT                                 13596100        4.97    3536613.5055    31.75
==================================================================================================
Total Population in Area :          273523621
Total Area calculated    :                                  11138483.4821
```

Figure 8: Coverage of the area with 330 transmitters

4.4. Planning Result

To cover the Indonesian region, a minimum of 330 transmitters are needed with a distribution of transmitter locations, as in Figure 9. The transmitter with the green symbol is an RRI transmitter, and the transmitter with the red symbol is a TVRI transmitter with the purple symbol is a new transmitter.

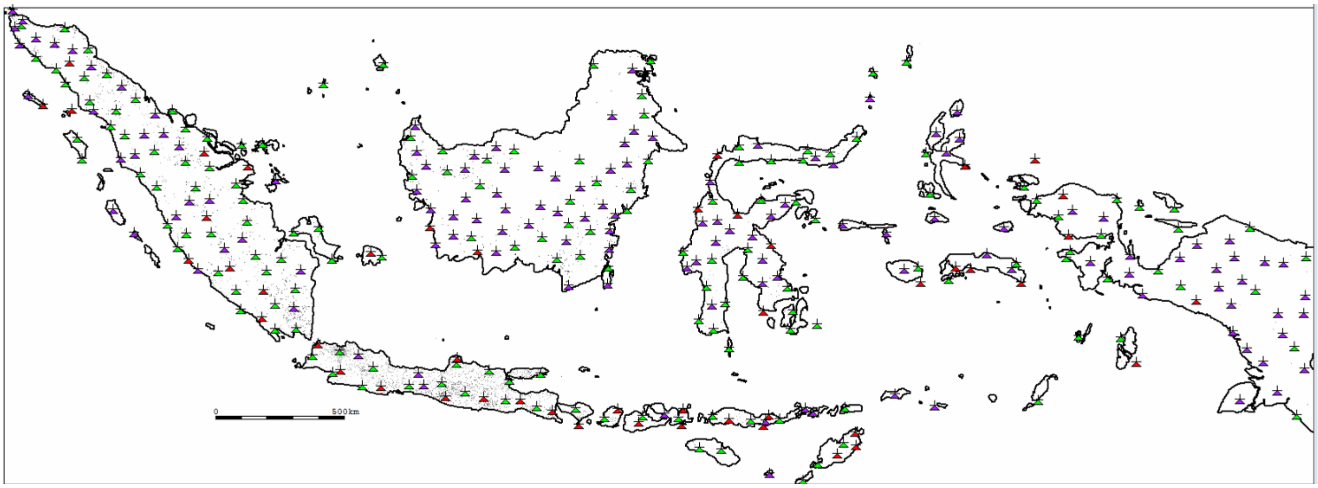

Figure 9. Distribution of 330 SFN transmitters throughout Indonesia

The distribution of transmitters in each province is shown in Table 7. Each province has a different number of transmitters, including existing and new transmitters. This depends on the area to be covered and the geographical contours of each region.

Table 7. Number of Transmitters by Province

Provinsi	RRI	TVRI	NEW Transmitter
Daerah Istimewa Aceh	8	3	9
Sumatera Utara	7	-	6
Sumatera Barat	3	-	4
Riau	8	2	3
Jambi	4	1	1
Sumatera Selatan	4	2	2
Bengkulu	3	1	1
Lampung	4	1	1
Kepulauan Bangka Belitung	4	2	-
Kepulauan Riau	4	-	1
DKI Jakarta	1	-	-
Jawa Barat	3	-	1
Jawa Tengah	3	-	2
Daerah Istimewa Yogyakarta	-	1	-
Jawa Timur	6	3	-
Banten	1	1	-
Bali	1	1	-
Nusa Tenggara Barat	3	4	1
Nusa Tenggara Timur	9	6	4

Provinsi	RRI	TVRI	NEW Transmitter
Kalimantan Barat	7	1	14
Kalimantan Timur	6	-	9
Kalimantan Tengah	6	1	11
Kalimantan Selatan	3	-	4
Kalimantan Utara	3	-	1
Sulawesi Utara	5	-	3
Sulawesi Tengah	6	3	7
Sulawesi Selatan	7	-	2
Sulawesi Tenggara	5	1	3
Gorontalo	2	-	-
Sulawesi Barat	1	1	3
Maluku	6	4	5
Maluku Utara	2	2	7
Papua	10	1	22
Papua Barat	8	3	5
	153	45	132

Analysis of differences in the number of transmitters in each province can be grouped into three criteria as follows:

a. The area of a province determines the need for transmitters. The bigger a province, the more transmitters are needed. For lowland areas like DKI Jakarta, which has an area of 7,659 km2 (Badan Pusat Statistik Provinsi DKI Jakarta, 2022), only one transmitter is needed to cover that area. Likewise, Provinsi Gorontalo only requires two RRI transmitters to cover a large area of 11,257 km2 (Badan Pusat Statistik Provinsi Provinsi Gorontalo, 2019). However, it's different for regions in Papua or Kalimantan provinces, which require more transmitters. For example, in Papua Province, with an area of 319,036 km2 (Badan Pusat Statistik Provinsi Papua, 2021), which has mountainous geographical contours with vast expanses and heights, a minimum of 33 transmitters are needed.
b. Geographical conditions, such as mountains, dense forests, and island areas, require more transmitters. The Province of Aceh still requires nine transmitters due to a large number of blocks from dozens of high mountains, 800 meters to 3,404 meters (Wikipedia, 2024). In contrast, the Provinces of North Maluku and East Nusa Tenggara require more transmitters because the distribution of transmitters is based on the number of islands in the province.
c. The number of existing transmitters is still tiny. The addition of more transmitter locations in several provinces is due to existing conditions where there are still few transmitters at this time. The province of West Kalimantan Barat, Central Kalimantan dan Papua, still needs additional transmitters, which account for almost 50% of the existing transmitters (RRI dan TVRI). They are generally located in areas with geographical conditions, as mentioned in point number 2 because construction of transmitters in these areas requires relatively high costs compared to places on the island of Java.

Based on the simulation results, 330 transmitters are needed, consisting of 198 existing transmitters owned by RRI and TVRI and the addition of 132 transmitters in blank spot locations. This means that to reach 95% of the population in Indonesia, it is still necessary to build 40% of the total transmitters needed. Most of the new transmitter locations are in underdeveloped, frontier, and remote areas that are difficult to access because there are no adequate facilities and infrastructure. This is a challenge for network operators to be able to build an SFN throughout Indonesia.

5. Conclusion

The challenge of analog radio broadcasting is its restriction on the use of frequencies. One frequency channel is assigned to a single broadcast service in analog broadcasting. To fulfil the need for information services in all of Indonesia's major cities, this analog broadcast radio is heavily used. However, not all parts of Indonesia could be reached or covered by analog radio transmission. Although 2,054 FM radio service regions are defined by the current radio legislation, at least 50% of Indonesia's administrative areas still need to be accounted for

To reach every region of Indonesia, this research has created a broadcast radio design scenario using a single-frequency network. 87.1 MHz is the only frequency that is possible for use. The design process is used to identify the sites of transmitters progressively—both new and existing—in blank spot zones. To meet the 0.25 ms guard interval time, the transmitters to be deployed must adhere to the maximum distance of 75 km.

The simulation results showed that not all of Indonesia has been covered by the SFN design, with only the 153 RRI transmitters now in use. Even with the addition of 45 TVRI, the maximum outcome has yet to be achieved. A total of 132 new transmitters were added to fill the blank spot areas still uncovered by LPP (RRI and TVRI) transmitters. The scenario study demonstrates that 330 transmitters could cover 95.03% of Indonesia's land area, paving the way for the deployment of DRM SFN on VHF Band II frequency in that country. Utilizing the LPP RRI and TVRI existing transmitters makes this research more visible to be used by the Government Broadcasting Institution

Further research can be developed by calculating the need to build 132 transmitters in new locations and creating a business model for digital radio operations so that the burden of operating broadcast radio is more affordable.

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